ARI Working Papers

Manned Systems Group

1987-1991

Volume I

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July 2001

United States Army Research Institute for the Behavioral and Social Sciences

REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) July 2001	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) 1987-1991
4. TITLE AND SUBTITLE ARI Working Papers: Manned Systems Group, 1987-1991 Volume I		5a. CONTRACT OR GRANT NUMBER
		5b. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Alderman, I.N., Narva, M., Ditzian, J.L., Roth, J.T., Johnston, E., Harvey, D.T., Hyman, A., Kaplan, J.D., Miles, J.L. Jr., Holman, C.E., Katznelson, J., Klaus, D.J., Niernberger, K.J., Maisano, R.E., Rodgers, R.L., Lindquist, J.W., Statler, L.H., Welp, R.L., Geddie, J.C., Purifoy, G.R. Jr., Sidorsky, R.C., and Stewart, J.E.		5c. PROJECT NUMBER
		5d. TASK NUMBER
		5e. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Attn: TAPC-ARI-PO Alexandria, VA 22333-5600		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600		10. MONITOR ACRONYM ARI
		11. MONITOR REPORT NUMBER WP MSG I

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

ARI working papers were originally unofficial documents intended for limited distribution to obtain comments. These working papers are being archived in order to preserve material that was not included in other ARI publications. The material contained herein may not meet ARI's usual scientific or professional standards for publication.

14. ABSTRACT *(Maximum 200 words)*:

Twenty-two working papers dealing with manpower requirements, unit performance, the Army manpower cost system, MANPRINT, tactical operations, workload, HARDMAN, materiel development, comparability analysis, military standards, and embedded training.

15. SUBJECT TERMS

Manpower requirements, unit performance, the Army manpower cost system, MANPRINT, tactical operations, workload, HARDMAN, materiel development, comparability analysis, military standards, embedded training, TCEA, HARDMAN III, ECA, LHX, ITCS, M-CON, Aquila

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON (Name and Telephone Number)
16. REPORT Unclassified	17. ABSTRACT Unclassified	18. THIS PAGE Unclassified	Unlimited	1342	David W. Witter (703) 617-0324

Manned Systems Group Working Papers – Volume I

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Working Paper

MODELING UNIT PERFORMANCE AND MANPOWER REQUIREMENTS

CONTRACT NUMBER: OPM-87-9035
OPM WORK ORDER NUMBER: 535-008
(ARI AFAS MODELING)

AUGUST 1988

U.S. Army Research Institute
for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria VA 22333

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1.0 Introduction

1.1 Background

The Army Research Institute for the Behavioral and Social Sciences (ARI) is developing methods to accurately predict and model needed maintenance and support manpower requirements for emerging systems within the Army. A product being developed to support the ARI efforts in this area is a generic top-down manpower modeling tool for the operator, maintenance, supply, and support requirements for an organization. Specifically, the tool will:

- focus on the effects of weapons system parameters (such as RAM factors) on manpower requirements in an organizational context;
- output measures (such as equipment availability) must be sensitive to changing manpower factors or assumptions;
- output to be aggregated for unit sizes from platoon to division; and
- be applicable to all Army systems (generic).

In support of this objective, ARI has initiated a three phase project o develop a PC-based tool to aid combat developers in the early manpower assessment of various weapon system configurations within alternative operational and organizational (O & O) concepts for maintenance, supply, and support.

The generic tool has been dubbed the Organizational Level Manpower Analysis Tool (OLMAT). Specifically, OLMAT provides manpower estimates for a given system design and organizational structure in an operational environment based on:

- RAM parameters
- support concepts
- supply concepts

Phase I of the OLMAT development project was the definition of general specifications for the tool. Phase II will be the development of the detailed design specifications for the tool and its required data libraries. Phase III will be the implementation and test of the tool (OLMAT prototype) and its application to the Advanced Field Artillery System (AFAS).

1.2 Purpose

The purpose of this report is to document the results of the Phase I effort and provide a plan for the accomplishment of Phases II and III.

The work plan which guided the activities of the Phase I effort is at Appendix A. Since the work plan is a very general document, early discussions and meetings with ARI personnel resulted in the drafting of a more detailed concept paper which outlined the technical details for accomplishing the tasks outlined in the work plan. The concept paper is at Appendix B. The Phase I tasks addressed in this report are:

- Task 1 Development functional specifications and requirements for OLMAT
- Task 2 Conduct a detailed examination of MANCAP
- Task 3 Assess feasibility of using MANCAP as the OLMAT centerpiece

- Task 4 Identify OLMAT development alternatives
- Task 5 Develop implementation plan for selected alternative.

The remaining sections (Sections 2 through 6) of this report document the activities and results of each of these tasks.

2.0 Develop Requirements and Functional Specifications for OLMAT

These three subtasks defined for this task were the development of "straw-man" requirements for a general manpower requirements tool, a review of existing models applicable to Army systems, and the conceptual (functional) specifications for an ideal tool to estimate manpower requirements in the combat and combat support services areas.

2.1 User Requirements

Since OLMAT was envisioned for use primarily prior to Milestone I of the systems acquisition cycle, it was felt that the initial user of the tool would be the TRADOC combat developments community. The tentative travel outlined in the concept paper at Appendix B included materiel developer activities (weapons systems project management offices) as well as the major combat arms schools since the tool would also be effectively used throughout a system's acquisition with more refined data as the system matured. However, time constraints limited travel to the Logistics Center at Fort Lee, the Field Artillery School at Fort Sill, the Aviation School at Fort Rucker, the Infantry School at Fort Benning, and the Armor School at Fort Knox. Each school visit was made by both a contractor and the ARI sponsor. The interviews with the potential users at the schools were kept fairly unstructured to facilitate the fact finding nature of the visits. A typical agenda for a visit is contained in the concept paper at Appendix B. Although the primary purpose of these visits was to identify user requirements for an OLMAT tool, a secondary purpose was the identification of existing models, tools, and data sources that would be used to facilitate the OLMAT effort.

The initial visit was made to the Logistics Center at Fort Lee to collect data on the ongoing Manpower Requirements Criteria (MARC) modeling program. Although the Logistics Center was not seen as a major user of the OLMAT tool, we wanted to ensure that OLMAT was not duplicating ongoing work. We also wanted to identify potential modeling techniques and data sources. The trip was very beneficial. The Logistics Center personnel openly described their effort but could not provide extensive written documentation due to the sensitive nature of the studies in the program. More information on the MARC models will be provided in the next section. The conclusion drawn from the visit was that OLMAT does not duplicate the MARC modeling initiatives. MARC modeling is very data intensive, bottom-up process designed to be used primarily for fielded systems to provide an auditable rationale for manpower factors. However, some of the MARC output, as well as the supporting data bases, may become a valuable source of data for OLMAT's system libraries.

The visits to Forts Sill, Rucker, Benning and Knox were equally productive. Since the information obtained was very consistent, the findings will be summarized in terms of who the potential user are and their specifications for a tool to help them in their jobs.

2.1.1 Potential Users

The interview protocol established for the school visits generally started with an overview briefing on the purpose and status of the OLMAT effort followed by a group discussion and then one-on-one discussions with action officer personnel who were identified as the actual users (the workers who would use the OLMAT as a job aid). These users typically were in the school's Directorate of Combat Developments (DCD) and fell primarily into two categories:

- DCD Specials Studies Group - Used primarily by the action officers involved in developing the system operational mode summaries and mission profiles (OMS/MP) and the organizational and operational (0 & 0) plans for the system.

  The primary use of an OLMAT tool would be to examine the effects of alternative profiles, and to organize the mission capability. Typically, after lengthy discussions on various measures of organizational effectiveness, operational availability (the percent of operational equipment over time) was the only consistent (general) measure identified.

- DCD RAM - All DCD's have a section or group which deals primarily with the system reliability, availability, and maintainability (RAM) parameters. The specification of these parameters early in the system's development have major operational, organizational and cost impacts, and typically they are made with very little analytical rationale. The existing tools focus and optimize at the system level. Those who work with establishing the RAM parameters could see a great need for a tool that would enable them to examine RAM effects at the organizational level.

  We feel that as OLMAT is developed and is used to support systems acquisitions, more users will be found in the TRADOC Systems Manager (TSM) activities as well as by the DCD MANPRINT point of contact (POC). The TSM activities typically tasks information generation and analyses and accept what is returned. They can potentially use OLMAT to ensure that components are not sub-optimized at the expense of overall system effectiveness. Similarly, the MANPRINT POCs now have fairly limited roles and responsibilities in the area of analysis. As their roles mature, OLMAT may be used to assess the effects of system and organizational modifications on the MANPRINT objectives.

Figure 2.1 is a summary of the user demographics identified during the school visits. of the potential users, about half were military action officers (mostly captains with about 7 to 10 years of service) and about half were civilian (mostly GS-11 to GS-13 who had held several different positions within DCD). For the action officers, most were comfortable with computer tools and had a bachelors degree as well as additional education in operations

TRADOC COMBAT DEVELOPMENT ACTIVITIES

- 50% MILITARY
  - SHORT TERM OUTLOOK
  - 25% MASTERS LEVEL ORSA OR COMPUTER SCIENCE
  - 25% SERVICE SCHOOL ORSA
  - 50% BACHELORS DEGREE
  - MOSTLY CPTs -- 7-10 YOS
  - MOST ARE COMPUTER LITERATE
- 50% CIVILIAN
  - LONG TERM OUTLOOK ("DON'T ROCK THE BOAT")
  - MOSTLY BACHELORS DEGREE
  - GS 11-13
  - LOW EXPOSURE TO COMPUTERIZED TOOLS

Figure 2.1 User demographics.

research or computer science. The military group, however, had a very short-term outlook for their DCD work. Most saw their job as a temporary stopping place to get a ticket punched prior to their next field job or school. They did not have a good appreciation of the overall context or importance of their DCD work and would only use a new tool if they were told to do so or if they could master it quickly and expected immediate return in terms of job performance or quality. The civilians, on the other hand, had not had much formal technical training subsequent to their bachelor's degree and typically had low exposure to computerized tools. They were comfortable with doing their work on "the back of an envelope" the way it had always been done. While their long term outlook seemed to be "don't rock the boat", they had a better feel for the context of their work than their military counterparts and could see the benefits of an OLMAT-type tool and would use it if it were accepted by the miliary hierarchy.

Discussions with potential users in the categories discussed above led to the following generalized set of user specifications for an OLMAT tool.

- It must help them to do their work better and and faster. Typically, the DCD action officer is over burdened. There are always more demands than there are resources. The choice is to do a lot of things poorly or a few with excellence. Typically, the action officer will reach a middle ground where tasks are prioritized and some tasks don't get done at all. In this environment, a tool will be beneficial if it will save him time or provide him with a better product for a light time penalty.

- It must be easy to learn and easy to use. This relates to the first requirement. The military or civilian analyst typically does not have the time to devote to new tools or training unless he can expect a large return on his investment. He is reacting to demands and does not have the time to devote to something his superiors might view as inefficient.

- The setup and run-time must be fairly short. Our best estimate (interpretation) of this requirement is a target of about four hours for setup and our hour for run-time. A target time is specified since these times will drive the design of the tool. If it appears that the target times will be significantly breached, the users should again be surveyed to ensure that the emerging product could be effectively used.

- A related requirement is that the tool use available data. That is, the user does not have to make formal data requests to the activities to provide required input. The input data must be routinely available "in-house" or readily available from resident experts.

- The tool must run on an IBM PC compatible machine. The Zenith Z248 is the most prevalent PC and every DCD section we surveyed had at least one work station readily available usually with a 20M hard disk. Since the equipment is typically used by several people, the tool cannot effectively dedicate a machine by requiring too much storage space or taking too long to use (set-up and run).

- The tool must run on unclassified data. Classified data would require that the work station or the hard disk be secured. This would effectively remove the tool from the easy reach of the analyst and may cause him to ignore it.

The user requirements are summarized at Figure 2.2. The requirements flow primarily from the perspective of the analyst who is working on or assigned to an emerging system since these were the ones who expressed a keen interest in an OLMAT tool. The requirements could be significantly relaxed if the tool were to be used by the modeling or gaming groups which are a part of each DCD. These groups are comprised of military and civilian professionals who develop data, run, and modify computer models, simulations and tools to support the major study efforts of the school. Since these groups are tasked by other activities, they showed little interest in having or using an OLMAT tool due to the fact that they were never tasked to or organizational manpower analyses.

- **VISITED:**

FORT LEE	–	LOG CENTER
FORT SILL	–	FIELD ARTILLERY SCHOOL
FORT RUCKER	–	AVIATION SCHOOL
FORT BENNING	–	INFANTRY SCHOOL
FORT KNOX	–	ARMOR SCHOOL

- **POTENTIAL USERS:**

DCD SPECIAL STUDIES	–	OMS/MP & O&O PLAN WRITERS
DCD RAM	–	ROC RQMTS
TSM	–	?
MANPRINT POC	–	?

- **USER SPECIFICATIONS:** FRIENDLY!!
  - EASY TO LEARN
  - EASY TO USE
  - QUICK SETUP (TARGET: <4 HRS.)
  - QUICK RUN TIME (TARGET: <4 HRS.)
  - USES AVAILABLE DATA
  - IBM PC COMPATIBLE (ZENITH: Z248)
  - NO DEDICATED EQUIPMENT
  - UNCLASSIFIED

Figure 2.2 User requirements.

2.2 Review of Models

A critical element of this task was a review of existing models to identify tools and techniques applicable to Army systems. The objective was not only to ensure that this effort did not "reinvent the wheel" but also identify elements and concepts of existing models that could be tailored to help meet the OLMAT requirements. A review of the literature (such as the Catalog of Simulation Models and Wargames, TPDC 1987), and discussions with DCD personnel at various TRADOC Schools identified twelve models (two of which are PC-based -- MANCAP and BRAT) which seemed to provide OLMAT type results or data. These models are shown in Figure 2.3 and are discussed below.

- **MANCAP**: The Manpower Capability Model (MANCAP) is a model sponsored by ARI. MANCAP is a prototype front-end analysis tool which has been used to determine the manpower requirements for the LHX weapon system. Task 2 of this project is the detailed examination of MANCAP to determine its suitability of being modified to become the OLMAT tool. The results of this assessment are addressed in Tasks 2 and 3. Since the overall goal of this project is to produce a generic manpower analysis tool using as much of the MANCAP work as possible, the MANCAP review had a significant impact on the functional specifications for the OLMAT tool presented in section 2.3.

- **LEO**: In response to the Navy's need to include reliability, maintainability, and availability (RMA) considerations in the systems design phase to avoid costly attempts to correct design after acquisition, Advanced Technology has developed the LEO family of models. The Lagrangian Equipment Optimization (LEO) models incorporate a new analytic technique for maximizing the availability of complex systems subject to simultaneous multiple resource constraints such as total cost, total weight, and total volume. The technique maps objective function contours in multi-dimensional selection space and considers the intersections of these contours (surfaces) in the resulting homing algorithm. In this way, the optimization procedure results in execution times that are nearly linear with increasing system complexity rather than exponential (or factorial). Variations of the algorithm have produced two versions of the LEO models; LEO Version 1.2, a design-to-availability model, and

- MANCAP (ARI)
- LEO (NAVY)
- TIGER (NAVY)
- LCOM (AIR FORCE)
- TSAR (AIR FORCE)
- BRAT (AIR FORCE)
- ERAMS (TRADOC)
- RET COM (TRADOC)
- MACATAK (LOG CEN)
- AVLOG (LOG CEN)
- WHEELS (LOG CEN)
- COSAGE (CAA)

Figure 2.3 Models selected for review.

LEO Version 2.0, a sparing-to-availability model. Figure 2.4 is the run diagram for Version 1.2

Advanced Technology designed and developed LEO 1.2, a design-to-availability optimization methodology and associated computer model, which selects the set of equipments and the number (and types) of redundancies to optimize system availability, subject to three resource constraints (cost, weight, and volume). The method developed in the mathematical model is a form of generalized Lagrange optimization in which notational reliability block diagrams are constructed and compared. For example, LEO 1.2 might indicate that the designer should select a heavy, expensive, but reliable equipment, rather than a lighter, less costly one which would require a redundant configuration to achieve the same reliability.

In follow-on tasking for the Navy, Advanced Technology designed and developed LEO Version 2.0 for use in sparing optimization. LEO 2.0 is an automated sparing to availability model that selects spares to optimize the operational availability of an equipment or system. The optimization considers either mission or steady state operating scenarios and as many as three resource constraints. The features of the LEO 2.0 model include the following:

- Ability to optimize sparing allowances with any number of indentures;
- Spares allocations to support multi-phase missions;
- Sparing to steady-state availability;
- Spares allocations which allow for resupply of onboard spares.

The LEO models have shown that, even for relatively simple systems consisting of approximately 30 components, each having no more than three alternative choices, the execution time for optimization is less than one billionth of that for a global search. Both versions of LEO can optimize systems with several thousand components in a few minutes when provided with the core memory of a mainframe. Both versions of LEO also include time-dependent, mission-oriented operational availability, as well as the more traditional steady-state operational availability. Time-dependent operational availability is particularly useful in analyses that consider engagement scenarios during which the mean value of instantaneous availability would be expected to vary over the duration of the engagement.

- <u>TIGER</u>: TIGER is a simulation model, developed under NAVSEA 05MR, which calculates reliability, maintainability, and availability (RMA) values for complex systems under various operating scenarios. Inputs to the TIGER model include equipment parameters (mean time between failures (MTBF), mean time to repair (MTTR) and duty cycle), the system configuration (in the form of a Reliability block diagram

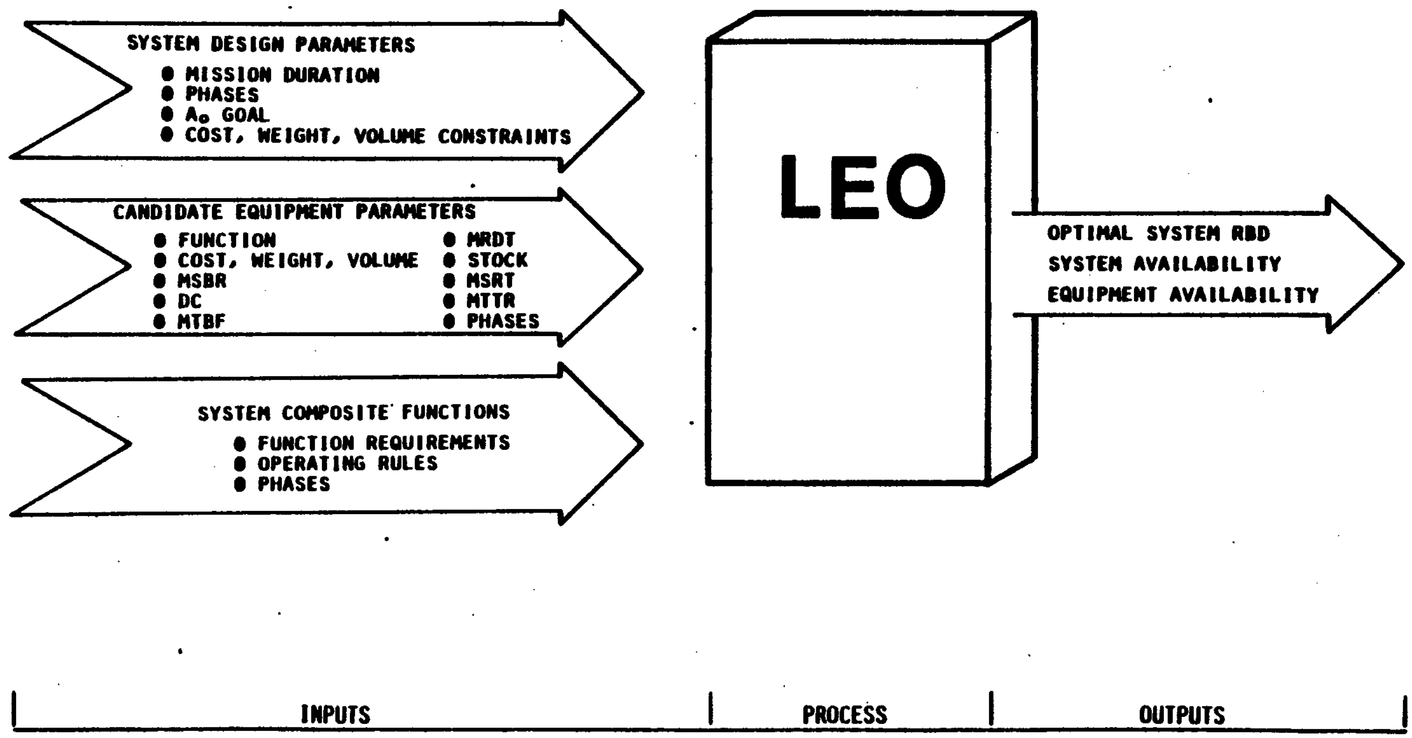


Figure 2.4 LEO 1.2 run diagram.

(RBD), and the system operating rules (allowable downtime, mission time lines, equipment spares, and maintenance policy). The TIGER model is an event-driven, Monte Carlo stochastic simulation model. The models' output include estimators of the systems reliability, readiness, availability, and a list of critical equipments. The TIGER model is written in a transportable ANSI 77 FORTRAN and is transferrable to the Cray, Cyber, IBM, VAX UNIVAC, etc. mainframes with few modifications. Because TIGER is a simulation model, the run time required for a system to approach steady-state is a function of the desired precision of the results and the size of the system modeled. As an approximation of run time, TIGER execution time increases roughly exponentially with the number of RBD blocks in the system. Figure 2.5 is the TIGER run diagram.

- **LCOM**: The Logistics Composite Model (LCOM) system is a large scale computer simulation system used to model base support resources requirements and assess the impact of their availability on the operational status of a weapon system. The system is a composite of several individual software systems that provide data extraction, analysis, simulation, and graphical display capabilities. It is an extremely powerful tool capable of simulating virtually any military maintenance environment. LCOM possesses the capability to define a resource objective while other resources are adjusted through heuristics to meet the defined objective. For instance, A/C sorties rate objectives can be set and maintenance manpower resources adjusted to meet the sorties rate objective.

An LCOM study, as depicted in Figure 2.6, involves two parallel efforts in the development of main and task networks. The main networks (mains) are developed based upon an approved operational scenario. Once the mains are constructed they are run through a compilation, referred to as Phase 1 & 2, to identify networking errors and create the majority of the LCOM Forms. Once a good compilation is achieved, the LCOM Forms are used to create a initialization file. To validate the main networks, simulations are run on the main networks in isolation. Both exogeneous and initialization files are required to run an LCOM simulation and are addressed later in this section.

Parallel to the main network effort is the building of task networks which contain the majority of maintenance actions associated with the aircraft. The process begins with the generation of a task listing and networks. This is done, for the most part, through computerized data extraction from the output file of the Maintenance Data Collection system and an automatic network generation program. The task listing is operationally audited using functional expert's technical estimates and historical records to obtain task times and crew sizes for maintenance actions.

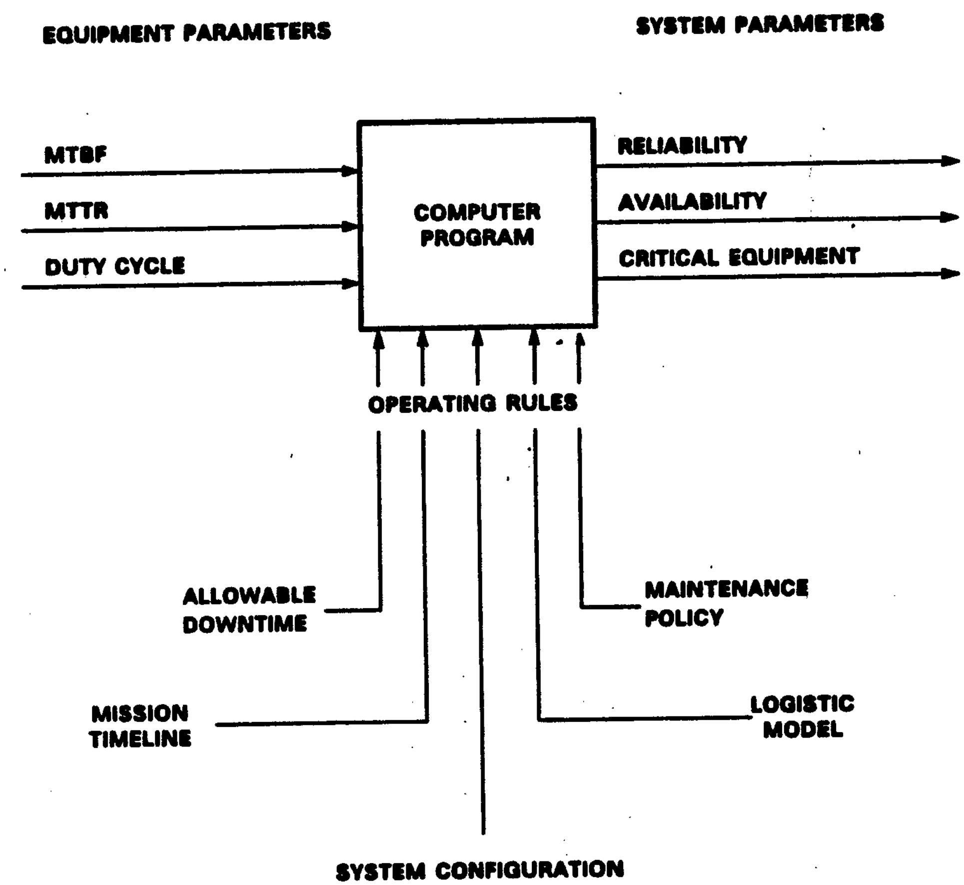


Figure 2.5 TIGER run diagram.

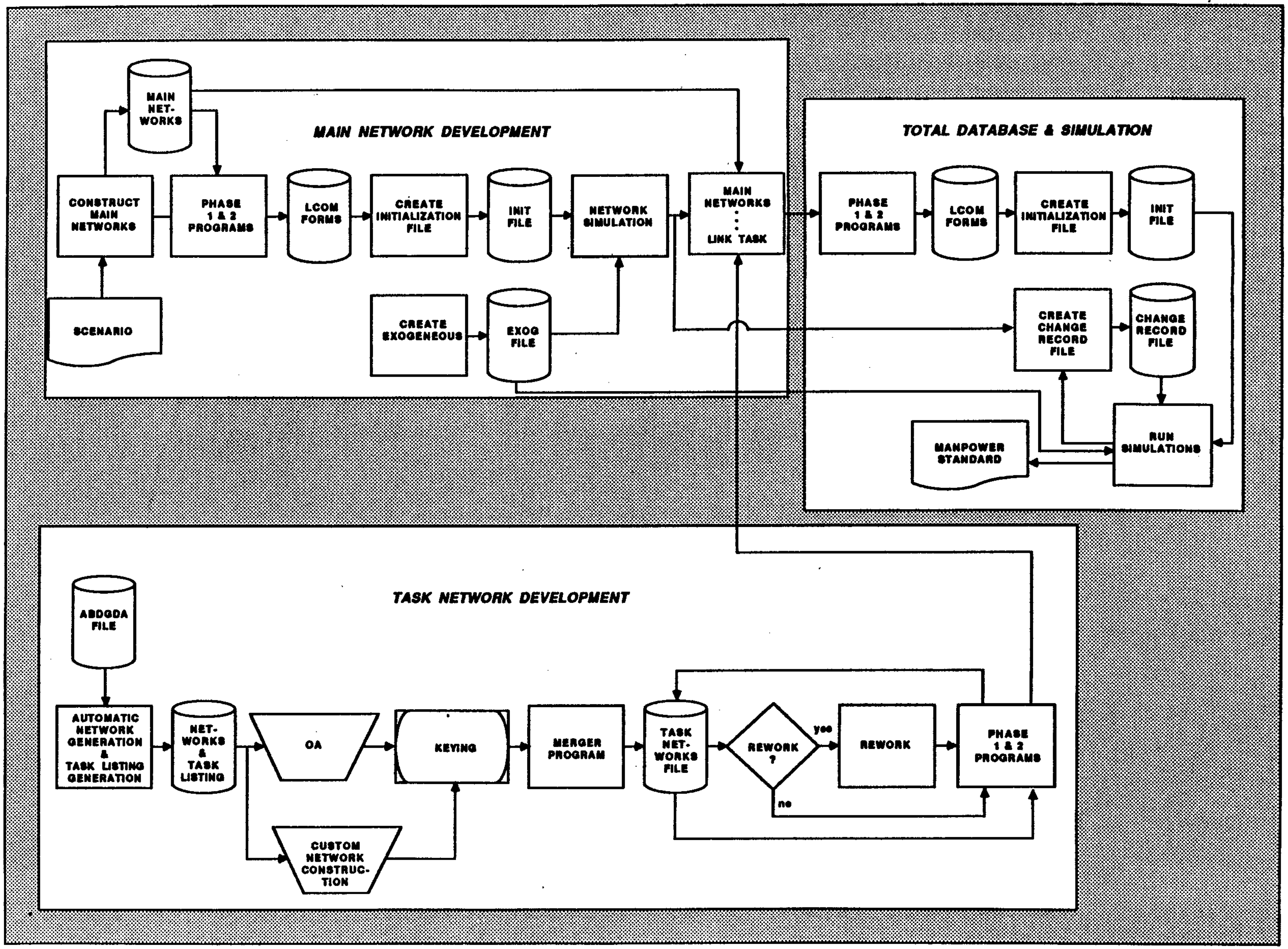


Figure 2.6 Generalized LCOM manpower study process.

Task networks undergo the same compilation process as the mains. Once a good compilation is achieved, then the mains and task networks are linked together. At this juncture the analyst runs the Phase 1 & 2 programs again, then proceeds to the completion of the LCOM forms. The analyst must add any forms not automatically generated by the Phase 1 & 2 programs. When this is accomplished the analyst can create an initialization file to run the simulation. Up to this point no simulation has been run to start the manpower determination process. Only now can the analyst begin the interactive process of determining a resource mix to meet the operational requirements of the scenario.

The LCOM simulation is a composite of individual subsystems which all contribute directly to the LCOM study process. The Simulation Subsystem consists of the three modules displayed in Figure 2.7.

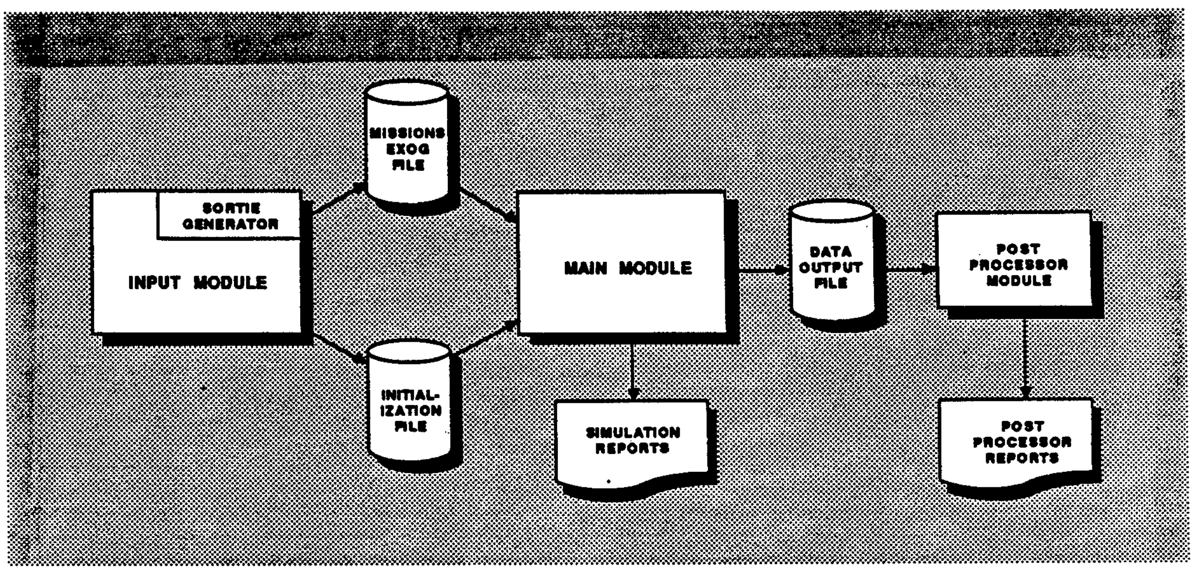


Figure 2.7 LCOM simulation subsystem.

The Simulation Subsystem is a stand-alone system used in the actual simulation process. The first module, the Input Module, translates the analyst-supplied data into a form which can be used by the Main Module. The translation process consists of:

- Initial conditions identification
- Event identification.

The initial conditions identification process translates LCOM input forms into an initialization file. The event identification process converts the sorties generation data into the exogeneous file which is a listing of sorties and activities the analyst schedules to occur at predetermined times in the simulation.

The Main Module, the second in the series, is the actual simulation itself which executes the scheduling of events, maintenance, and supply functions for the particular scenario. The Main Module uses the exogeneous and initialization files to run the actual simulation of aircraft maintenance task processing. Data are also collected at this time for inclusion in the simulation reports. The third module, the Post Processor, organizes a large number of detailed statistics to represent simulation results. The statistics to be displayed are specified by cards in the Change Record file.

- <u>**TSAR**</u>: The Theater Simulation of Airbase Resources (TSAR) is a simulation program developed to simulate a system of interdependent theater airbases through aircraft operations, unscheduled and scheduled aircraft maintenance, possible centralized intermediate repair facilities (CIRF) and theater-wide management of manpower, support equipment, spares, and aircraft resources. The model also permits the user to introduce damage to airbase facilities in order to evaluate its impact on base operations.

  TSAR is a Monte Carlo discrete-event simulation model that analyzes the interrelations among available resources and the capability of the airbases to generate aircraft sorties in a dynamic, rapidly evolving wartime environment. On-equipment maintenance tasks, parts and equipment repair jobs, munitions assembly, and facilities repair tasks are simulated at each of several airbases. A broad range of policy options that would increase initial resources, accelerate task completion, or improve theater resource utilization may be assessed using TSAR. Provisions also are included that provide the user a capability to assess dynamic variations in key management policies. The classes of resources treated in TSAR are (1) the aircraft, (2) the aircrews, (3) the ground personnel, (4) support equipment (AGE), (5) aircraft parts, (6) aircraft shelters, (7) munitions, (8) TRAP, (9) fuel, (10) building materials, and (11) airbase facilities.

  In broadest terms the TSAR simulation can be divided into three phases; the input and initialization phase, the simulation, and the output phase. The MAIN executive routine initiates these computational phases and, assisted by the TRIALS subroutine, controls processing for the specified number of trials as suggested in Figure 2.8. Each of the three phases uses various subroutines to carry out the required computations.

- <u>**BRAT**</u>: The Budget/Readiness Analysis Technique (BRAT) model was developed to provide a link between support resources and weapon system readiness. BRAT allows the user to examine the relationships which exist between the support system and the operating system.

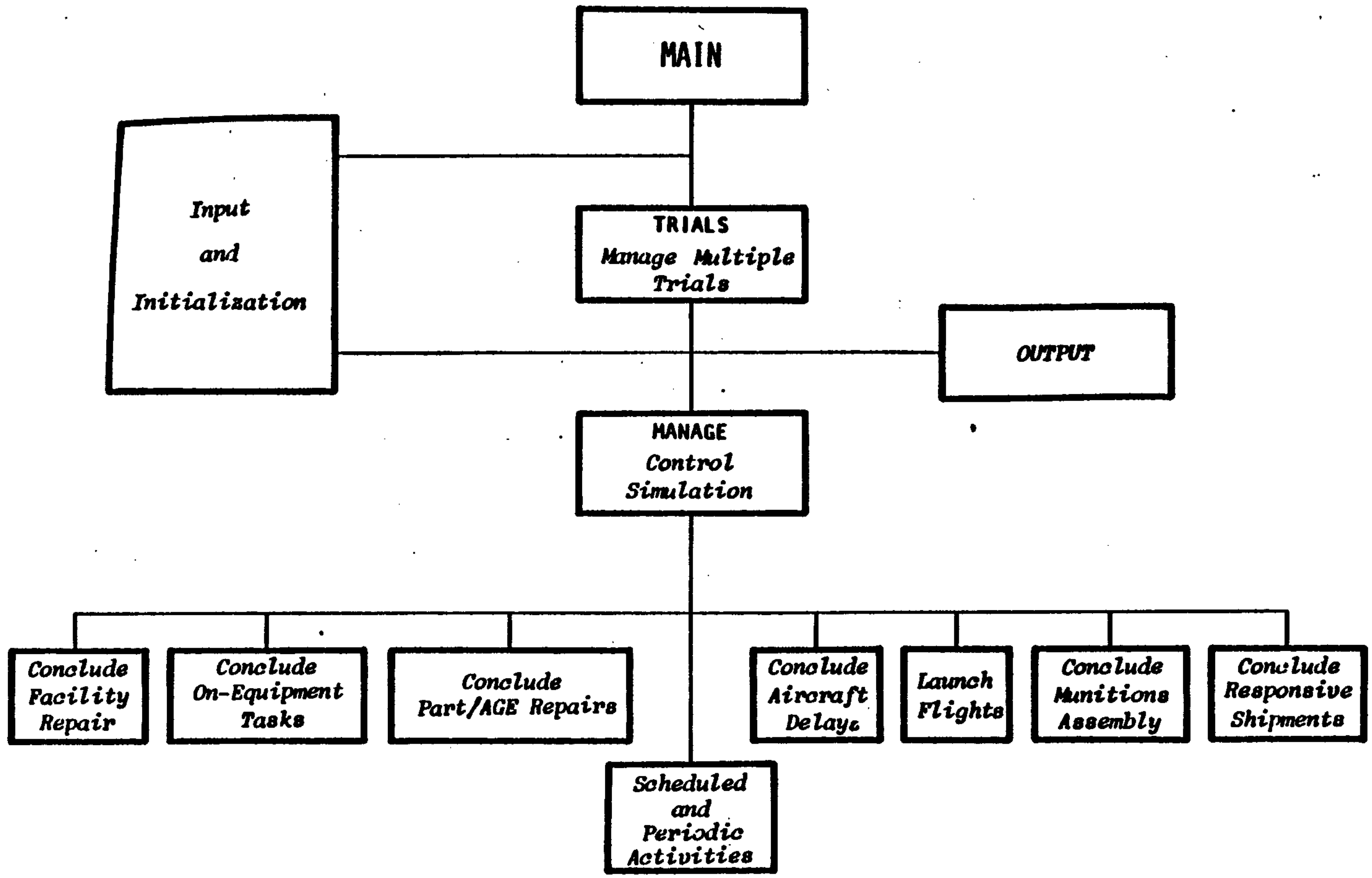


Figure 2.8 Basic structure of the TSAR simulation.

BRAT translates support resources (spares, support, equipment, and maintenance manpower) into a corresponding level of readiness. In this way, the user can test for limitations caused by these support resources. He can also use BRAT to determine adequate quantities of resources to achieve a target level of readiness. It can also be used to compare alternative support concepts and operational procedures. The readiness impact of hardware characteristics (e.g., reliability) can also be assessed.

BRAT is an event-sequenced Monte Carlo simulation model. The user is given a look at system operation over simulation time. Each day is divided into "time-slices." The model steps through each day by processing the events which occur in one time-slice and then moving on to process events in the next time-slice. All the events which are scheduled to occur in one time-slice are processed at a single point in time. The "clock" which is used to simulate time is then advanced by a fixed increment.

Thirteen types of primary events can occur during a BRAT run, each of which would change the status of the system. One additional event, Start-Surge, can occur but that is an infrequent event. Figure 2.9 is a graphic representation of the BRAT events and how they interrelate.

All resources which are directly modeled in BRAT (i.e., spares, manpower, and support equipment) are held in resource pools until needed. When the various events need resources in order to begin maintenance , these resource pools may become limiting constraints. When one (or more) of the pools become empty, then any activity needing that resource cannot proceed. The aircraft or component to be worked on is then placed in a holding mode, awaiting one or more of the resources.

- **<u>ERAMS and RETCOM</u>**: The Electronic RAM Simulation (ERAMS) and the Return to Combat (RETCOM) models are simulations resident at the Data Processing Field Office at Fort Leavenworth, KS. Although the RAM actions officers at the DCD's visited were aware of these tools available for system level analyses, no one we surveyed actually used them. The documentation was not available for a detailed review and should be obtained for review and possible use during Phase II of this effort.

- **<u>MACATK, AVLOG, and Wheels</u>**: These three models are in various stages of development and use at the Logistics Center at Fort Lee, VA. The models are used to support the maintenance Manpower Requirements Criteria (MARC) studies. All of the models are bottom-up, stochastic, event-sequenced simulations designed to produce auditable MARC data for manning levels which optimize the operational availability of the equipment being examined.

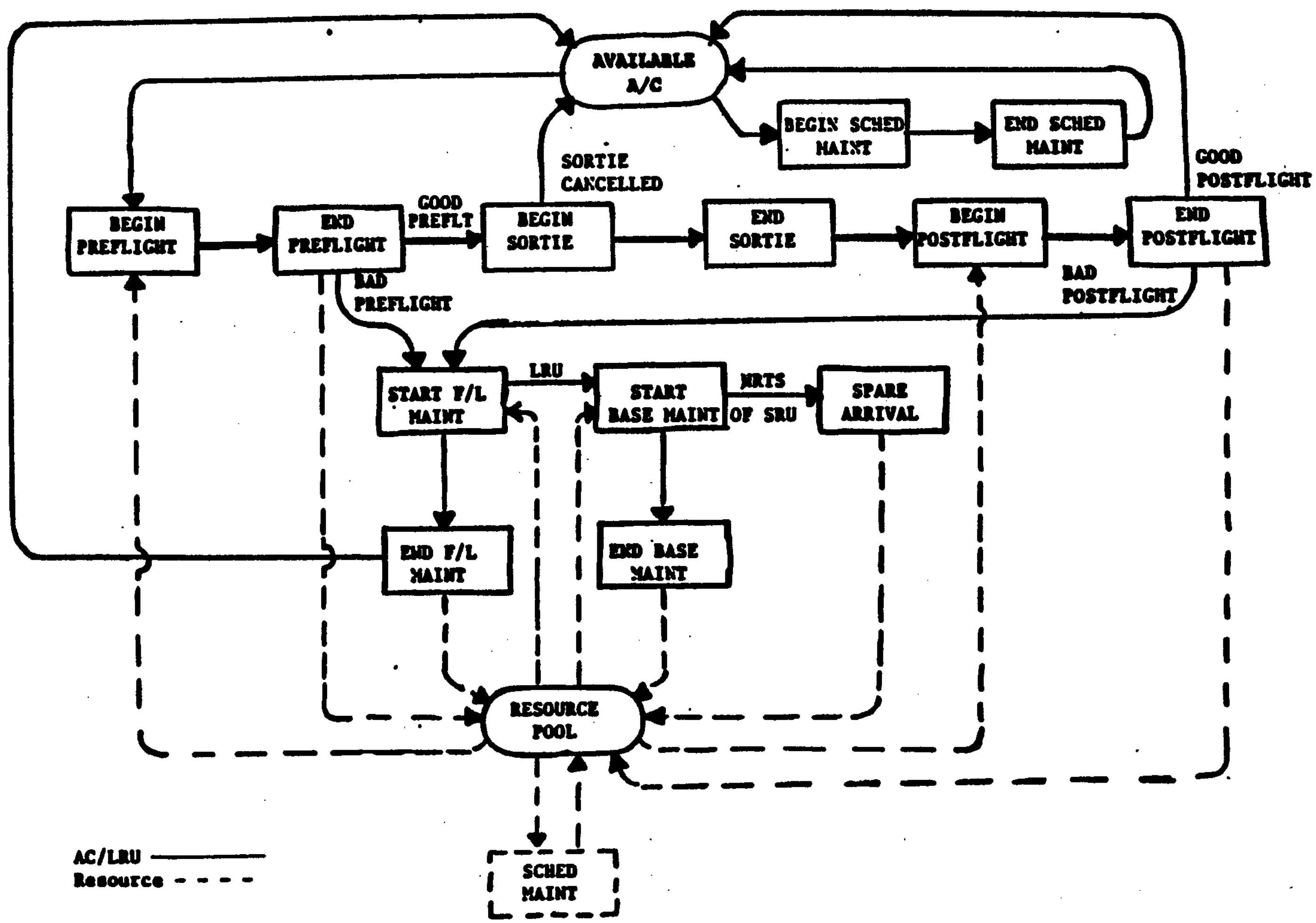


Figure 2.9 BRAT simulation events.

MACATK models tracked vehicles such as tasks, personnel carriers and howitzers and is presently being modified to support the first MARC track vehicle study. The study effort was begun two years ago. Both data collection, model modification, and execution are a time consuming process. It is estimated that after MACATK is fully developed, subsequent MARC studies will require 6 to 9 months for data collection and about 2 to 4 weeks to run the simulation.

The AVLOG model was recently used to support the Aviation MARC study. AVLOG is an event-sequenced, stochastic simulation designed specifically to evaluate aviation requirements. The modeling approach is shown in Figure 2.10. The primary model outputs are:

- Achieved Flight Hours vs. Requested Flight Hours
- Total manhours servicing and maintaining aircraft
- Manhours available for non-aircraft activities

Three primary sets of data are required for AVLOG. These are maintenance data, combat repair data, and scenario data. AVSCOM provides unscheduled maintenance data derived from the sample data collection (SDC) program. These data are developed by the Quality Assurance Directorate and provided to the Maintenance Directorate at AVSCOM where a preliminary data scrub is performed in order to score the data to doctrinally correct MOS types. AVSCOM then forwards both the doctrinal unscheduled maintenance burden data as well as the scheduled maintenance requirements which represent the phase maintenance requirements to the TRADOC community. All basic combat damage requirements are derived through the Ballistic Research Laboratories which provides simulated lab data for selected Soviet threats. These data are augmented by historical data obtained from SURVIAC at Wright-Patterson Air Force Base which is used to calibrate maintenance times derived from the labs. The TRADOC community then develops from the basic data representative work packages which include MOS requirements. Additionally, the modelling process requires scenario oriented data. The operating tempo and threat levels are obtained from the TRADOC community while specific aircraft loss rates due to combat are derived from the Concepts Analysis Agency through the total Army analysis process.

The WHEELS model is under development and has not been used for a MARC Study. It is anticipated that WHEELS will also be a stochastic simulation with setup and run times equivalent to MACATK and AVLOG.

- **COSAGE:** The Combat Sample Generator (COSAGE), although not a logistics model, was examined to determine its utility for providing combat damage data for model use similar to the way it is used by AVLOG. COSAGE is a two-sided, symmetrical, high-resolution,

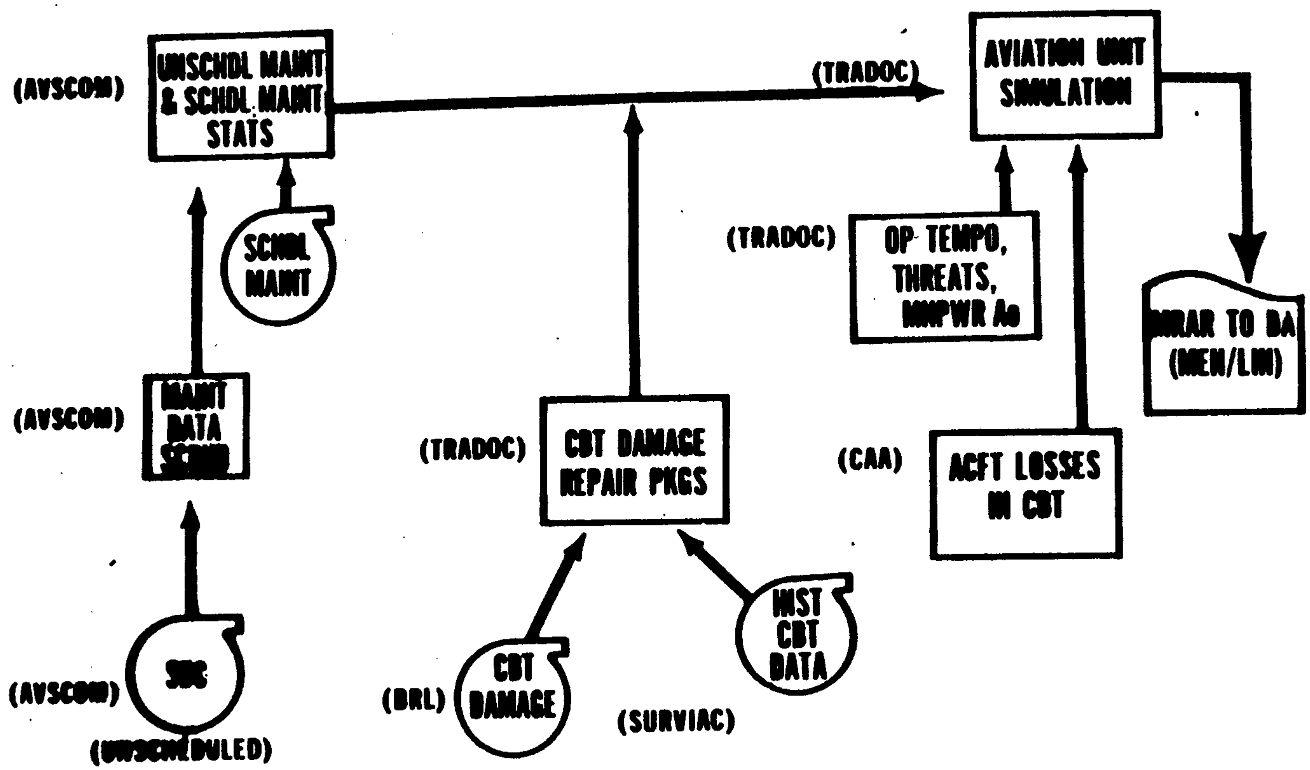


Figure 2.10 AVLOG simulation.

stochastic simulation model of combat between two forces. It is a discrete event simulation with stochastic phenomena modeled through events and processes. The Blue force can be modeled from as small as a fraction of a division up to a Combined Arms Army depending on the posture being simulated. The model simulates a 24-hour period of combat and produces expenditures of ammunition by type and caliber, losses of personnel (infantry, armor, artillery, other), and losses of major items of equipment. It generates combat samples for specified combat postures (e.g., attack, defense, delay, or defense light) on three terrain types (flat, rolling, and mountain). The Attrition Calibration Algorithm (ATCAL) is a two-part computer program which provides an interface for COSAGE and the Concepts Evaluation Model (CEM). The first part of ATCAL processes the results of the high-resolution model to produce attrition equation constants for CEM. These constants are readily available for a wide variety of equipment types and can provide an efficient means of accounting for combat damage in logistics simulation.

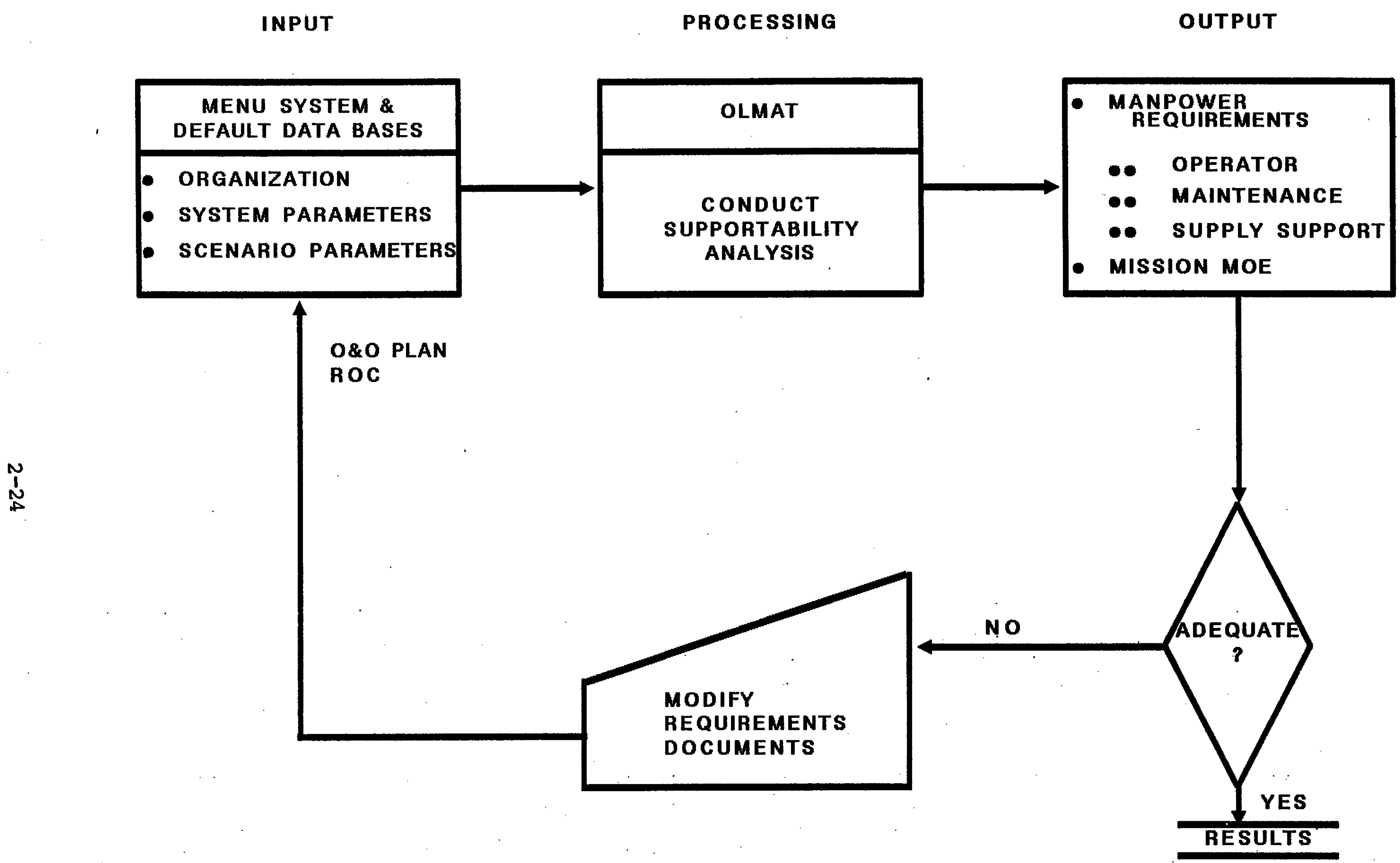


Figure 2.11 OLMAT level 0 specification.

2.3 Functional Definition

Figure 2.11 is the Level 0 specification for an OLMAT tool that fulfills the user requirements and functions identified during the analysis of user requirements and the model review. The specification shows that the model input will be via a very user friendly menu system which makes maximum use of default data bases which describe various organizations, weapon system parameters, and scenarios. The concept is that the user is never presented a "blank page". The input defaults for an organization, system parameter, or scenario will be logically modified by the user based on the current status of readily available information and documents normally developed by the TRADOC DCD's for an emerging weapon system, such as the Organizational and Operational Plans (O & O plans) and the Required Operational Capability (ROC). The OLMAT processing will conduct the supportability analysis (organizational level simulation) to estimate the system manpower requirements in terms of operator, maintenance and supply support and generate system appropriate measures of effectiveness such as the overall system operational availability. After a user review of the output, a determination will be made as to the adequacy of the manpower resources. If system or organizational modifications were indicated these changes are made in the appropriate document and the input data would be modified for an additional OLMAT run.

Based on what we know about Army user demographics, the requirements for an OLMAT type tool, and the interrelationships existing in the maintenance environment, OLMAT will possess the following factors as variable constraints:

- Organizational Parameters
- Operational Parameters
- RAM Parameters
- Combat Damage Parameters
- Logistics (Supply) Parameters
- Manpower Parameters
- Munitions Parameters

These factors all will affect organizational performance and all are variables in designing a new system. For example, RAM factors not only impact manpower requirements, but also operational and supply processes which can constrain organizational performance. Treating such factors as variables which are easy to change allows the user considerable power in performing sensitivity analyses and assessing system trade offs. The power to conduct sensitivity and trade off analyses will be further enhanced by a model with rapid run times.

OLMAT will combine the characteristics of the Logistics Composite Model (LCOM) and the Manpower Capabilities (MANCAP) Model in that it will have high capacity and be microcomputer-based. However, OLMAT will also incorporate capabilities of other models, such as deferring maintenance the way the Aviation Logistics (AVLOG) Model does, and looking ahead at equipment operating requirements such as the Theater Simulation of Airbase Resources Simulation does. Run times can be enhanced by programming efficiencies if a decision is made to design OLMAT as a stochastic simulation. If a decision is made to make OLMAT a deterministic model, short run times will be gained with efficient algorithms and computational procedures. The knowledge base gained from experience with models such as LCOM, MANCAP, and TIGER make a deterministic simulation a feasible alternative. Either modeling approach can be effectively applied to an OLMAT tool which meet the user requirements for a top-down, user friendly tool which will allow the user to assess the organizational impact of system and organizational requirements specified in the O & O plan and ROC for an emerging weapon system. The essential features of OLMAT will be a comprehensive default data library system and a menu system to guide the DCD action officer user through the data entry and execution processes.

The essence of any computerized tool is the data system. OLMAT will incorporate a default library concept to provide the user with data for comparability analysis, scenario data for organizations, event schedules for each scenario, equipment lists for organizations, and task data for each equipment item. The default libraries help the user set input parameters and select databases for the manpower simulation.

Figure 2.12 shows the default data library concept. Identification of the organizational type, level, and equipment will identifu approved generic scenarios and the equipment lists for that organization. The scenario and equipment lists will drive the default combat damage parameters. Each scenario will have three event schedules associated with it. Selection of a scenario will allow the choosing of one of the event schedules to be run. The RAM factors in the equipment lists and the combat damage parameters (which may be modified by the user) will determine the failure rates for the specific run. The user will have the capability to modify their RAM Factor for the specific system. Once all the inputs are specified, then the manpower simulation will be executed. For each simulation run

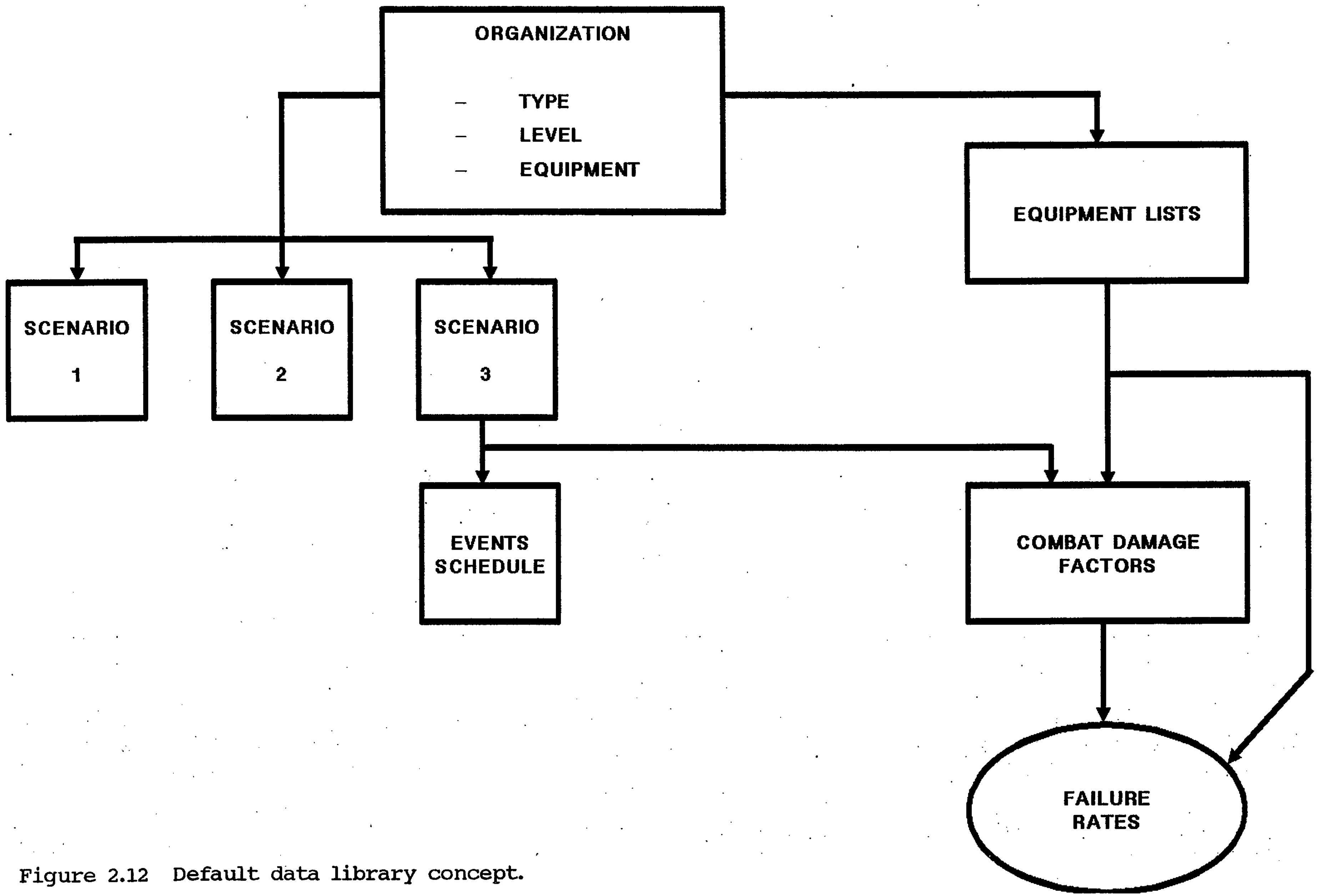


Figure 2.12 Default data library concept.

input parameters are saved as part of the Performance Summary Reports providing a complete audit trail.

The OLMAT menu system will provide the user an easy-to-use, top-down modeling approach which allows selection of a weapons system and its associated organizational, combat damage, RAM, scenario, and events schedule parameters in concert with the default libraries. The menus will control the Level 1 OLMAT process shown in Figure 2.13. The main menu configuration is shown in Figure 2.14.

Selecting Option 1 on the Main Menu will provide access to Process 1.0. Here, the user will first set the organization type, then the organization level, and finally specify the equipment resident in the organization. The user will never presented a blank screen. As a minimum, the available default data will be presented. The default values will be accepted or modified as required. Figure 2.15 shows a typical detail for the Organizational Menu.

Once organizational specifications are complete, the Main Menu will be accessed and Option 2 will be selected to provide access to Process 2.0. The Parameters Menu will present the user with the options shown in Figure 2.16. Setting RAM parameters will relate to the selection of the equipment made in the organizational specifications. OLMAT will search its data libraries for the selected system. If not found, it will ask the user to select a comparable system to be modified for the analysis. An Equipment List Editing Screen will allow the user to change information on individual tasks or modify subsystem parameters.

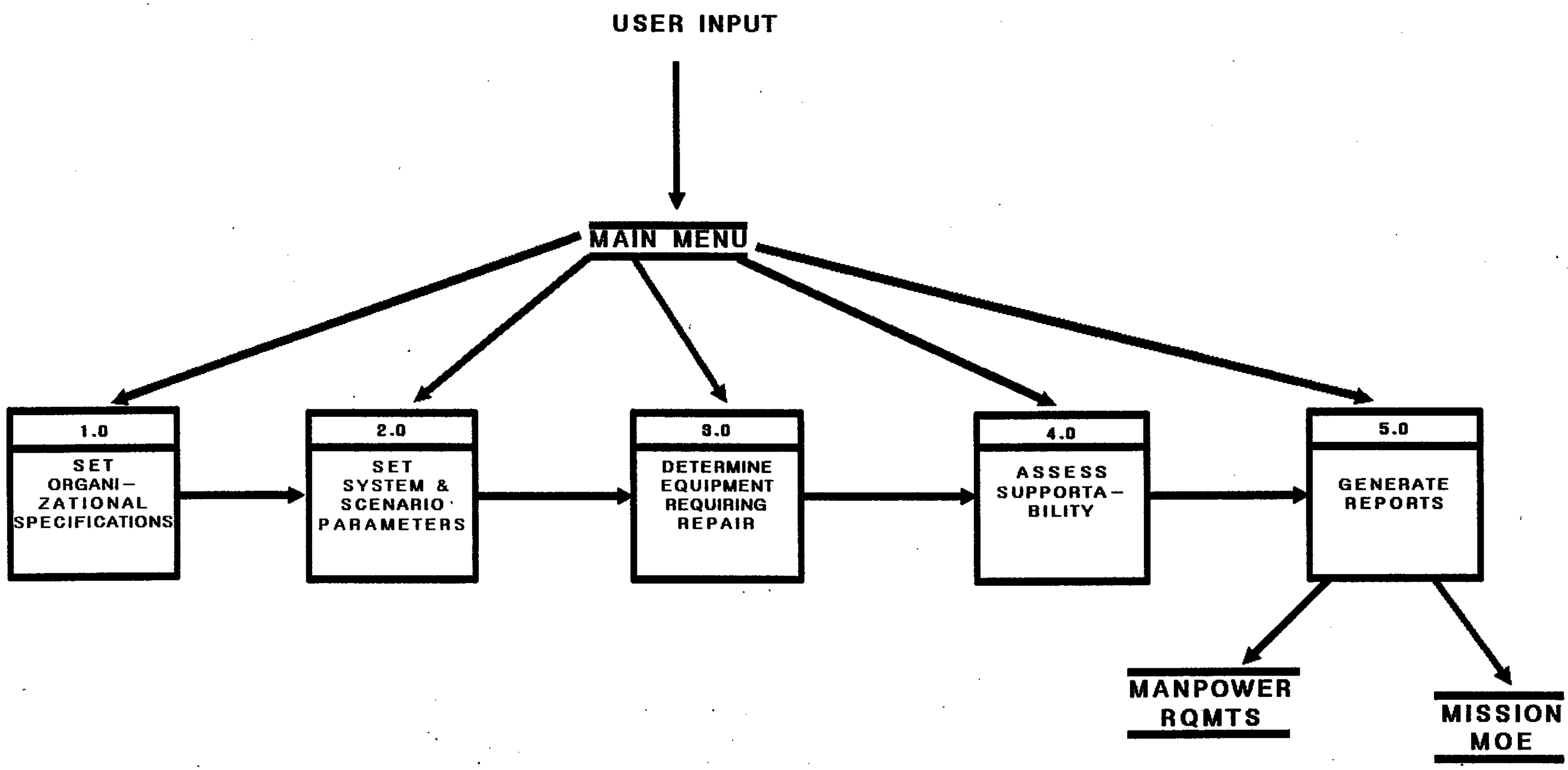


Figure 2.13 OLMAT level 1 specification.

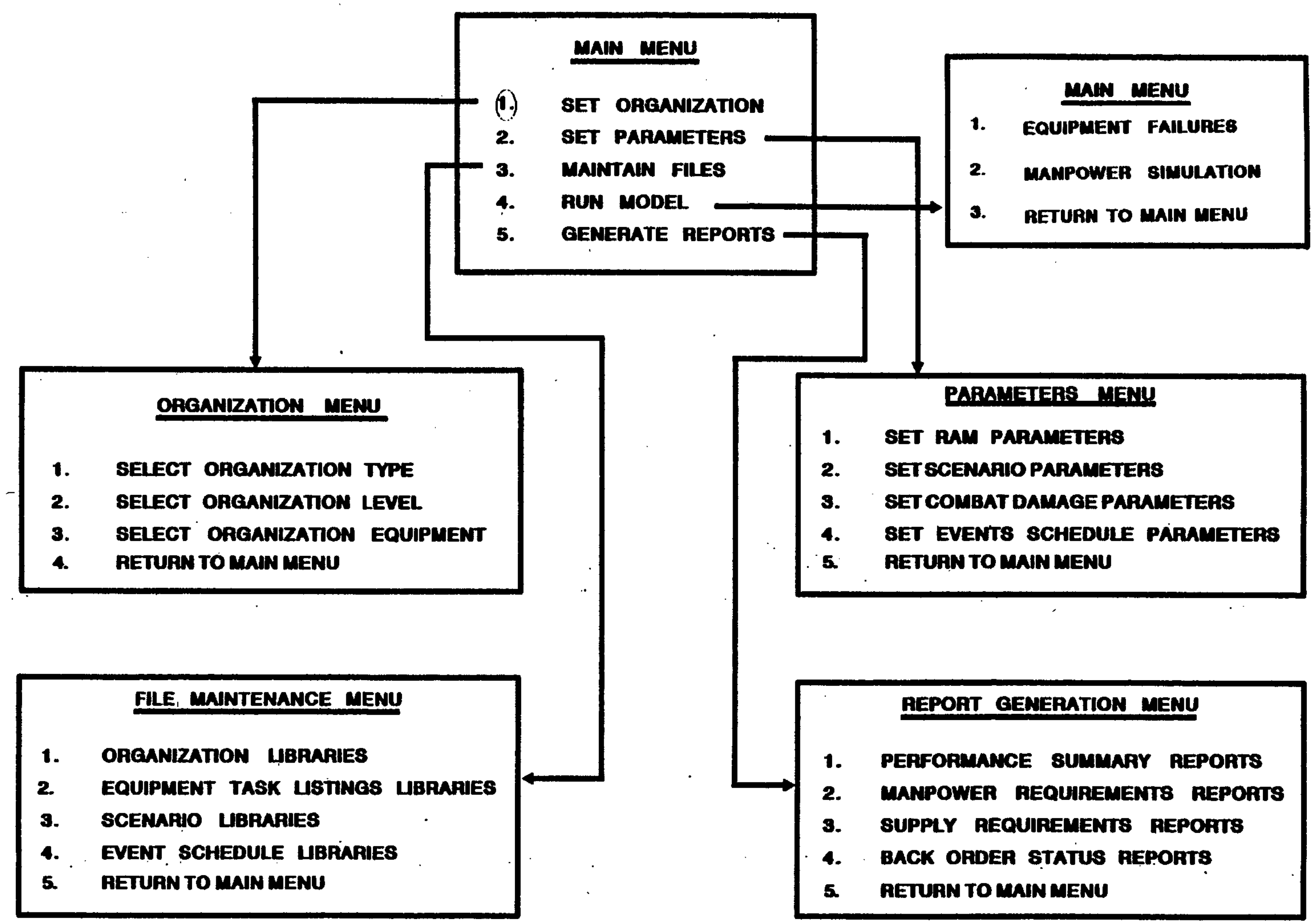


Figure 2.14 OLMAT Main Menu Configuration

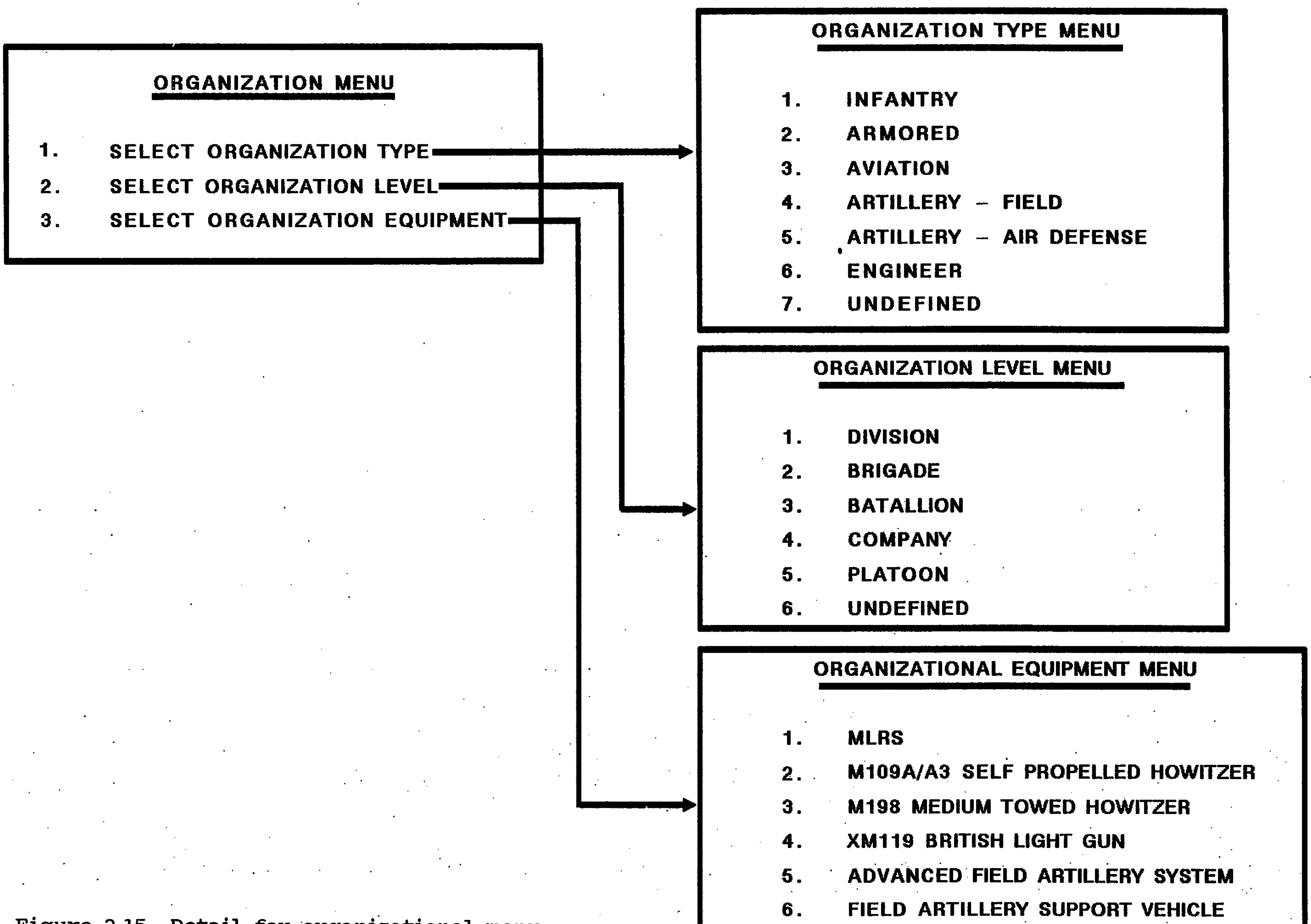


Figure 2.15 Detail for organizational menu.

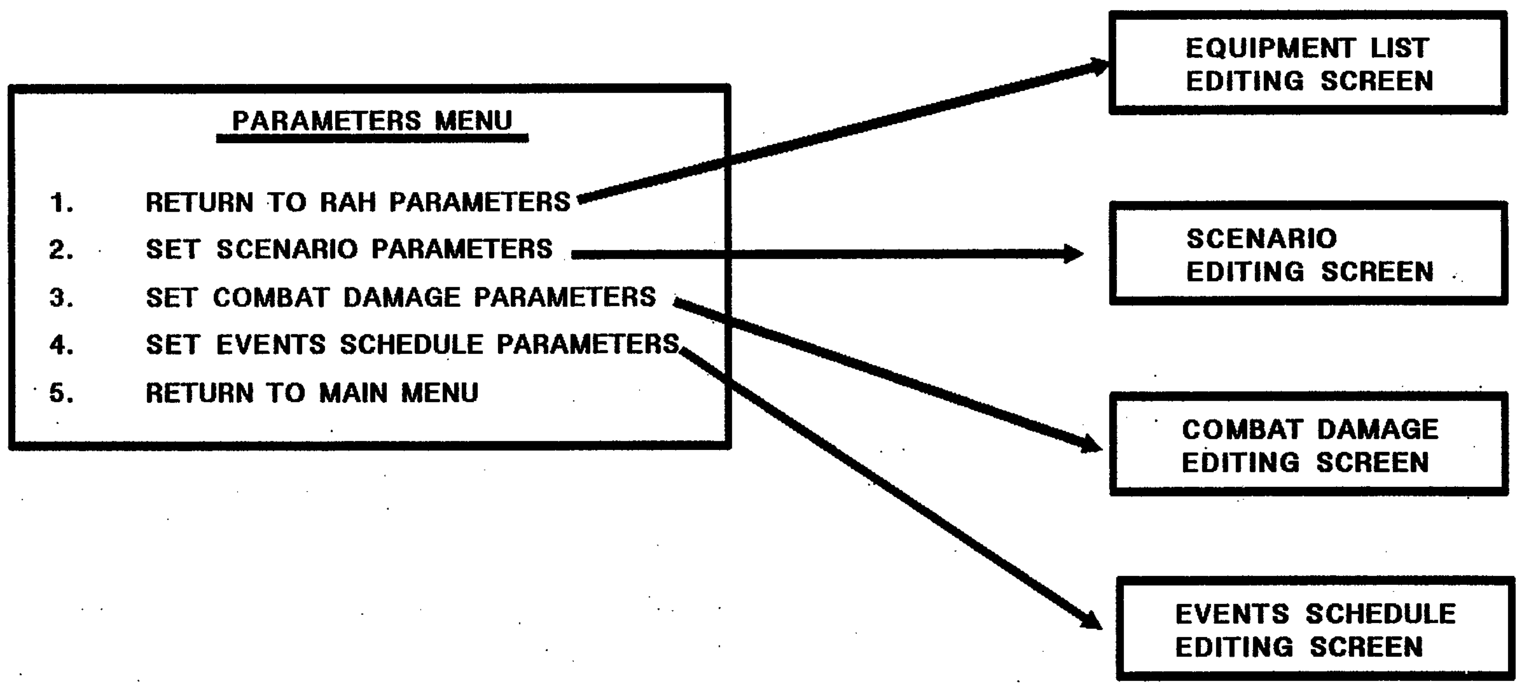


Figure 2.16 Detail for parameters menu.

The scenario parameters will be set in the same way. The scenario will be driven by the organization selection since OLMAT selects the default scenarios based upon the organization type specified, and the user will set the combat damage parameters through the use of a Combat Damage Editing Screen. The event schedule will be dependent upon the scenario selected. Some of the items on the Event Schedule Editing Screen cannot be edited without changing the scenario. For example, if changes were made to the amount of time spent, or the number of rounds to be fired in an operating mode, then the scenario which defines the operations mode must be changed. The chaining to the scenario will be automatic to insure a proper accounting and documentation of the input variables which drive the model run.

When the data input is complete, the main menu again will be accessed and Option 3 provides access to Processes 3.0 and 4.0. Process 3.0 is a preprocessor for the operations and maintenance simulator which defines the equipment requiring repair in terms of combat damage and RAM failures. Combat damage will be assessed during a time increment based on the scenario defined combat actions (defense, delay, offense, reserve) which occur. The analytical basis for the assessment are COSAGE generated attrition rates for the weapon type and the established ACTAL methodology for using the COSAGE output to model the combat effects for varying size groups of equipment. The RAM portion of Process 3.0 will be designed to operate automatically or be assessed by menu to be used as a stand alone module to be used by the RAM analyst in establishing or analyzing RAM parameters at the system level. In its normal operating mode the RAM module accounts for equipment usage during a time increment and will modify failure rates based on the expected combat damage (similar processes are

A Parameters Report will specify all the parameters selected for the subject run. This will include:

The Organization -

Equipment type(s)

Organization level

Organization type

The Scenario -

Ops Modes

Length of time in Ops Modes

Sequencing of Ops Modes

Number of maintenance levels

Number of groups with their assigned equipment

Length of time for the simulation run

Number of groups

Groups sizes

Combat damage losses by Ops Mode (killed vs. recoverable)

The Events Schedule -

A listing event by event which shows:

Time Period (TP) start time

TP length

Group designator

Ops Mode

Group size

RAM Parameters -

A listing of the tasks will show:

- Trigger tasks which designates the subsystem
- Failure indicators for all tasks
- Assigned MOS(s)
- Maintenance Level(s)
- Tasks that are designated as parts
- Task time
- Crew size
- Priority
- Task name
- Ops Mode indicator

Combat Damage Parameters -

- Affected tasks
- Increase in failures due to combat damage
- Impact on equipment (killed or repairable)

A Performance Summary Report will capitulate the results of the selected simulation run. It will display by Group and TP the following items:

- Equipment Type
- Equipment Availability
- Maintenance Level(s)
- MOS(s)
- Manpower Required by MOS

A Back Order Status Report will contain a listing of all items which show back order by Group, Maintenance Level, and TP. Thus, back order resources can be traced to a specific group if the back order occurred at Maintenance Level I or II. The following items will bee contained in the report:

The item which went back order

The TP the back order occurred in

The quantity of items which went back order

The Default Libraries Listing will allow the user to specify a library listing which contains all of the items in each library. The Maintain Files Option of the Main Menu (Option 4) will provide the user the capability to edit the libraries. Once selected a Files Selection Menu will be presented. For each selection a formatted screen will be presented to facilitate the changing of task library information.

employed in MANCAP and LCOM), and will identify maintenance tasks for input to Process 4.0. Process 4.0 will simulate the ability of the organization and its support structure (defined by Processes 1.0 and 2.0) to maintain and supply the system. The simulation process is defined for MANCAP. If a decision were to be made to incorporate a major revision of the simulation to improve run time and capacity, the simulation process will be modified to incoporate appropriate concepts employed in LCOM, TSAR, TIGER, AVLOG, and MACATK, as well as MANCAP. In fact, it is experience with these simulations (particularly LCOM, MANCAP, and TIGER) which make an extremely fast running deterministic simulation a feasible alternative. This alternative is described in Section 4 with additional modeling concepts in Appendix C.

When the simulation is complete the main menu will again be retrieved and Option 5 will provid eaccess to Process 5.0, the Report Generator. After selecting this option from the Main Menu, the Generate Reports Menu (Figure Needed) will be presented. This menu contains four options:

1 -- Parameters Report
2 -- Performance Summary Report
3 -- Back Order Status Report
4 -- Default Library Listings

3.0 MANCAP EXAMINATION

The Army Research Institute for Behavioral and Social Sciences managed the development of a prototype front-end analysis tool to determine manpower requirements for the LHX weapon system. This computerized tool is called MANCAP, and was programmed originally to operate on an Apple Macintosh computer, and then converted for use on an IBM-PC compatible. Figure 3.1 provides an overview of the MANCAP modules and functions. MANCAP consists of a supply support, operations and maintenance, and operator support modules. Data are entered into each module, and supply, maintenance, and operator manpower requirements and mission MOE are generated as output. The supply support and operator support modules consist of Lotus 1-2-3 spreadsheet programs, while the operations and maintenance module is a simulation program written in TURBO PASCAL.

Task 3 of this project involved examining the logic of the MANCAP program. Since the largest module of the MANCAP program, the operations and maintenance module, is a large simulation program, the main focus was on this module. Section 3.1 describes the process and evaluation questions considered for the review of the operations and maintenance module; the process and related questions for evaluating the supply and operators modules are described in section 3.2.

3.1 Operations and Maintenance Module Review Process

The first operation conducted under this task was loading the operations and maintenance module software onto the hard disk of the computer. The time required to perform a simulation was recorded, and the output reviewed and evaluated for utility.

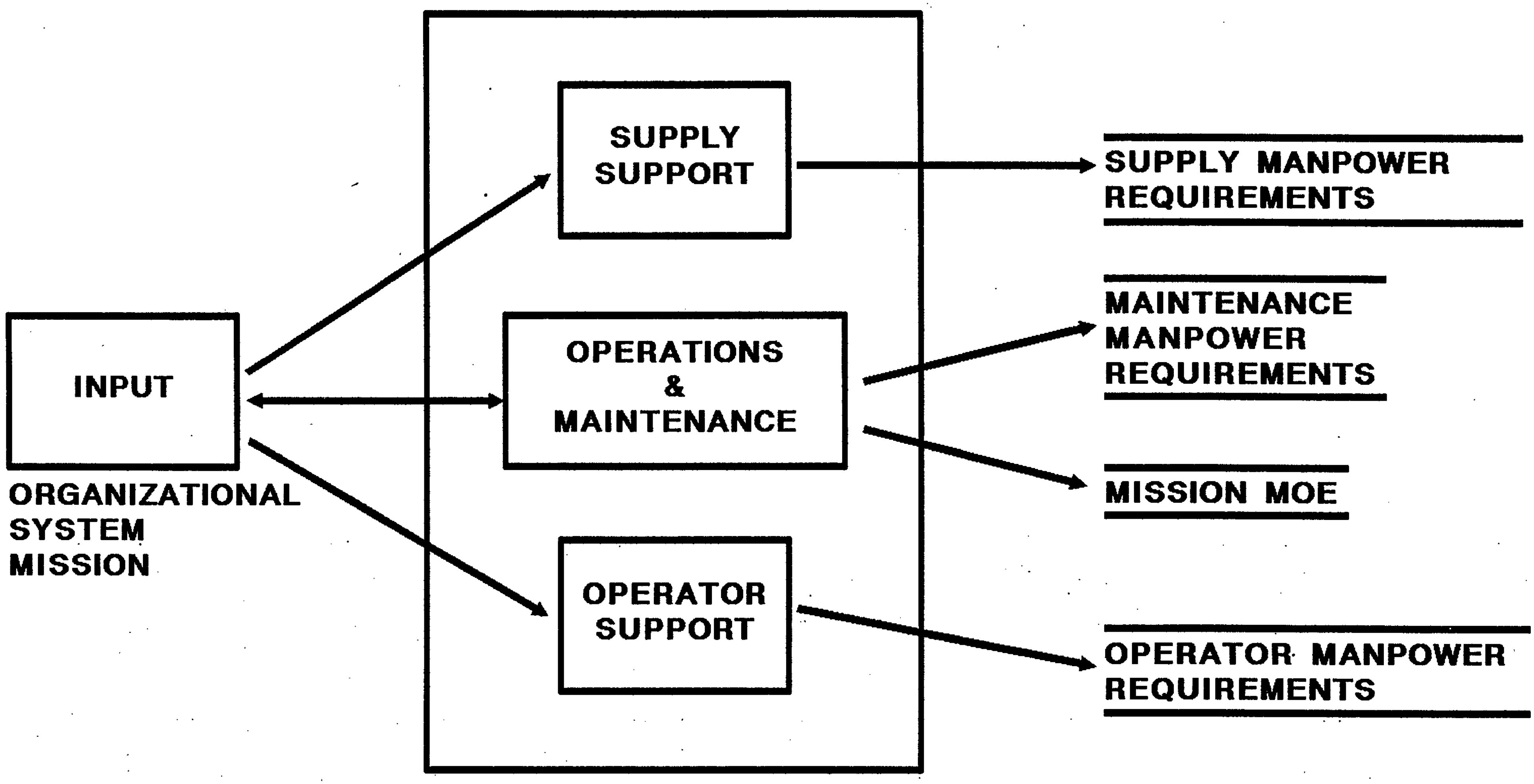


Figure 3.1 MANCAP modules and functions.

DATA INPUT (SETUP MODULE)

- ESTIMATED TIME FOR INITIAL SETUP – 1 WEEK (3 DAYS AFTER LEARNING)
- ESTIMATED TIME TO MODIFY INPUT FOR SENSITIVITY ANALYSES – (<1 HOUR AFTER LEARNING)
- ALL INPUT DATA ARE "HARDWIRED"
- NOT INTERACTIVE (MUST USE PASCAL EDITOR THEN RECOMPILE)
- DATA ELEMENT DEFINITIONS NOT WELL DOCUMENTED
- PRIMARY DATA ITEMS
  - COMMAND, SERVICE, & SUPPLY HIERARCHY
  - PROPERTIES & TYPES OF WEAPONS SYSTEMS, MOSs, MISSIONS
  - WEAPON SYSTEM ARRAYS (FAILURE DATA, MOSs, SERVICE LEVELS)
  - MISSION DATA (# WEAPONS OPERATIONAL TO COMPLETE, DELTA RAM FOR COMBAT DAMAGE)
  - SUPPLY DATA (PROBABILITY OF HAVING PART, ETC.)
  - SETUP SERVICE QUEUES (PERSONNEL, SHIFTS, WEAPON SYSTEM)

Figure 3.2 Mancap input requirements.

- OPERATIONS & MAINTENANCE MODULE
  - EVENT SEQUENCED, MONTE CARLO SIMULATION
  - SIMULATION PARAMETERS "HARD–WIRED" (# OF MOS, # CMD SVC & SUPPLY LEVELS, # OF WEAPON SYSTEMS, # MISSION TYPES)
  - RUNTIME FOR SIX 24–HOUR CYCLES (8 ITERATIONS): 18 HOURS (FAST PC–AT)
- SUPPLY SUPPORT MODULE
  - REQUIRES LOTUS 1–2–3 SOFTWARE
  - LOTUS SPREADSHEETS FOR FUEL, AMMUNITION, AND REPAIR PARTS NOT INTERFACED WITH OPERATIONS & MAINTENANCE MODULE (ALL INPUT MANUAL)
  - SETUP TIME (1 HOUR AFTER LEARNING)
- OPERATOR SUPPORT MODULE
  - REQUIRES LOTUS 1–2–3 SOFTWARE
  - LOTUS SPREADSHEET NOT INTERFACED WITH OPERATIONS & MAINTENANCE MODULE
  - SETUP TIME (10 MIN AFTER LEARNING)

Figure 3.3 MANCAP processing.

- OPERATION & MAINTENANCE MODULE
  - MAINTENANCE MOS REQUIREMENTS BY ORGANIZATION LEVEL, BY SHIFT
  - MOE: SERVICE PROCESSING BY LEVEL,
    FREQUENCY OF REPAIR BY LEVEL,
    AVERAGE TIME–TO–REPAIR BY LEVEL,
    MISSION FREQUENCY COUNT,
    AVERAGE FLIGHT TIME
- SUPPLY SUPPORT MODULE
  - MANPOWER REQUIREMENTS SPREADSHEETS
- OPERATOR SUPPORT MODULE
  - MANPOWER REQUIREMENTS SPREADSHEETS

Figure 3.4 MANCAP output.

Detailed information on the input, process, and output for each of the three modules are listed in detail below. This information is provided in list format for ease of review, and to clarify recurring data information requirements across organizations, weapons systems, etc.

OPERATIONS AND MAINTENANCE MODULE

INPUT:

Service Organization Data for each level of service
Name of the organization
Ordered supply support company choices
Travel time to Supply
Travel time to next level
    Personnel Data:
        MOS loading by shift
        Start and Stop times for each shift

Personnel required for each weapon system:
    Position title
    Indirect maintenance time percentage
    Direct maintenance time percentage

For each weapon system:
    Weapon system name
    Failure statistics:
        Mean time between failure
        Mean Time to Essential Maintenance Action
        Mean Time To Repair
        Mean time to require parts
        Percent of time that weapon system is :
            repairable at each service level
        Percent of time repair requires technical inspection
        How long technical inspection is
            available at each supply level
        Who technical inspector is by MOS

    MOS preferences: Percent of time the weapon system requires each MOS

    MOS preference for each level one service
        Percentage of time personnel in each MOS perform level one services
        Time to perform level one service
        Number of personnel in the MOS
        Percent of time performing technical inspections
        Time to perform technical inspection
            Priority level

Mix of missions performed for each type of mission:
    Name of mission
    Time to perform mission
    Number and type of weapon systems required to start mission
    Number and type of weapon systems required to finish mission

Change in failure statistics as a result of performing mission:
Mean Time Between Failure
Mean Time to Essential Maintenance Action

Supply hierarchy data
Location
Probability of having parts for each weapon system'
Time to get to next supply level if parts unavailable

Command mission data:
Number of missions to be performed by each command
Mission cycle start time

Set length of simulation run time

PROCESS:

The simulation module is built up on a series of queues: personnel (by MOS), events, and weapon systems, and a modeling of a number of functions: mission scenario, aircraft maintenance, repair parts supply, petroleum, oil and lubricants (POL) supply, and ammunition supply. The probabilities of the weapon system requiring repair are determined from RAM data, and are mission dependent. The execution of the simulation is from event to event, where the events are ordered based upon the mission, the organization, and the priorities entered by the user. Failures are exponentially distributed across the duration of the mission. As personnel requirements are generated, they are placed in a "tub file". There is a "tub file" for each work center that is required. As personnel in the MOS become available, they remove work from the "tub file" in priority sequences.

The first operating cycle generates the first set of events (mission start, mission completion, mission failure, maintenance required). These events generate manpower requirements, which are prioritized, and filed. As simulated personnel become available, they perform prioritized work from the tub file. This constitutes one cycle. As many cycles as desired can be run separately, in order to reach "steady state". The simulation is constrained by computer RAM and program structure: The file accumulates information in the volatile computer memory, and saves the data to the hard disk at the normal completion of the simulation. The length of the cycle can be increased, but this decreases the number of cycles that can be simulated by the same factor.

OUTPUT:

Cumulative Statistics by MOS
Shift
Direct Time
Indirect Time
Other Time
Total Time
Workload Required
Personnel Strength

Aircraft Hours Per Day at Each Service Level for Weapon System
Process Time for:
    Average time at each service level
    Average travel time from level one to each higher level
    Average travel time from higher level to level one

Frequency of Repair for Weapon Systems and Mission
Average Time to Repair at Each Service Level for Weapon System
Mission Frequency Count by Mission Name and Weapon System
Number of Aircraft Starting by No. of Aircraft Completing for Weapon System
Column and Row Percents
Average Flying Time Per Aircraft Launched by Mission Name
Number of Aircraft Starting by No. of Aircraft Completing for Weapon System
Overall Average Mission Time

Grand total:
    Total time of weapon system by mission
    Time available
    Time flying
    Time asleep
    Time at each supply level
    Time at each service level
    Total simulation time

<u>Operator Support Module:</u>

<u>INPUT:</u>
    Average mission durations
    Number of operations required/day
    Number of systems engaged in operation
    Doctrinal requirements
    By unit:
        Average number of aircraft launched
        Average mission duration
        Number of missions per day
    Number of days
    Environmental relative factor

<u>PROCESS:</u>

Interactive Lotus 1-2-3 spreadsheet based upon output from operations and maintenance module.

<u>OUTPUT:</u>

Number of pilots required.

<u>Supply Support Module:</u>

<u>INPUT:</u>
    Stockage level
    Lines or levels
    Number of requirements
    Number of days

PROCESS:

Interactive Lotus 1-2-3 spreadsheet based upon output from operations and maintenance module.

OUTPUT:

Number of supply personnel required.

MANCAP CONSTRAINTS

Users must define operating scenario for each system to be modeled.

The simulation is mission dependent, with combat damage parameters specified for each mission by a predetermined decrement in the RAM parameters.

Model output provides the ability to infer personnel and training requirements.

Model assesses direct role of personnel only. Indirect workload is not assessed.

4.0 Feasibility of Modifying MANCAP for OLMAT

This task examined the technical feasibility of modifying or enhancing the MANCAP model to correct any shortfalls in its ability to meet the user specifications and the ideal OLMAT functions identified in Task 1. This assessment entailed an examination of the MANCAP code and data flows for the affected functions and the modules to ensure that recommended "fixes" would not destroy the model's integrity.

The first shortfall identified was that of a user-friendly data entry model. MANCAP is coded in PASCAL and the user must have some knowledge of PASCAL simply to input data. Much of the data are hardwired and located in numerous different arrays. Once data entry is complete, the model must be re-compiled. The entire data entry process is difficult and time consuming. The user-friendly "front-end" described for OLMAT must be constructed in order for MANCAP to achieve the user requirements for ease and speed of data entry and modification.

The second shortfall is that the RAM failure generator is embedded in the Operations and Maintenance Module which was designed specifically for aircraft operations. In order to efficiently simulate other types of systems, the RAM failure generator should be a separate module which provides RAM failures to the maintenance simulation.

A related shortfall is that MANCAP requires that the user adjust the system's RAM parameters to account for combat damage. The model provides no rational basis for the requested modifications. A separate combat damage generator is needed. The AVLOG model uses COSAGE (both models described in Task 1) attrition factors as the basis for assessing combat damage in a variety of scenarios and could provide the factors necessary for assessing combat damage.

A minor shortfall is that the supply support and operator support modules are not linked to the operations and maintenance module. This causes the user to pay an additional time penalty by having to manually input the simulation results from the operations and maintenance modules. These modules could easily be linked to help achieve the user requirements for a user-friendly, short setup and runtime simulation.

Another minor shortfall is that MANCAP is poorly documented and there are no user instructions. Although the program is well documented internally (in PASCAL code), numerous data items are not defined and are difficult to locate. Also, there is not user instruction. A well documented model and a DCD user-oriented user instruction is essential to meet the user-friendly test. A revised systems documentation and a user instruction will significantly decrease the user's learning curve as well as the frustration level often associated with learning to use a new tool.

In summary, MANCAP performs all the OLMAT functions and can be used as the OLMAT centerpiece. Relatively minor, but essential, modifications can create a generic manpower analysis tool and improve both setup and runtime while decreasing learning time and frustrations. Several modification alternatives which involve MANCAP are addressed in Task 4.

5.0 OLMAT Development Alternatives

This task examined three alternative approaches to developing a tool which achieves the OLMAT goals. Each alternative achieves the OLMAT form and function goals (a generic, top-down tool) but meets the user requirements for runtime to varying degrees. Figure 5.1 displays the features of the three alternatives compared to the MANCAP base case. Figure 5.2 displays the development work required for each alternative and provides an estimate of the professional staff months required.

Of primary importance, the base case is not generic. MANCAP models an aviation organization and must be modified to simulate other types of organizations. All alternatives are generic. They incorporate a user-friendly front-end which employes a library system of organization, scenarios, and data which facilitate the model setup. The proposed OLMAT data entry module would reduce the initial setup time to about four hours (from 3 to 10 days for MANCAP) for each alternative. Subsequent modifications for sensitivity analyses would be much faster (on the order of 10 to 30 minutes, depending on the scope of the modification).

Each alternative also requires a similar RAM failure generator and a combat damage generator. The RAM failure generator used for MANCAP can be broken out from the operations and maintenance module and used to create a separate module for alternatives 1 and 2. A new module must be built for alternative 3 to provide RAM failure data in a form required by a deterministic operations and support module. The module development time for each alternative is the same

FEATURE	BASE CASE (MANCAP)	ALT 1	ALT 2	ALT 3
PROGRAMMING LANGUAGE	PASCAL	PASCAL	PASCAL OR "C"	MICROSAINT OR "C"
SETUP TIME	3 – 10 DAYS	TARGET: < 4 HRS	TARGET: < 4 HRS	TARGET: < 4 HRS
RUNTIME				
• 6 – 24 HR CYCLES (8 REPS) AND 20 MIE	18 HOURS	TARGET: 18 HRS	TARGET: 10 – 12 HRS	TARGET: < 4 HRS
• INCREASE REPS, CYCLES OR MIE	NON – LINEAR INCREASE	NON – LINEAR INCREASE	NON – LINEAR INCREASE	LINEAR INCREASE
ORGANIZATIONAL SIZE	PLT TO BN	PLT TO DIV	PLT TO DIV	PLT TO DIV
MAXIMUM TIME SIMULATED	6 – 12 DAYS	6 – 12 DAYS	6 – 18 DAYS	180 DAYS
GENERIC	NO	YES	YES	YES

Figure 5.1 OLMAT alternative features.

COMPONENT	BASE CASE	ALT 1 (MINOR MANCAP MOD)	ALT 2 (MAJOR MANCAP MOD)	ALT 3 NEW MODEL
DATA ENTRY MODULE	MISSING	DEVELOP: 8 – 10 PSM	DEVELOP: 7 – 9 PSM	DEVELOP: 6 – 8 PSM
RAM FAILURE GENERATOR	IMBEDDED IN O&M MODULE	MODIFY: 2 – 3 PSM	DEVELOP: 1 – 2 PSM	DEVELOP: 1 – 2 PSM
COMBAT DAMAGE GENERATOR	MISSING	DEVELOP: 1 – 2 PSM	DEVELOP: 1 – 2 PSM	DEVELOP: 1 –2 PSM
O&M MODULE	EVENT SEQUENCED MONTE CARLO	EVENT SEQUENCED MONTE CARLO MODIFY: 1 – 2 PSM	MONTE CARLO MODIFY: 2 – 3 PSM	TIME SEQUENCED DETERMINISTIC DEVELOP: 2 – 3 PSM
SUPPLY SUPPORT & OPERATER SUPPORT MODULE	USES LOTUS SPREADSHEETS	CONNECT TO O&M MODULE MODIFY: 0 – 1 PSM	CONNECT TO O&M MODULE MODIFY: 0 – 1 PSM	IMBEDDED IN SIMULATION DEVELOP: 0 PSM
SYSTEM DOCUMENTATION	INCOMPLETE	MODIFY: 1 PSM	DEVELOP: 2 PSM	DEVELOP: 2 PSM
USER INSTRUCTION	MISSING	DEVELOP: 3 PSM	DEVELOP: 3 PSM	DEVELOP: 3 PSM
TOTAL PSM ESTIMATES	———	RANGE: 16 – 22 PSM EXPECTED: 19 PSM	RANGE: 16 – 22 PSM EXPECTED: 19 PSM	RANGE: 15 – 20 PSM EXPECTED: 17.5 PSM

NOTE: PSM = PROFESSIONAL STAFF MONTHS

Figure 5.2 OLMAT development alternatives.

since the RAM modeling concepts are straight forward and well known. The combat generator module will also be similar for each alternative. The proposed module will employ COSAGE generated attrition calibration (ATCAL) results to provide the automatic adjustment of the RAM parameters to account for combat damage. A similar adjustment is made in the MANCAP base case, but the user is asked to make the modification as input data.

The primary difference among the alternatives is the manner in which the operations and maintenance module is handled. The module for alternative 1 is simply the MANCAP operations and support module with the RAM failure generator removed. The data entry module, RAM failure generator, and combat damage generator are designed to provide the data required to run the module as it currently exists. We would then expect only minor improvements in runtime (about 18 hours for 8 replications) and practical constraints on the size of the organization to be simulated. Although it is theoretically feasible to define large units to be simulated by the MANCAP operations and support module as it exists, the runtime would increase in a non-linear (perhaps exponential) fashion as the number of equipment items increases from the twenty items normally simulated in MANCAP.

The operations and support module for alternative 2 is the MANCAP Monte Carlo simulation with major modifications to incorporate programming and modeling efficiencies aimed at reducing the runtime and increasing the capability for handling larger, non-aviation units. It is expected that runtime could be reduced to about 10 to 12 hours for the size units currently modeled in MANCAP and have the capability to handle maneuver battalion size units without severe runtime penalties. Efficiencies could be gained in the development of the data entry, RAM failure and combat damage generator modules since the linkages to the operator support module would not be pre-defined. This alternative also incorporates a potential programming language change from PASCAL to "C" if it found that the simulator modifications would work more efficiently in that environment.

Alternative 3 proposes the most drastic change in the simulation concept for the operations and maintenance module. A deterministic simulation is proposed to make a large reduction in runtime and provide the capability to simulate much larger units (up to division level) without significant runtime penalties. Typically, deterministic models are feasible only after stochastic simulations have laid the conceptual framework. Our knowledge of MANCAP gained as a result of tasks 2 and 3, our very detailed work with LCOM and TSAR and our review of MACATK and AVLOG provide the conceptual framework for the development of a new operations and support module which should reduce runtimes to significantly less than the target of four hours. Appendix C contains the general approach envisioned for the deterministic simulations of the operations and support module. The programming language envisioned is "C".

The supply support and operator support models for the MANCAP base case are deterministic LOTUS spreadsheets. In alternatives 2 and 3, these spreadsheets would be modified to accept input directly from the operation and support module.

In alternative 3, these functions are embedded in the simulation as described in Appendix C.

All alternatives will provide system documentation and user instructions designed to reduce the user learning curve.

A fourth alternative was considered when the project results were briefed to ARI. This alternative was similar to alternative 3 in that a completely new simulation would be built, but the concept for the new operations and support module was a Monte Carlo simulation. Since the effort would be constrained to the MANCAP approach, it was felt that the development time would be the same as for alternative 3. It is expected that a new Monte Carlo simulation could be designed to reduce runtime to around 8 hours for a division level organization. The programming language would be MICROSAINT or "C" and determined based on efficiency when the programming specifications are defined.

6.0 Work Plan for OLMAT Development

As a result of a briefing to ARI, alternative 3 was selected for development. The work plan for this development is contained in Appendix D. The plan provides schedule and resource projections as well as procedures for data collection, quality control and model verification and validation.

APPENDIX A

PROJECT WORK PLAN

Modeling of Unit Performance and Manpower Requirements

Work Order No.: 535.002

Submitted to OPM 16 November 1987

Cost Code No.: 20-32-0553-AN

Submitted by: Advanced Technology, Inc.
12001 Sunrise Valley Drive
Reston, Virginia 22091

Submitted to: Office of Personnel Management
Attn: Mr. Jack Vincent (632-6172)

1. Project Synopsis

ARI has been providing MANPRINT support for the Advanced Field Artillery System (AFAS) project for over a year. AFAS is very large and complex and the ability to answer questions about manpower and personnel at this stage is critical to the success of the project. Manpower and personnel information affects not only the individual piece of equipment, but the entire organization for which the system is a part. This includes the maintenance, supply, and support personnel. To answer questions about the cost of a new system in terms of manpower and personnel depends on being able to consider all aspects of the system and the organization. This project will have as its focus both of these aspects. This project, however, deals with the broader issue of developing a capability to answer these questions for any system, and have that capability within the Army itself. It is necessary to answer the questions about AFAS, by itself and as part of the Armored Family of Vehicles (AFV), and also to devleop generic tools for MANPRINT. AFAS provides a test case for development of an ideal General Purpose MANPRIINT Model. The project deliverables are phased to provide a clean audit of the research that leads to the development of a model of systems/organizational performance. The project phasing also provides ARI with maximum control over the direction of the research effort. Phase I is an examination of the applicability of adapting the LHX MANCAP Model to support a full range of Army modeling requirements (TRADOC needs and requirements) and concludes with a recommendation for a generic modeling approach to be pursued in Phase II. Phase II is the implementation of the Phase I recommendations.

2. Agency Objective

In order to ensure that existing methods and techniques used for manpower and personnel modeling are developed and adapted to fulfill Army requirements to the extent possible, the first objective of this study will be to examine existing models. Applicability of these methods for use on Army systems must be determined and the need for tailoring established. Once the capability has been established, it will be applied to an Army system (the AFAS) to serve as an examplar for training Army scientists and manpower/personnel specialists in the TSM activities at proponent schools and at AMC's project offices and laboratories. This effort will focus on the development of a model of systems/organizational performance which is sensitive to the soldier-system interface. TRADOC and AMC users will be trained to use the analytic capabilities of the model to assess the resource implementations system decisions prior to "bending metal".

3. Plan Summary

Phase 1, Task 1

TITLE: General Purpose Model Definition

DELIVERABLE: In Process Review Briefing and Letter Report (Model Conceptual Specification)

This task will identify the specifications for an ideal General Purpose MANPRINT Model in relation to Army systems. Deliverables are an In Process Review (IPR) for ARI, OPM, TRADOC, and AMC; and a letter report outlining general conceptual specifications of the General Purpose MANPRINT Model (GPM^2).

Phase 1 Task 2

TITLE: LHX MANCAP Model Comparison to GPM^2

DELIVERABLE: In Process Review Briefing and Letter Report

This task will identify the capabilities of the LHX MANCAP Model, then compare those capabilities with the capabilities of the ideal model for MANPRINT as specified in Task 1. Deliverables are an IPR and letter report on comparison of the two models.

Phase 1, Task 3

TITLE: LHX Model Modification Assessment

DELIVERABLE: In Process Review Briefing and Letter Report

Task 3 assesses the feasibility of modifying the LHX MANCAP model to meet GPM^2 requirements. If feasible, the nature and extent of the modifications will be identified. The deliverables are an IPR Briefing for ARI and OPM to present the findings and a letter report on the modifications assessment.

Phase 1, Task 4

TITLE: Recommendations

DELIVERABLE: Findings Report and Decision Briefing

Task 4 will present the contractor's recommendations to ARI.

The deliverables are a findings report and a decision briefing which synthesizes the results and findings of the previous subtasks. A course of action is recommended for the general purpose model development in Phase 2.

Phase 1, Task 5

TITLE: Management Plan Development

DELIVERABLE: Management Plan for Phase 2

The last task in Phase 1 will be to develop the management plan for Phase 2 based upon ARI's decision to continue model development and the selected course of action.

The deliverable is the Phase 2 Management Plan in the appropriate OPM format.

4. Activity Schedule

Phase 1, Task 1

TITLE: General Purpose Model Definition

DELIVERABLE: In Process Review Briefing and Letter Report (Model Conceptual Specification)

This task will identify the specifications for an ideal General Purpose MANPRINT Model in relation to Army systems. Deliverables are an In Process Review (IPR) Briefing for ARI, OPM and other agencies such as TRADOC and AMC that ARI may desire to invite; and a letter report outlining general conceptual specifications of the General Purpose MANPRINT Model (GPM^2).

Task 1 incorporates four subtasks.

Subtask 1.1 - Hardware and Software Definition. The first step is to define the type of hardware and software envisioned for GPM^2. This subtask will be accomplished in tandem with Subtask 1.2. A requirements analysis of potential users for the ideal model will be conducted to solidify the hardware and software requirements.

Subtask 1.2 - Army Systems Needs. The goal of this subtask is to specify the input, output, and operational requirements to properly analyze not only AFAS and LHX unit performance, but the unit performance requirements of a wide range of Army systems. Visits will be made to the Army Logistics Center at Fort Lee, the TSM-Cannon at Fort Sill, and the Armament Labs and Project Management Office at Picatinny Arsenal, the Infantry School at Fort Benning, and the Armor School at Fort Knox to obtain a complete picture of TRADOC and AMC requirements for the ideal MANPRINT Model. In the midst of this process, the preliminary requirements for an AFAS application will be identified.

Subtask 1.3 - Alternative Models. This subtask will review Army models currently in use or under development. Many of these will be identified through research at the Army Logistics Center and others through documents provided by ARI. Other DoD models will also be reviewed for their general purpose capabilities.

Subtask 1.4 - General Purpose MANPRINT Model Conceptual Specifications. This subtask is the synthesis of all the research in the other Task 1 subtasks into the conceptual definition of GPM^2. The input and output reuirements will be specified for the model. Also, system design options will be shown to incorporate the various Army families of weapons systems and their respective operating environments. In this subtask, the hardware/software specifications will be incorporated into the definition of the ideal General Purpose MANPRINT Model capabilities.

Phase 1 Task 2

TITLE: LHX MANCAP Model Comparison to GPM^2

DELIVERABLE: In Process Review Briefing and Letter Report

This task will identify the capabilities of the LHX MANCAP Model, then compare those capabilities with the capabilities of the ideal model for MANPRINT as specified in Task 1. Deliverables are an IPR Briefing and a letter report on comparison of the two models.

The LHX MANCAP Model Comparison to GPM^2 Evaluation incorporates two subtasks.

Subtask 2.1 - Evaluate the MANCAP Model Capabilities. The documentation and model software provided by ARI will be analyzed to produce a statement of MANCAP Model capabilities to be compared to the ideal General Purpose MANPRINT Model's capabilities as specified in Task 1. The documentation review will produce a statement of what the model is supposed to do. The model will be made operational at ATI asnd exercised to determine what it can do.

Subtask 2.2 - LHX MANCAP Model Modification Requirements Analysis. The MANCAP capabilities identified in Subtask 2.1 will be compared to those specified for the the GPM^2 in Task 1 to identify shortfalls in meeting the requirements for a general purpose model. Trips to AVSCOM in St. Louis and the Aviation School at Ft. Rucker will insure that the GPM^2 encompasses the Army's aviation requirements. The comparisons will include an examination and assessment of input/output requirements and the processing algorithms. The results of this subtask provide the basis for the Task 3 assessment.

Phase 1, Task 3

TITLE: LHX MANCAP Model Modification Assessment

DELIVERABLE: In Process Review Briefing and Letter Report

Task 3 assesses the feasibility of modifying the LHX model to meet the GPM^2 requirements. If feasible, the nature and extent of the modifications will be identified. The deliverables are an IPR Briefing for ARI and OPM to present the findings, and a letter report on the modifications assessment.

Task 3 uses the results of Tasks 1 and 2 to determine the modifications necessary to the MANCAP model. Given the requirements and capabilities shortfalls established in Tasks 2 and 3, we will work backwards from output, to process, to input modifications to assess whether or not such modifications are feasible. A set of achievable modifications will be identified and a crosswalk to the General Purpose MANPRINT Model requirements developed. The results will be briefed to ARI and OPM during a project IPR.

Phase 1, Task 4

TITLE: Recommendations

DELIVERABLE: Findings Report and Decision Briefing

Task 4 will present the contractor's recommendations to ARI.

The deliverables are a findings report and a decision briefing which synthesizes the results and findings of the previous subtasks. A course of action is recommended for the general purpose model development in Phase 2.

Task 4 synthesizes the results of Tasks 1, 2, and 3 and develops alternatives for building a General Purpose Model for MANPRINT. The alternatives will include MANCAP modifications alternatives and new model development alternatives. Each alternative will be assessed based on cost and effectiveness (the degree to which the alternative provides capabilities which map to user requirements). Recommendations will be presented in a written report which summarizes the research/analysis effort and a decision briefing for ARI and OPM. All previous IPRs and findings will be rolled into the final report.

Phase 1, Task 5

TITLE: Management Plan Development

DELIVERABLE: Management Plan for Phase II

The last task in Phase 1 will be to develop the management plan for Phase 2 based upon ARI's decision to continue model development and the selected course of action.

The deliverable is the management plan for Phase 2 in the appropriate OPM format.

The management plan will detail the development of the alternative selected in Phase 1, Task 4 and provide schedule and resource projections. The plan will include the procedures for data collection, quality control and model verfication/validation.

5. Schedule of Deliverables

Phase 1, Task 4

TITLE: Recommendations

DELIVERABLE: Findings Report

The Findings Report will contain the following sections:

1.0 Needs Assessment

- 1.1 GPM^2 Requirements
- 1.2 Army Systems Requirements in General
- 1.3 AFAS Test Case Needs

2.0 Input Data Assessment

- 2.1 GPM^2 Input Data Assessment
- 2.2 AFAS Input Data Assessment

3.0 Output Assessment

- 3.1 LHX Output Assessment
- 3.2 AFAS Output Assessment

4.0 LHX Assessment

- 4.1 Assessment of LHX Input vs. GPM^2 Requirements
- 4.2 Assessment of LHX Output vs. GPM^2
- 4.3 Assessment of LHX Processor

5.0 Alternative Models

- 5.1 Modifications to meet AFAS needs
- 5.2 Modifications to meet GPM^2 Requirements

6.0 GPM^2 Construction

- 6.1 Short summaries of other model capabilities

7.0 GPM^2 Development

Phase 1, Task 5

TITLE: Management Plan Development

DELIVERABLE: Management Plan for Phase 2

The management plan for Phase 2 will contain the following sections:

1. Title Page
2. Project Synopsis
3. Agency Objective
4. Plan Summary
5. Activity Schedule
6. Schedule of Deliverables
7. Schedule of Resource Requirements
8. Cost Schedule
9. Administrative Information
10. General Guidance
11. Key Words

Phase 1, Task 1

TITLE:	General Purpose Model Definition
DELIVERABLE:	In Process Review
	General Purpose Model Conceptual Specification

This task will identify the specifications for an ideal General Purpose MANPRINT Model in relation to Army systems. Deliverables are an In Process Review (IPR) for ARI, OPM, TRADOC, and AMC; and a report outlining general conceptual specifications of the General Purpose MANPRINT Model (GPM^2).

Labor:

Labor Category	# Days
Principal Investigator	21
Management Analyst	10
Systems Analyst	15
Clerical	5

Total Elapsed Time - 8 weeks

Travel:

Destination	Ft. Sill
Length of Stay	2 days
Number of Trips	1

Total Days - 2

Destination	Picatinny Arsenal
Length of Stay	2 days
Number of Trips	1

Total Days - 2

Destination	Army Logistics Center
Length of Stay	2 Days
Number of Trips	2

Total Days- 4

Destination	Fort Knox
Length of Stay	2 days
Number of Trips	1

Total Days - 2

Destination	Fort Benning
Length of Stay	2 days
Number of Trips	1

Total Days - 2

6. Schedule of Resource Requirements

Phase 1, Task 2

TITLE: LHX MANCAP Model Comparison to General Purpose MANPRINT Model

DELIVERABLE: In Process Review

This task will identify the capabilities of the LHX MANCAP Model, then compare those capabilities with the capabilities of the ideal model for MANPRINT as specified in Task 1. Deliverables are an IPR and brief report on comparison of the two models.

Labor:

Labor Category	# Days
Principal Investigator	20
Management Analyst	10
Systems Analyst	15
Clerical	5

Total Elapsed Time - 8 weeks

Travel:

Destination	AVSCOM, St. Louis
Length of Stay	2 days
Number of Trips	1

Total Days - 2

Destination	Aviation School, Fort Rucker
Length of Stay	2 days
Number of Trips	1

Total Days - 2

Computer Requirements:

Microcomputer for 6 weeks

Phase 1, Task 3

TITLE: LHX Model Modification Assessment

DELIVERABLE: In Process Review

Task 3 assesses the feasibility of modifying the LHX MANCAP model to meet General Purpose Model's requirements. If feasible, the nature and extent of the modifications will be identified. The deliverable is a briefing review for ARI and OPM to present the findings and a brief report on the modifications assessment.

Labor:

Labor Category	# Days
Principal Investigator	10
Management Analyst	10
Systems Analyst	10
Clerical	5

Total Elapsed Time - 6 weeks

Travel:

None

Computer Requirements:

Microcomputer for 6 weeks

Phase 1, Task 4

TITLE: Recommendations

DELIVERABLE: Findings Report

Task 4 will present the contractor's recommendations to ARI.

Labor:

Labor Category	# Days
Principal Investigator	30
Management Analyst	30
Systems Analyst	10
Clerical	15

Total Elapsed Time - 6 weeks

Travel:

None

Computer Requirements:

None

Phase 1, Task 5

TITLE: Management Plan Development

DELIVERABLE: Management Plan for Phase 2

The first task in Phase 2 will be to develop the management plan for Phase 2 based upon ARI's needs to continue model development.

Labor:

Labor Category	# Days
Principal Investigator	4
Management Analyst	2
Clerical	3

Total Elapsed Time - 2 weeks

Travel:

None

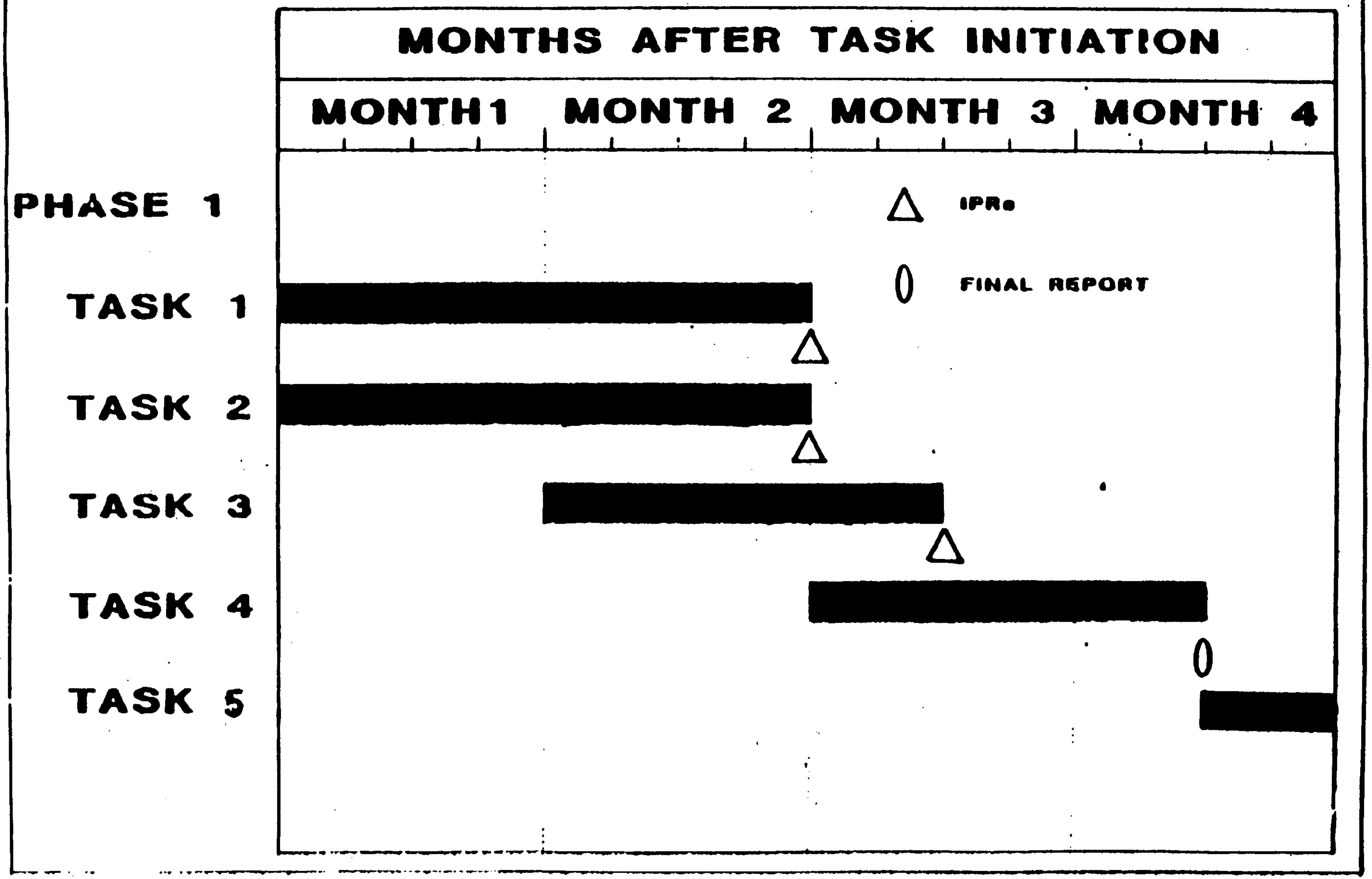
Computer Requirements:

None

8. Project Schedule

ATI has designed a project schedule to allow the best possible analysis to be performed. Definition of user needs, input and output requirements are the most critical factors of model development. Too often this phase is glossed over, resulting in a longer model development phase. The model development depends entirely on correct definition of user needs along with input and output requirements. Insufficient attention to appropriate detail and definitions in the requirements analysis may cause a retracing of steps to fill in missing gaps during model development. In short, a more thorough requirements analysis results in a shorter model development. The next page displays Phase I in chart format.

PROJECT SCHEDULE
MODELING OF UNIT PERFORMANCE AND MANPOWER REQUIREMENTS



APPENDIX B

CONCEPT PAPER

Appendix B

Concept Paper

Modeling Of Unit Performance And Manpower Requirements

The purpose of this concept paper is to outline the technical details for accomplishing the tasks outlined in the revised work plan submitted to OPM and ARI, dated 16 November 1987. During the project kickoff meeting at ARI on January 12, 1988, it was agreed that a series of informal concept papers prepared by ATI will be reviewed and commented on by ARI until both ATI and ARI have a precise, common understanding of the project goals and the paths to be taken in achieving the goals. Once this understanding is achieved, the project management/work plan will be revised as necessary.

Project Objective:

ARI's overall objective is the development of a top-down, very front-end model to predict maintenance, supply, and support manpower requirements for emerging systems within the Army. The focus of the model will be on the maintenance, supply, and support of specific weapons systems in an organizational context. Model output is to be aggregrated at the division level, if feasible. Measures of unit effectiveness or performance should be sensitive to changing manpower factors or assumptions. Although the model is to be applicable for systems under development in combat, combat support, and combat service support areas, the model will be tested for the Advanced Field Artillery System (AFAS).

The project's objective will be accomplished in two phases: The Phase 1 goal is the development of the model's general specifications and an implementation plan for continued development during Phase 2. Phase 1 is broken into 5 major tasks: Task 1 develops the general system specifications and requirements. Task 2 is a detailed examination of the MANPRINT Mission Capability (MANCAP) model assumptions, input data requirements, processes, and outputs and a comparison with those established for an ideal model in Task 1. Task 3 assesses the feasibility of modifying the MANCAP model to meet the Task 1 specifications. Task 4 synthesizes the results of the previous tasks and recommends a course of action for the Phase 2 implementation for the AFAS testbed. Task 5 is the management plan for the Phase 2 course of action selected by ARI subsequent to Task 4. Phase 2 is the implementation of the management plan.

Task 1:

During this task, we will develop the "straw-man" requirements for a general manpower requirements model. These requirements will be developed primarily by reviewing the literature (documentation for existing manpower models) and interviews/discussions with potential users at various schools and centers. The ultimate objective of this task is the development of the conceptual specifications for an ideal manpower requirements model. The specifications will include the identification of hardware and software requirements, input data requirements and how the input data are handled, output data requirements and displays, processing techniques, runtime constraints, and organizational level at which results are aggregated.

The ATI project team has reviewed the documentation attained during the project kick off meeting and developed a tentative list of model input/output variables (Enclosure 1). This list will be expanded/refined as additional documentation is obtained and reviewed and meetings/discussions with potential users progress. The current draft list of input and output requirements will be used as the primary means to generate interest and focus discussion during visits to schools and centers. We feel that the interviews with the potential users should be kept fairly unstructured since we are primarily in a fact finding mode. We want to facilitate the flow of information, not restrict it by creating a perception that a CPT or GS9 may be commuting his Two-star to something he may have to defend later. Generally our discussions should generate interest and support for our project, provide leads to other models and potential users, identify input data availability, output requirements, processing requirements, hardware/software requirements, and current availability of data.

A recommended list of schools and centers to be visited is in Enclosure 2. Visits to these locations should provide a broad perspective of requirements in the combat, combat support, and combat service support areas. The trips are listed in the general order in which they should be conducted. Fort Lee is listed first since it is the TRADOC logistics integrating center and directs the MACRIT/MARC modeling effort being conducted at Fort Lee as well as other schools. A concern is that we may not be able to gain access to their classified data. Although we do not envision a classified model, understanding what classified work is being done would facilitate the effort by lowering the likelihood of "reinventing the wheel." Visits to Fort Rucker and Fort Sill are positioned late on the list to allow for the development of a more refined specification list prior to our visits. This should allow us to maximize the quality of the information we get from schools (Rucker) and who will first use the new/revised model (Sill). The general agenda for each of the visits is in Enclosure 3.

A critical element of this task is the review of existing models to identify tools and techniques applicable to Army systems. Our review of each model will be summarized in a standard format (Enclosure 4). The model review will allow us to revise our "strawman" input/output requirements used during discussions with potential users and identify tools and techniques for use by the ideal manpower requirements model. Consideration will also be given to using existing models or model components as preprocessors or modules for the ideal model.

The results of this task will be the conceptual specifications for an ideal organizational top-down, very front-end model to estimate manpower requirements in the combat, combat support, and service support areas. The specifications will be documented in data flow diagrams which describe the user interface with the model; the relationships among model functions and modules; how the data are used; a proposed data dictionary, and proposed model output formats. At the completion of Task 1, the specification will be in draft form. The draft will be revised as appropriate based on the Task 2 and 3 results and recommendations from ARI and the user community.

Task 2:

This task results in a detailed comparison of the ideal model specifications with the capabilities and structure of the MANCAP model. Although the MANCAP model documentation will be reviewed and serve as input for Task 1, this task requires a detailed examination to determine what the model actually does - how it handles and processes data, and what the output looks like. This entails having an operational model at ATI and running the model with existing data. Running the model will allow us to track the functional data flow; and develop a detailed understanding of the model's data requirements and output capabilities. We will develop a detailed display of input/output requirements and the processing algorithms for a direct comparison to the corresponding specifications for the ideal model. The comparison will tell us what additional capabilities must be developed for MANCAP to provide the capabilities envisioned for the ideal model. This provides the basis for the Task 3 assessment.

Task 3:

This task examines the technical feasibility of modifying/enhancing the MANCAP model to correct any shortfalls identified in Task 2. This entails examining the code and the data flow for the affected functions/modules to ensure that recommended "fixes" do not destroy the model's integrity. A measure of the technical feasibility of modifying MANCAP is:

- o An estimate of runtime
- o Whether a modified model will operate efficiently (if at all) in MANCAP's existing environment
- o Offers an adequate expansion capability.

A new comparison will be made which shows the shortfall (if any) between an enhanced version of the MANCAP model and the ideal model.

Task 4:

This task summarizes the results of Tasks 1, 2, and 3 and presents recommendations for continued model development and implementation. The alternatives considered will include as a minimum the modified MANCAP model and new model development. Other potential alternatives include using existing models or components as "off-the-shelf" modules to act as pre-processors or major components for MANCAP or the ideal model. The primary criteria for recommending an alternative will be the degree to which the alternative provides capabilities which map to user needs and requirements. The secondary criteria will be cost. Additional considerations will be implementation time, runtime, capability for model improvement/expansion, and user-friendliness.

Task 5:

This task details the development of the alternative selected subsequent to Task 4 and provides schedule and resource projections for the projects completion. The plan will include the procedures for data collection, quality control and model verification/validation.

DRAFT MODEL REQUIREMENTS

Input

Scenarios -

- o Operational - defines number of missions, mission types, theater, operating constraints, mission objective
- o Maintenance - defines the when, where, what, and how of maintenance taskings
- o Supply - defines the supply philosophy as far as what is stocked where, what is delivered where, etc.

Data -

- o Task listing by location
- o Task probability of occurrence by location - function of RAM
- o Performing MOS by location
- o Task times
- o # Maintenance people required for task
- o Does task require a part?
  If so, what part.
- o MTBF/RAM

Output

Mission Statistics -

- o Measurement of mission accomplishment
  ex. # sorties flown,
  # rounds fired.

Enclosure 1

- oo # Missions Requested
  - # accomplished
  - % accomplished
- oo Number of Attritions
- oo Average post-mission maintenance time
- oo Average pre-mission maintenance time

o System Performance Measurements
- oo # of Systems Authorized
- oo Breakdown of % times spent in different types of maintenance
- oo Average pre and post-mission maintenance times.

o Manpower Measurements (by MOS and Location)
- oo Man-hours available
- oo % of utilization
- oo Man-hours Used
- oo Breakout of time spent on different types of maintenance
- oo Number of men demanded
- oo Number of substitutes
- oo % substitutes manpower
- oo % available by pre-emption
- oo % demands not available
- oo overtime man-hours used

o Off-Equipment Repair Statistics
- oo # Repairs
- oo % site repair
- oo % higher level repair
- oo # Backlogged items

o Supply Statistics (includes munitions)
- oo Fill rate %
- oo Number of back order days
- oo Number of units demanded
- oo Number cannibilizations
- oo % demands not satisfied
- oo # items on back order

o Equipment Statistics
- oo Equipment hours authorized
- oo Breakout of use for different types of maintenance
- oo Number of back order days
- oo Number of units demanded
- oo % availability
- oo % not available
- oo Equipment hours backlog

Enclosure 1

Additional Optional Output

1. Graphics capability to show MOS backlog overtime.
2. Matrix of number of times tasks occurred.

Desirable Model Characteristics

1. Ability to interface with more than one source of data to develop the task listings.
2. Ability to defer maintenance.
3. Ability to "look ahead" at mission requirements.
4. Ability to coperform tasks.
5. Ability to run different maintenance locations separately.
6. Ability to develop the event schedule and accommodate various weapons systems.
7. Ability to trade-off manpower vs. supply mission objectives, vs. RAM attributes (sensitivity analyses).
8. Ability to do multiple runs.
9. Ability to define a work center by location or MOS.
10. Ability to define substitute MOSs for a task.
11. DBMS to alter the input data and data parameters.
12. DBMS for up front-end data construction and maintenance.

RECOMMENDED TRAVEL

Location	Agency	Date Scheduled	POC
Fort Lee (two trips)	Army Log TR Center (Modeling Group)	ASAP	Jim Clark X1845
Fort Knox	Armor School (Combat Developments Tsm-tank)	TBD	TBD
Fort Benning	Infantry School (Combat Developments, TSM-Fv)	TBD	TBD
Fort Rucker	Aviation School TSM-LHX	TBD	TBD
St. Louis	AVSCOM (PMO)	TBD	TBD
Picatinny Arsenal	Armament Lab (Cannon PMO)	TBD	TBD
Fort Sill	Artillery School (TSM-Cannon)	TBD	TBD

Travel is listed in the recommended order and should be completed by 18 March 1988.

Enclosure 2

RECOMMENDED AGENDA FOR SCHOOL/CENTER VISITS

Day 1: 1300-1700

1300-1400:	In-briefing for POC/AO's/Mgt to provide overview of project and outline our need for information/data.
1400-1700:	Meet with individual AO's to discuss modeling specifics, input/output/processing requirements, and develop POC's for modeling/manpower efforts at other locations.

Day 2: 0800-1700

0800-1000:	Review documentation received, organize notes, develop additional questions for AO's & POC.
1000-1600:	Continue meetings with selected/additional AO's.
1600-1700:	Out-brief or POC/AO's/Mgt.

Enclosure 3

MODEL REVIEW FORMAT

TITLE:

MODEL CATEGORY:

PROPONENT:

DEVELOPER:

PURPOSE:

GENERAL DESCRIPTION:

INPUT:

OUTPUT:

PROCESSING:

MODEL LIMITATIONS:

HARDWARE:

SOFTWARE:

STAFF:

GENERAL DATA:

POINT OF CONTACT:

Enclosure 4

Appendix C

General Approach for a Deterministic Simulation

Appendix C

General Approach for a Deterministic Simulation

Manpower Simulation Basic Program Specifications

The main impetus here is to create a simulation with the following characteristics:

- o Accommodates deferrable maintenance,
- o Varying levels of accuracy coincident with run time,
- o Determines manpower requirements by MOS and location,
- o Determines manpower requirements based on crew usage,
- o Determines manpower utilization based on consumed manhours,
- o Simulates up to five maintenance levels,
- o Tracks parts consumption,
- o Tracks manpower requirements,
- o Simulates from platoon to battalion organizations,
- o Uses multiple performance indicators.

The manpower simulation encompasses five levels of maintenance. Levels I and II determine manpower requirements fro each group, while Levels III, IV, and V determine manpower requirements for the aggregated groups. Figure C-1 shows the basic flow of the simulation.

After all parameters have set the simulation is activated by selecting the Run Models option from the Main Menu. The simulation processes each group separately for Levels I and II. Then the processing aggregates at Levels III, IV, and V. The simulation is broken into four functional blocks.

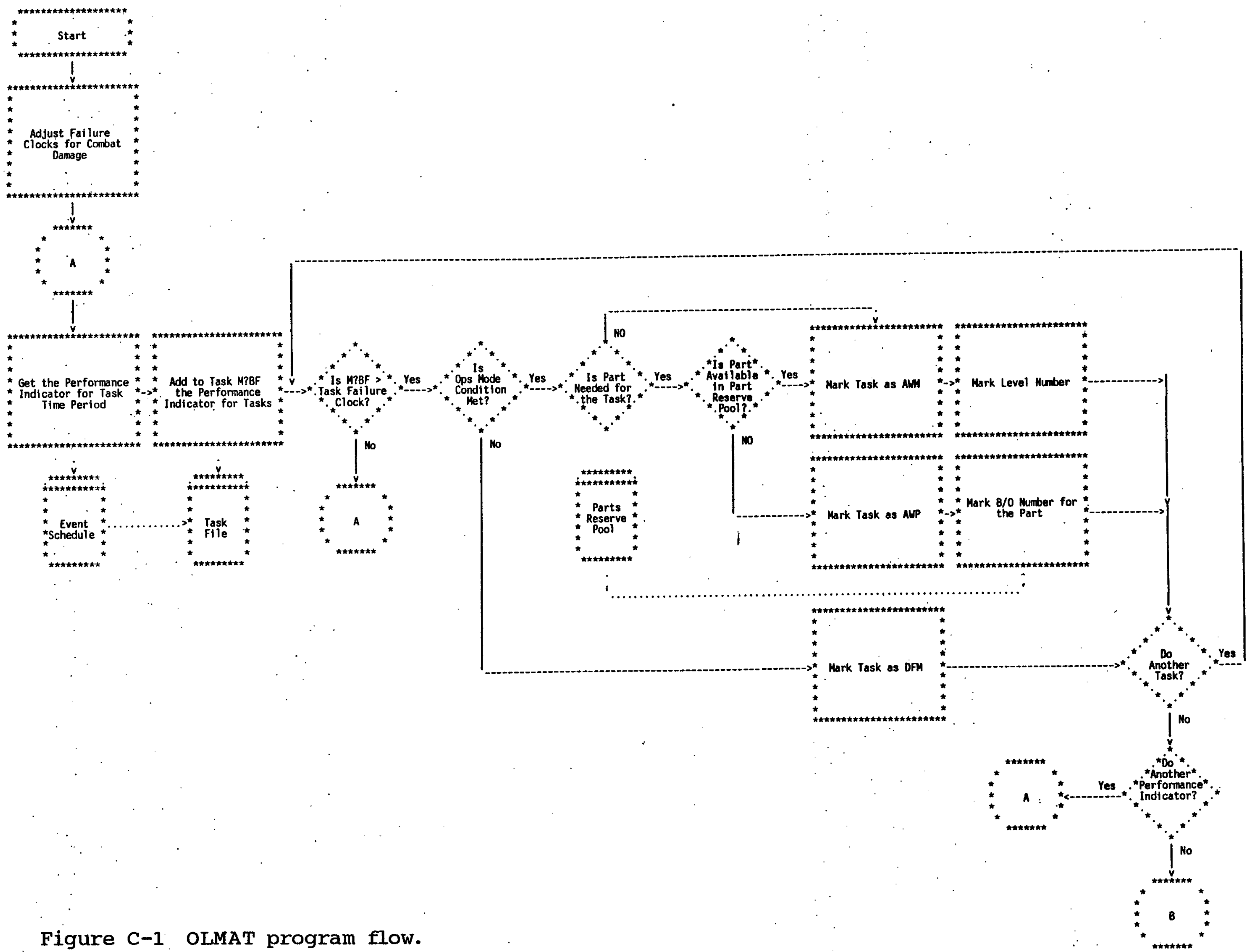


Figure C-1 OLMAT program flow.

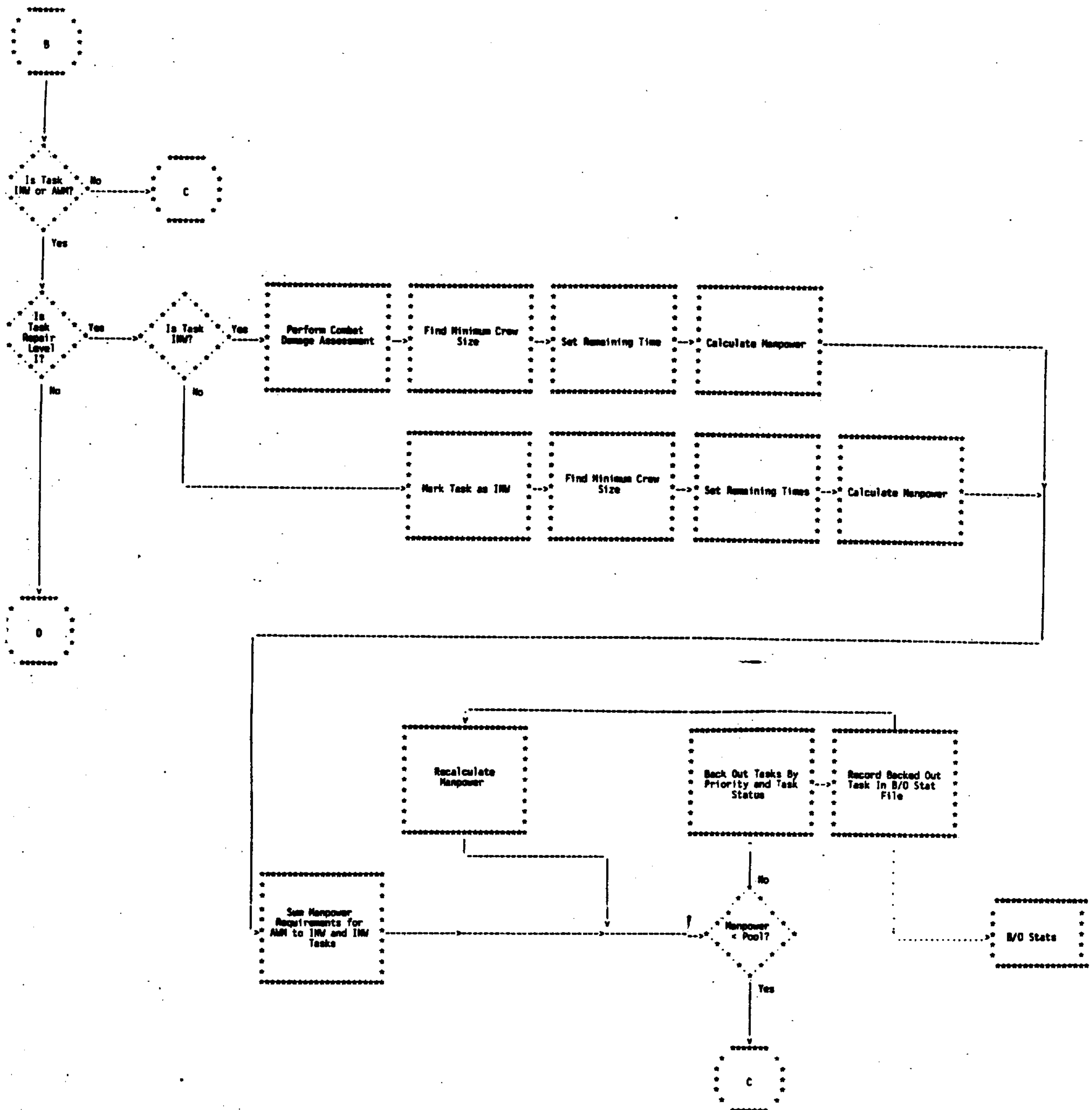


Figure C-1 continued.

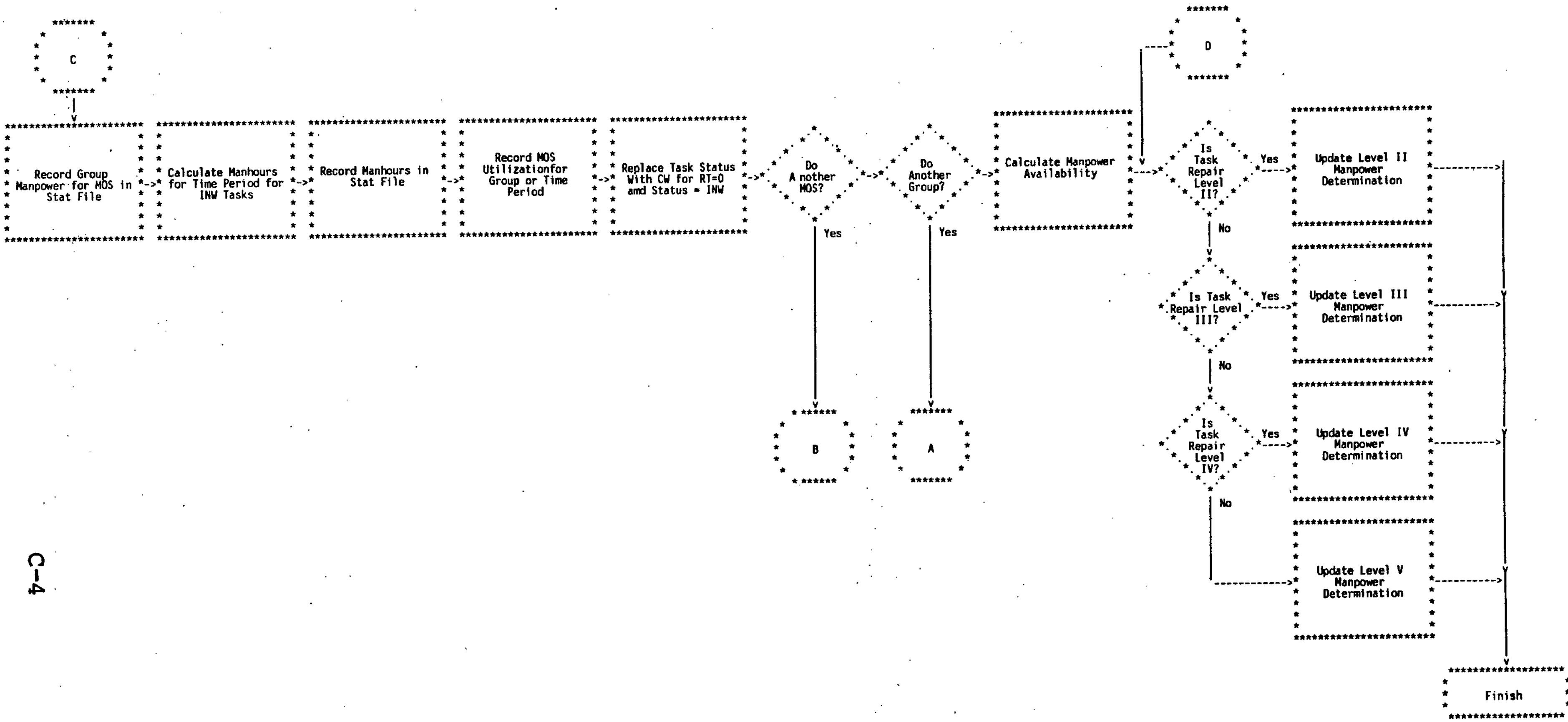


Figure C-1 continued.

The first function is failure identification. This function determines the RAM failures. (Note that combat damage failures have already been identified). Every task is checked to see if it has failed based on the Time Period (TP) and operating mode (Ops Mode). The second function determines the supply level. Each group of tasks that has come up for maintenance is checked to see if a part is needed, then the appropriate task status is set. The third function calculates the manpower requirements in terms of the number of crews required. The fourth function determines the equipment availability.

Detailed Simulation Flow

The Failure Identification and Task Loop

This section defines the detailed flow of the manpower simulation. The failure identification and supply level checks are performed by two loops. The outside (performance indicator) loop checks the Event Schedule for the performance indicators used in the TP. The inside (task) loop checks each task with the subject performance indicator for failures and supply requirements. Both loops are inside the group loop which performs the four functions for each group.

The following text goes through the loops one time. These loops are for one group. The actions would be repeated for each group active in the TP. The first action is to retrieve a performance indicator from the Event Schedule. The performance indicator is added to the task clock for all Complied With (CW) tasks. CW tasks are those that are not currently in a Awaiting Maintenance (AWM), Awaiting Parts (AWP), In Work (INW), or Deferred Maintenance (DFM) status. The Task Libraries for the selected equipment are accessed for this action.

At this point the task loop is entered. Each task is checked to see if the task performance indicator is less than the task clock. If it is, then the task is a failure and will generate maintenance. If the task is not due for maintenance then the CW status is maintained. Next, the Ops Mode Flag is checked to see if the task can be performed in the current Ops Mode. If it cannot, then it is marked as DFM and held until the next TP that has an Ops Mode condition that allows performance of the task.

Next, the task in the loop is checked to see if it requires a part. If it does, then the Parts Resource Pool is checked to see if the parts balance is sufficient to support the parts request. If the request cannot be met then the task is marked as AWP and the back order is recorded. Otherwise, the task is marked as AWM and the consumption level is recorded. The consumption level is recorded so that the user will know the exact number of parts consumed by TP. The number of parts consumed and back order is recorded in statistics files for use in reports. The parts Resource Pool is a file containing the default or user constrained supply levels.

The simulation is now at the end of the task loop. It checks to see if another task is to be done. If yes, then the task loop is repeated. Next it checks to see if another performance indicator was used in the TP. If yes, then the task performance indicator loop is repeated until no more task performance indicators are left to be checked for the TP.

The MOS Loop

The next major section within the group loop is the MOS loop. The MOS loop calculates the manpower requirement for each MOS within the group for Level I and Level II maintenance successively. The Level I and Level II calculations are identical with the exception of the maintenance level. The concept of having two levels of group maintenance allows the user the flexibility to separate FLOT and company level maintenance by group. A maintenance level does not have to be used. The maintenance level is set for each task with the Maintenance Flag. So, if no tasks have Level II maintenance designated, then the simulation takes not actions for Level II maintenance.

The next decision determines whether the task is to calculate the manpower requirement for the INW tasks by finding the minimum crew size* required, setting the remaining time for each task, and then calculating the manpower. To find the minimum crew size, the simulation looks through all the INW tasks until it finds the largest crew size requirement. In other words, if one task requires that the crew size be three, then that number of maintenance people must be available at all times in case that task comes up. The next step sets the remaining times. If any task has a task time greater than the TP, then only that portion of the task that can be done in that TP is used in the manpower calculations. The remainder of the task is saved until the next TP. Hence, the task remains INW into the next TP. The same procedure is followed for AWM tasks except that the tasks are marked as INW.

*NOTE: Crew size refers only to maintenance crew size - the number of maintenance personnel required to complete a maintenance action or task.

Manpower is determined by finding the number of crews needed. An important assumption here is that if the maintenance will be spread across the TP. In other words, if the TP is eight hours and there are eight hours of maintenance required in that TP, then the maintenance is spread across the eight hours. If the minimum crew size was three, then the manpower requirement is three irregardless of whether there was thirty minutes of maintenance or eight hours of maintenance to be performed. If the amount of maintenance to be performed is greater than the TP, then the number of crews for each portion of the maintenance time over the TP is the manpower requirement. For example, if the TP equals eight hours, the maintenance time is 12 hours, and the minimum crew size is three. Then the manpower requirement is six. If the maintenance time had been 20 hours, then the manpower requirement is nine.

Manpower Constraining

Once these procedures are completed, then the manpower requirements are summed for both types of processing. Now the manpower constraints come into play. The computed manpower is compared against the manpower level in the Manpower Pool for that MOS and Maintenance Level. If the required manpower is less than the constraint value, then the simulation continues processing. However, if it is more than the constraint value, then the simulation starts backing out the tasks by Priority. The tasks are marked as AWM and any tasks having remaining time are adjusted. After each task is backed out the manpower is recalculated and rechecked against the constraints, and the task is recorded in the Back Order Statistics File as being back order due to lack of manpower. If the constraints are not met, then the process is repeated until they do.

Prior to entering the simulation an utilization process checks all tasks and builds the Manpower Pool. During this process the minimum crew sizes are set. The simulation will not allow the setting of a manpower level constraints below the minimum crew size.

Once the manpower requirements are determined, the requirements are recorded in the Statistics File. Next the manhours expended are calculated for the MOS and group for the tasks accomplished. The manhours and MOS utilization for the group are recorded in the Statistics File.

All tasks that were completed in this TP are marked as CW. The simulation now checks to see if another MOS is to be assessed for the subject group. If so, then the process is repeated. If not, then the simulation checks to see another group is to be processed.

Maintenance Levels II, III, IV, and V

If all groups have been processed for Level I, the simulation proceeds to the next maintenance level. The Level II process is identical except for an automatic check of the equipment availability.

The Level III, IV and V manpower calculations are the same with two important exceptions. The first is that manpower is based on the total workload, not a group workload. The second is that if a task completion results in the repair of a part, then the part is returned to the Parts Resource Pool.

DATA SPECIFICATIONS

Data Files

Back Order (B/O) File

This file is a statistics file used to collect data for the Back Order Report. It contains the data items to show the number of individual parts that have gone back order for a specific TP. The needed data items are Item, TP Indicator, and Number B/O.

ITEM (Item)
TPIND (TP Indicator)
BOQUANT (Number B/O)

Event Schedule Libraries

The Event Schedule Libraries contain the data needed for execution of the simulation in the order of events specified. It contains the following data items.

TPS (TP Start)
TPL (TP Length)
TPLTYPE (TP Length Type)
TPDESIGN (TP Designator)
EQUIPCDE (Equipment Code)
DGRPDESIG (Group Designator)
GRPCONT (Group Content)

Mission Statistics File

The Mission Statistics File is a statistics file which contains the items showing the vital mission data used to measure MOE. The required data items are listed below.

TPIND (TP Indicator)
EQUIPCDE (Equipment Code)
DGRPDESIG (Group Designator)
STRTEQIP (Starting Equipment)
MSSNEFF (Mission Effectiveness)

Task Libraries

The Task File will be derived from a set of maintenance networks. Once derived, the Task File itself can be modified for minor differences in the data items, adding tasks, or deleting tasks.

EQUIPCDE (Equipment Code)
TASKNAME (Task Name)
PARTFLAG (Part Flag)
TRIGFLAG (Trigger Flag)
TASKCLK (Task Clock)
TMF (Task Mean Failures)
MNTFLAG (Maintenance Flag)
OPSMDIN (Ops Mode Indicator)
PRIORITY (Priority)
MOS (MOS)
TASKTIME (Task Time)
CS (Crew Size)
MNTLEVEL (Maintenance Level)
ONEQIPIN (On Equipment Indicator)
REMTIME (Remaining Time)
MANHOURS (Manhours)

DATA DEFINITIONS

<u>Data Name:</u> BOQUANT

<u>Type:</u> Numeric

<u>Length:</u> 5

<u>File(s):</u> Back Order File

<u>Description:</u> BOQUANT (Number B/O shows the number of items back ordered for the indicated TP.

<u>Data Name:</u> CS

<u>Type:</u> Numeric

<u>Length:</u> 2

<u>File(s):</u> Task File Libraries

<u>Description:</u> CS (Crew Size) is the crew size required for the task.

<u>Data Name:</u> EQUIPCDE

<u>Type:</u> Alphanumeric

<u>Length:</u> 8

<u>File(s):</u> Events Schedule Libraries, Task Libraries, Mission Statistics File

<u>Description:</u> EQUIPCDE (Equipment Code) specifies the type of equipment for the group. Each group is limited to one type of equipment.

<u>Data Name:</u> GRPCONT

<u>Type:</u> Numeric

<u>Length:</u> 3

<u>File(s):</u> Events Schedule Libraries

<u>Description:</u> GRPCONT (Group Content) specifies the number of pieces of equipment in the group.

Data Name: GRPDESIG

Type: Alphanumeric

Length: 1

File(s): Events Schedule Libraries, Mission Statistics File

Description: GRPDESIG (Group Designator) identifies the group.

Data Name: ITEM

Description: MANHOURS (Manhours) contains the number of manhours consumed by that task in that particular time interval. It is the product of REMTIME and CS.

Data Name: MNTFLAG

Type: Alphanumeric

Length: 1

File(s): Task File Libraries

Description: MNTFLAG (Maintenance Flag) shows the maintenance condition of the task such as INW, AWP, AWM, DFM, and CW.

Data Name: MNTLEVEL

Type: Alpha

Length: 8

File(s): Task File Libraries

Description: MNTLEVEL (Maintenance Level) is the maintenance level at which the task is most likely to be performed.

Data Name: MOS

Type: Alphanumeric

Length: 4

File(s): Task File Libraries

Description: MOS (MOS) is the MOS required to perform the task.

Data Name: MSSNEFF

Type: Numeric

Length: 5

File(s): Mission Statistic File

Description: (Mission Effectiveness) The percentage of failure indicators that did not cause failure.

Data Name: ONEQUIPIN

Type: Alpha

Length: 3

File(s): Task File Libraries

Description: ONEQIPIN (On Equipment Indicator) shows whether the task in On Equipment or Off Equipment. It is designated by the terms "On" and "Off".

Data Name: OPSMDIN

Type: Alphanumeric

Length: 1

File(s): Task File Libraries

Description: OPSMDIN (Ops Mode Indicator) shows the lowest priority Ops Mode the task may be performed in.

Data Name: PARTFLAG

Type: Alphanumeric

Length: 1

File(s): Task File Libraries

Description: PARTFLAG (Part Flag) flags a task as a supply resource.

Data Name: PRIORITY

Type: Alphanumeric

Length: 2

File(s): Task File Libraries

Description: PRIORITY (Priority) indicates the priority of the task.

Data Name: REMTIME

Type: Numeric

Length: 8

File(s): Task File Libraries

Description: REMTIME (Remaining Time) is the time remaining for an INW task that needs to be carried to the next time interval.

Data Name: STRTEQIP

Type: Numeric

Length: 5

File(s): Mission Statistics File

Description: (Starting Equipment) The amount of equipment the specified group started the TP with.

Data Name: TASKCLK

Type: Numeric

Length: 5

File(s): Task File Libraries

Description: TASKCLK (Task Clock) defines the quantity of a failure indicator needed before the task string is triggered. For example, rounds fired, miles traveled, hours flown, are failure indicators which tie machine operation to failure.

Data Name: TASKNAME

Type: Alphanumeric

Length: 8

File(s): Task File Libraries

Description: TASKNAME (Task Name) specifies the type of task as well as identifying the equipment the work is being performed on.

Data Name: TASKTIME

Type: Numeric

Length: 8

File(s): Task File Libraries

Description: TASKTIME (Task Time) is the time, specified in decimal hours, required to perform the task for the assigned MOS/crew size combination.

Data Name: TMF

Type: Numeric

Length: 5

File(s): Task File Libraries

Description: TMF (Task Mean Failure) indicates the actual quantity of a failure indicator for the TP.

Data Name: TPDESIG

Type: Alphanumeric

Length: 3

File(s): Events Schedule Libraries

Description: TPDESIG (TP Designator) is an item identifying the TP.

Data Name: TPIND

Type: Numeric

Length: 3

File(s): Back Order File, Mission Statistics File

Description: TPIND (TP Indicator) contains the number of the Time Period the Item went back order in.

Data Name: TPL

Type: Numeric

Length: 5

File(s): Events Schedule Libraries

Description: TPL (TP Length) is the length of time covered in the TP. This may be in hours or days.

Data Name: TPLTYPE

Type: Alpha

Length: 3

File(s): Events Schedule Libraries

Description: TPLTYPE (TP Length Type) specifies the type of TPL in hours or days.

Data Name: TPS

Type: Numeric

Length: 5

File(s): Events Schedule Libraries

Description: TPS (TP Start) specifies the start time for the period in clock hours, such as 0700 hours.

Data Name: TRIGFLAG

Type: Alphanumeric

Length: 1

File(s): Task File Libraries

Description: TRIGFLAG (Trigger Flag) flags a task as a trigger task.

Figure C-1 OLMAT program flow.

Figure C-1 continued.

Figure C-1 continued.

APPENDIX D

Proposed Work Plan for OLMAT Development

Revised 7/13

DRAFT

Modeling of Unit Performance and Manpower Requirements

Work Plan for the Devvelopment of an

Organizational Level Manpower Analysis Tool (OLMAT)

Work Order No.:

Submitted to OPM July 1988

Cost Code No.:

Submitted by: Advanced Technology, Inc.
12001 Sunrise Valley Drive
Reston, VA 22091

Submitted to: Office of Personnel Management
Attn: Mr. Jack Vincent
(632-6172)

1. Project Synopsis

ARI has been providing MANPRINT support for the Advanced Field Artillery System (AFAS) project for over a year. AFAS is very large and complex and the ability to answer questions about manpower and personnel at this stage is critical to the success of the project. Manpower and personnel information affects not only the individual piece of equipment, but the entire organization for which the system is part. This includes the maintenance, supply, and support personnel. To answer questions about the cost of a new system in terms of manpower and personnel depends on being able to consider all aspects of the system and the organization. This project will have as its focus both of these aspects. This project, however, deals with the broader issue of developing a capability to answer these questions for any system, and have that capability within the Army itself. It is necessary to answer the questions about AFAS, by itself and as part of the Armored Family of Vehicles (AFV), and also to develop generic tools for MANPRINT. AFAS provides a test case for development of an ideal General Purpose MANPRINT Model. The project deliverables are phased to provide a clean audit of the research that leads to the development of a model of system/organizational performance. The project phasing also provides ARI with maximum control over the direction of the research effort. Phase I was an examination of the applicability of adapting the LHX MANCAP Model to support a full range of Army modeling requirements (TRADOC needs and requirements). Phase I resulted in a decision by ARI to pursue the development of an Organizational Level Manpower Analysis Tool (OLMAT). Phase I provided the general specifications for the tool. Phase II is the development of the detailed design specifications for the tool and its required data libraries. Phase III is the implementation and test of the tool (OLMAT prototype) and its application to the Advanced Field Artillery System (AFAS).

2. Agency Objective

The Army Research Institute for the Behavioral and Social Sciences (ARI) is developing methods to accurately predict and model needed maintenance and support manpower requirements for emerging systems within the Army. A product being developed to support the ARI efforts in this area is a generic top-down manpower modeling tool for the operator, maintenance, supply, and support requirements for an organization. Specifically, the tool will:

- o focus on the effects of weapons system parameters (such as RAM factors) or manpower requirements in an organizational context;
- o output measures (such as equipment availability) must be sensitive to changing manpower factors or assumptions;
- o output to be aggregated for unit sizes from platoon to division; and
- o be applicable to all Army systems (generic).

In support of this objective, ARI has initiated a three phase project to develop a PC-based tool to aid combat developers in the early manpower assessment of various weapon system configurations within alternative operational and organizational (O & O) concepts for maintenance, supply, and support.

The generic tool has been dubbed the Organizational Level Manpower Analysis Tool (OLMAT). Specifically, OLMAT provides manpower estimates for a given system design and organizational structure in an operational environment based on:

- RAM parameters

- support concepts

- supply concepts

Phase I of the OLMAT development project is the definition of general specifications for the tool. Phase II is the development of the detailed design specifications for the tool and its required data libraries. Phase III is the implementation and test of the tool (OLMAT prototype) and its application to the Advanced Field Artillery System (AFAS). ARI and Field Artillery School users will be trained in the use of OLMAT to support their input to the weapons acquisition process.

3. Plan Summary

<u>PHASE 2</u>: Develop Detailed Design Specifications

Phase 2, Task 1

<u>TITLE</u>: Develop Data Libraries and Menu System

<u>DELIVERABLE</u>: In Process Review Briefing and Draft Documentation for the Data Entry Module

This task produces the generic structure of the OLMAT Data Entry Module. Menus are designed and linked to generic data libraries. The Data Entry Module is programmed and demonstrated for ARI and the DCD user at Fort Sill. Deliverables are an In Process Review (IPR) for ARI and a draft documentation of the Data Entry Module.

Phase 2, Task 2

<u>TITLE</u>: Develop System and Subsystem Specifications

<u>DELIVERABLE</u>: IPR and Draft System and Subsystem Specification Documentation

This task produces the detailed design specification for the RAM Failure Generator, the Combat Damage Generator, and the Operations and Maintenance simulation modules. Deliverables are an IPR and the draft System and Subsystem Specification Documentation.

Phase 2, Task 3

<u>TITLE</u>: Data Collection

<u>DELIVERABLE</u>: IPR and Letter Report on Results of the Data Collection Effort

This task identifies data sources to support Phase, Task 1 and begins to collect data to fill the OLMAT data libraries. Deliverables are an IPR and a letter report documenting the results of the data collection effort.

<u>PHASE 3</u>: AFAS Implementation

Phase 3, Task 1

<u>TITLE</u>: Code and Test Simulation Modules

<u>DELIVERABLE</u>: IPR, Letter Report on Verification Testing, and Draft Program Documentation

This task develops and tests the OLMAT simulation modules. The system and subsystem specifications developed in Phase 2, Task 2 are translated to programming specifications and pseudocode. The specific programming language is selected and the simulation modules are coded and verified. Deliverables are an IPR, a letter report documenting the verification testing, and draft program documentation.

Phase 3, Task 2

<u>TITLE</u>: Integrate and Test OLMAT

<u>DELIVERABLE</u>: IPR, System Demonstration, letter report on validation results, and draft user instruction

This task integrates the OLMAT Data Entry Modules with the Simulation Modules and conducts system verification and validation. The system will be validated using AFAS data collected during Phase 3, Task 3. Validation runs will also be conducted using the available LHX data collected for the MANCAP model. The AFAS application will be demonstrated to ARI and DCD to determine face validity. Deliverables are an IPR, demonstration, a letter report on the validation results and draft user instruction.

Phase 3, Task 3

<u>TITLE</u>: Data Collection

<u>DELIVERABLE</u>: Completed cannon artillery data base and a letter report of the data collection sources and procedures

This task collects data and completes the data libraries to support the Phase 3, Task 2 AFAS application of OLMAT. Deliverables are a completed cannon artillery data base and a letter report of the data collection effort which outlines sources and procedures.

Phase 3, Task 4

<u>TITLE</u>: Documentation and Training

<u>DELIVERABLE</u>: System Documentation, User Instruction, and User Training

This task produces the final documentation package and training ARI and Fort Sill DCD users on the use of OLMAT. Documentation consists of System and Program Documentation, and a User Instruction Manual. The user training will consist of a two day training session at Fort Sill and a one day training session for ARI. Deliverables are the System documentation, user instruction, and training sessions.

4. Activity Schedule

PHASE 2: Develop Detailed Design Specifications

Phase 2, Task 1

TITLE: Develop Data Libraries and Menu System

DELIVERABLE: In Process Review Briefing and Draft Documentation for the Data Entry Module

This task produces the generic structure of the OLMAT Data Entry Module. Menus are designed and linked to generic data libraries. The Data Entry Module is programmed and demonstrated for ARI and the DCD user at Fort Sill. Deliverables are an In Process Review (IPR) for ARI and a draft documentation of the Data Entry Module.

Subtask 2.1.1 - Define Data Elements. Preliminary data element definitions were established in the OLMAT functional description developed during Phase 1. This subtask finalizes the data element dictionary which contains a complete description of each data element to include its source, library address, and interpretation.

Subtask 2.1.2 - Design Data Libraries. A general outline of the OLMAT data libraries was established in the OLMAT functional description. This subtask defines the common structure for all libraries, provides for the interactive modification of data elements, and loads the libraries with test data sufficient to support the linkage with the menu system and test of the Data Entry Module.

Subtask 2.1.3 - Design the OLMAT Menu System. An initial menu system was established in the OLMAT functional description. This subtask completes the menu system at all levels and provides for the interface with the data libraries to provide default values for user acceptance or modification.

Subtask 2.1.4 - Link and Test the Data Entry Module. This subtask links the menu system with the data libraries and conducts component verification testing. Demonstrations of this module for ARI and the DCD user will provide the basis for modifying the model components to closely meet the user requirements.

Subtask 2.1.5 - Develop Draft Documentation. This subtask documents the Data Entry Module for inclusion in the final system documentation.

Phase 2, Task 2

TITLE: Develop System and Subsystem Specifications

DELIVERABLE: IPR and Draft System and Subsystem Specification Documentation

This task produces the detailed design specification for the RAM Failure Generator, the Combat Damage Generator, and the Operations and Maintenance simulation modules. Deliverables are an IPR and the draft System and Subsystem Specification Documentation.

Subtask 2.2.1 - Develop System and Subsystem Specifications for the equipment damage process. This subtask breaks down the functional process for determining equipment requiring repair to the system and subsystem levels. The major subsystems of this process are the combat damage generator and the RAM failure generator. The detailed specifications show the flow of data (files from which data are retrieved) and how the data are processed and stored for use by the supportability simulation. The subtask determines how the data are processed and identifies whether processes are handled stochastically or deterministically.

Subtask 2.2.2 - Develop System and Subsystem Specifications for the maintenance and supply simulation. This subtask breaks down the simulation process developed during Phase I. Detailed specifications show data flows and how the data are processed and stored and provide the basis for the programming specifications and pseudocode. A determination is made whether each process is to be handled stochastically or deterministically.

Phase 2, Task 3

TITLE: Data Collection

DELIVERABLE: IPR and Letter Report on Results of the Data Collection Effort

This task identifies data sources to support Phase, Task 1 and begins to collect data to fill the OLMAT data libraries. Deliverables are an IPR and a letter report documenting the results of the data collection effort.

Subtask 2.3.1 - Develop Data Collection Plan. This subtask documents the sources of data to be collected during Subtask 2.3.1. The plan documents the sources which provide the data elements defined during Subtask 2.1.1. The plan must identify sources for all types of equipment since the data must fill a common library structure.

Subtask 2.3.2 - Data Collection. Data collection will be continuous throughout both phases of the project. Data Collection during this subtask is actually a secondary effort to the Data Collection Plan development. Data for all types of equipment will be collected and loaded into the appropriate library as it is obtained as a by-product of the effort to identify specific sources. The Data Collection effort for Phase 3 will focus on specifically collecting data to fill the libraries for field artillery cannon systems.

PHASE 3: AFAS Implementation

Phase 3, Task 1

TITLE: Code and Test Simulation Modules

DELIVERABLE: IPR, Letter Report on Verification Testing, and Draft Program Documentation

This task develops and tests the OLMAT simulation modules. The system and subsystem specifications developed in Phase 2, Task 2 are translated to programming specifications and pseudocode. The specific programming language is selected and the simulation modules are coded and verified. Deliverables are an IPR, a letter report documenting the verification testing, and draft program documentation.

Subtask 3.1.1 - Develop Programming Specifications and Pseudocode. Programming specifications and pseudocode are the final levels of detail necessary to permit coding the simulation modules and integrating with the data libraries and menu system developed in Phase 2. In some cases existing software such as LOTUS 1-2-3, DBASE III, or graphics packages may be integrated with unique software instead of programming the total model. The choice of software packages and programming language is determined at this stage.

Subtask 3.1.2 - Code the Simulation Modules. The modules will be coded in accordance with the programming specifications developed in Subtask 3.1.1 and tested in accordance with Subtask 3.1.3.

Subtask 3.1.3 - Test the Simulation Modules. This subtask provides for error detection during the coding phase. We will conduct design reviews with the systems analysts and programmers, conduct a design walk-through in which programmers explain each line of their coding step-by-step to the project manager, systems analysts, and other programmers; and make a compiler review to find ill-defined variables and array definitions. After a module has been designed, coded, and compiled, simple tests with existing data will determine whether modules are working properly.

Phase 3, Task 2

TITLE: Integrate and Test OLMAT

DELIVERABLE: IPR, System Demonstration, letter report on validation results, and draft user instruction

This task integrates the OLMAT Data Entry Modules with the Simulation Modules and conducts system verification and validation. The system will be validated using AFAS data collected during the Phase 3, Task 3 data collection effort described below. Validation runs will also be conducted using the available LHX data collected for the MANCAP model. The AFAS application will be demonstrated to ARI and DCD to determine face validity. Deliverables are an IPR, demonstration, a letter report on the validation results and draft user instruction.

Subtask 3.2.1 - Integrate OLMATE modules. After the module tests of Subtask 3.1.3 verify the accuracy of the OLMAT modules, the modules are linked to operate as a complete system and tested as outlined in Subtask 3.2.2.

Subtask 3.2.2 - Test the OLMAT System. This subtask conducts both verification and validation testing of the OLMAT system. The verification testing ensures that the modules are properly linked and operating as intended. The procedures are the same as those described for Subtask 3.1.3. Validation testing will be accomplished using AFAS data collected during the Phase 3, Task 3 data collection and also the available LHX data collected for the MANCAP model. The OLMAT output will be compared to the results of the ongoing AFAS manpower analyses and the past results of the LHX MANCAP model output and LHX studies. The validation tests will ensure that a desired accuracy or correspondence exists between OLMAT and the "real system" (current accepted analytical results). A critical aspect of the validation test is the demonstration for ARI and for the Field Artillery School DCD personnel.

Phase 3, Task 3

TITLE: Data Collection

DELIVERABLE: Completed cannon artillery data base and a letter report of the data collection sources and procedures

This task collects data and completes the data libraries to support the Phase 3, Task 2 AFAS application of OLMAT. Deliverables are a completed cannon artillery data base and a letter report of the data collection effort which outlines sources and procedures.

Subtask 3.3.1 - Collect Cannon Artillery Data. This subtask collects data for cannon artillery from the sources identified in Phase 2. Additionally, LHX data are extracted from the MANCAP model.

Subtask 3.3.2 - Implement Libraries for Cannon Artillery System. This subtask assembles the cannon artillery data collected in Subtask 3.3.1 into data libraries for cannon artillery weapon systems. The available aviation data are merged with LHX data collected in Subtask 3.3.1 to load, to the extent possible, aviation libraries. These data libraries are used in Task 3.2 to test the validity of OLMAT.

Phase 3, Task 4

TITLE: Documentation and Training

DELIVERABLE: System Documentation, User Instruction, and User Training

This task produces the final documentation package and training ARI and Fort Sill DCD users on the use of OLMAT. Documentation consists of System and Program Documentation, and a User Instruction Manual. The user training will consist of a two day training session at Fort Sill and a one day training session for ARI. Deliverables are the System documentation, user instruction, and training sessions.

Subtask 3.4.1 - Develop OLMAT Documentation. Since parts of the OLMAT documentation are developed during subsequent phases and tasks, this subtask assembles the documentation to form a complete package. Additionally, a user instruction is developed.

Subtask 3.4.2 - Conduct User Training. This subtask develops and conducts user training for ARI and Fort Sill DCD. The training will be "case study" oriented and based on realistic examples drawn from the validation testing and demonstration of Subtask 3.2.2. Lesson outlines for the training sessions developed and approved by ARI.

5. Schedule of Deliverables

Phase 2: Develop Detailed Design Specifications

Task	Deliverable
1	IPR Briefing and Demonstration
1	Draft Documentation of Data Entry Module
1	Data Entry Module Software
2	IPR Briefing
2	Draft System and Subsystem Documentation
3	IPR Briefing
3	Letter Report of Data Collection Effort

Phase 3: Code and Test Simulation Modules

Task	Deliverable
1	IPR Briefing
1	Letter Report on Verification Testing
1	Draft Program Documentation
2	IPR Briefing and System Demonstration
2	Letter Report on Validation Results
2	Draft User Instruction
3	Completed Cannon Artillery Data Base
3	Letter Report on Data Collection Sources and Procedures
4	System Documentation
4	User Instruction
4	User Training

6. Schedule of Resource Requirements

PHASE 2: Develop Detailed Design Specifications

Phase 2, Task 1

TITLE: Develop Data Libraries and Menu System

DELIVERABLE: In Process Review Briefing and Draft Documentation for the Data Entry Module

This task produces the generic structure of the OLMAT Data Entry Module. Menus are designed and linked to generic data libraries. The Data Entry Module is programmed and demonstrated for ARI and the DCD user at Fort Sill. Deliverables are an In Process Review (IPR) for ARI and a draft documentation of the Data Entry Module.

LABOR:

Labor Category	# Days
Principal Investigator	50
Management Analyst	40
Systems Analyst	25
Computer Programmer	60
Clerical	15

TOTAL TIME: 16 weeks

TRAVEL:

Destination	# Trips	# Days	# People
Fort Sill	1	3	1

COMPUTER REQUIREMENTS:

Microcomputer for 16 weeks

Phase 2, Task 2

TITLE: Develop System and Subsystem Specifications

DELIVERABLE: IPR and Draft System and Subsystem Specification Documentation

This task produces the detailed design specification for the RAM Failure Generator, the Combat Damage Generator, and the Operations and Maintenance simulation modules. Deliverables are an IPR and the draft System and Subsystem Specification Documentation.

LABOR:

Labor Category	# Days
Principal Investigation	30
Management Analyst	10
Systems Analyst	20
Clerical	10

TOTAL TIME: 8 weeks

TRAVEL: None (Local only)

COMPUTER REQUIREMENTS: None

Phase 2, Task 3

TITLE: Data Collection

DELIVERABLE: IPR and Letter Report on Results of the Data Collection Effort

This task identifies data sources to support Phase, Task 1 and begins to collect data to fill the OLMAT data libraries. Deliverables are an IPR and a letter report documenting the results of the data collection effort.

LABOR:

Labor Category	# Days
Principal Investigator	10
Management Analyst	10
Systems Analyst	20
Computer Programmer	35
Clerical	10

TOTAL TIME: 16 weeks

TRAVEL:

Destination	# Trips	# Days	# People
Fort Lee	2	2	1
Fort Leavenworth	1	2	1
Aberdeen P.G.	4	1	2
St. Louis (AVSCOM)	1	3	1
Fort Benning	1	3	1
Fort Sill	1	3	1
Fort Knox	1	2	1
Lexington, Ky (MRSA)	1	2	1
Picatinni Arsenal	1	2	1

COMPUTER REQUIREMENTS: None

PHASE 3: AFAS Implementation

Phase 3, Task 1

TITLE: Code and Test Simulation Modules

DELIVERABLE: IPR, Letter Report on Verification Testing, and Draft Program Documentation

This task develops and tests the OLMAT simulation modules. The system and subsystem specifications developed in Phase 2, Task 2 are translated to programming specifications and pseudocode. The specific programming language is selected and the simulation modules are coded and verified. Deliverables are an IPR, a letter report documenting the verification testing, and draft program documentation.

LABOR:

Labor Category	# Days
Principal Investigator	15
Management Analyst	30
Systems Analyst	20
Clerical	5

TOTAL TIME: 16 weeks

TRAVEL:

Destination	# Trips	# Days	# People
Aberdeen P.G.	2	2	1
Fort Lee	1	2	1

COMPUTER REQUIREMENTS: None

Phase 3, Task 4

TITLE: Documentation and Training

DELIVERABLE: System Documentation, User Instruction, and User Training

This task produces the final documentation package and training ARI and Fort Sill DCD users on the use of OLMAT. Documentation consists of System and Program Documentation, and a User Instruction Manual. The user training will consist of a two day training session at Fort Sill and a one day training session for ARI. Deliverables are the System documentation, user instruction, and training sessions.

LABOR:

Labor Category	# Days
Principal Investigator	10
Management Analyst	10
Systems Analyst	25
Technical Editor	5
Junior Instructional Technologist	10
Clerk Typist	25

TOTAL TIME: 8 weeks

TRAVEL:

Destination	# Trips	# Days	# People
Fort Sill	1	5	3

COMPUTER REQUIREMENTS:

Microcomputer for 4 weeks

7. Cost Schedule

Phase 2: Develop Detailed Design Specifications

LABOR:

Task	Principal Investigator Days	Management Analyst Days	Systems Analyst Days	Computer Programmer Days	Clerical Days	Cost
1	50	40	25	60	15	$48,055
2	30	10	20	0	10	19,890
3	10	10	20	35	10	19,010
TOTAL	90	60	65	95	35	$86,955

TRAVEL:

Task	Destination	#Trips	# Days	#People	Cost
1	Fort Sill	1	3	1	$ 900
3	Fort Lee	2	2	1	500
3	Fort Leavenworth	1	2	1	820
3	Aberdeen P.G.	4	1	2	325
3	St. Louis	1	3	1	900
3	Fort Benning	1	3	1	840
3	Fort Sill	1	3	1	900
3	Fort Knox	1	2	1	840
3	Lexington, Ky.	1	2	1	840
3	Picatinni	1	2	1	270
					$7,135

COMPUTER:

Task	Weeks Required	Cost
1	16	$1160
2	0	0
3	0	0
TOTAL	16	PHASE TOTAL $1160

Phase 3: AFAS Implementation

LABOR:

Task	Prin. Ivest. Days	Manage. Analyst Days	Systems Analyst Days	Computer Programmer Days	Techn. Editor Days	Jr. Instruct. Tech. Days	Clerical Days	Cost
1	15	10	20	30	0	0	5	$19,230
2	45	20	30	45	0	0	15	39,430
3	15	30	20	0	0	0	5	18,970
4	10	10	25	0	5	10	25	18,745
TOTAL	85	70	95	75	5	10	50	$96,375

TRAVEL:

Task	Destination	#Trips	# Days	#People	Cost
2	Fort Sill	2	3	1	$ 1800
3	Aberdeen P.G.	2	2	1	120
3	Fort Lee	1	2	1	250
4	Fort Sill	1	5	3	1900
					$4,070

COMPUTER:

Task	Weeks Required	Cost
1	8	$ 580
2	8	580
3	0	0
4	4	290
TOTAL	20	PHASE TOTAL $1450

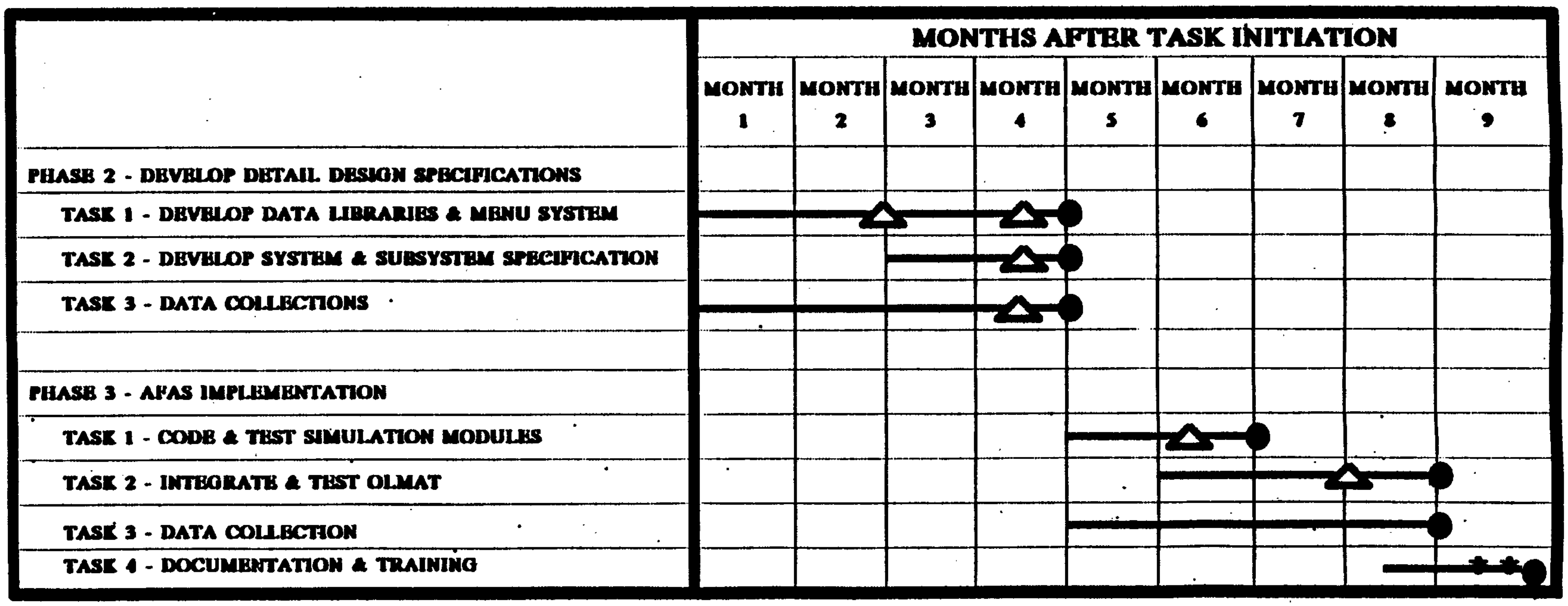
PHASE 2 & 3 TOTALS

LABOR:	$86,955	+	$96,375	=	$183,330
TRAVEL:	$ 7,135	+	$ 4,070	=	$ 11,205
COMPUTER:	$ 1,160	+	$ 1,450	=	$ 2,610
	$95,250		$101,895		
	TOTAL				$197,145

8. Project Schedule

The attached chart displays the sequencing of the Phases and tasks described in Section 4.

OLMAT DEVELOPMENT PROJECT SCHEDULE



KEY

● : Documentation or Report

* : Training Sessions

△ : IPR

Working Paper

WP MSG 90-04

APPLICATION OF THE ARMY MANPOWER COST SYSTEM TO DERIVE COST BURDENS FOR THE FUTURE ARMORED COMBAT SYSTEM MANPOWER REQUIREMENTS

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APPLICATION OF THE ARMY MANPOWER COST SYSTEM TO DERIVE COST BURDENS FOR THE FUTURE ARMORED COMBAT SYSTEM MANPOWER REQUIREMENTS.

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ACKNOWLEDGEMENT

The assistance of Kevin Beares, Consortium student, in the execution of the AMCOS analyses is gratefully acknowledged.

Application of the Army Manpower Cost System to derive cost burdens for the Future Armored Combat System manpower requirements.

INTRODUCTION

The development of emerging weapon systems must take into account the reality of increasing constraints both in manpower availability and availability of funds. To meet these constraints and to produce the most cost-effective system, an assessment of the manpower, personnel and training (MPT) aspects of an emerging system must be performed early in the development cycle when most leverage may be exerted upon system design. The US Army Research Institute has been developing methodologies to assess the MPT aspects of emerging systems. One effort already in use, the HARDMAN Comparability Methodology (HCM), develops system MPT resource requirements while another, the Army Manpower Cost System (AMCOS), calculates the costs associated with Army manpower. There is a need for both methodologies to be used in conjunction with each other in order to convert manpower requirements into costs for determining the most cost-effective system and to answer questions which may be posed by financial managers. Methodology such as the HCM derives the manpower requirements necessary to make costing determinations, while AMCOS provides a mechanism to translate such requirements into costs. The relationship of HCM to AMCOS is illustrated in Figure 1.

A HCM analysis has been conducted on the Future Armored Combat System (FACS). The FACS is a variant included within the Armored Family of Vehicles (AFV). The AFV program having been superseded by and incorporated into the Armored Systems Modernization (ASM) program, the FACS is now known as the Block III tank. The results of the HCM analysis have been presented in the report " Apply the Army HARDMAN Comparability Methodology (HCM) to the Future Armored Combat System (FACS), Volume 1." by Hay Systems, Inc. (Shotzbarger, et. al., 1989). Therefore, while the FACS is now known as the Block III tank, FACS shall be the designation used in this report.

OBJECTIVE

The objective of this project was to apply the AMCOS methodology to selected manpower requirements derived by the HCM analysis performed on the FACS in order to assess the associated manpower costs and their implications.

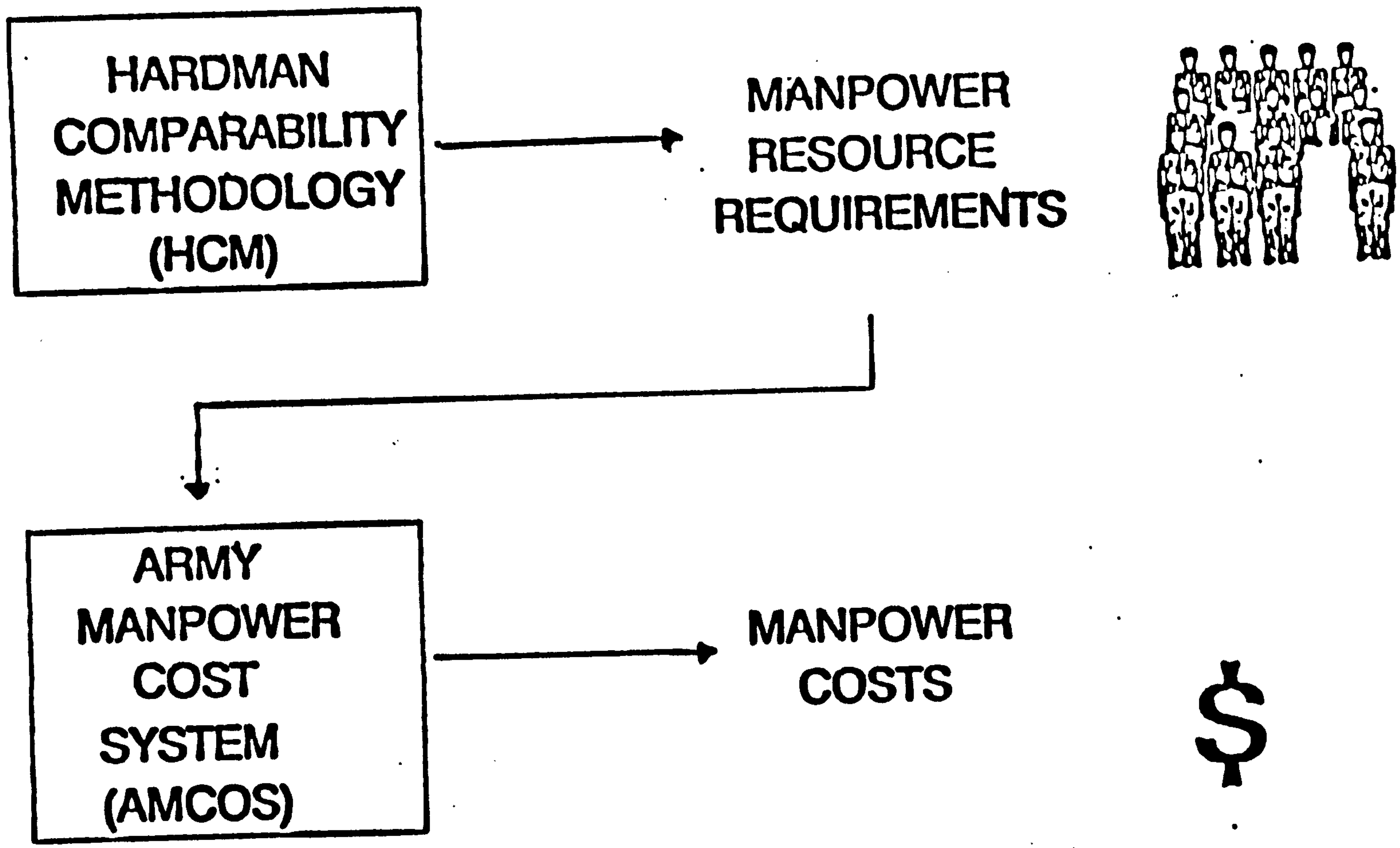

Figure 1. Relation of HARDMAN Comparability Methodology to Army Manpower Cost System.

APPROACH

Manpower requirements data were obtained from the report "Apply the Army HARDMAN Comparability Methodology (HCM) to the Future Armored Combat System (FACS). Volume 1", prepared by Hay Systems, Inc. (Shotzbarger, et. al., 1989). These data were used to create unit manpower cost databases using the AMCOS program (Version 4.0). These databases in turn were fed into the AMCOS life cycle model program to generate the first year and over thirty years costs for the manpower requirements. Discussions of the HARDMAN Comparability Methodology and Army Manpower Cost System follow.

The HARDMAN comparability methodology.

The HARDMAN comparability methodology (HCM) provides a structured approach to the determination of manpower, personnel and training (MPT) requirements early in the development process. The documented audit trail supports subsequent impact and trade-off analyses between design and MPT alternatives. As the alternatives are adopted and the system design evolves, it also provides updated assessments of requirements. Comparability analysis is based on the formulation of two notional design concepts; a Baseline Comparison System (BCS) and a representative configuration for the new system, in this case, the FACS. Both design concepts satisfy the system functional performance requirements. To the extent possible, the BCS is based on knowledge of subsystems and equipments in mature fielded systems. In the FACS configuration, BCS deficiencies are resolved by adopting technological opportunities as design alternatives or as improvements for further consideration. Software programs, known as HARDMAN II and HARDMAN II.2, have been developed to assist in the execution of the HCM. A set of software tools, subsumed under the rubric of HARDMAN III, are being developed to facilitate the execution of more in-depth analyses of the manpower, personnel and training aspects of system development.

The HCM consists of six steps, as shown in Figure 2, taken from the " Manager's Guide" (Mannle, et. al., 1985). The BCS and FACS are defined following a top-down analysis beginning with the missions and probable system usage or activity rates. A functional requirements analysis establishes the functions necessary to conduct the missions and the performance required for mission success. Based on these functional performance requirements, specific subsystems or equipments are selected for the BCS. The BCS configuration, with proposed technology based system alternatives, defines the FACS as a new system construct. Reliability and maintainability estimates for the FACS and its alternatives are used to generate a maintenance demand as a basis for maintainer workload requirements. Using the preceding analysis, generic tasks for operators and maintainers are determined. With completion of step 1, the manpower requirements analysis can develop an initial qualitative and quantitative

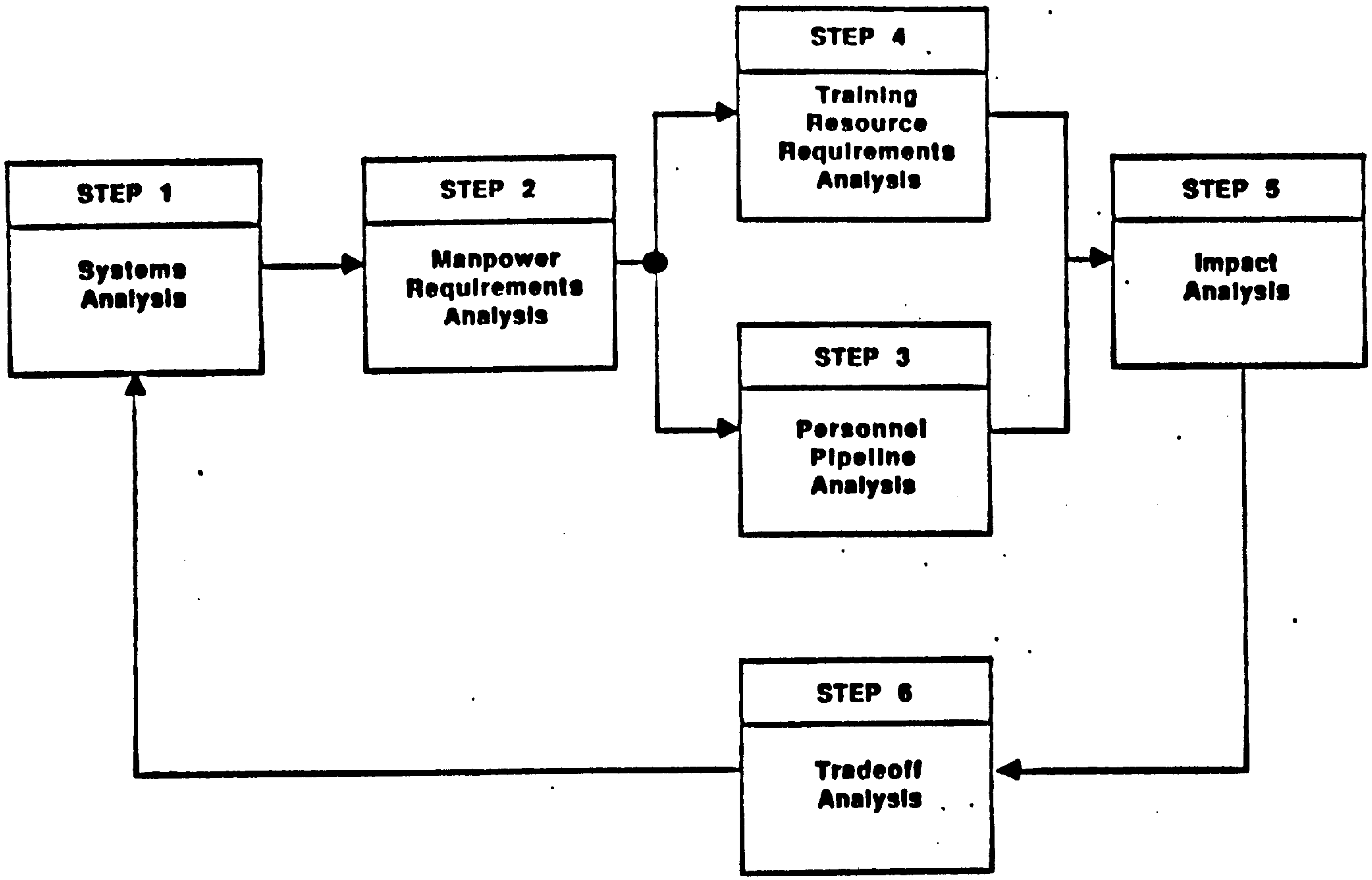

Figure 2. Steps in the HARDMAN Comparability Methodology.

manpower requirement estimate. Analyses of personnel necessary to support the new system permit an estimation of both personnel pipeline requirements and training resources necessary to man the system. Additional analyses, trade-off and impact, examine the impact of the MPT requirements on the available MPT resources. Trade-off studies evaluate the MPT requirements for the technology alternatives and other alternatives with a potential for reducing high-MPT impacts. More information may be obtained by referring to the "Manager's Guide" (Mannle, et. al., 1985).

The assumptions and constraints used in estimating the manpower requirements were as follows:

o A representative FACS configuration was selected for comparison with the M1A1. As illustrated in Figure 3, this configuration consisted of the following subsystem alternatives;

Propulsion:	Diesel
Vehicle Drive:	Conventional (Advanced)
Turret Drive:	Conventional (Advanced)
Suspension:	Hydropneumatic
Armament:	120 mm Lightweight Gun

o The FACS Force Structure consists of armored battalions (AR BN) and armored calvary squadrons (ACS). There are 58 tanks in each armored battalion and 41 in each armored calvary squadron. There are 54 armored battalions in the active force (3132 tanks) and 9 armored cavalry squadrons (369 tanks), giving a total of 3501 tanks for the active force. It is intended to replace the MI on a one-for-one basis with the FACS.

o Crew-level manpower requirements were determined by Army manning standards. The introduction of an autoloader permits reduction of crew size from 4 men in the M1A1 (the predecessor system) to 3 men in the FACS.

o Maintenance will be performed in accordance with the conventional Army Maintenance concept, i.e. at the organizational and intermediate levels.

o The FACS will replace the M1A1 on a one-for-one basis.

o Only manpower spaces directly attributable to the FACS were estimated.

o Officer spaces were not included.

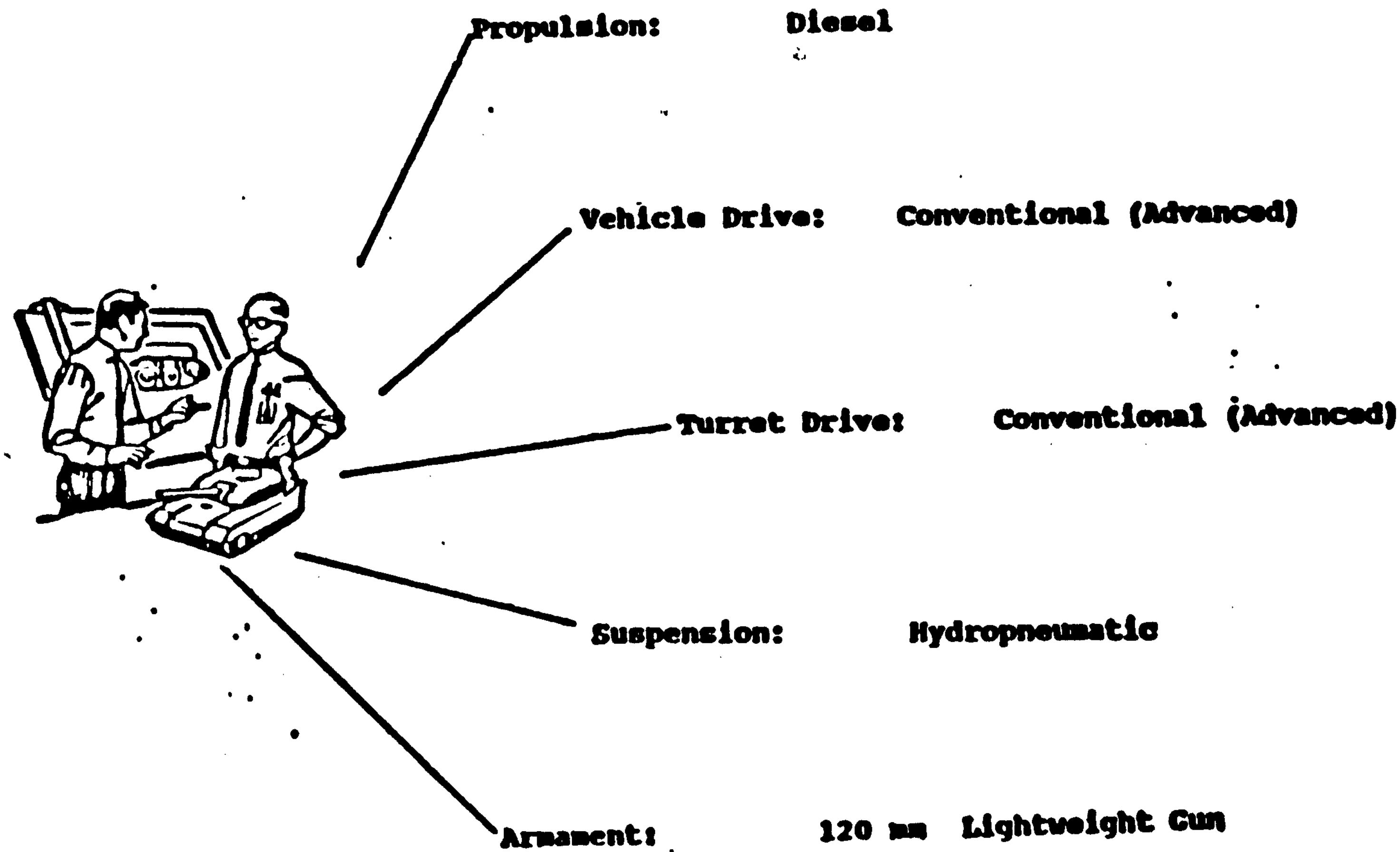

Figure 3. FACS Representative Configuration.

The Army Manpower Cost System.

The Army Manpower Cost System (AMCOS) is a PC-based set of automated costing tools presently under development for ARI. As presently envisioned, component models will deal with active force, reserve component and civilian work force costing. However, only the active force model is presently operational. AMCOS is a manpower life cycle cost model which calculates the costs involved in filling a manpower requirement ("space") from recruitment to retirement. These costs can then be used in the determination of the costs of manning a system over its life cycle. This permits comparison of manpower costs for alternative systems or system configurations, as long as manpower requirements are available from another methodology such as HCM.

AMCOS makes use of "policy modules" which reflect the effects of Army personnel policies on costs. These modules include sets of equations that generate cost flows for 11 major cost elements. The 11 cost elements are as follows:

- Military Compensation
- Enlisted Recruiting
- Officer Acquisition
- Training
- Permanent Change of Station
- Retired Pay Accrual
- Selective Reenlistment Bonus
- Special Pays
- Medical Support
- Other Benefits
- The New GI Bill

Within each of these elements are underlying cost components, which are briefly described in Table A-1 in Appendix A. A more detailed listing of the variables within each of the cost elements is given in Table A-2.

In addition to structuring these components in terms of elements, they may be structured in terms of budget appropriation categories. The equations underlying the data flow and processing within each of the modules are designed to be amenable to change to reflect policy changes and also to accommodate future increases in the complexity or sophistication of the equations. The user may introduce changes in the underlying assumptions or structure. The policy modules access an underlying data base which organizes such data as pay, policy, demographics, special allowances, etc., which are MOS-or pay grade-specific or which apply across MOSs. This data base contains all the data needed for the execution of the policy modules. The policy modules in turn produce cost estimates that are placed into a structured cost data base which stores cost data by MOS, pay grade, major cost element, budget appropriation, and marginal or average cost. A cost estimation model draws upon this data base to produce a time-phased profile of manpower costs over a system's life cycle. It is through use of this cost estimating model that the personnel costs in the structured data base interact with the manpower requirements previously determined for the system, to derive system manpower costs. More detailed information about the model may be obtained by referring to "Army Manpower Cost Systems: Army Active Component Life Cycle Cost Estimation Model, Information Book" (Hogan, et. al., 1989).

The 4.0 version of AMCOS was used in the analyses presented in this report. Since these analyses were performed, a 4.1 version of AMCOS, with updated costing data, has appeared. More information may be obtained by referring to the User's manual for the 4.1 version (Doering, et. al., 1990).

RESULTS AND DISCUSSION

The organization of the results is as follows: The first section presents the results of the comparison of the representative FACS configuration (as defined in the section on the HARDMAN comparability methodology) with the M1A1 (the predecessor system). The second section presents comparisons between alternative technologies (that selected for the representative FACS configuration versus an alternative) for each of the five subsystems. The third section represents an amalgamation of the first two in that it presents the manpower requirements and costs relative to the M1A1 for various configurations of subsystem alternatives other than that chosen for the representative FACS configuration. The fourth section presents the results of three tradeoff analyses exploring the consequences of different assumptions than those used in the initial comparison of the representative FACS configuration with the M1A1.

Within each section (with the exception of the third), manpower requirements which resulted from the HCM analyses are summarized. These results are derived from the Hay Systems report (Shotzbarger, et. al., 1989), to which the reader is referred for more detailed results dealing with manpower requirements. The manpower costs resulting from the AMCOS analyses are then presented and discussed.

Comparison of M1A1 and representative FACS configuration.

Manpower requirements. In the HARDMAN analyses, manpower requirements for the FACS as compared with the predecessor system, the M1A1, were derived for the active force, the armored battalion and the armored cavalry squadron levels. The savings in manpower requirements found for the FACS, as compared with the M1A1, rank ordered by MOS, are summarized in Table 1. The table also gives savings in terms of an individual tank. (Those figures in parenthesis represent cases where requirements were found to be more for the FACS than for the M1A1). The identifications of

Table 1. Savings in Manpower Space Requirements for the FACS, Rank Ordered by MOS

MOS	PER TANK	ARMOR CAVALRY SQUADRON	ARMOR BATTALION	ACTIVE FORCE
19K	1.0000	41.00	58.00	3,501.00
63H	0.2053	8.42	11.91	718.84
45K	0.1461	5.99	8.47	511.19
45E	0.0732	3.00	6.00	351.00
41C	0.0376	1.54	2.17	131.12
29E	0.0039	0.16	0.22	13.15
63J	0.0022	0.09	0.14	8.30
39E	0.0017	0.07	0.10	6.08
45G	0.0015	0.06	0.09	5.49
31V	0.0000	0.00	0.00	0.00
63E	0.0000	0.00	0.00	0.00
44E	(0.0002)	(0.01)	(0.01)	(0.87)
44B	(0.0059)	(0.24)	(0.34)	(20.63)
63G	(0.0124)	(0.51)	(0.73)	(43.79)
TOTAL	1.4530	59.57	86.02	5,180.88

the MOSs for the crew and the maintenance MOSs at the two maintenance levels are given in Table 2. Manpower requirements are expressed in whole spaces for the crew and organizational level MOSs, as each soldier at these levels is totally committed to one system, and in fractional spaces for the MOSs at the intermediate level, as maintainers at this level deal also with systems other than the one being analyzed. Therefore, the fractional manpower space requirements represent the portion of time that the MOS will devote to the particular system being analyzed. It will be recalled that the active force represents 3501 tanks, the armored battalion represents 58 tanks and the armored calvary squadron represents 41 tanks.

As shown by Table 1, savings in manpower space requirements were found for nine of the MOSs, more then offsetting increases found for three of the MOSs, resulting in a net decrease in manpower space requirements for the FACS, as compared with the M1A1. The greatest savings occurs for the crew, 19K, due to the change from a four man to a three man crew. The largest saving for the maintenance MOSs is for the 63H (Track Vehicle Repairer), followed by the 45K (Tank Turret Repairer). The next rank order savings is for the 45E (Tank Turret Mechanic), which is the only organization level maintainer impacted upon by the change to the FACS. (For the other two MOSs at the organizational maintenance level, the 31V (Communications Maintainer) and the 63E (Tank System Mechanic), there is no change in manpower requirements.) For three of the MOSs, 44E (Machinist), 44B (Metal Worker) and 63G (Fuel and Electrical Systems Repairer), manpower space requirements were found to be more for the FACS as compared to the M1A1. (For the 44E and 44B, these MOSs were not required for maintenance of the M1A1 but become necessary for the FACS.)

Manpower costs. AMCOS was applied to the manpower space requirements to derive cost estimates at four levels: one tank, an armor calvary squadron (41 tanks), an armor battalion (58 tanks), and the total active force (3501 tanks). (As AMCOS can deal only with the active component at this time, reserve component manpower requirements were not subjected to the costing estimation.) Manpower costs were derived, at each level , for one year and for the total cost over 30 years, considered the life span of the system. The costs are given in terms of undiscounted costs, which include, but do not compensate for, the effects of inflation. In other words, the total costs over 30 years reflect the effects of inflation and are not in terms of "constant dollars."

The savings found in manpower costs for the FACS as compared to the M1A1 by MOS for the four levels are summarized for the first year in Table 3 and over thirty years in Table 4. The savings in manpower costs reflect the savings in manpower space requirements, derived in the HARDMAN analysis, upon which the AMCOS analysis was based. The manpower costs savings for the active force for the first year is also presented diagrammatically in Figure 4.

Table 2. MOSs by Maintenance Level

The MOSs involved in the two maintenance levels, shown with title, are as follows, along with the crew:

Crew	19K	M1 (FACS) Armor Crewman
Organizational	31V	Unit Level Comm. Maintainer
	45E	M1 (FACS) Tank Turret Mechanic
	63E	M1 (FACS) Tank System Mechanic
Intermediate	29E	Radio Repairer
	39E	Special Electronics Devices Repairer
	41C	Fire Control Instrument Repairer
	44B	Metal Worker
	44E	Machinist
	45G	Fire Control Systems Repairer
	45K	Tank Turret Repairer
	63G	Fuel and Electrical Systems Repairer
	63H	Track Vehicle Repairer
	63J	Quartermaster and Chemical Equipment Repairer

Table 3. Savings in Manpower Costs for the FACS, First Year, Rank Ordered by MOS

MOS	PER TANK	ARMOR CAVALRY SQUADRON	ARMOR BATTALION	ACTIVE FORCE
19K	$25,063	$1,027,580	$1,453,650	$87,745,250
63H	$7,551	$310,160	$438,660	$26,435,530
45K	$6,259	$255,540	$360,220	$21,770,850
45E	$3,513	$105,140	$210,290	$12,302,240
41C	$1,430	$59,310	$83,330	$5,007,260
29E	$138	$6,000	$8,120	$482,850
63J	$88	$3,360	$5,170	$307,560
39E	$61	$2,530	$3,550	$216,770
45G	$60	$2,750	$3,890	$212,040
31V	$0	$0	$0	$0
63E	$0	$0	$0	$0
44E	($10)	($310)	($310)	($33,360)
44B	($210)	($8,630)	($12,170)	($734,710)
63G	($459)	($18,530)	($26,690)	($1,607,100)
TOTAL	$43,484	$1,744,900	$2,527,710	$152,105,180

Table 4. Savings in Manpower Costs for the FACS, Thirty Years, Rank Ordered by MOS (Undiscounted Costs).

MOS	PER TANK	ARMOR CAVALRY SQUADRON	ARMOR BATTALION	ACTIVE FORCE
19K	$1,166,558	$47,828,950	$67,660,410	$4,084,121,260
63H	$350,282	$14,364,970	$20,316,340	$1,224,337,380
45K	$287,911	$11,846,100	$16,698,830	$1,009,230,530
45E	$168,074	$4,874,140	$9,748,280	$570,274,170
41C	$66,518	$2,746,100	$3,858,080	$231,842,410
29E	$6,497	$278,500	$376,770	$22,394,810
63J	$4,133	$155,940	$239,720	$14,261,700
39E	$2,841	$117,180	$164,780	$10,051,770
45G	$3,100	$127,570	$179,790	$9,812,630
31V	$0	$0	$0	$0
63E	$0	$0	$0	$0
44E	($244)	($14,170)	($14,170)	($1,545,570)
44B	($9,722)	($400,050)	($563,870)	($34,054,440)
63G	($21,302)	($858,110)	($1,235,550)	($74,390,320)
TOTAL	$2,024,646	$81,067,120	$117,429,410	$7,066,336,330

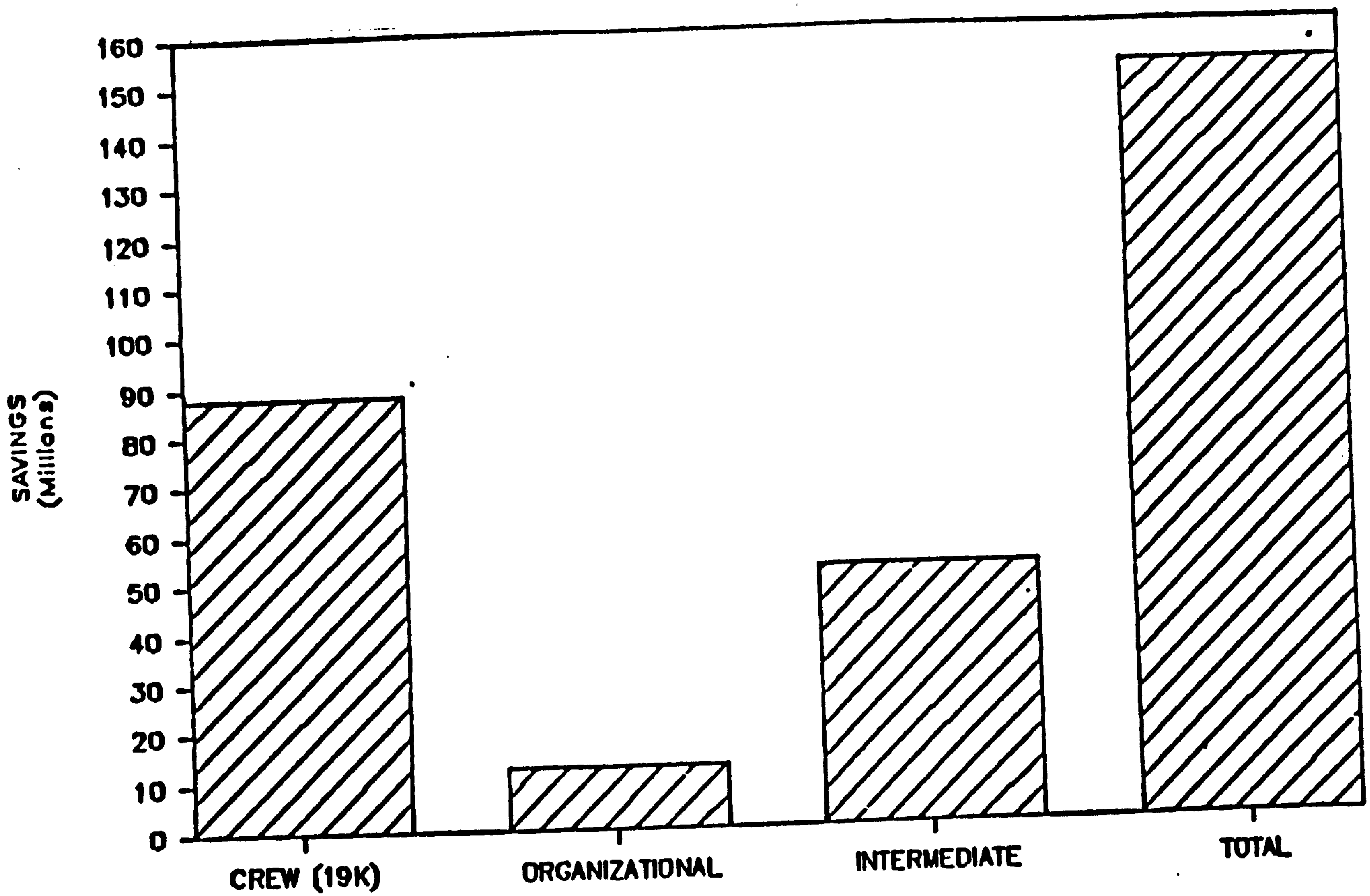

Figure 4. Manpower Cost Savings for the FACS for the First Year for the Active Force.

As may be seen by reference to Table 3, the total manpower cost associated with the FACS is $43,484. less for the first year, per tank, than that for the M1A1. This lower cost translates to a savings of $2,024,646. per tank over a period of thirty years (undiscounted costs), as may be seen by reference to Table 4. These costs are further magnified when the various multiples of tanks are considered at the various levels. For the active force, the manpower cost savings per tank is multiplied by 3501 tanks, giving a cost savings of $152,105,180. for the first year, as shown in Table 3 and Figure 4. The savings grow to $7,066,336,330. over thirty years, as shown in Table 4.

Of the total savings found for the FACS, the savings for the 19K (Armor Crewman) represents the greatest proportion of this savings. This reflects the reduction in the crew size from four in the M1A1 to three in the FACS. As may be seen by reference to Table 4 and Figure 4, the savings for the crew represents more than half the total savings. (For the active force for the first year, the savings for the crew is $87,745,250. out of the total savings of $152,105,180.). However, savings were also found for maintenance manpower costs. As shown diagrammatically in Figure 4, there is a savings of $52,057,690. for intermediate level maintenance manpower costs and $12,302,240. in savings for organizational level maintenance, for the active force for the first year.

The savings per MOS, for the active force for the first year, arranged in decreasing order, is also shown in Table 3 and diagrammatically in Figure 5. (The savings per MOS over thirty years is given in Table 4). Savings range from $87,745,250 for the 19K (Armor Crewman), for the active force for the first year, and $26,435,530 for the 63H (Track Vehicle Repairer) to $212,040 for the 45G (Fire Control Systems Repairer). For two of the MOSs (31V (Unit Level Communications Maintainer) and 63E (Tank System Mechanic)) there are no savings and for three (44B (Metal Worker), 44E (Machinist), and 63G (Fuel and Electrical Systems Repairer)) there are increased costs in going from the M1A1 to the FACS. However, the increases in cost for these three MOSs are much smaller than the decreases in costs for the other MOSs, yielding a total savings in manpower costs.

The manpower costs for the FACS as compared to the M1A1 calculated by use of AMCOS, are presented in Tables C-1 through C-8 in Appendix C. These Tables present the results for the first year (Tables C-1 through C-4) and over thirty years (Tables C-5 through C-8) for the four levels (tank, AR BN, ACS and Active Force).

In considering the costs associated with each of the MOSs involved, the greatest savings is that associated with 19K, the crew member. This reflects the reduction in the crew size from four in the M1 to three in the FACS. It should also be pointed out that the AMCOS analysis takes into account the different

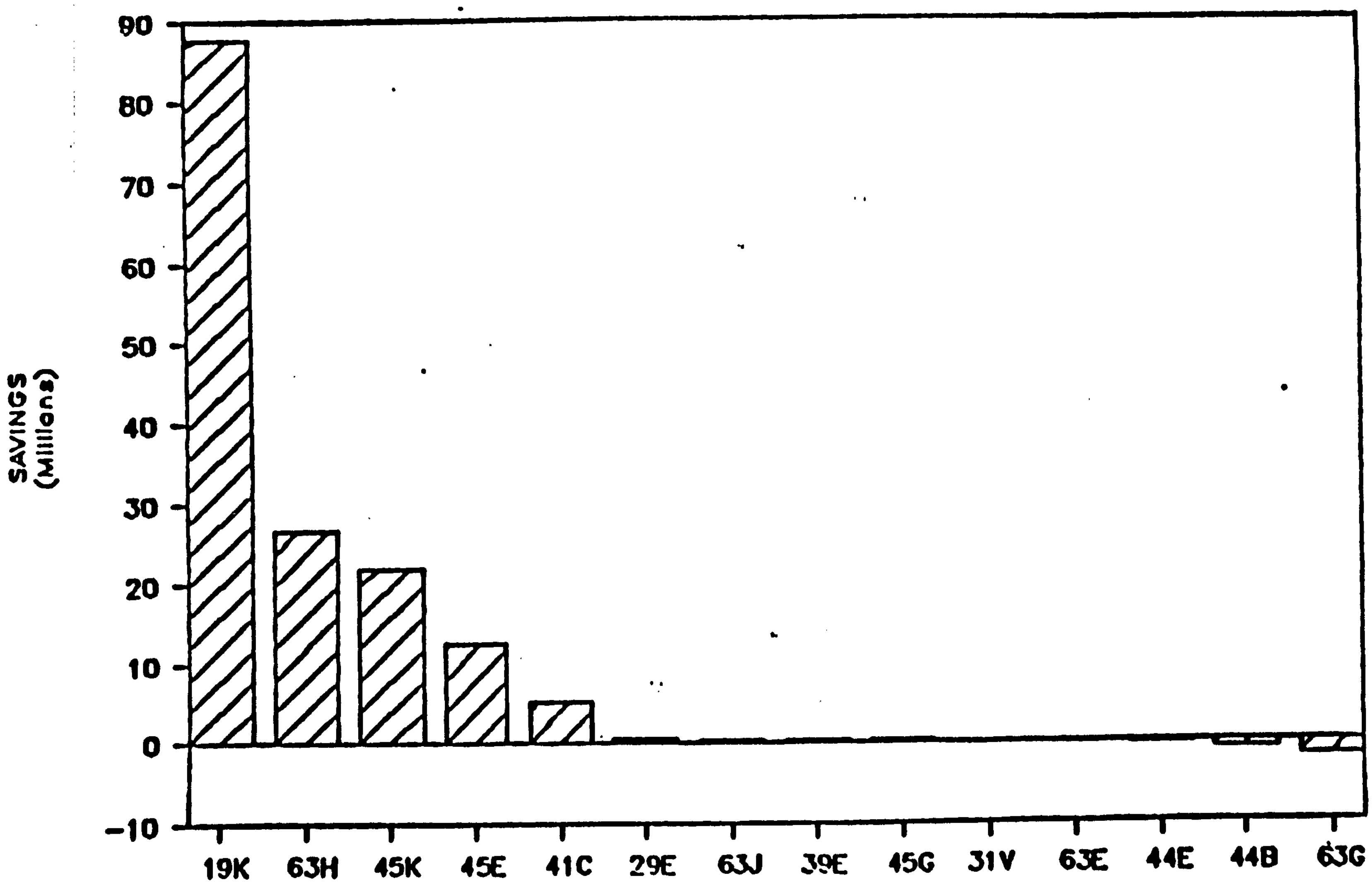

Figure 5. Manpower Cost Savings for the FACS by MOS for the First Year for the Active Force.

manpower space, and associated cost, requirements for each pay grade within an MOS. For all the MOSs except the 19K a 3-3-3-1 split among the pay grades was used. For the 19K, the first pay grades (PVT and PFC) were eliminated, reflecting the elimination of the loader position on the crew. (The HARDMAN analysis has discussed the disruption of the promotion pathway for 19K that may result.) The breakdown of manpower requirements, for the active force, for the M1 by MOS and rank is given in Table B-1 in Appendix B while the same breakdown for the FACS is given in Table B-2.

The breakdown on costs per year for an individual soldier, derived by AMCOS, at each grade level for an MOS is given in Table 5. It can be seen that costs vary for MOS and grade level. It is to be noted that for some of the MOSs there is a cap to the grade level involved. There is obviously a variation in costs over MOSs and grade level. It is to be noted that the costs given in Table 5 were produced by the 4.0 version of AMCOS which was used for these analyses. The 4.1 version which became available subsequent to these analyses incorporates updated cost data. An example of the cost breakdown for an MOS (63H (Track Vehicle Repairer)) by paygrade and cost variable, drawn from the 4.1 version, is given in Table A-3 in Appendix A. Generally, there is an increase in cost in going from the 4.0 to the 4.1 version. However, this increase in cost varies widely over MOS and paygrade within MOS.

The variation encountered over the cost elements over MOSs results in the variation in total cost over MOSs. For example, the average cost of recruiting will vary over MOSs due to variation in the use of recruiting incentives, such as enlistment bonuses, for various MOSs. In addition, such incentives may be offered only to "high quality" recruits (defined as high school graduates whose scores place them in AFQT categories I-IIIA) and each MOS may have a different mix of high and low quality recruits. This variation in cost due to varying characteristics of an MOS is reflected in Figure 6, which depicts the relationship between savings in cost-per-tank and the aptitude area cutoff scores required for entry into the MOSs involved. The magnitude of the savings is the sum of all savings attributable to the MOSs having the indicated cutoff score. With some exceptions for individual MOSs, the trend is for reduced savings as the cutoff score increases. The savings shown at the lowest cutoff score, 90, is due to the reduction in crew size from 4 in the M1A1 to 3 in the FACS. A possible contributor to this trend is the increased cost of recruiting and retaining soldiers in the MOSs having higher cutoff scores. This trend suggests that, as systems are acquired with reduced demands on the soldier quality, savings may be realized in personnel costs per soldier.

Table 5. Costs for an Individual Soldier by MOS and Rank

Maintenance Level	MOS	PVT - PFC	SPC	SGT	SSG	SFC
Crew	19K	$25,063	$30,791	$36,623	$43,275	$50,303
Organizational	31V	$28,975	$33,889	$39,922	$48,599	$55,625
	45E	$29,366	$34,498	$42,346	$0	$0
	63E	$28,997	$34,790	$42,334	$51,012	$57,737
Intermediate	29E	$29,153	$34,806	$41,974	$49,982	$61,912
	39E	$28,146	$33,898	$40,607	$47,909	$0
	41C	$30,821	$36,648	$43,233	$49,711	$0
	44B	$29,780	$35,660	$42,447	$0	$0
	44E	$30,599	$35,680	$43,820	$52,566	$59,252
	45G	$31,670	$38,001	$43,139	$50,060	$0
	45K	$35,543	$40,875	$46,831	$56,153	$65,760
	63G	$31,565	$36,868	$42,784	$0	$0
	63H	$29,653	$35,240	$40,859	$50,478	$57,628
	63J	$28,532	$34,231	$41,859	$56,685	$0

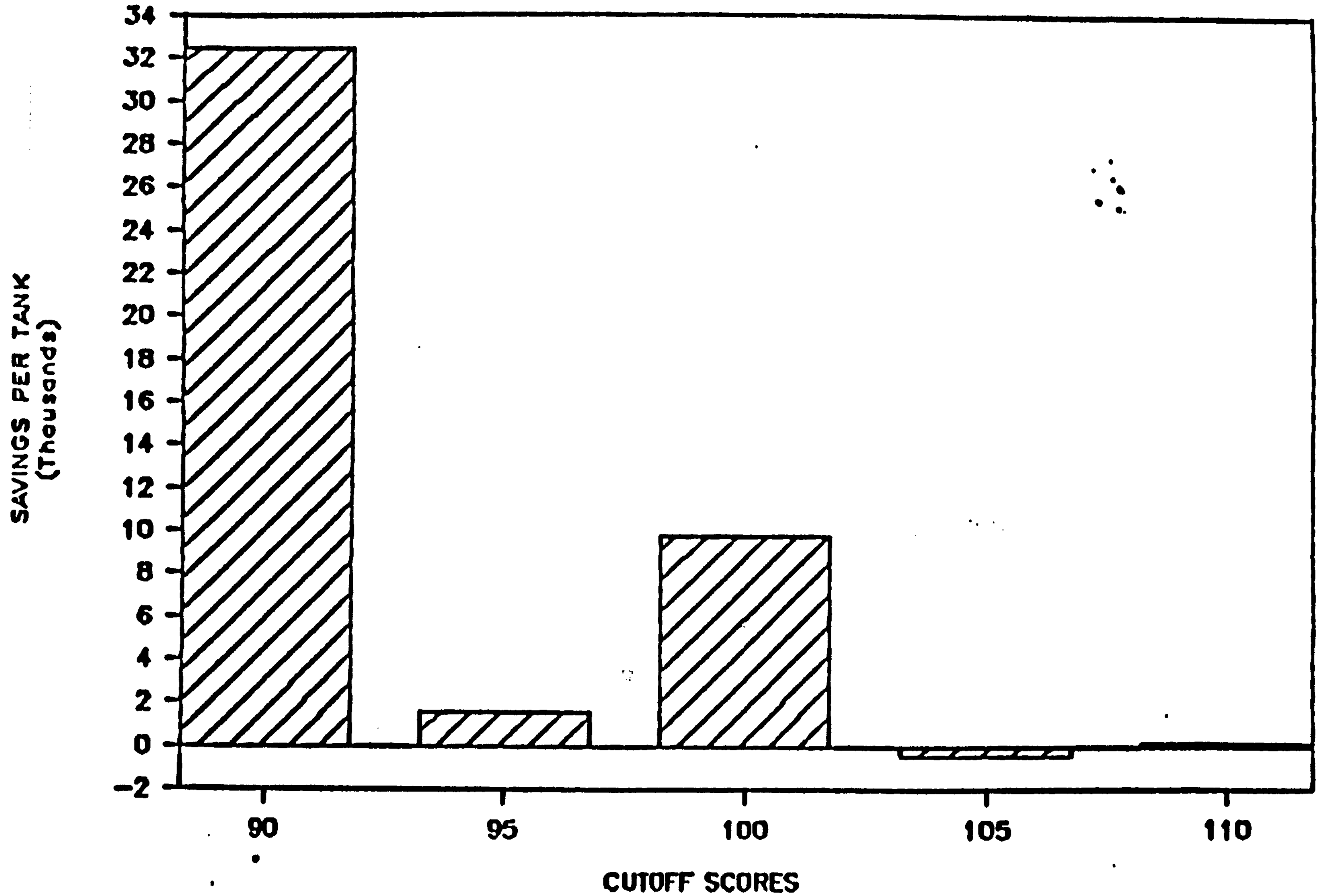

Figure 6. Manpower Cost Savings per Tank by MOS Cutoff Score

Comparison of FACS alternative subsystem technologies.

Manpower requirements. In addition to comparison of the FACS representative configuration with the predecessor system (M1A1), the HARDMAN analysis also made comparisons between alternative technologies for the five subsystems; propulsion, vehicle drive, turret drive, suspension and armament. The manpower spaces required for each alternative technology and the differences for the manpower spaces required, for the active force, are given on Table 6, which shows the alternatives for each of the subsystems. The alternative included in the representative FACS configuration is indicated by an asterisk. It can be seen that the technologies in the FACS for the propulsion, vehicle drive, and armament subsystens require fewer manpower spaces than do the alternative technologies. For the turret drive and suspension subsystems, the FACS representative configuration was found to require more spaces.

Manpower costs. The savings found for the technology used for each of the subsystems for the representative FACS configuration, as compared with an alternative, per MOS involved, are summarized in Table 7. Paralleling the results with the manpower requirements, savings in manpower costs for the alternatives in the representative FACS configuration were obtained for the propulsion, vehicle drive and armament subsystems while increases in manpower costs were obtained for the turret drive and suspension subsystems.

For the propulsion subsystem, most of the savings in the use of the diesel alternative represented in the FACS configuration may be attributed to the savings in the use of the 63E (Tank System Mechanic).

For the vehicle drive subsystem, the savings in the use of the conventional alternative chosen for the representative FACS configuration may be attributed to the elimination of the need for the 52D (Power Generation Equipment Repairer) for the electric alternative.

For the turret drive subsystem, the increase in the manpower costs for the conventional alternative may be attributed to the requirement for the use of the 63E (Tank System Mechanic) and 63H (Track Vehicle Repairer) which are not required for the electric alternative. This increased cost offsets the reduced costs associated with the use of 45E (Tank Turret Mechanic) and 45K (Tank Turret Repairer).

For the suspension subsystem, the greater cost for the hydropneumatic alternative in the representative FACS configuration can be attributed to the greater cost associated with the use of the 63H (Track Vehicle Repairer) for this alternative as compared with the conventional alternative.

Table 6. First Year Maintenance Manpower Spaces Required for Alternative Technologies (Active Force)

SYSTEM	ALTERNATIVE	MANPOWER	DIFFERENCE
Propulsion	Turbine	1312.22	
	Diesel *	865.08	447.14
Vehicle Drive	Electric	1806.14	
	Conventional *	865.08	941.06
Turret Drive	Electric	34.50	
	Conventional *	69.11	(34.61)
Suspension	Conventional	84.79	
	Hydropneumatic *	246.79	(162.00)
Armament	LP GUN	118.45	
	120 MM *	87.53	30.92

* Used in FACS.

Table 7. Savings in First Year Maintenance Manpower Costs for the FACS by Subsystem (Active Force)

MOS	PROPULSION	VEHICLE DRIVE	TURRET DRIVE	SUSPENSION	ARMAMENT
63H	$452,320	($5,328,210)	($2,920)	($6,371,320)	
45K	($200,730)	$0	$460,850		$403,380
45E	($18,350)	$0	$807,190		$751,960
41C					
29E					
63J					
39E					
45G					
31V					
63E	$17,166,910	($2,160,840)	($2,526,090)	$415,820	
44E	($29,530)	($1,100)			
44B	($678,610)	$0			
63G	($178,740)	$0			
52D		$40,665,690			
TOTAL	$16,513,270	$33,175,540	($1,260,970)	($5,955,500)	$1,155,340

For the armament subsystem, the decreased cost associated with the use of the 120 mm alternative as compared with the LP gun alternative results from the decreased costs for the MOSs involved, the 45K (Tank Turret Repairer) and the 45E (Tank Turret Mechanic).

The manpower costs for the alternative technologies for the various subsystems, broken down by the MOSs involved, are given in Tables C-9 through C-13 in Appendix C.

Alternative FACS configurations.

It will be recalled that the previously discussed comparisons were based on the use of the representative FACS configuration originally used in the HARDMAN II analyses. As presented previously, this configuration consisted of the following subsystem alternatives:

Propulsion:	Diesel
Vehicle Drive:	Conventional (Advanced)
Turret Drive:	Conventional (Advanced)
Suspension:	Hydropneumatic
Armament:	120 MM Lightweight Gun

It will be further recalled, that for each subsystem, the following alternative subsystem technologies were compared with that chosen for the representative FACS configuration:

Propulsion:	Turbine compared with Diesel
Vehicle Drive:	Electric compared with Conventional
Turret Drive:	Electric compared with Conventional
Suspension:	Conventional compared with Hydropneumatic
Armament:	Liquid Propellant compared with 120 MM

As may be seen by reference to Table 7, for three of the subsystems (propulsion, vehicle drive, armament), there was a savings in manpower costs for the subsystem alternative chosen for the FACS representative configuration. For the other two systems (turret drive, suspension), the manpower costs for the subsystem alternative chosen for the FACS representative configuration were greater than those for the alternatives. As also may be seen by reference to Table 7, the savings or increase in costs may be attributed to the resultant of the impacts on costs for the MOSs involved in the maintenance of the alternative technologies. For example, as discussed previously, the savings for the propulsion subsystem for the representative FACS configuration may be attributed primarily to savings in the use of the 63E (Tank System Mechanic) while the increase in the cost for the turret drive subsystem may be attributed primarily to an increase in the use of that same MOS.

In order to determine the effects on manpower costs of the use of a configuration other than that chosen as the FACS representative configuration, a program was developed. This program factors in and combines the differences between the configurations (M1A1 versus FACS representative configuration) and the technologies used in the previous comparisons; in essence amalgamating the results discussed in the previous two sections.

As there are five subsystems, each with two alternatives, there are 2 X 2 X 2 X 2 X 2 or 32 possible combinations or configurations. One of these has already been chosen to be the representative FACS configuration. This configuration, labeled "00", and the other 31 configurations are show diagrammatically in Table 8. For the other 31 configurations, a "C" in the column(s) for the subsystem(s) indicates that the configuration uses the alternative technology to that used in the FACS representative configuration. The second column gives the manpower spaces required for each configuration while the third column presents the associated manpower costs. The fourth column gives the difference in manpower costs between the M1A1 and that particular FACS configuration, which is always a savings. The difference for the "00" configuration is the same as the difference between the M1 and the representative FACS configuration for the total active force for the first year, as given on Table 4. The cost for each of the configurations is less than that for the M1. However, as changes are made in the configurations, the differences either increase or decrease. This is shown in the last column, which gives either the increase or decrease in manpower costs for that configuration relative to the original representative FACS configuration. For example, using alternative technologies (turbine, electric drive) for the propulsion and vehicle drive subsystems, as exemplified by configuration "06" would increase the manpower cost by $49,688,810., as compared with the original FACS representative configuration ("00"), for the active force during the first year. Back tracking through the roll-up of costs, MOS 52D (power Generation Equipment Repairer) accounts for $40,665,690. in cost associated with these subsystem alternatives, which was saved in the FACS representative configuration.

While all of the configurations involve less cost than the M1A1, it can be seen that, except for six configurations, going to another configuration would involve an increase in manpower costs. For the six configurations (03, 04, 13, 14, 15 and 25) which yield a decrease in costs, there is the use of alternative technology (electric, conventional) for either the turret drive or suspension subsystem with decreased costs which override any increase in costs for the other subsystems involved in those configurations.

The manpower costs of three of the alternative configurations, along with the representative FACS configuration, are depicted in Figure 7. These were chosen to represent configurations having implications for two operational functions, movement and engagement of target. For the configuration illustrating impact on movement, alternative

Table 8. First Year Manpower Costs for Alternative FACS Configurations. (Active Force)

##	SUBSYSTEM* P	V	T	S	A	MANPOWER* SPACES	COST* CFACS	SAVINGS* M1-FACS	FACS-CFACS
00	0	0	0	0	0	12,809.49	$473,693,750	$152,105,180	$ 0
01	C	0	0	0	0	13,256.63	490,207,020	135,591,910	(16,513,270)
02	0	C	0	0	0	13,750.55	506,869,290	118,929,640	(33,175,540)
03	0	0	C	0	0	12,774,88	472,432,780	153,366,150	1,260,970
04	0	0	0	C	0	12,647.49	467,738,250	158,060,680	5,955,500
05	0	0	0	0	C	12,840.41	474,849,090	150,949,840	(1,155,340)
06	C	C	0	0	0	14,197.69	523,382,560	102,416,370	(49,688,810)
07	C	0	C	0	0	13,222,02	488,946,050	136,852,880	(15,252,300)
08	C	0	0	C	0	13,094.63	484,251,520	141,547,410	(10,557,770)
09	C	0	0	0	C	13,287.55	491,362,360	134,436,570	(17,668,610)
10	0	C	C	0	0	13,715.94	505,608,320	120,190,610	(31,914,570)
11	0	C	0	C	0	13,588.55	500,813,790	124,885,140	(27,220,040)
12	0	C	0	0	C	13,751.47	508,024,630	117,774,300	(34,330,880)
13	0	0	C	C	0	12,612.88	466,477,280	159,321,650	7,216,460
14	0	0	C	0	C	12,805.80	473,588,120	152,210,810	105,630
15	0	0	0	C	C	12,678,41	468,893,590	156,905,340	4,800,160
16	C	C	C	0	0	14,163.08	522,121,590	103,677,340	(48,427,840)
17	C	C	0	C	0	14,035.69	517,427,060	108,371,870	(43,733,310)
18	C	C	0	0	C	14,228.61	524,537,900	101,261,030	(50,844,150)
19	C	0	C	C	0	13,060.02	482,990,550	142,808,380	(9,296,800)
20	C	0	C	0	C	13,252.94	490,101,390	135,697,540	(16,407,640)
21	C	0	0	C	C	13,125.55	485,406,860	140,392,070	(11,713,110)
22	0	C	C	C	0	13,553.94	499,652,020	126,146,110	(25,959,070)
23	0	C	C	0	C	13,746.86	506,743,660	119,035,270	(33,069,910)
24	C	0	0	C	C	13,619.47	502,069,130	123,729,800	(28,375,380)
25	0	0	C	C	C	12,643.80	467,632,620	158,166,310	6,061,130
26	C	C	C	C	0	14,001.08	516,166,090	109,632,840	(42,472,340)
27	0	C	C	C	C	13,584.86	500,808,160	124,990,770	(27,114,410)
28	C	0	C	C	C	13,090.94	484,145,890	141,653,040	(10,452,140)
29	C	C	0	C	C	14,066.61	518,582,400	107,216,530	(49,588,650)
30	C	C	C	0	C	14,194.00	523,276,930	102,522,000	(49,583,180)
31	C	C	C	C	C	14,032.00	517,321,430	108,477,500	(43,627,680)

*LEGEND:

* - Negative savings or additional cost is shown by "($)".
- Configuration Number (00 is the FACS)
FACS - FACS Representative Configuration
CFACS - FACS with Changes in selected technology options:
0 is option selected for representative configuration;
C is change to alternative technology for the indicated subsystem.

SUBSYSTEM	FACS	CFACS
P - Propulsion:	0 Diesel	C Turbine
V - Vehicle Drive:	0 Conventional	C Electric
T - Turret Drive:	0 Hydraulic	C Electric
S - Suspension:	0 Hydropneumatic	C Conventional
A - Armament:	0 120 mm. Gun	C LP Gun

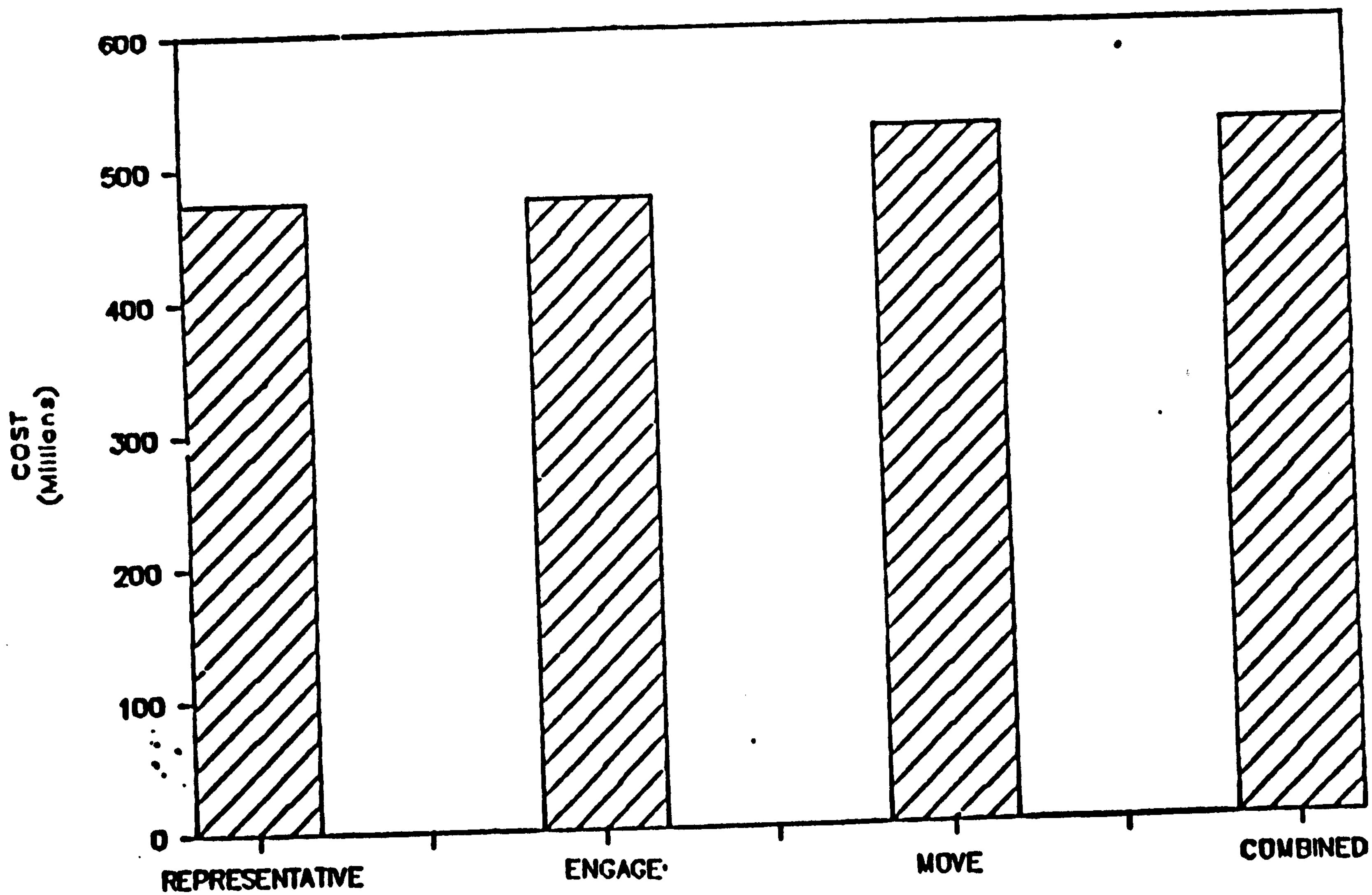

Figure 7. Manpower Costs for Alternative FACS Configurations Impacting Operational Functions for the First Year for the Active Force.

technologies were used for the propulsion and vehicle drive subsystems. This is configuration "06" in Table 8. For the configuration demonstrating cost impact on the ability to engage a target, alternative technologies were used for the turret drive and armament subsystems. This is configuration "14" in Table 8. The configuration illustrating engagement has costs somewhat less than the initial representative configuration ($473,588,120 as compared to $473,693,750 for the initial configuration) while the configuration illustrating movement costs more than the representative configuration ($523,382,560). The configuration illustrating impacts on both movement and engagement incorporates the use of alternative technologies for the propulsion, vehicle drive, turret drive and armament subsystems. This is configuration "30" in Table 8. Its cost ($523,276,930) is close to that for the configuration illustrating the impact on movement only. This indicates that it costs more to have an impact on ability to move as opposed to engaging a target. However, it should be noted that all such FACS configurations still have lower manpower costs than the M1A1.

Tradeoff analyses.

In the HARDMAN II analysis conducted on the FACS, six tradeoff analyses were performed. These tradeoff analyses were performed to examine the consequences of using different assumptions than those used in the basic analysis, i. e., the comparison of M1A1 with the representative FACS configuration under a given mission scenario, which was considered previously. Of these six HARDMAN II tradeoffs, it was considered feasible to apply the AMCOS procedure to three of the tradeoffs. These tradeoffs were; (1) evaluation of the manpower implications of increasing the reliability and maintainability (RAM) assumptions, (2) evaluation of the maintenance manpower implications of changing the assumed operational intensity, and (3) evaluation of the manpower requirements implications of adding an additional platoon to each tank company in the armor battalion.

Comparisons of effects of improvements in reliability and maintainability.

Manpower requirements. To examine the manpower implications of improving reliability and maintainability, two increments (15% and 30%) were added to the RAM assumptions used in constructing the original FACS configuration. The manpower requirements derived in the HARDMAN tradeoff analysis, for the total active force, are given in Table B-3 in Appendix B. This table gives the manpower requirements for the M1A1, the initial FACS representative configuration (unchanged from the basic analysis) and the 15% and 30% incremented RAM construct configurations. It is to be noted that these tables do not include the crew (19K), as only corrective maintenance tasks, as opposed to preventive maintenance tasks, were adjusted.

This table shows that most of the intermediate level MOSs showed progressively decreasing manpower requirements for the 15% and 30% increments in RAM. However, one of the intermediate level MOSs (44B (Metal Worker)) and two of the organizational level MOSs (45E (Tank Turret Mechanic) and 63E (Tank System Mechanic)) displayed an increase in manpower requirements in going to either the 15% or 30% increments. The HARDMAN analysis attributes these anomalies to operation of selective difference indexes used in the construction of the initial FACS configuration which are not reflected in this tradeoff.

Manpower costs. The savings in manpower costs relative to the M1A1 for the initial FACS and for the concepts incorporating 15% and 30% increments in RAM are summarized in Table 9 for the first year and in Table 10 for thirty years. This is for the total active force. The savings for the first year are also presented in Figure 8.

These tables include the costs associated with the crew member, 19K, in order to present the total manpower costs associated with the operation and maintenance of the system. In this analysis, the savings for the 19K are constant over the concepts, as the RAM increment has no effect on the 19K. For 7 of the 13 maintenance MOSs, successively greater savings relative to the M1A1 were obtained for the 15% and 30% RAM increments. Of these MOSs, the 63H (Track Vehicle Repairer) represents the greatest savings, in absolute amounts; $27,028,620 for the first year for the 15% increment and $28,826,620 for the 30% increment, relative to the M1A1. For the 45E (Tank Turret Mechanic) and the 63E (Tank System Mechanic), there was less savings for the 15% RAM increment, reflecting the artifact discussed above. For the three MOSs which had required more manpower for the initial FACS as compared with the M1A1; 44E (Machinist), 44B (Metal Worker) and 63G (Fuel and Electric Systems Repairer), more manpower costs were still associated with the FACS constructs, but somewhat attenuated for the 30% RAM increment.

The total savings do not reflect any trend towards increased savings with increased RAM; however these figures have been influenced by the HARDMAN artifact impacting on the organizational MOSs discussed above. The subtotals for the Intermediate Level do show definite incremental savings in manpower costs for the 15% and 30% RAM increments.

The results of the application of the AMCOS analyses to the manpower requirements for the increments in RAM are presented in Tables C-14 through C-17 in Appendix C. For the total active force, the comparison of the 15% increment in RAM relative to the M1, for the first year, is shown in Table C-14 with the 30% increment shown in Table C-15. The effects of the 15% and 30% increments over thirty years are shown in Tables C-16 and C-17 respectively.

Table 9. Savings in Manpower Costs for the First Year for the FACS, Rank Ordered by MOS, for 15% and 30% increments in RAM (Active Force)

MOS	INITIAL FACS	15% FACS CONSTRUCT	30% FACS CONSTRUCT
19K	$87,745,250	$87,745,250	$87,745,250
63H	$26,435,530	$27,028,620	$28,826,620
45K	$21,770,850	$23,606,670	$25,634,670
45E	$12,302,240	$10,279,710	$12,190,710
41C	$5,007,260	$5,029,550	$5,048,550
29E	$482,850	$553,560	$610,560
63J	$307,560	$313,780	$318,780
39E	$216,770	$224,210	$230,210
45G	$212,040	$542,600	$1,255,600
31V	$0	$0	$0
63E	$0	($11,303,230)	($8,643,230)
44E	($33,360)	($34,000)	($29,000)
44B	($734,710)	($765,000)	($678,000)
63G	($1,607,100)	($1,644,170)	($1,140,170)
TOTAL	$152,105,180	$141,577,550	$151,370,550

Table 10. Savings in Manpower Costs for Thirty Years for the FACS, Rank Ordered by MOS, for 15% and 30% increments in RAM (Active Force) (Undiscounted Costs)

MOS	INITIAL FACS	15% FACS CONSTRUCT	30% FACS CONSTRUCT
19K	$4,084,121,260	$4,084,121,260	$4,084,121,260
63H	$1,224,337,380	$1,251,806,830	$1,355,074,830
45K	$1,009,230,530	$1,094,341,880	$1,118,360,880
45E	$570,274,170	$476,532,760	$565,104,760
41C	$231,842,410	$232,865,800	$233,731,800
29E	$22,394,810	$25,653,200	$28,297,200
63J	$14,261,700	$14,550,970	$14,790,970
39E	$10,051,770	$10,395,690	$10,675,690
45G	$9,812,630	$25,114,060	$58,104,060
31V	$0	$0	$0
63E	$0	($523,727,370)	($400,497,370)
44E	($1,545,570)	($1,561,000)	($1,366,000)
44B	($34,054,440)	($35,470,000)	($31,404,000)
63G	($74,390,320)	($76,123,030)	($52,784,030)
TOTAL	$7,066,336,330	$6,578,501,050	$6,982,210,050

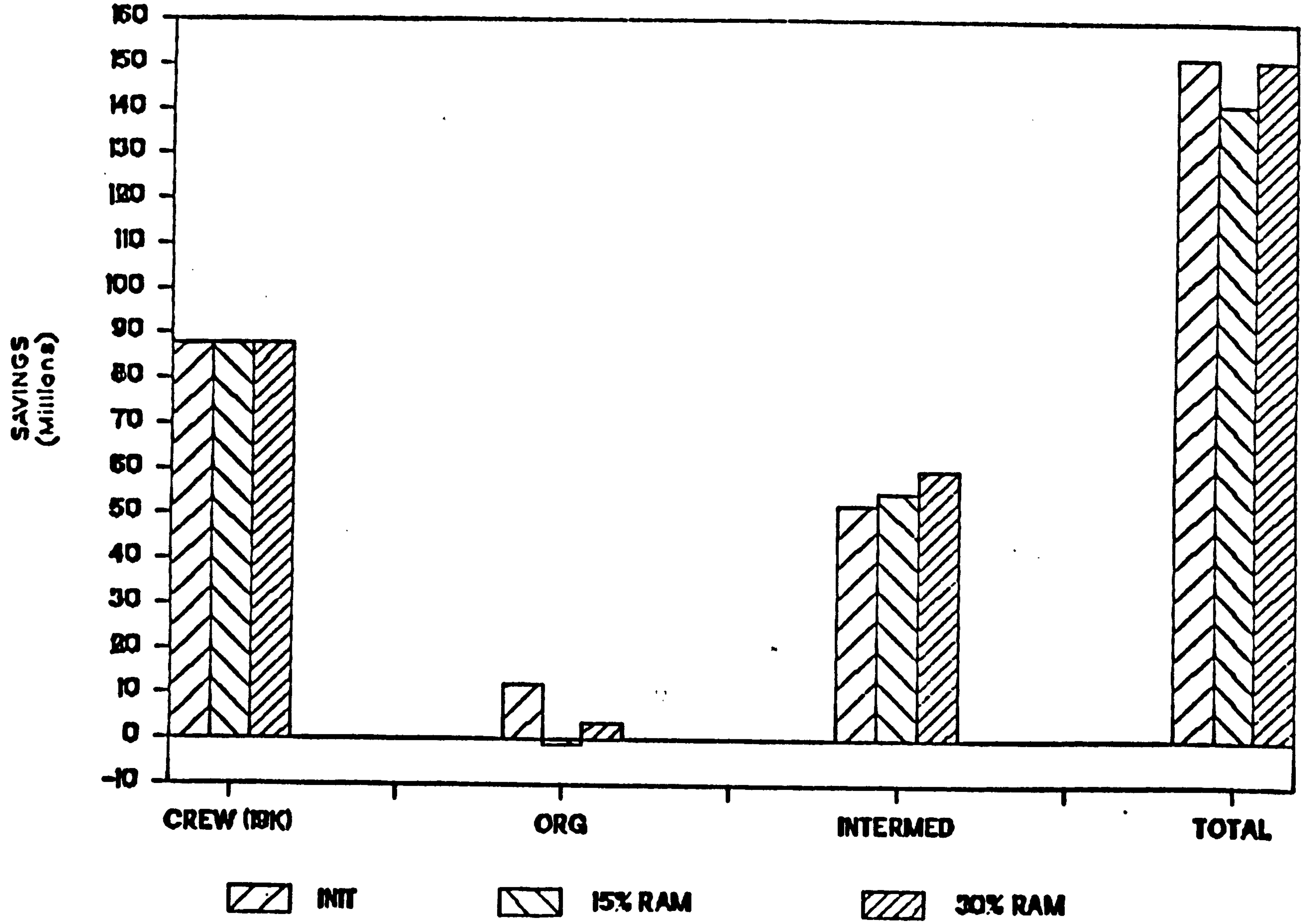

Figure 8. Manpower Cost Savings for the FACS for 15% and 30% Increments in RAM for the First Year for the Active Force.

Comparisons of effects of alternative operational intensities.

Manpower requirements. In order to assess the effects upon manpower requirements of varying equipment usage rates, alternative operational intensities to that utilized in the initial analysis were subjected to the HARDMAN analysis. The definition of these various operational intensities, along with the initial scenario, are presented in Table 11. Three alternative intensities were established, 50%, 75% and 135% of the initial operational scenario intensity. The manpower space requirements derived from the HARDMAN analysis are presented in Tables B-4 through B-12 in Appendix B. For each organizational echelon, Active Force (Tables B-4 - B-6), Armor Battalion (Tables B-7 - B-9), and Armored Cavalry Squadron (Tables B-10 - B-12) the results for each of the three operational scenarios are presented. These results are for the original FACS representative configuration at the various operational intensities compared with the M1A1 at the original intensity. The results consistently yield an overall savings in manpower requirements for the FACS as opposed to the M1A1. This holds even for the increased operational intensity (135%), indicating that the overall net savings in manpower requirements for the FACS more than compensates for any increased manpower requirements due to the increased operational intensity. With reduced operational intensities (50% and 75%), the savings are even more.

Manpower costs. The savings in manpower costs for the FACS as compared to the M1A1 over the various operational intensities are summarized for the various echelons in Tables 12 - 14 for the first year and in Tables 15 - 17 for over thirty years. The savings in cost relative to the M1A1 for the various operational intensities, for the active force for the first year, is also given in Figure 9. The savings in manpower costs show increased savings for the reduced intensities relative to the initial intensity. There is less savings in manpower costs for the increased intensity of 135%, but yet, even for this increase of almost 50% over the initial intensity, an overall savings in manpower costs is manifest.

The results of the application of the AMCOS procedure to the manpower requirements for the alternative operational intensities are presented in Tables C-18 through C-35 in Appendix C. As before, for each echelon, Active Force (Tables C18 - C20), Armor Battalion (Tables C21 - C23), and Armored Cavalry Squadron (Tables C24 - C26) the comparison of costs, per MOS, for each of the three operational intensities, for the first year of operational life, are presented. The same comparisons, but over thirty years, are presented in Tables C27 - C29 for the Active Force, Tables C30 - C32 for an Armor Battalion, and Tables C33 - C35 for an Armor Cavalry Squadron.

Table 11. Alternative FACS Operational Intensities

MISSION ESSENTIAL FUNCTION	INITIAL	50%	75%	135%
Move (Miles)	8,159	4079.50	6119.25	11,014.65
Moving - Engine On (HRS)	721	360.50	540.75	973.35
Idle - Engine On (HRS)	951	475.50	713.25	1283.85
Surveillance (HRS)	1,710	855	1282.50	2308.50
Acquire Targets (HRS)	18.15	9.08	13.61	24.50
Communication (HRS)	48	24	36	64.80
Engage Targets/ Main Weapon (HRS)	13	6.50	9.75	17.55
Smoke Grenade Launch (HRS)	.58	.29	.44	.78
Smoke Screen (HRS)	35	17.5	26.25	47.25
Secondary Weapon System Surveillance and Fire Control (HRS)	1700	850	1275	2295
NBC Protection (HRS)	288	144	216	388.80
Radios On (HRS)	2880	1440	2160	3888

Table 12. Savings in Manpower Costs for the First Year for the FACS, Rank Ordered by MOS, for Alternative FACS Operational Intensities (Active Force)

MOS	INITIAL FACS	FACS 50% OPERATIONAL INTENSITY	FACS 75% OPERATIONAL INTENSITY	FACS 135% OPERATIONAL INTENSITY
19K	$87,745,250	$87,745,250	$87,745,250	$87,745,250
63H	$26,435,530	$34,517,620	$30,475,620	$20,779,620
45K	$21,770,850	$31,484,670	$26,625,670	$14,969,670
45E	$12,302,240	$12,190,710	$12,190,710	$12,190,710
41C	$5,007,260	$5,096,550	$5,051,550	$4,942,550
29E	$482,850	$763,560	$623,560	$287,560
63J	$307,560	$331,780	$319,780	$289,780
39E	$216,770	$247,210	$231,210	$194,210
45G	$212,040	$3,470,600	$1,842,600	($2,071,400)
31V	$0	$0	$0	$0
63E	$0	$26,927,000	$6,648,770	($9,419,230)
44E	($33,360)	($16,000)	($22,000)	($45,000)
44B	($734,710)	($371,000)	($557,000)	($1,002,000)
63G	($1,607,100)	$536,830	($557,170)	($3,182,170)
TOTAL	$152,105,180	$202,924,780	$170,618,550	$125,679,550

Table 13. Savings in Manpower Costs for the First Year for the FACS, Rank Ordered by MOS, for Alternative FACS Operational Intensities (Armor Battalion)

MOS	INITIAL FACS	FACS 50% OPERATIONAL INTENSITY	FACS 75% OPERATIONAL INTENSITY	FACS 135% OPERATIONAL INTENSITY
19K	$1,453,650	$1,453,650	$1,453,650	$1,453,650
63H	$438,660	$572,050	$505,050	$345,050
45K	$360,220	$521,190	$440,190	$247,190
45E	$210,290	$210,290	$210,290	$210,290
41C	$83,330	$84,640	$83,640	$81,640
29E	$8,120	$12,330	$10,330	($33,670)
63J	$5,170	$5,800	$4,800	$4,800
39E	$3,550	$4,580	$3,580	$3,580
45G	$3,890	$58,420	$31,420	($33,580)
31V	$0	$0	$0	$0
63E	$0	$221,870	$110,870	($185,130)
44E	($310)	$0	$0	($1,000)
44B	($12,170)	$6,000	$9,000	($17,000)
63G	($26,690)	$9,600	$8,400	($52,400)
TOTAL	$2,527,710	$3,160,420	$2,871,220	$2,023,420

Table 14. Savings in Manpower Costs for the First Year for the FACS, Rank Ordered by MOS, for Alternative FACS Operational Intensities (Armor Cavalry Squadron)

MOS	INITIAL FACS	FACS 50% OPERATIONAL INTENSITY	FACS 75% OPERATIONAL INTENSITY	FACS 135% OPERATIONAL INTENSITY
19K	$1,027,580	$1,027,580	$1,027,580	$1,027,580
63H	$310,160	$404,060	$357,060	$243,060
45K	$255,540	$368,790	$311,790	$175,790
45E	$105,140	$105,140	$105,140	$105,140
41C	$59,310	$59,910	$59,910	$58,910
29E	$6,000	$9,590	$7,590	$3,590
63J	$3,360	$3,990	$3,990	$2,990
39E	$2,530	$3,150	$2,150	$2,150
45G	$2,750	$40,580	$21,580	($24,420)
31V	$0	$0	$0	$0
63E	$0	$148,190	$74,190	($147,810)
44E	($310)	$0	$0	$0
44B	($8,630)	($4,000)	($6,000)	($12,000)
63G	($18,530)	$5,830	($7,170)	($37,170)
TOTAL	$1,744,900	$2,172,810	$1,957,810	$1,397,810

Table 15. Savings in Manpower Costs for Thirty Years for the FACS, Rank Ordered by MOS, for Alternative FACS Operational Intensities (Active Force) (Undiscounted Costs)

MOS	INITIAL FACS	FACS 50% OPERATIONAL INTENSITY	FACS 75% OPERATIONAL INTENSITY	FACS 135% OPERATIONAL INTENSITY
19K	$4,084,121,260	$4,084,121,260	$4,084,121,260	$4,084,121,26
63H	$1,224,337,380	$1,598,633,830	$1,411,458,830	$962,380,83
45K	$1,009,230,530	$1,459,537,880	$1,234,300,880	$693,942,88
45E	$570,274,170	$565,104,760	$565,104,760	$565,104,76
41C	$231,842,410	$235,994,800	$233,908,800	$228,852,80
29E	$22,394,810	$35,427,200	$28,928,200	$13,320,20
63J	$14,261,700	$15,392,970	$14,825,970	$13,450,97
39E	$10,051,770	$11,450,690	$10,725,690	$8,995,69
45G	$9,812,630	$160,616,060	$85,269,060	($95,843,94
31V	$0	$0	$0	$
63E	$0	$616,149,630	$308,074,630	($436,439,37
44E	($1,545,570)	($763,000)	($1,029,000)	($2,093,00
44B	($34,054,440)	($17,202,000)	($25,820,000)	($46,439,00
63G	($74,390,320)	$24,834,970	($25,807,030)	($147,303,03
TOTAL	$7,066,336,330	$8,789,299,050	$7,924,062,050	$5,842,051,05

Table 16. Savings in Manpower Costs for Thirty Years for the FACS, Rank Ordered by MOS, for Alternative FACS Operational Intensities (Armor Battalion) (Undiscounted Costs)

MOS	INITIAL FACS	FACS 50% OPERATIONAL INTENSITY	FACS 75% OPERATIONAL INTENSITY	FACS 135% OPERATIONAL INTENSITY
19K	$67,660,410	$67,660,410	$67,660,410	$67,660,410
63H	$20,316,340	$26,501,260	$23,401,260	$15,958,260
45K	$16,698,830	$24,144,610	$20,412,610	$11,449,610
45E	$9,748,280	$9,748,280	$9,748,280	$9,748,280
41C	$3,858,080	$3,924,890	$3,888,890	$3,800,890
29E	$376,770	$581,750	$456,750	($1,563,250)
63J	$239,720	$251,840	$234,840	$216,840
39E	$164,780	$196,390	$179,390	$146,390
45G	$179,790	$2,680,260	$1,440,260	($1,562,740)
31V	$0	$0	$0	$0
63E	$0	$10,269,460	$5,134,460	($8,557,540)
44E	($14,170)	($18,000)	($18,000)	($35,000)
44B	($563,870)	($283,000)	($433,000)	($767,000)
63G	($1,235,550)	$428,730	($412,270)	($2,419,270)
TOTAL	$117,429,410	$146,086,880	$131,693,880	$94,075,880

Table 17. Savings in Manpower Costs for Thirty Years for the FACS, Rank Ordered by MOS, for Alternative FACS Operational Intensities (Armor Cavalry Squadron) (Undiscounted Costs)

MOS	INITIAL FACS	FACS 50% OPERATIONAL INTENSITY	FACS 75% OPERATIONAL INTENSITY	FACS 135% OPERATIONAL INTENSITY
19K	$47,828,950	$47,828,950	$47,828,950	$47,828,950
63H	$14,364,970	$18,736,700	$16,539,700	$11,276,700
45K	$11,846,100	$17,118,020	$14,446,020	$8,154,020
45E	$4,874,140	$4,874,140	$4,874,140	$4,874,140
41C	$2,746,100	$2,775,380	$2,757,380	$2,704,380
29E	$278,500	$430,040	$362,040	$175,040
63J	$155,940	$168,060	$168,060	$151,060
39E	$117,180	$129,960	$112,960	$96,960
45G	$127,570	$1,887,420	$1,006,420	($1,114,580)
31V	$0	$0	$0	$0
63E	$0	$6,845,840	$3,422,840	($6,846,160)
44E	($14,170)	($18,000)	($18,000)	($18,000)
44B	($400,050)	($200,000)	($300,000)	($550,000)
63G	($858,100)	$289,150	($311,850)	($1,736,850)
TOTAL	$81,067,130	$100,865,660	$90,888,660	$64,995,660

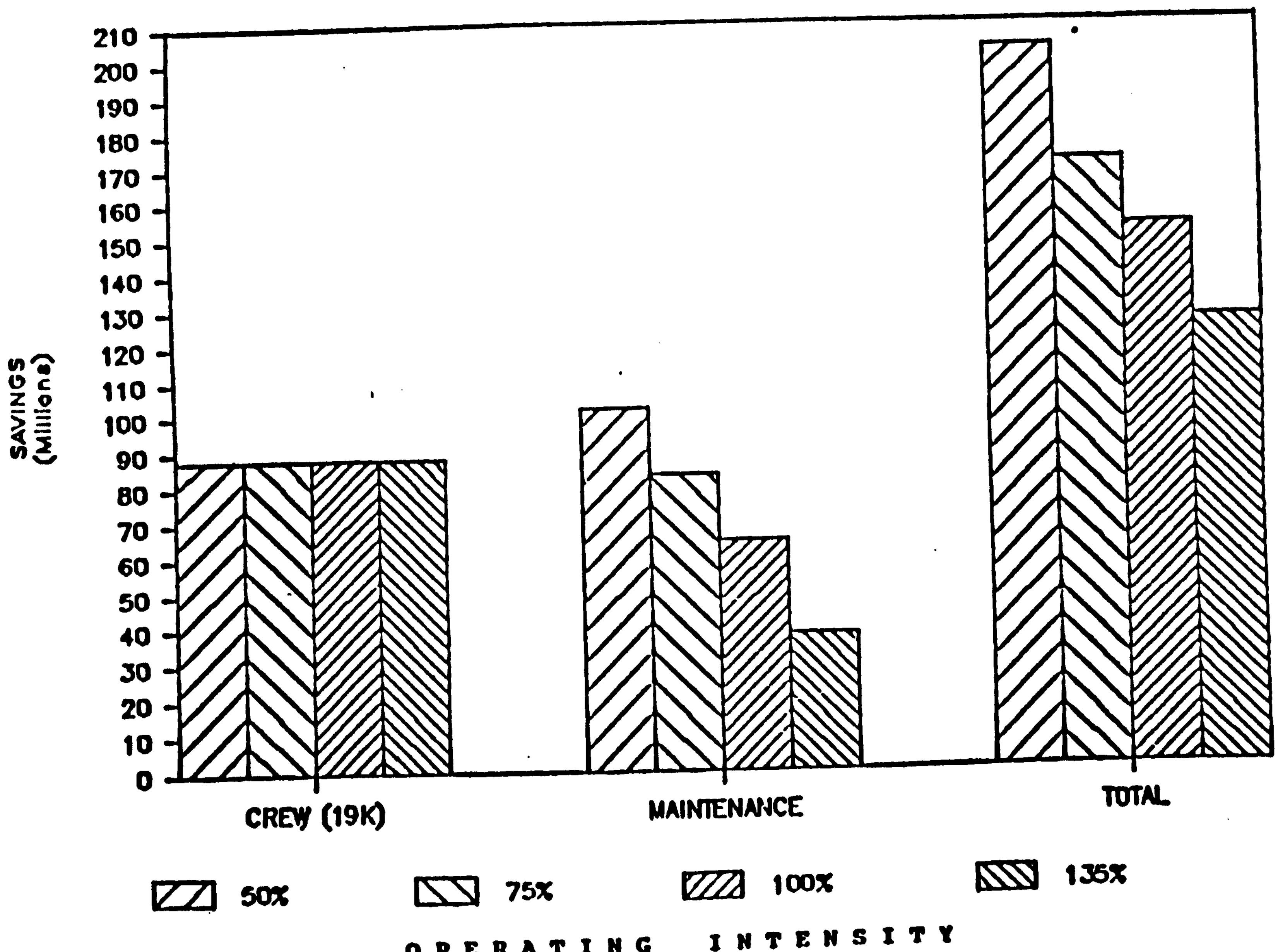

Figure 9. Manpower Cost Savings for the FACS for Alternative Operational Intensities for the First Year for the Active Force.

Enhanced operational intensity capability for the FACS

The preceding discussions have focused on the cost savings associated with improvements in RAM and at four levels of operating intensity, respectively, for the FACS as compared to the predecessor system, the M1A1. These findings may be integrated to extrapolate the enhanced operational intensity under which the FACS may be operated. In Figure 10 these savings have been replotted as a continuous function of operating intensity (solid line) with a parallel function added (dotted line) that is displaced above by an amount equal to the saving realized by a 30% improvement in RAM. The intersection of the respective lines with the x-axis provides an estimate of the operating intensity with and without the 30% RAM improvement and represents zero savings or costs equal to maintenance costs of the M1A1 under the initial scenario. Thus, the projected lines suggest an operating intensity of approximately 210% or 225% with the RAM improvements could be attained for the FACS within the same costs required for maintaining the M1AI.

Comparison of a 58 tank M1A1 armor battalion with a 74 tank FACS armor battalion.

A HARDMAN trade-off analysis was conducted to examine the impact on manpower requirements of restructuring the FACS armor battalion by adding a FACS platoon to each company, resulting in an increase from 58 to 74 tanks for a FACS battalion. The costs of these manpower requirements were then determined through use of AMCOS and compared with the cost for a 58 tank M1A1 battalion. This comparison is shown in Table 18 for the first year costs, and Table 19 for costs over thirty years. The costs for the first year are also presented in Figure 11. It can be seen that the manpower costs associated with adding an additional platoon to each FACS company, resulting in a 74 tank FACS armor battalion, does not exceed that for a 58 tank M1A1 armor battalion.

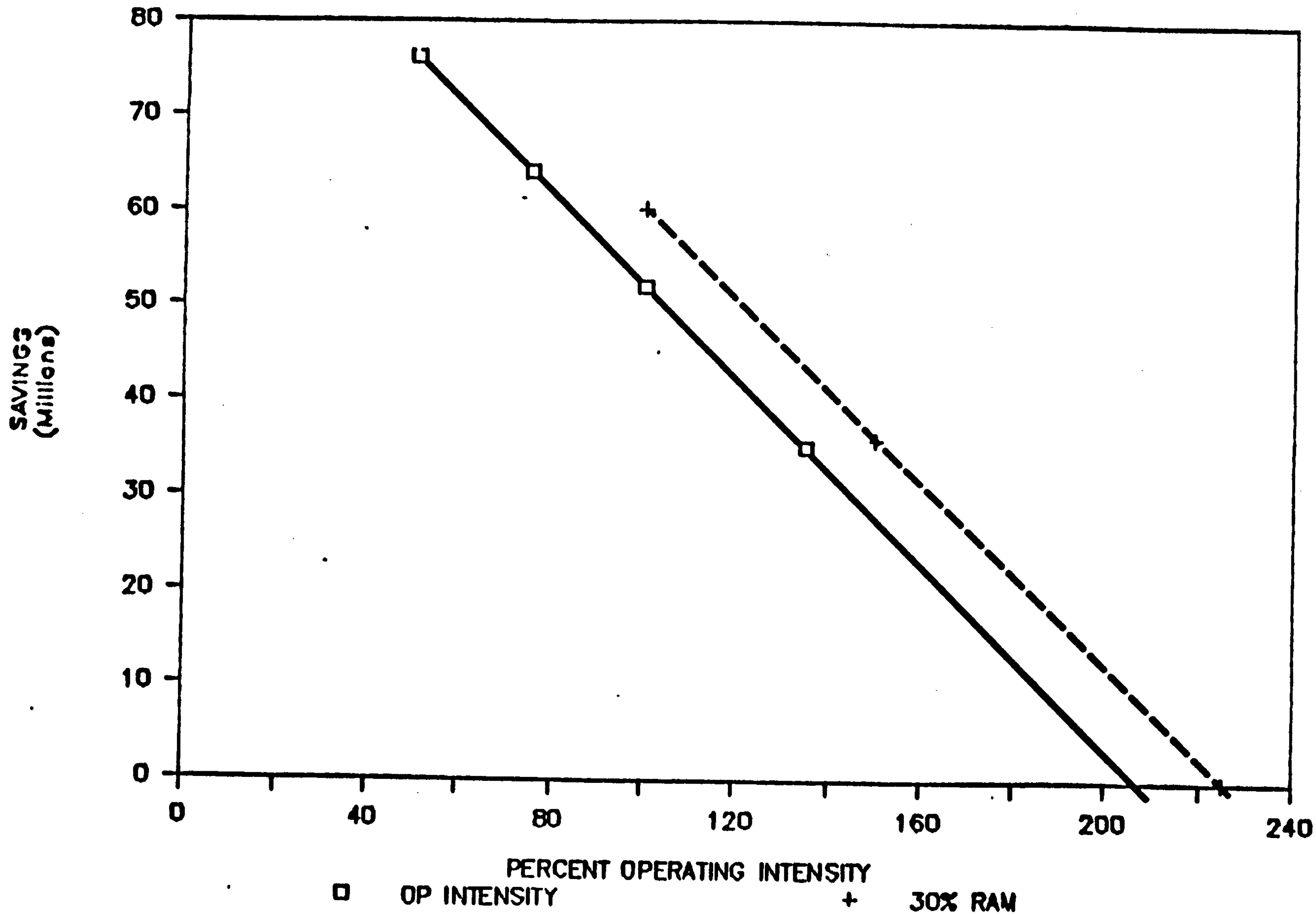

Figure 10. Operational Intensity Capability for the FACS with and without 30% Increment in RAM.

Table 18. Manpower Costs for the First Year for a 58 Tank M1A1 and a 74 Tank FACS Armor Battalion

Maintenance Level	MOS	M1A1	FACS 74 TANKS	Difference
Crew	19K	$7,411,350	$7,584,000	($172,650)
Organizational	31V	$214,170	$214,170	$0
	45E	$385,540	$177,000	$208,540
	63E	$664,870	$850,000	($185,130)
Org subtotal		$1,264,580	$1,241,170	$23,410
Intermediate	29E	$17,330	$12,000	$5,330
	39E	$4,580	$1,000	$3,580
	41C	$91,640	$11,000	$80,640
	44B	$0	$16,000	($16,000)
	44E	$0	$1,000	($1,000)
	45G	$115,420	$142,000	($26,580)
	45K	$691,190	$423,000	$268,190
	63G	$45,600	$92,000	($46,400)
	63H	$706,050	$342,000	$364,050
	63J	$5,800	$1,000	$4,800
Intermed subtotal		$1,677,610	$1,041,000	$636,610
Total all levels		$10,353,540	$9,866,170	$487,370

Table 19. Manpower Costs for Thirty Years for a 58 Tank M1A1 and a 74 Tank FACS Armor Battalion (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 74 TANKS	Difference	%
Crew	19K	$344,601,940	$352,522,000	($7,920,060)	-2%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$17,871,840	$8,205,000	$9,666,840	54%
	63E	$30,807,460	$39,365,000	($8,557,540)	-28%
Org subtotal		$58,604,250	$57,494,950	$1,109,300	2%
Intermediate	29E	$803,750	$551,000	$252,750	31%
	39E	$212,390	$61,000	$151,390	71%
	41C	$4,242,890	$491,000	$3,751,890	88%
	44B	$0	$727,000	($727,000)	
	44E	$0	$32,000	($32,000)	
	45G	$5,341,260	$6,580,000	($1,238,740)	-23%
	45K	$32,041,610	$19,601,000	$12,440,610	39%
	63G	$2,110,730	$4,282,000	($2,171,270)	-103%
	63H	$32,700,260	$15,824,000	$16,876,260	52%
	63J	$268,840	$48,000	$220,840	82%
Intermed subtotal		$77,721,730	$48,197,000	$29,524,730	38%
Total all levels		$480,927,920	$458,213,950	$22,713,970	5%

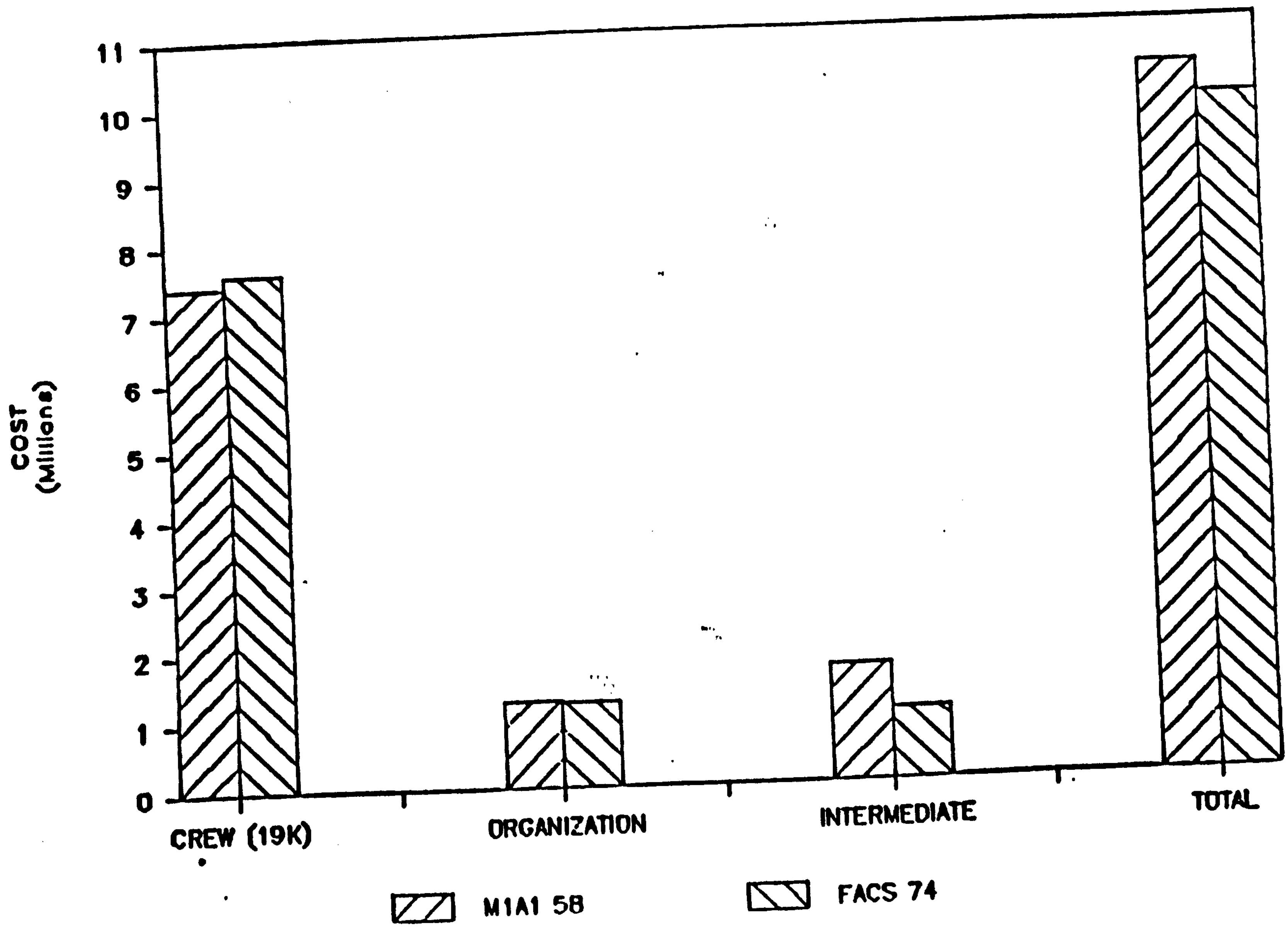

Figure 11. Manpower Costs for an M1A1 58 Tank and a FACS 74 Tank Armor Battalion for the First Year.

SUMMARY

The development of emerging systems must take into account the reality of increasing constraints in the availability of both manpower and funds. To meet these constraints and produce the most cost-effective system, an assessment of the cost aspects of manpower requirements must be performed early in the development cycle when most leverage may be exerted upon system design. One methodology already in use, the HARDMAN Comparability Methodology (HCM), develops system manpower requirements, while another under development, the Army Manpower Cost System (AMCOS), develops associated costs.

AMCOS was applied to the results of a HCM analysis which had previously been conducted for the Future Armored Combat System (FACS). The HCM analysis was based on the formulation of a representative FACS configuration, consisting of selected technology alternatives for five subsystems (e. g., diesel for propulsion). Manpower cost impacts were described in terms of the costs of the MOSs involved in operations and maintenance of the FACS as compared with its predecessor system, the M1A1.

It was found that the manpower costs for the FACS were appreciably less than those for the predecessor system (M1A1). About half of these savings could be attributed to the reduction in crew size from four in the M1A1 to three in the FACS. However, the other half was associated with savings in maintenance manpower costs. The relative costs associated with the use of alternative technologies for each of the subsystems were also determined, with differential results, depending on the MOSs involved. By adjusting the cost of the original FACS representative configuration to take into account the different costs associated with alternative technologies, the costs of alternative FACS configurations were derived. While the costs for the different configurations varied with the alternative technologies involved, all such configurations were found to have lower manpower costs that those for the M1A1.

Increments in the underlying assumptions for reliability and maintainability were found to result in successively greater savings for the FACS relative to the M1 for 7 of the 13 maintenance MOSs involved. The use of alternative operational intensities for the underlying scenario also resulted in savings in manpower costs for the FACS, even at an intensity 35% greater than the initial intensity used. Extrapolation of the data led to a projection that the FACS could operate at an operational intensity more than double that of the base without exceeding the cost of maintaining the M1A1.

It was determined that the reduced costs associated with the FACS configuration would permit organizational restructuring, with a 74 tank FACS armor batallion being fielded at no greater manpower cost than a 58 tank M1A1 battalion.

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APPENDIX A

DESCRIPTIONS OF AMCOS COST ELEMENTS

APPENDIX A

DESCRIPTIONS OF COST ELEMENTS.

These brief descriptions of the 11 cost elements of AMCOS ,in terms of their constituent components, are extracted from ARMY MANPOWER COST SYSTEM: ARMY ACTIVE COMPONENT LIFE CYCLE COST ESTIMATION MODEL INFORMATION BOOK (Hogan, et. al., 1989). More detailed information concerning these cost components may be found in that reference.

Military Compensation: All variable costs underlying basic pay , basic allowances for quarters and subsistence, and variable housing allowances.

Enlisted Recruiting: All variable costs involved in recruiting and processing enlisted personnel into the Army. Includes such costs as recruiters, Army share of advertising, enlistment bonuses, targeted educational benefits, and inprocessing of recruits.

Officer Acquisition: Costs involved in the acquisition of officers into the Army. Includes such costs as advertising, scholarships, military pay and allowances for cadets, and operations and support costs for the Reserve Officer's Training Corps (ROTC) and the US Military Academy.

Training: All variable costs for individual training, including initial training and specialized individual skill and professional training.

Permanent Change of Station: Costs for rotational, operational and seperation moves.

Retired Pay Accrual: Cost for contribution to the miltary retirement fund. This is determined by multiplying basic pay by a fixed normal cost percentage rate obtained from the DOD actuary.

Selective Reenlistment Bonus: Cost for reenlistment bonuses offered to soldiers in an MOS on a discretionary basis at reenlistment decision points. This is determined by multiplying the "award level" (which varys from 0 to 6) by monthly basic pay and years of reenlistment.

Special Pays: Cost of special duty assigment pay for soldiers assigned to duties involving greater demands or responsibilities, e. g., hazardous duty, medical personnel, recruiters.

Medical Support: All fixed and variable non-pay costs involved in providing health care to the soldier and his family.

Other Benefits: All fixed and variable costs that support miscellaneous benefits, e. g., survivor benefits, clothing allowance, separation pay.

New GI Bill: Estimated cost of the present value of the basic benefit. This is funded by the Department of Veteran's Affairs.

Table A- 2. Listing of Cost Variables for each Cost Element

ELEMENT -- MILITARY COMPENSATION

STRUCTURED VARIABLES

VARIABLE	DEFINITION
ac_bp	average annual base pay
ac_baq1	average cost of baq paid in-cash
ac_vha1	average cost of vha paid in-cash
ac_baq2	average cost of baq paid in-kind
ac_vha2	average cost of vha paid in-kind
ac_bas	average basic allowance for subsistence
ac_tax	average annual tax benefit
ac_rmc	average annual compensation

ELEMENT - RECRUITING

STRUCTURED COST DATABASE VARIABLES

VARIABLE	DEFINITION
ac_mos	avg recruiting cost by mos
ac_h	avg cost of a high quality recruit
ac_l	avg cost of a low quality recruit
mc_mos	marginal cost by MOS

ELEMENT - OFFICER'S ACQUISITON

STRUCTURED COST DATABASE VARIABLES

VARIABLE	DEFINITION
ac_ocs	Average cost of training an OCS candidate
ac_wp	Average cost of training a West Point cadet
ac_rotc	Average cost of training an ROTC cadet
ac_hp	Average cost of an HPSF scholarship
ac_off	Average cost of accessing an officer
mc_off	Marginal cost of accessing an officer

ELEMENT -- TRAINING

STRUCTURED COST DATABASE VARIABLES

VARIABLE	DEFINITION
ac_btr	average cost of basic training
ac_osut	average cost of one station unit training
ac_istr	average cost of initial skill training
ac_proftr	average cost of professional training
ac_upt	average cost of undergraduate pilot training
ac_ofltr	average cost of other flight training
ac_cartr	average cost of career training

ELEMENT - PERMANENT CHANGE OF STATION

STRUCTURED COST DATABASE VARIABLES

VARIABLE	DEFINITION
ac_amov	Average cost of an accession move
ac_ops	Average cost of an operational move
ac_rots	Average cost of a rotational move
ac_smov	Average cost of a separation move
ac_tmov	Average cost of a training move
ac_pcs	Average cost of pcs moves

ELEMENT -- RETIRED PAY ACCRUAL

STRUCTURED COST DATABASE VARIABLES

VARIABLE	NAME
ac_rp	avg cost per capita of retired pay accrual
ac_rp_hi	avg cost per capita of retired pay accrual-hi qual
ac_rp_lo	avg cost per capita of retired pay accrual-lo qual
ac_rp_av	avg cost per capita of retired pay accrual-weighted avg

ELEMENT -- SELECTED REENLISTMENT BONUS

STRUCTURED COST DATABASE VARIABLES

VARIABLE	DEFINITION
ac_srb	average SRB cost weighted by prob of receiving
srb	value of SRB conditional upon receiving
mc_srb	marginal SRB cost

ELEMENT NAME -- SPECIAL PAYS

STRUCTURED COST DATABASE VARIABLES

NAME	DEFINITION
ac_acip	Average cost of aviation career incentive pay
ac_fd	Average cost of foreign duty pay
ac_os	Average cost of oversea duty pay
ac_haz	Average cost of hazardous duty pay
ac_med	Average cost of medical professional pay
ac_fsa	Average cost of family separation allowance
ac_sp	Average cost of special pay

ELEMENT -- MEDICAL SUPPORT

STRUCTURED COST DATABASE VARIABLES

NAME	DEFINITION
acms_g	Avg medical support costs per soldier by grade
ac_c_g	Avg cost of CHAMPUS per soldier per grade

ELEMENT -- OTHER BENEFITS

STRUCTURED COST DATABASE VARIABLES

VARIABLE	DEFINITION
ac_cloth	Average cost of clothing allowance
ac_fica	Average cost of govt contribution to FICA
ac_sepcos	Avarage cost of separation from service
ac_survben	Average cost of survivor's benefits
ac_misc	Average cost of misc benefits(death grat, appr of deserters and unemployment compensation)
ac_mwr	Average cost of MWR
ac_ob	Average cost of other benefits

ELEMENT - NEW GI BILL

STRUCTURED COST DATABASE VARIABLES

NAME	DEFINITION
ac_gib	Average cost of the New GI Bill

Table A- 3. Costs for MOS 63H (Track Vehicle Repairer) by Cost Variable and Rank (4.1 Version)

MOS 63H (TRACK VEHICLE REP)

	PVT — PFC	SPC	SGT	SSG	SFC	MSG	SGM
Final costs from DEFAULT.FDE							
mpa	26148.87	31961.06	36552.93	46943.41	55265.93	62760.85	0.00
oma	5092.63	6312.83	7488.60	10235.46	11524.80	11505.07	0.00
other	505.70	505.70	505.70	505.70	505.70	505.70	0.00
total	31747.21	38779.59	44547.24	57684.57	67296.44	74771.62	0.00
Structured Cost Database							
MC (MPA)							
ac_bp	9809.01	12638.14	14956.72	18010.71	21706.42	24482.40	0.00
ac_baq1	2481.95	3124.60	3896.00	4519.38	5073.05	5555.44	0.00
ac_vha1	895.40	929.04	1067.04	1209.96	1389.96	1425.96	0.00
ac_baq2	779.82	1451.29	2199.91	2797.18	3171.13	3711.44	0.00
ac_vha2	180.90	361.68	563.08	730.82	863.17	949.40	0.00
ac_bas	2404.80	2404.80	2404.80	2404.80	2404.80	2404.80	0.00
ac_tax	487.48	921.43	1207.50	1467.97	1514.28	1676.92	0.00
ac_rmc	16078.63	20018.01	23532.07	27612.82	32088.51	35545.52	0.00
REC (MPA)							
ac_rec	3975.73						
ac_h	7230.36						
ac_l	2484.74						
mc_rec	10326.17						
mc_h	27442.91						
PCS (MPA)							
ac_rots	1144.06	1991.12	2589.73	3426.33	3957.60	4689.75	0.00
ac_ops	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ac_tmov	775.39	1478.38	1686.16	2107.73	2493.41	2710.43	0.00
ac_amov	362.84	0.00	0.00	0.00	0.00	0.00	0.00
ac_smov	424.63	809.61	923.40	1154.26	1365.47	1484.32	0.00
ac_pcs	453.37	859.63	988.46	1240.34	1464.90	1602.14	0.00
RPA (MPA)							
ac_rp	4306.15	5548.14	6566.00	7906.70	9529.12	10747.77	0.00
ac_rp_hi	1325.43	2480.51	2935.58	3958.34	4770.57	5380.67	0.00
ac_rp_lo	1454.10	2681.35	3173.27	4274.48	5151.58	5810.40	0.00
ac_rp_av	1404.88	2604.53	3082.35	4153.55	5005.84	5646.03	0.00

SRB (MPA)	SRB A E4	E5	E6	SRB B E5	E6	E7
srb	0.00	0.00	0.00	0.00	0.00	0.00
ac_srb	0.00	0.00	0.00	0.00	0.00	0.00
mc_srb	25865.50	25865.50	25865.50	60091.55	60091.55	60091.55

OB (MPA)							
ac_survben	31.34						
ac_misc	101.83						

ac_sepcos	86.75	188.36	174.75	130.40	226.41	494.10	0.00
ac_cloth	416.13	195.86	195.86	195.86	195.86	195.86	0.00
ac_fica	750.39	966.82	1144.19	1377.82	1660.54	1872.90	0.00
ac_ob	1386.45	1484.22	1647.97	1837.26	2215.99	2696.04	0.00

SP (MPA)							
ac_fd	13.58	24.20	16.69	9.42	20.04	2200.19	0.00
ac_os	129.63	225.35	266.95	315.94	368.90	404.00	0.00
ac_haz	83.04	83.04	83.04	83.04	83.04	83.04	0.00
ac_fsa	0.00	2.36	21.72	83.30	98.41	247.76	0.00
ac_dive	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ac_lang	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ac_sd	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ac_sp	226.26	334.95	388.41	491.70	570.40	2935.00	0.00
TNG (MPA)							
ac_btr	4143.00						
ac_istr	11134.51						
ac_osut	0.00						
REC (OMA)							
ac_rec	2572.46						
ac_h	3500.69						
ac_l	2147.23						
mc_rec	2572.46						
mc_h	3500.69						
MDB (OMA)							
ac_mdsp	1035.72	1428.61	1972.52	2402.32	2738.55	2729.42	0.00
ac_champ	1203.22	1659.65	2291.52	2790.82	3181.43	3170.83	0.00
TNG (OMA)							
ac_btr	2149.00						
ac_istr	6161.00						
ac_osut	0.00						
ac_cartr		1528.00	0.00	12906.00	4050.00	0.00	0.00
mc_tng	8310.00						
ac_tng	8310.00	1528.00	0.00	12906.00	4050.00	0.00	0.00
MWR (OMA)							
ac_mwr	487.94						
TNG (OTH)							
ac_btr	460.00						
ac_istr	0.00						
ac_osut	0.00						
ac_cartr		0.00	0.00	0.00	0.00	0.00	0.00
mc_tng	460.00						
ac_tng	460.00	0.00	0.00	0.00	0.00	0.00	0.00
GIB (OTH)							
ac_gib	1866.23						
AFH (OTH)							
ac_afh	2137.21	2152.27	2174.06	2174.09	2399.75	2310.83	0.00

APPENDIX B

MANPOWER REQUIREMENTS DERIVED BY THE HCM ANALYSES

(Derived from Shotzbarger, et. al., 1989).

Table B- 1. Manpower Requirements by MOS and Rank for the M1A1 for the Active Force

Maintenance Level	MOS	PVT - PFC	SPC	SGT	SSG	SFC
Crew	19K	3,982.50	3,982.50	3,982.50	1,327.50	0.00
Organizational	31V	113.40	113.40	113.40	37.80	0.00
	45E	219.78	219.78	219.78	0.00	0.00
	63E	326.70	326.70	326.70	108.90	0.00
Org subtotal		659.88	659.88	659.88	146.70	0.00
Intermediate	29E	8.53	8.53	8.53	2.84	0.00
	39E	2.35	2.35	2.35	0.78	0.00
	41C	43.28	43.28	43.28	14.43	0.00
	44B	0.00	0.00	0.00	0.00	0.00
	44E	0.00	0.00	0.00	0.00	0.00
	45G	53.59	53.59	53.59	17.86	0.00
	45K	294.27	294.27	294.27	98.09	0.00
	63G	24.50	24.50	24.50	0.00	0.00
	63H	347.52	347.52	347.52	115.84	0.00
	63J	2.89	2.89	2.89	0.96	0.00
Intermed subtotal		776.93	776.93	776.93	250.80	0.00
Total all levels		5,419.31	5,419.31	5,419.31	1,725.00	0.00

Table B- 2. Manpower Requirements by MOS and Rank for the FACS for the Active Force

Maintenance Level	MOS	PVT-PFC	SPC	SGT	SSG	SFC
Crew	19K	0.00	3,780.00	3,501.00	1,458.00	1,035.00
Organizational	31V	113.40	113.40	113.40	37.80	0.00
	45E	103.95	103.95	103.95	0.00	0.00
	63E	326.70	326.70	326.70	108.90	0.00
Org subtotal		544.05	544.05	544.05	146.70	0.00
Intermediate	29E	4.59	4.59	4.59	1.53	0.00
	39E	0.52	0.52	0.52	0.17	0.00
	41C	3.94	3.94	3.94	1.31	0.00
	44B	6.81	6.81	6.81	0.00	0.00
	44E	0.26	0.26	0.26	0.09	0.00
	45G	51.95	51.95	51.95	17.32	0.00
	45K	140.92	140.92	140.92	46.97	0.00
	63G	38.95	38.95	38.95	0.00	0.00
	63H	131.86	131.86	131.86	43.95	0.00
	63J	0.40	0.40	0.40	0.13	0.00
Intermed subtotal		380.20	380.20	380.20	111.47	0.00
Total all levels		924.25	4,704.25	4,425.25	1,716.17	1,035.00

Table B- 3. Maintenance Manpower Requirements for the M1A1 and 15% and 30% increments in RAM for the FACS for the Active Force

LEVEL/MOS	M1A1	INITIAL FACS	15% FACS CONSTRUCT	30% FACS CONSTRUCT
UNIT				
31V	378.00	378.00	378.00	378.00
45E	666.00	315.00	369.00	315.00
63E	1089.00	1089.00	1395.00	1323.00
SUBTOTAL	2133.00	1782.00	2142.00	2016.00
INT				
29E	28.44	15.29	13.39	11.84
39E	7.83	1.75	1.52	1.35
41C	144.27	13.15	12.55	12.06
44B	0.00	20.63	21.28	18.84
44E	0.00	0.87	0.88	0.77
45G	178.65	173.16	164.66	146.31
45K	980.91	469.72	426.62	379.00
63G	74.25	118.04	117.86	104.26
63H	1158.39	439.55	423.40	374.51
63J	9.63	1.33	1.16	1.02
SUBTOTAL	2582.37	1253.49	1183.32	1049.96
TOTAL	4715.37	3035.49	3325.32	3065.96

Table B- 4. Maintenance Manpower Requirements for the M1A1 and the FACS 50% Operational Intensity for the Active Force

MOS		PRED	FACS	CHANGE
ORG:	31V	378.00	378.00	0.00
	45E	666.00	315.00	-351.00
	63E	1089.00	729.00	-360.00
INT:	29E	28.44	7.66	-20.78
	39E	7.83	0.88	-6.95
	41C	144.27	10.78	-133.49
	44B	0.00	10.32	+10.32
	44E	0.00	0.43	+0.43
	45G	178.65	89.29	-89.36
	45K	980.91	241.65	-739.26
	63G	74.25	59.03	-15.22
	63H	1158.39	219.76	-938.63
	63J	9.63	0.67	-8.96
TOTALS		4715.37	2062.47	-2652.90

Table B- 5. Maintenance Manpower Requirements for the M1A1 and the FACS 75% Operational Intensity for the Active Force

MOS	PRED	FACS	CHANGE
ORG: 31V	378.00	378.00	0.00
45E	666.00	315.00	-351.00
63E	1089.00	909.00	-180.00
INT: 29E	28.44	11.47	-16.97
39E	7.83	1.32	-6.51
41C	144.27	11.96	-132.31
44B	0.00	15.49	+15.49
44E	0.00	0.58	+0.58
45G	178.65	131.20	-47.45
45K	980.91	355.72	-625.19
63G	74.25	88.54	+14.29
63H	1158.39	329.66	-828.73
63J	9.63	1.00	-8.63
TOTALS	4715.37	2548.94	-2166.43

Table B- 6. Maintenance Manpower Requirements for the M1A1 and the FACS 135% Operational Intensity for the Active Force

MOS	PRED	FACS	CHANGE
ORG: 31V	378.00	378.00	0.00
45E	666.00	315.00	-351.00
63E	1089.00	1344.00	+255.00
INT: 29E	28.44	20.62	-7.82
39E	7.83	2.37	-5.46
41C	144.27	14.82	-129.45
44B	0.00	27.86	+27.86
44E	0.00	1.18	+1.18
45G	178.65	231.94	+53.29
45K	980.91	629.42	-351.49
63G	74.25	159.34	+85.09
63H	1158.39	593.34	-565.05
63J	9.63	1.80	-7.83
TOTALS	4715.37	3719.69	-995.68

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Table B- 7. Maintenance Manpower Requirements for the M1A1 and the FACS 50% Operational Intensity for an Armor Battalion

MOS		PRED	FACS	CHANGE
ORG:	31V	6.00	6.00	0.00
	45E	11.00	5.00	-6.00
	63E	18.00	12.00	-6.00
INT:	29E	0.47	0.13	-0.34
	39E	0.13	0.01	-0.12
	41C	2.39	0.18	-2.21
	44B	0.00	0.17	+0.17
	44E	0.00	0.01	+0.01
	45G	2.96	1.48	-1.48
	45K	16.25	4.00	-12.25
	63G	1.23	0.98	-0.25
	63H	19.19	3.64	-15.55
	63J	0.16	0.01	-0.15
TOTALS		77.78	33.61	-44.17

Table B- 8. Maintenance Manpower Requirements for the M1A1 and the FACS 75% Operational Intensity for an Armor Battalion

MOS		PRED	FACS	CHANGE
ORG:	31V	6.00	6.00	0.00
	45E	11.00	5.00	-6.00
	63E	18.00	15.00	-3.00
INT:	29E	0.47	0.19	-0.28
	39E	0.13	0.02	-0.11
	41C	2.39	0.20	-2.19
	44B	0.00	0.26	+0.26
	44E	0.00	0.01	+0.01
	45G	2.96	2.17	-0.79
	45K	16.25	5.89	-10.36
	63G	1.23	1.47	+0.24
	63H	19.19	5.46	-13.73
	63J	0.16	0.02	-0.14
TOTALS		77.78	41.69	-36.09

Table B- 9. Maintenance Manpower Requirements for the M1A1 and the FACS 135% Operational Intensity for an Armor Battalion

MOS	PRED	FACS	CHANGE
ORG: 31V	6.00	6.00	0.00
45E	11.00	5.00	-6.00
63E	18.00	23.00	+5.00
INT: 29E	0.47	0.34	-0.13
39E	0.13	0.04	-0.09
41C	2.39	0.25	-2.14
44B	0.00	0.46	+0.46
44E	0.00	0.02	+0.02
45G	2.96	3.84	+0.88
45K	16.25	10.43	-5.82
63G	1.23	2.64	+1.41
63H	19.19	9.83	-9.36
63J	0.16	0.03	-0.13
TOTALS	77.78	61.88	-15.90

Table B-10. Maintenance Manpower Requirements for the M1A1 and the FACS 50% Operational Intensity for an Armor Cavalry Squadron

MOS		PRED	FACS	CHANGE
ORG:	31V	6.00	6.00	0.00
	45E	8.00	5.00	-3.00
	63E	13.00	9.00	-4.00
INT:	29E	0.34	0.09	-0.25
	39E	0.09	0.01	-0.08
	41C	1.69	0.13	-1.56
	44B	0.00	0.12	+0.12
	44E	0.00	0.01	+0.01
	45G	2.09	1.05	-1.04
	45K	11.49	2.83	-8.66
	63G	0.87	0.69	-0.18
	63H	13.57	2.57	-11.00
	63J	0.11	0.01	-0.10
TOTALS		57.25	27.51	-29.74

Table B-11. Maintenance Manpower Requirements for the M1A1 and the FACS 75% Operational Intensity for an Armor Cavalry Squadron

MOS		PRED	FACS	CHANGE
ORG:	31V	6.00	6.00	0.00
	45E	8.00	5.00	-3.00
	63E	13.00	11.00	-2.00
INT:	29E	0.34	0.13	-0.21
	39E	0.09	0.02	-0.07
	41C	1.69	0.14	-1.55
	44B	0.00	0.18	+0.18
	44E	0.00	0.01	+0.01
	45G	2.09	1.54	-0.55
	45K	11.49	4.17	-7.32
	63G	0.87	1.04	+0.17
	63H	13.57	3.86	-9.71
	63J	0.11	0.01	-0.10
TOTALS		57.25	33.10	-24.15

Table B-12. Maintenance Manpower Requirements for the M1A1 and the FACS 135% Operational Intensity for an Armor Cavalry Squadron

MOS	PRED	FACS	CHANGE
ORG: 31V	6.00	6.00	0.00
45E	8.00	5.00	-3.00
63E	13.00	17.00	+4.00
INT: 29E	0.34	0.24	-0.10
39E	0.09	0.03	-0.06
41C	1.69	0.17	-1.52
44B	0.00	0.33	+0.33
44E	0.00	0.01	+0.01
45G	2.09	2.72	+0.63
45K	11.49	7.37	-4.12
63G	0.87	1.87	+1.00
63H	13.57	6.95	-6.62
63J	0.11	0.02	-0.09
TOTALS	57.25	47.71	-9.54

APPENDIX C

MANPOWER COSTS DERIVED BY AMCOS

Table C- 1. Manpower Costs for the M1A1 and the FACS for the First Year per Tank

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$127,823	$102,760	$25,063	20%
Organizational	31V	$3,854	$3,854	$0	0%
	45E	$6,667	$3,154	$3,513	53%
	63E	$11,490	$11,490	$0	0%
Org subtotal		$22,011	$18,498	$3,513	16%
Intermediate	29E	$299	$161	$138	46%
	39E	$79	$18	$61	77%
	41C	$1,573	$143	$1,430	91%
	44B	$0	$210	($210)	
	44E	$0	$10	($10)	
	45G	$1,982	$1,922	$60	3%
	45K	$11,973	$5,714	$6,259	52%
	63G	$778	$1,237	($459)	-59%
	63H	$12,168	$4,617	$7,551	62%
	63J	$102	$14	$88	86%
Intermed subtotal		$28,954	$14,046	$14,908	51%
Total all levels		$178,788	$135,304	$43,484	24%

Table C- 2. Manpower Costs for the M1A1 and the FACS for the first Year for an Armor Cavalry Squadron

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$5,255,220	$4,227,640	$1,027,580	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$280,390	$175,250	$105,140	37%
	63E	$480,190	$480,190	$0	0%
Org subtotal		$974,750	$869,610	$105,140	11%
Intermediate	29E	$12,590	$6,590	$6,000	48%
	39E	$3,150	$620	$2,530	80%
	41C	$64,910	$5,600	$59,310	91%
	44B	$0	$8,630	($8,630)	
	44E	$0	$310	($310)	
	45G	$81,580	$78,830	$2,750	3%
	45K	$489,790	$234,250	$255,540	52%
	63G	$31,830	$50,360	($18,530)	-58%
	63H	$499,060	$188,900	$310,160	62%
	63J	$3,990	$630	$3,360	84%
Intermed subtotal		$1,186,900	$574,720	$612,180	52%
Total all levels		$7,416,870	$5,671,970	$1,744,900	24%

Table C- 3. Manpower Costs for the M1A1 and the FACS for the First Year for an Armor Battalion

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$7,411,350	$5,957,700	$1,453,650	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$385,540	$175,250	$210,290	55%
	63E	$664,870	$664,870	$0	0%
Org subtotal		$1,264,580	$1,054,290	$210,290	17%
Intermediate	29E	$17,330	$9,210	$8,120	47%
	39E	$4,580	$1,030	$3,550	78%
	41C	$91,640	$8,310	$83,330	91%
	44B	$0	$12,170	($12,170)	
	44E	$0	$310	($310)	
	45G	$115,420	$111,530	$3,890	3%
	45K	$691,190	$330,970	$360,220	52%
	63G	$45,600	$72,290	($26,690)	-59%
	63H	$706,050	$267,390	$438,660	62%
	63J	$5,800	$630	$5,170	89%
Intermed subtotal		$1,677,610	$813,840	$863,770	51%
Total all levels		$10,353,540	$7,825,830	$2,527,710	24%

Table C- 4. Manpower Costs for the M1A1 and the FACS for the First Year for the Active Force

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$447,509,670	$359,764,420	$87,745,250	20%
Organizational	31V	$13,492,960	$13,492,960	$0	0%
	45E	$23,342,710	$11,040,470	$12,302,240	53%
	63E	$40,224,770	$40,224,770	$0	0%
Org subtotal		$77,060,440	$64,758,200	$12,302,240	16%
Intermediate	29E	$1,045,560	$562,710	$482,850	46%
	39E	$278,210	$61,440	$216,770	78%
	41C	$5,508,550	$501,290	$5,007,260	91%
	44B	$0	$734,710	($734,710)	
	44E	$0	$33,360	($33,360)	
	45G	$6,939,600	$6,727,560	$212,040	3%
	45K	$41,776,670	$20,005,820	$21,770,850	52%
	63G	$2,724,830	$4,331,930	($1,607,100)	-59%
	63H	$42,598,620	$16,163,090	$26,435,530	62%
	63J	$356,780	$49,220	$307,560	86%
Intermed subtotal		$101,228,820	$49,171,130	$52,057,690	51%
Total all levels		$625,798,930	$473,693,750	$152,105,180	24%

Table C- 5. Manpower Costs for the M1A1 and the FACS for Thirty Years per Tank (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$5,941,412	$4,774,854	$1,166,558	20%
Organizational	31V	$171,120	$171,120	$0	0%
	45E	$308,135	$140,061	$168,074	55%
	63E	$531,163	$531,163	$0	0%
Org subtotal		$1,010,418	$842,344	$168,074	17%
Intermediate	29E	$13,858	$7,361	$6,497	47%
	39E	$3,662	$821	$2,841	78%
	41C	$73,153	$6,635	$66,518	91%
	44B	$0	$9,722	($9,722)	
	44E	$0	$244	($244)	
	45G	$92,091	$88,991	$3,100	3%
	45K	$552,442	$264,531	$287,911	52%
	63G	$36,392	$57,694	($21,302)	-59%
	63H	$563,798	$213,516	$350,282	62%
	63J	$4,635	$502	$4,133	89%
Intermed subtotal		$1,340,031	$650,017	$690,014	51%
Total all levels		$8,291,861	$6,267,215	$2,024,646	24%

Table C- 6. Manpower Costs for the M1A1 and the FACS for Thirty Years for an Armpr CAvalry Squadron (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$244,340,970	$196,512,020	$47,828,950	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$12,997,700	$8,123,560	$4,874,140	38%
	63E	$22,249,840	$22,249,840	$0	0%
Org subtotal		$45,172,490	$40,298,350	$4,874,140	11%
Intermediate	29E	$584,040	$305,540	$278,500	48%
	39E	$145,960	$28,780	$117,180	80%
	41C	$3,005,380	$259,280	$2,746,100	91%
	44B	$0	$400,050	($400,050)	
	44E	$0	$14,170	($14,170)	
	45G	$3,775,420	$3,647,850	$127,570	3%
	45K	$22,705,020	$10,858,920	$11,846,100	52%
	63G	$1,473,150	$2,331,260	($858,110)	-58%
	63H	$23,113,700	$8,748,730	$14,364,970	62%
	63J	$185,060	$29,120	$155,940	84%
Intermed subtotal		$54,987,730	$26,623,700	$28,364,030	52%
Total all levels		$344,501,190	$263,434,070	$81,067,120	24%

Table C- 7. Manpower Costs for the M1A1 and the FACS for Thirty Years for an Armor Battalion (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS	Difference	%
Crew	19K	$344,601,940	$276,941,530	$67,660,410	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$17,871,840	$8,123,560	$9,748,280	55%
	63E	$30,807,460	$30,807,460	$0	0%
Org subtotal		$58,604,250	$48,855,970	$9,748,280	17%
Intermediate	29E	$803,750	$426,980	$376,770	47%
	39E	$212,390	$47,610	$164,780	78%
	41C	$4,242,890	$384,810	$3,858,080	91%
	44B	$0	$563,870	($563,870)	
	44E	$0	$14,170	($14,170)	
	45G	$5,341,260	$5,161,470	$179,790	3%
	45K	$32,041,610	$15,342,780	$16,698,830	52%
	63G	$2,110,730	$3,346,280	($1,235,550)	-59%
	63H	$32,700,260	$12,383,920	$20,316,340	62%
	63J	$268,840	$29,120	$239,720	89%
Intermed subtotal		$77,721,730	$37,701,010	$40,020,720	51%
Total all levels		$480,927,920	$363,498,510	$117,429,410	24%

Table C- 8. Manpower Costs for the M1A1 and the FACS for Thirty Years for the Active Force (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS	Difference
Crew	19K	$20,807,573,120	$16,723,451,860	$4,084,121,260
Organizational	31V	$625,271,980	$625,271,980	$0
	45E	$1,082,058,760	$511,784,590	$570,274,170
	63E	$1,863,851,630	$1,863,851,630	$0
Org subtotal		$3,571,182,370	$3,000,908,200	$570,274,170
Intermediate	29E	$48,493,200	$26,098,390	$22,394,810
	39E	$12,900,690	$2,848,920	$10,051,770
	41C	$255,052,800	$23,210,390	$231,842,410
	44B	$0	$34,054,440	($34,054,440)
	44E	$0	$1,545,570	($1,545,570)
	45G	$321,143,060	$311,330,430	$9,812,630
	45K	$1,936,639,880	$927,409,350	$1,009,230,530
	63G	$126,128,970	$200,519,290	($74,390,320)
	63H	$1,972,915,830	$748,578,450	$1,224,337,380
	63J	$16,543,970	$2,282,270	$14,261,700
Intermed subtotal		$4,689,818,400	$2,277,877,500	$2,411,940,900
Total all levels		$29,068,573,890	$22,002,237,560	$7,066,336,330

Table C- 9. First Year Maintenance Manpower Costs for Propulsion System Alternatives for the Active Force

PROPULSION SYSTEM ALTERNATIVES

	MOS	TURBINE	DIESEL *	DIFFERENCE
ORG:	45E	$2,120	$20,470	($18,350)
	63E	$40,576,740	$23,409,830	$17,166,910
INT:	44B	$4,320	$682,930	($678,610)
	44E	$0	$29,530	($29,530)
	45K	$113,200	$313,930	($200,730)
	63G	$28,120	$206,860	($178,740)
	63H	$7,726,150	$7,273,830	$452,320
TOTALS		$48,450,650	$31,937,380	$16,513,270

* Used in FACS.

Table C-10. First Year Maintenance Manpower Costs for Vehicle Drive Alternatives for the Active Force

VEHICLE DRIVE SYSTEM ALTERNATIVES

	MOS	ELECTRIC	CONVENTIONAL *	DIFFERENCE
ORG:	45E	$20,470	$20,470	$0
	52D	$22,653,940	$0	$22,653,940
	63E	$21,248,990	$23,409,830	($2,160,840)
INT:	44B	$682,930	$682,930	$0
	44E	$27,900	$29,000	($1,100)
	45K	$313,930	$313,930	$0
	52D	$18,011,750	$0	$18,011,750
	63G	$206,860	$206,860	$0
	63H	$1,945,620	$7,273,830	($5,328,210)
TOTALS		$65,112,390	$31,936,850	$33,175,540

* Used in FACS.

Table C-11. First Year Maintenance Manpower Costs for Turret Drive Alternatives for the Active Force

TURRET DRIVE SYSTEM ALTERNATIVES

	MOS	ELECTRIC	CONVENTIONAL *	DIFFERENCE
ORG:	45E	$811,730	$4,540	$807,190
	63E	$0	$2,526,090	($2,526,090)
INT:	45K	$482,500	$21,650	$460,850
	63H	$0	$2,920	($2,920)
TOTALS		$1,294,230	$2,555,200	($1,260,970)

* Used in FACS.

Table C-12. First Year Maintenance Manpower Costs for Suspension System Alternatives for the Active Force

SUSPENSION SYSTEM ALTERNATIVES

	MOS	CONVENTIONAL	HYDROPNEUMATIC *	DIFFERENCE
ORG:	63E	$3,118,570	$2,702,750	$415,820
INT:	63H	$13,650	$6,384,970	($6,371,320)
TOTALS		$3,132,220	$9,087,720	($5,955,500)

* Used in FACS.

Table C-13. First Year Maintenance Manpower Costs for Armament System Altenatives for the Active Force

ARMAMENT SYSTEM ALTERNATIVES

	MOS	LP GUN	120 MM *	DIFFERENCE
ORG:	45E	$1,938,320	$1,186,360	$751,960
INT:	41C	$14,840	$14,840	$0
	45K	$2,673,430	$2,270,050	$403,380
TOTALS		$4,626,590	$3,471,250	$1,155,340

* Used in FACS.

Table C-14. Manpower Costs for the First Year for the M1A1 and the FACS 15% Increment in RAM for the Active Force

Maintenance Level	MOS	M1A1	FACS 15% RAM	Difference	%
Crew	19K	$447,509,670	$359,764,420	$87,745,250	20%
Organizational	31V	$13,492,960	$13,492,960	$0	0%
	45E	$23,342,710	$13,063,000	$10,279,710	44%
	63E	$40,224,770	$51,528,000	($11,303,230)	-28%
Org subtotal		$77,060,440	$78,083,960	($1,023,520)	-1%
Intermediate	29E	$1,045,560	$492,000	$553,560	53%
	39E	$278,210	$54,000	$224,210	81%
	41C	$5,508,550	$479,000	$5,029,550	91%
	44B	$0	$765,000	($765,000)	
	44E	$0	$34,000	($34,000)	
	45G	$6,939,600	$6,397,000	$542,600	8%
	45K	$41,776,670	$18,170,000	$23,606,670	57%
	63G	$2,724,830	$4,369,000	($1,644,170)	-60%
	63H	$42,598,620	$15,570,000	$27,028,620	63%
	63J	$356,780	$43,000	$313,780	88%
Intermed subtotal		$101,228,820	$46,373,000	$54,855,820	54%
Total all levels		$625,798,930	$484,221,380	$141,577,550	23%

Table C-15. Manpower Costs for the First Year for the M1A1 and the FACS 30% Increment in RAM for the Active Force

Maintenance Level	MOS	M1A1	FACS 30% RAM	Difference	%
Crew	19K	$447,509,670	$359,764,420	$87,745,250	20%
Organizational	31V	$13,492,960	$13,492,960	$0	0%
	45E	$23,342,710	$11,152,000	$12,190,710	52%
	63E	$40,224,770	$48,868,000	($8,643,230)	-21%
Org subtotal		$77,060,440	$73,512,960	$3,547,480	5%
Intermediate	29E	$1,045,560	$435,000	$610,560	58%
	39E	$278,210	$48,000	$230,210	83%
	41C	$5,508,550	$460,000	$5,048,550	92%
	44B	$0	$678,000	($678,000)	
	44E	$0	$29,000	($29,000)	
	45G	$6,939,600	$5,684,000	$1,255,600	18%
	45K	$41,776,670	$16,142,000	$25,634,670	61%
	63G	$2,724,830	$3,865,000	($1,140,170)	-42%
	63H	$42,598,620	$13,772,000	$28,826,620	68%
	63J	$356,780	$38,000	$318,780	89%
Intermed subtotal		$101,228,820	$41,151,000	$60,077,820	59%
Total all levels		$625,798,930	$474,428,380	$151,370,550	24%

Table C-16. Manpower Costs for Thirty Years for the M1A1 and the FACS 15% Increment in RAM for the Active Force (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 15% RAM	Difference
Crew	19K	$20,807,573,120	$16,723,451,860	$4,084,121,260
Organizational	31V	$625,271,980	$625,271,980	$0
	45E	$1,082,058,760	$605,526,000	$476,532,760
	63E	$1,863,851,630	$2,387,579,000	($523,727,370)
Org subtotal		$3,571,182,370	$3,618,376,980	($47,194,610)
Intermediate	29E	$48,493,200	$22,840,000	$25,653,200
	39E	$12,900,690	$2,505,000	$10,395,690
	41C	$255,052,800	$22,187,000	$232,865,800
	44B	$0	$35,470,000	($35,470,000)
	44E	$0	$1,561,000	($1,561,000)
	45G	$321,143,060	$296,029,000	$25,114,060
	45K	$1,936,639,880	$842,298,000	$1,094,341,880
	63G	$126,128,970	$202,252,000	($76,123,030)
	63H	$1,972,915,830	$721,109,000	$1,251,806,830
	63J	$16,543,970	$1,993,000	$14,550,970
Intermed subtotal		$4,689,818,400	$2,148,244,000	$2,541,574,400
Total all levels		$29,068,573,890	$22,490,072,840	$6,578,501,050

Table C-17. Manpower Costs for Thirty Years for the M1A1 and the FACS 30% Increment in RAM for the Active Force (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 30% RAM	Difference
Crew	19K	$20,807,573,120	$16,723,451,860	$4,084,121,260
Organizational	31V	$625,271,980	$625,271,980	$0
	45E	$1,082,058,760	$516,954,000	$565,104,760
	63E	$1,863,851,630	$2,264,349,000	($400,497,370)
Org subtotal		$3,571,182,370	$3,406,574,980	$164,607,390
Intermediate	29E	$48,493,200	$20,196,000	$28,297,200
	39E	$12,900,690	$2,225,000	$10,675,690
	41C	$255,052,800	$21,321,000	$233,731,800
	44B	$0	$31,404,000	($31,404,000)
	44E	$0	$1,366,000	($1,366,000)
	45G	$321,143,060	$263,039,000	$58,104,060
	45K	$1,936,639,880	$748,279,000	$1,188,360,880
	63G	$126,128,970	$178,913,000	($52,784,030)
	63H	$1,972,915,830	$637,841,000	$1,335,074,830
	63J	$16,543,970	$1,753,000	$14,790,970
Intermed subtotal		$4,689,818,400	$1,906,337,000	$2,783,481,400
Total all levels		$29,068,573,890	$22,036,363,840	$7,032,210,050

Table C-18. Manpower Costs for the First Year for the M1A1 and the FACS 50% Operational Intensity for the Active Force

Maintenance Level	MOS	M1A1	FACS 50%	Difference	%
Crew	19K	$447,509,670	$359,764,420	$87,745,250	20%
Organizational	31V	$13,492,960	$13,492,960	$0	0%
	45E	$23,342,710	$11,152,000	$12,190,710	52%
	63E	$40,224,770	$26,927,000	$13,297,770	33%
Org subtotal		$77,060,440	$51,571,960	$25,488,480	33%
Intermediate	29E	$1,045,560	$282,000	$763,560	73%
	39E	$278,210	$31,000	$247,210	89%
	41C	$5,508,550	$412,000	$5,096,550	93%
	44B	$0	$371,000	($371,000)	
	44E	$0	$16,000	($16,000)	
	45G	$6,939,600	$3,469,000	$3,470,600	50%
	45K	$41,776,670	$10,292,000	$31,484,670	75%
	63G	$2,724,830	$2,188,000	$536,830	20%
	63H	$42,598,620	$8,081,000	$34,517,620	81%
	63J	$356,780	$25,000	$331,780	93%
Intermed subtotal		$101,228,820	$25,167,000	$76,061,820	75%
Total all levels		$625,798,930	$436,503,380	$189,295,550	30%

Table C-19. Manpower Costs for the First Year for the M1A1 and the FACS 75% Operational Intensity for the Active Force

Maintenance Level	MOS	M1A1	FACS 75%	Difference	%
Crew	19K	$447,509,670	$359,764,420	$87,745,250	20%
Organizational	31V	$13,492,960	$13,492,960	$0	0%
	45E	$23,342,710	$11,152,000	$12,190,710	52%
	63E	$40,224,770	$33,576,000	$6,648,770	17%
Org subtotal		$77,060,440	$58,220,960	$18,839,480	24%
Intermediate	29E	$1,045,560	$422,000	$623,560	60%
	39E	$278,210	$47,000	$231,210	83%
	41C	$5,508,550	$457,000	$5,051,550	92%
	44B	$0	$557,000	($557,000)	
	44E	$0	$22,000	($22,000)	
	45G	$6,939,600	$5,097,000	$1,842,600	27%
	45K	$41,776,670	$15,151,000	$26,625,670	64%
	63G	$2,724,830	$3,282,000	($557,170)	-20%
	63H	$42,598,620	$12,123,000	$30,475,620	72%
	63J	$356,780	$37,000	$319,780	90%
Intermed subtotal		$101,228,820	$37,195,000	$64,033,820	63%
Total all levels		$625,798,930	$455,180,380	$170,618,550	27%

Table C-20. Manpower Costs for the First Year for the M1A1 and the FACS 135% Operational Intensity for the Active Force

Maintenance Level	MOS	M1A1	FACS 135%	Difference	%
Crew	19K	$447,509,670	$359,764,420	$87,745,250	20%
Organizational	31V	$13,492,960	$13,492,960	$0	0%
	45E	$23,342,710	$11,152,000	$12,190,710	52%
	63E	$40,224,770	$49,644,000	($9,419,230)	-23%
Org subtotal		$77,060,440	$74,288,960	$2,771,480	4%
Intermediate	29E	$1,045,560	$758,000	$287,560	28%
	39E	$278,210	$84,000	$194,210	70%
	41C	$5,508,550	$566,000	$4,942,550	90%
	44B	$0	$1,002,000	($1,002,000)	
	44E	$0	$45,000	($45,000)	
	45G	$6,939,600	$9,011,000	($2,071,400)	-30%
	45K	$41,776,670	$26,807,000	$14,969,670	36%
	63G	$2,724,830	$5,907,000	($3,182,170)	-117%
	63H	$42,598,620	$21,819,000	$20,779,620	49%
	63J	$356,780	$67,000	$289,780	81%
Intermed subtotal		$101,228,820	$66,066,000	$35,162,820	35%
Total all levels		$625,798,930	$500,119,380	$125,679,550	20%

Table C-21. Manpower Costs for the First Year for the M1A1 and the FACS 50% Operational Intensity for an Armor Battalion

Maintenance Level	MOS	M1A1	FACS 50%	Difference	%
Crew	19K	$7,411,350	$5,957,700	$1,453,650	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$385,540	$175,250	$210,290	55%
	63E	$664,870	$443,000	$221,870	33%
Org subtotal		$1,264,580	$832,420	$432,160	34%
Intermediate	29E	$17,330	$5,000	$12,330	71%
	39E	$4,580	$0	$4,580	100%
	41C	$91,640	$7,000	$84,640	92%
	44B	$0	$6,000	($6,000)	
	44E	$0	$0	$0	
	45G	$115,420	$57,000	$58,420	51%
	45K	$691,190	$170,000	$521,190	75%
	63G	$45,600	$36,000	$9,600	21%
	63H	$706,050	$134,000	$572,050	81%
	63J	$5,800	$0	$5,800	100%
Intermed subtotal		$1,677,610	$415,000	$1,262,610	75%
Total all levels		$10,353,540	$7,205,120	$3,148,420	30%

Table C-22. Manpower Costs for the First Year for the M1A1 and the FACS 75% Operational Intensity for an Armor Battalion

Maintenance Level	MOS	M1A1	FACS 75%	Difference	%
Crew	19K	$7,411,350	$5,957,700	$1,453,650	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$385,540	$175,250	$210,290	55%
	63E	$664,870	$554,000	$110,870	17%
Org subtotal		$1,264,580	$943,420	$321,160	25%
Intermediate	29E	$17,330	$7,000	$10,330	60%
	39E	$4,580	$1,000	$3,580	78%
	41C	$91,640	$8,000	$83,640	91%
	44B	$0	$9,000	($9,000)	
	44E	$0	$0	$0	
	45G	$115,420	$84,000	$31,420	27%
	45K	$691,190	$251,000	$440,190	64%
	63G	$45,600	$54,000	($8,400)	-18%
	63H	$706,050	$201,000	$505,050	72%
	63J	$5,800	$1,000	$4,800	83%
Intermed subtotal		$1,677,610	$616,000	$1,061,610	63%
Total all levels		$10,353,540	$7,517,120	$2,836,420	27%

Table C-23. Manpower Costs for the First Year for the M1A1 and the FACS 135% Operational Intensity for an Armor Battalion

Maintenance Level	MOS	M1A1	FACS 135%	Difference	%
Crew	19K	$7,411,350	$5,957,700	$1,453,650	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$385,540	$175,250	$210,290	55%
	63E	$664,870	$850,000	($185,130)	-28%
Org subtotal		$1,264,580	$1,239,420	$25,160	2%
Intermediate	29E	$17,330	$51,000	($33,670)	-194%
	39E	$4,580	$1,000	$3,580	78%
	41C	$91,640	$10,000	$81,640	89%
	44B	$0	$17,000	($17,000)	
	44E	$0	$1,000	($1,000)	
	45G	$115,420	$149,000	($33,580)	-29%
	45K	$691,190	$444,000	$247,190	36%
	63G	$45,600	$98,000	($52,400)	-115%
	63H	$706,050	$361,000	$345,050	49%
	63J	$5,800	$1,000	$4,800	83%
Intermed subtotal		$1,677,610	$1,133,000	$544,610	32%
Total all levels		$10,353,540	$8,330,120	$2,023,420	20%

Table C-24. Manpower Costs for the First Year for the M1A1 and the FACS 50% Operational Intensity for an Armor Cavalry Squadron

Maintenance Level	MOS	M1A1	FACS 50%	Difference	%
Crew	19K	$5,255,220	$4,227,640	$1,027,580	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$280,390	$175,250	$105,140	37%
	63E	$480,190	$332,000	$148,190	31%
Org subtotal		$974,750	$721,420	$253,330	26%
Intermediate	29E	$12,590	$3,000	$9,590	76%
	39E	$3,150	$0	$3,150	100%
	41C	$64,910	$5,000	$59,910	92%
	44B	$0	$4,000	($4,000)	
	44E	$0	$0	$0	
	45G	$81,580	$41,000	$40,580	50%
	45K	$489,790	$121,000	$368,790	75%
	63G	$31,830	$26,000	$5,830	18%
	63H	$499,060	$95,000	$404,060	81%
	63J	$3,990	$0	$3,990	100%
Intermed subtotal		$1,186,900	$295,000	$891,900	75%
Total all levels		$7,416,870	$5,244,060	$2,172,810	29%

Table C-25. Manpower Costs for the First Year for the M1A1 and the FACS 75% Operational Intensity for an Armor Cavalry Squadron

Maintenance Level	MOS	M1A1	FACS 75%	Difference	%
Crew	19K	$5,255,220	$4,227,640	$1,027,580	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$280,390	$175,250	$105,140	37%
	63E	$480,190	$406,000	$74,190	15%
Org subtotal		$974,750	$795,420	$179,330	18%
Intermediate	29E	$12,590	$5,000	$7,590	60%
	39E	$3,150	$1,000	$2,150	68%
	41C	$64,910	$5,000	$59,910	92%
	44B	$0	$6,000	($6,000)	
	44E	$0	$0	$0	
	45G	$81,580	$60,000	$21,580	26%
	45K	$489,790	$178,000	$311,790	64%
	63G	$31,830	$39,000	($7,170)	-23%
	63H	$499,060	$142,000	$357,060	72%
	63J	$3,990	$0	$3,990	100%
Intermed subtotal		$1,186,900	$436,000	$750,900	63%
Total all levels		$7,416,870	$5,459,060	$1,957,810	26%

Table C-26. Manpower Costs for the First Year for the M1A1 and the FACS 135% Operational Intensity for an Armor Cavalry Squadron

Maintenance Level	MOS	M1A1	FACS 135%	Difference	%
Crew	19K	$5,255,220	$4,227,640	$1,027,580	20%
Organizational	31V	$214,170	$214,170	$0	0%
	45E	$280,390	$175,250	$105,140	37%
	63E	$480,190	$628,000	($147,810)	-31%
Org subtotal		$974,750	$1,017,420	($42,670)	-4%
Intermediate	29E	$12,590	$9,000	$3,590	29%
	39E	$3,150	$1,000	$2,150	68%
	41C	$64,910	$6,000	$58,910	91%
	44B	$0	$12,000	($12,000)	
	44E	$0	$0	$0	
	45G	$81,580	$106,000	($24,420)	-30%
	45K	$489,790	$314,000	$175,790	36%
	63G	$31,830	$69,000	($37,170)	-117%
	63H	$499,060	$256,000	$243,060	49%
	63J	$3,990	$1,000	$2,990	75%
Intermed subtotal		$1,186,900	$774,000	$412,900	35%
Total all levels		$7,416,870	$6,019,060	$1,397,810	19%

Table C-27. Manpower Costs for Thirty Years for the M1A1 and the FACS 50% Operational Intensity for the Active Force (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 50%	Difference	%
Crew	19K	$20,807,573,120	$16,723,451,860	$4,084,121,260	20%
Organizational	31V	$625,271,980	$625,271,980	$0	0%
	45E	$1,082,058,760	$516,954,000	$565,104,760	52%
	63E	$1,863,851,630	$1,247,702,000	$616,149,630	33%
Org subtotal		$3,571,182,370	$2,389,927,980	$1,181,254,390	33%
Intermediate	29E	$48,493,200	$13,066,000	$35,427,200	73%
	39E	$12,900,690	$1,450,000	$11,450,690	89%
	41C	$255,052,800	$19,058,000	$235,994,800	93%
	44B	$0	$17,202,000	($17,202,000)	
	44E	$0	$763,000	($763,000)	
	45G	$321,143,060	$160,527,000	$160,616,060	50%
	45K	$1,936,639,880	$477,102,000	$1,459,537,880	75%
	63G	$126,128,970	$101,294,000	$24,834,970	20%
	63H	$1,972,915,830	$374,282,000	$1,598,633,830	81%
	63J	$16,543,970	$1,151,000	$15,392,970	93%
Intermed subtotal		$4,689,818,400	$1,165,895,000	$3,523,923,400	75%
Total all levels		$29,068,573,890	$20,279,274,840	$8,789,299,050	30%

Table C-28. Manpower Costs for Thirty Years for the M1A1 and the FACS 75% Operational Intensity for the Active Force (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 75%	Difference	%
Crew	19K	$20,807,573,120	$16,723,451,860	$4,084,121,260	20%
Organizational	31V	$625,271,980	$625,271,980	$0	0%
	45E	$1,082,058,760	$516,954,000	$565,104,760	52%
	63E	$1,863,851,630	$1,555,777,000	$308,074,630	17%
Org subtotal		$3,571,182,370	$2,698,002,980	$873,179,390	24%
Intermediate	29E	$48,493,200	$19,565,000	$28,928,200	60%
	39E	$12,900,690	$2,175,000	$10,725,690	83%
	41C	$255,052,800	$21,144,000	$233,908,800	92%
	44B	$0	$25,820,000	($25,820,000)	
	44E	$0	$1,029,000	($1,029,000)	
	45G	$321,143,060	$235,874,000	$85,269,060	27%
	45K	$1,936,639,880	$702,339,000	$1,234,300,880	64%
	63G	$126,128,970	$151,936,000	($25,807,030)	
	63H	$1,972,915,830	$561,457,000	$1,411,458,830	72%
	63J	$16,543,970	$1,718,000	$14,825,970	90%
Intermed subtotal		$4,689,818,400	$1,723,057,000	$2,966,761,400	63%
Total all levels		$29,068,573,890	$21,144,511,840	$7,924,062,050	27%

Table C-29. Manpower Costs for Thirty Years for the M1A1 and the FACS 135% Operational Intensity for The Active Force (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 135%	Difference	%
Crew	19K	$20,807,573,120	$16,723,451,860	$4,084,121,260	20%
Organizational	31V	$625,271,980	$625,271,980	$0	0%
	45E	$1,082,058,760	$516,954,000	$565,104,760	52%
	63E	$1,863,851,630	$2,300,291,000	($436,439,370)	
Org subtotal		$3,571,182,370	$3,442,516,980	$128,665,390	4%
Intermediate	29E	$48,493,200	$35,173,000	$13,320,200	27%
	39E	$12,900,690	$3,905,000	$8,995,690	70%
	41C	$255,052,800	$26,200,000	$228,852,800	90%
	44B	$0	$46,439,000	($46,439,000)	
	44E	$0	$2,093,000	($2,093,000)	
	45G	$321,143,060	$416,987,000	($95,843,940)	
	45K	$1,936,639,880	$1,242,697,000	$693,942,880	36%
	63G	$126,128,970	$273,432,000	($147,303,030)	
	63H	$1,972,915,830	$1,010,535,000	$962,380,830	49%
	63J	$16,543,970	$3,093,000	$13,450,970	81%
Intermed subtotal		$4,689,818,400	$3,060,554,000	$1,629,264,400	35%
Total all levels		$29,068,573,890	$23,226,522,840	$5,842,051,050	20%

Table C-30. Manpower Costs for Thirty Years for the M1A1 and the FACS 50% Operational Intensity for an Armor Battalion (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 50%	Difference	%
Crew	19K	$344,601,940	$276,941,530	$67,660,410	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$17,871,840	$8,123,560	$9,748,280	55%
	63E	$30,807,460	$20,538,000	$10,269,460	33%
Org subtotal		$58,604,250	$38,586,510	$20,017,740	34%
Intermediate	29E	$803,750	$222,000	$581,750	72%
	39E	$212,390	$16,000	$196,390	92%
	41C	$4,242,890	$318,000	$3,924,890	93%
	44B	$0	$283,000	($283,000)	
	44E	$0	$18,000	($18,000)	
	45G	$5,341,260	$2,661,000	$2,680,260	50%
	45K	$32,041,610	$7,897,000	$24,144,610	75%
	63G	$2,110,730	$1,682,000	$428,730	20%
	63H	$32,700,260	$6,199,000	$26,501,260	81%
	63J	$268,840	$17,000	$251,840	94%
Intermed subtotal		$77,721,730	$19,313,000	$58,408,730	75%
Total all levels		$480,927,920	$334,841,040	$146,086,880	30%

Table C-31. Manpower COsts for Thirty Years for the M1A1 and the FACS 75% Operational Intensity for an Armor Battalion (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 75%	Difference	%
Crew	19K	$344,601,940	$276,941,530	$67,660,410	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$17,871,840	$8,123,560	$9,748,280	55%
	63E	$30,807,460	$25,673,000	$5,134,460	17%
Org subtotal		$58,604,250	$43,721,510	$14,882,740	25%
Intermediate	29E	$803,750	$347,000	$456,750	57%
	39E	$212,390	$33,000	$179,390	84%
	41C	$4,242,890	$354,000	$3,888,890	92%
	44B	$0	$433,000	($433,000)	
	44E	$0	$18,000	($18,000)	
	45G	$5,341,260	$3,901,000	$1,440,260	27%
	45K	$32,041,610	$11,629,000	$20,412,610	64%
	63G	$2,110,730	$2,523,000	($412,270)	-20%
	63H	$32,700,260	$9,299,000	$23,401,260	72%
	63J	$268,840	$34,000	$234,840	87%
Intermed subtotal		$77,721,730	$28,571,000	$49,150,730	63%
Total all levels		$480,927,920	$349,234,040	$131,693,880	27%

Table C-32. Manpower Costs for Thirty Years for the M1A1 and the FACS 135% Operational Intensity for an Armor Battalion (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 135%	Difference	%
Crew	19K	$344,601,940	$276,941,530	$67,660,410	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$17,871,840	$8,123,560	$9,748,280	55%
	63E	$30,807,460	$39,365,000	($8,557,540)	-28%
Org subtotal		$58,604,250	$57,413,510	$1,190,740	2%
Intermediate	29E	$803,750	$2,367,000	($1,563,250)	-194%
	39E	$212,390	$66,000	$146,390	69%
	41C	$4,242,890	$442,000	$3,800,890	90%
	44B	$0	$767,000	($767,000)	
	44E	$0	$35,000	($35,000)	
	45G	$5,341,260	$6,904,000	($1,562,740)	-29%
	45K	$32,041,610	$20,592,000	$11,449,610	36%
	63G	$2,110,730	$4,530,000	($2,419,270)	-115%
	63H	$32,700,260	$16,742,000	$15,958,260	49%
	63J	$268,840	$52,000	$216,840	81%
Intermed subtotal		$77,721,730	$52,497,000	$25,224,730	32%
Total all levels		$480,927,920	$386,852,040	$94,075,880	20%

Table C-33. Manpower Costs for Thirty Years for the M1A1 and the FACS 50% Operational Intensity for an Armor Cavalry Squadron (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 50%	Difference	%
Crew	19K	$244,340,970	$196,512,020	$47,828,950	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$12,997,700	$8,123,560	$4,874,140	38%
	63E	$22,249,840	$15,404,000	$6,845,840	31%
Org subtotal		$45,172,490	$33,452,510	$11,719,980	26%
Intermediate	29E	$584,040	$154,000	$430,040	74%
	39E	$145,960	$16,000	$129,960	89%
	41C	$3,005,380	$230,000	$2,775,380	92%
	44B	$0	$200,000	($200,000)	
	44E	$0	$18,000	($18,000)	
	45G	$3,775,420	$1,888,000	$1,887,420	50%
	45K	$22,705,020	$5,587,000	$17,118,020	75%
	63G	$1,473,150	$1,184,000	$289,150	20%
	63H	$23,113,700	$4,377,000	$18,736,700	81%
	63J	$185,060	$17,000	$168,060	91%
Intermed subtotal		$54,987,730	$13,671,000	$41,316,730	75%
Total all levels		$344,501,190	$243,635,530	$100,865,660	29%

Table C-34. Manpower Costs for Thirty Years for the M1A1 and the FACS 75% Operational Intensity for an Armor Cavalry Squadron (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 75%	Difference	%
Crew	19K	$244,340,970	$196,512,020	$47,828,950	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$12,997,700	$8,123,560	$4,874,140	38%
	63E	$22,249,840	$18,827,000	$3,422,840	15%
Org subtotal		$45,172,490	$36,875,510	$8,296,980	18%
Intermediate	29E	$584,040	$222,000	$362,040	62%
	39E	$145,960	$33,000	$112,960	77%
	41C	$3,005,380	$248,000	$2,757,380	92%
	44B	$0	$300,000	($300,000)	
	44E	$0	$18,000	($18,000)	
	45G	$3,775,420	$2,769,000	$1,006,420	27%
	45K	$22,705,020	$8,259,000	$14,446,020	64%
	63G	$1,473,150	$1,785,000	($311,850)	-21%
	63H	$23,113,700	$6,574,000	$16,539,700	72%
	63J	$185,060	$17,000	$168,060	91%
Intermed subtotal		$54,987,730	$20,225,000	$34,762,730	63%
Total all levels		$344,501,190	$253,612,530	$90,888,660	26%

Table C-35. Manpower Costs for Thirty Years for the M1A1 and the FACS 135% Operational Intensity for an Armor Cavalry Squadron (Undiscounted Costs)

Maintenance Level	MOS	M1A1	FACS 135%	Difference	%
Crew	19K	$244,340,970	$196,512,020	$47,828,950	20%
Organizational	31V	$9,924,950	$9,924,950	$0	0%
	45E	$12,997,700	$8,123,560	$4,874,140	38%
	63E	$22,249,840	$29,096,000	($6,846,160)	-31%
Org subtotal		$45,172,490	$47,144,510	($1,972,020)	-4%
Intermediate	29E	$584,040	$409,000	$175,040	30%
	39E	$145,960	$49,000	$96,960	66%
	41C	$3,005,380	$301,000	$2,704,380	90%
	44B	$0	$550,000	($550,000)	
	44E	$0	$18,000	($18,000)	
	45G	$3,775,420	$4,890,000	($1,114,580)	-30%
	45K	$22,705,020	$14,551,000	$8,154,020	36%
	63G	$1,473,150	$3,209,000	($1,735,850)	-118%
	63H	$23,113,700	$11,837,000	$11,276,700	49%
	63J	$185,060	$34,000	$151,060	82%
Intermed subtotal		$54,987,730	$35,848,000	$19,139,730	35%
Total all levels		$344,501,190	$279,504,530	$64,996,660	19%

Working Paper

WP MSG 91-03

AN ASSESSMENT OF THE USE OF THE MANPOWER CONSTRAINTS (M-CON)
AID PROJECTION MODEL

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AN ASSESSMENT OF THE USE OF THE MANPOWERCONSTRAINTS (M-CON) AID PROJECTION MODEL.

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AN ASSESSMENT OF THE USE OF THE MANPOWER CONSTRAINTS (MCON) AID PROJECTION MODEL

INTRODUCTION

The Army Research Institute is developing two series of computerized aids: HARDMAN II for defining manpower, personnel and training requirements and HARDMAN III for estimating the availability of manpower which has the necessary characteristics to operate and maintain developing systems. The Manpower Constraints Aid (M-CON), one of the HARDMAN III series, generates early estimates of manpower-induced constraints on the system design. MCON includes a projection model for forecasting the availability of appropriate manpower at the fielding date and beyond.

MCON offers two alternative methods for estimating manpower availability. The first method is simple retrieval of the manpower data for systems to be replaced. The second alternative is use of the projection model, a PC-compatible adaptation of the Army Long Range Planning Model. The projection model is incorporated into the MCON aid as a step in the MCON estimation process. An earlier report, Narva and Alderman (1990), described the application of MCON to the Future Armored Combat System (FACS), a variant in the Armored Family of Vehicles (AFV) program. In that study, manpower requirements for the FACS were developed using the HARDMAN Comparability Methodology (HCM) (Shotzbarger et. al., 1989), and constraints on the availability of manpower for the FACS were estimated using the MCON 1987 data base, the first alternative method.

The objective of this effort was to assess the user interface while applying the current version (Version .91, dated April 1990) of the MCON aid projection model to the estimation of manpower availability for the FACS, i.e. to assess the user interface using the second alternative method.

APPROACH

MCON input parameters used by Narva and Alderman (1990) were duplicated in this study. They were derived from the assumptions adopted in the HCM FACS analysis. These assumptions are that the FACS will replace the M1A1 on a 1 for 1 basis, crew requirements will be reduced from 4 to 3, replacements will total 3501 systems, only manpower spaces directly attributable to the FACS are considered and officer spaces are not considered. In the present study, the working assumption is that FACS fielding occurs from 1995 to 2000. For analysis purposes, a baseline case for 1989 was computed to compare with the MCON data base estimate used in the previous study.

RESULTS AND DISCUSSION

Table 1 summarizes the maintenance manpower availability, or operating strength for the years 1989, 1990 and 2000; columns 2, 3 and 4 respectively, as computed by the MCON aid projection model. The MCON operating strength (column 1) is from the MCON data base and is the availability estimate used in the 1990 report. To maintain comparability between the manpower availability and requirements estimates, the FACS requirements in column 5 have been converted to operating strength using the adjustment factors used in MCON. Hyphens within the table indicate either manpower has not been assigned or the data is not available (columns 1 through 4); hyphens in the FACS column (5) indicates no requirement has been established.

Projected manpower availability and FACS requirements.

Since the projection model generates estimates of availability based on operating strength, it was necessary to adjust the FACS requirements which were characterized as "MARC" to operating strength. The adjustment factors computed by MCON permit converting values from MARC to authorized strength and from authorized strength to operating strength. These factors were applied to the FACS requirements to approximate FACS manpower requirements at operating strength. The total difference between the projected availability for 1995 (column 3) and the FACS requirements (column 5) was 973 excess maintenance spaces. This difference results from 1667 excess spaces in MOS 45E, 29E, 36H, 41C, 45B, 45K, 63H and 63J and the shortage of 694 in the remaining MOS (31V, 63E, 39E, 44B, 44E, 45G, and 63G). As noted by Narva and Alderman, comparability between the MCON and the FACS assumptions including system usage rates could not be demonstrated and must be assumed. To the extent they are comparable and the conversion to operating strength creditable, the above analysis may represent a reasonable approximation.

Comparison of the projected availability for the years 1995 (column 3) and 2000 (column 4) indicates a total difference of 31 excess spaces or approximately .7% due primarily to MOS 63E. This suggests relatively small variations over the six years. However, without a detailed description of the projection model and its data base, it is impossible to assess the variation.

MCON data base and projection model availability estimates.

The above comparison suggested a similar comparison of the MCON data base availability estimates for 1989 with projection model estimates for the same year (1989 is the earliest year which can be computed in the projection model). The difference

Table 1. Maintenance Manpower Availability and Requirements

	(1)	(2)	(3)	(4)	(5)	(6)
	MCON DBASE	PROJECTED AVAILABILITY (COMPUTED BY PROJ. MODEL)			FACS REQS	DIFFERENCE (1995)
MOS	OPST	1989	1995	2000	(OPST)	AVAIL-REQS
Organizational						
31V	34.61	22.25	25.20	25.20	525.72	(500.52)
45E	632.29	478.10	580.37	578.55	369.78	210.59
63E	908.38	839.23	1015.44	1046.18	1100.00	(84.56)
Intermediate						
29E	24.25	23.19	24.52	24.69	14.79	9.73
35H	5.35	4.95	4.50	4.62	–	4.50
39E	–	–	–	–	1.92	(1.92)
41C	167.71	120.22	118.75	119.11	15.56	103.19
44B	–	–	–	–	23.09	(23.09)
44E	–	–	–	–	.83	(.83)
45B	7.58	5.83	6.68	6.71	–	6.68
45G	174.77	145.56	125.48	127.30	182.67	(57.19)
45K	909.46	905.81	1048.43	1047.77	444.45	603.98
63G	60.23	71.95	76.50	76.20	101.89	(25.39)
63H	1599.75	1156.04	1304.14	1304.57	626.27	677.87
63J	67.78	53.25	52.21	52.23	1.50	50.71
TOTAL	4592.16	3826.38	4382.22	4413.13	3408.47	973.75

between the MCON data base operating strength estimate (column 1) and the projection model projected availability (column 2) was 765 spaces, or the projection model availability was approximately 20% less than the MCON data base values. A similar comparison of the data base values (column 1) with the projected 1995 estimates (column 3) yields a difference of 209 spaces or approximately 5% less than the 1989 estimates. Intuition implies that the two estimates for the nearest year (1989) to the data base creation date (1987) should have had the smallest percentage difference, with a possible larger difference in the out years. Yet, in this analysis, the sizes of the differences are the opposite of intuition. In the almost total lack of documentation on MCON and the complete lack of documentation on the projection model, it is impossible to explore the possible sources of these "discrepancies".

Overview of user interface.

A detailed screen by screen description of the user procedures and potential improvements are provided in the Appendix. In general, the problems and in some cases possible improvements, are discussed in the Narva and Alderman paper. The observations in this paper obtain for the projection model and may be more severe due to the greater need for documentation when using a simulation combined with the total lack of documentation for it.

Familiarization. The lack of documentation e.g. users guide, help screens, program description or other descriptive material for this pre-prototype version of MCON was a severe handicap to the user in learning how to use it and how to interpret the results, particularly the projection model. None of the considerable information that the user needs in the process of applying MCON, including completed inputs, is available. The outputs from the model are not explicit in what is being presented or their dimensions. The availability of extensive documentation is an important contributor to user acceptance, particularly in acceptance of the projection model estimates where credibility may be an issue.

Navigation. The confusing command prompts provided at the bottom of the screens, when combined with menu options, makes navigation considerably less than the straight forward process it should be. An atypical example of this, but no less severe, is at the completion of running the projection model when the screen prompt is "[RETURN] when finished." Since the model has completed execution, this would seem an appropriate choice but it reinitiates model execution. The appropriate choice should probably have been "[ESC] to quit." Navigation would be facilitated by providing only those screen prompts and menu options that are appropriate to the context.

Warnings. There are many "warnings" and "cautions" in those cases where the results are changed if the advice is inadvertently ignored. These warnings and cautions should be reduced. A more effective and user friendly approach would to disable the action and provide a window that describes the action. If there is a unique requirement for the user to override the disabling, the user could be directed as to how take the appropriate steps to enable the action.

SUMMARY AND CONCLUSIONS

The application of the MCON projection model to forecast the availability of manpower from the replacement of the M1A1 with the FACS is described. Differences between MCON data base availability and projected estimates are discussed in the context of model credibility. A screen-by-screen description of the user's procedure is provided with a discussion of potential problems and improvements. The total difference between FACS manpower requirements and projected availability are developed and the contribution of individual MOSs shortages and excesses to this total are described. Problems in assessing the comparability of manpower estimates are highlighted.

REFERENCES

Narva, M. A. and Alderman, I. N. (1990) An assessment of the use of the Manpower Constraint (M-CON) software aid. Manned Systems Group Working Paper 90-13. Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences (28 September).

Schotzbarger, L., Walker, L., Hackard, E., and Harrison, S. (1989) Apply the Army comparability methodology to the Future Armored Combat System (FACS), Volume 1. (Contract DABT60-87-D-3873), Hay Systems Inc., Alexandria, VA.

APPENDIX 1

DISCUSSION OF SCREENS AND REPORTS

This appendix provides a detailed discussion of the procedures involved in the use of the MCON projection model i.e., Step 5, "Running a projection model" of the MCON Step Menu. For a discussion of the screens for the other steps of M-CON, the reader is referred to the appendix in Narva and Alderman (1990).

In the following discussion, the screens are presented in order of occurrence and numbered sequentially, followed by short descriptions of the available reports. Printed representations of the screens and reports are presented on separate pages following the screen discussion.

SCREEN DISCUSSION

Screen 5.0, M-CON Step Menu.

Purpose: The step menu serves as the entry to each M-CON step beyond the introduction to M-CON.

Comments: The asterisk beside step 5 (as well as steps 6 and 7) indicates that this step provides for a more detailed or supplementary analysis to the main, "rapid", analysis, which may be executed with the other steps. The shading of these steps indicates they may not be executed until the previous steps have been completed.

Step 5 was selected to initiate the projection model. In this report it is assumed that the previous steps have been completed.

Screen 5.1, Available MOS Inventory.

Purpose: Permits the display and print-out of the results of a previously executed projection model to be reviewed or the initiation of the projection model.

Comments: "Review" was selected to illustrate the result of selecting "Review" before the projection model had been run.

Screen 5.2, Error Window.

Purpose: To warn of an error in conduct of the procedure.

Comments: The error message was presented indicating the projection model had not been executed and therefore was not

PATH:> Selecting Steps for Analysis   M-CON Ver 1.0

PROTOTYPE

M-CON Step Menu System: FACS Version: 1.0 PROJ	Latest Access Date
1. Identify Systems to be replaced	29 Oct 1990
2. Identify Additional MOSs	NA
3. Determine System Density	29 Oct 1990
4. Calculate Manpower Constraints	29 Oct 1990
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight   [Enter] to select
[F1] for help

Screen 5.0.

PATH:> Running projection model> Projecting MOSs Manpower M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ

Available MOS Inventory				
MOS	Projected Years			
19K	from		to	
29E	from		to	
31V	from		to	
35H	from		to	
41C	from		to	
44B	from		to	
45B	from		to	
	Review	Project		

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 5.1.

available for review. The "escape" key was used to return to the "Available MOS Inventory" screen. Note that the screen does not include a prompt to use this key.

Screen 5.3, Available MOS Inventory.

Purpose: Permits a previously executed projection to be reviewed or the initiation of the projection model.

Comments: "Project" was highlighted using the "cursor right" key and selected by pressing "enter".

Screen 5.4, Available MOS Inventory.

Purpose: Selection of MOSs to be projected and initiation of the projection model.

Comments: MOS to be projected are selected through use of the up and down keys and "tagged" by use of the space bar. There is no provision for selection of "ALL"; therefore each MOS to be projected was tagged individually. The MOS listed are those identified in Step 1, "Identify systems to be replaced", as being available from the baseline system, the M1. After the MOS were selected by tagging, "Project" was highlighted and the "Enter" key pressed to initiate the projection model.

Screen 5.5, Approach for Estimating Projected MOS Inventory.

Purpose: Permits choice of running projection model using default settings or changing model parameters prior to running the projection model.

Comments: Option 2 was selected to illustrate the result of enabling this option.

Screen 5.6, Warning Window.

Purpose: Warn of possible difficulties with changing model parameters.

Comments: This option offers the user the flexibility of changing stored parameters of the underlying model. However, the message alerts the user to the "complexity" of these parameters and the need to "know what you are doing". Since none of the help screens or documentation (there are none in this version) describes the necessary "familiarity", the user is unable to make the necessary judgement or forced to assume the option should not be selected. It is not clear how the user is to gain such an understanding. However, this option offers a powerful tool as the

PATH:ction model> Projecting MOSs Manpower> Reviewing Projections M-CON Ver 1.0

P R O T O T Y P E

Available MOS Inventory				
MOS	Projected Years			
19K	from		to	
29E	from		to	

E R R O R

Unable to find the furthest year flowed to by the model.

Review Project

Screen 5.2.

PATH:> Running projection model> Projecting MOSs Manpower M-CON Ver 1.Ø

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.Ø PROJ

Available MOS Inventory				
MOS	Projected Years			
19K	from		to	
29E	from		to	
31V	from		to	
35H	from		to	
41C	from		to	
44B	from		to	
45B	from		to	
	Review		Project	

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 5.3.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Available MOS Inventory				
MOS	Projected Years			
19K	from		to	
29E	from		to	
31V	from		to	
35H	from		to	
41C	from		to	
44B	from		to	
45B	from		to	
More				
Project				

Title: M1 Armor Crewmember

] to highlight [Enter] to edit [Esc] when finished
[F1] for help [P] to print

Screen 5.4.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0
P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Available MOS Inventory

Approach for Estimating Projected MOS Inventory

1. Run Projection Model
*2. Change Model Parameters

Select

45B | from | | to |
More

Project

] to highlight [Space] to select [Enter] when finished
[F1] for help [ESC] to quit

Screen 5.5.

Army is restructured and downsized and the quality of the manpower pool changes. This option requires extensive documentation including references to the appropriate guidance in developing the parameters or the source of creditable estimates. The question posed offers two response options; "No" returns to the previous screen, "Yes" accesses the model parameters, allowing the user to change the parameter values. "Yes" was selected.

Screen 5.7, Detailed Mode.

Purpose: Present menu of model parameters which may be changed.

Comments: Through selection of these options, the existing parameters may be displayed, accessed and changed. The first edit screen for each of the three options was selected and are presented as screens 5.7.1, 5.7.2 and 5.7.3.

Screen 5.7.1, Edit End Strength.

Purpose: Present end strengths per year presently stored in the model.

Comments: These end strengths can be edited directly on this screen. The new numbers input by the user will be used as projection model parameters instead of the default values. As the Army is downsized in the future, this, as well as the other options, may prove to be a useful feature. The "escape" key was used to return to the menu.

Screen 5.7.2, Edit Promotion Rates

Purpose: Stored values for promotion are displayed for user review and revision.

Comments: This is the first of four rate tables available. The others are separations, migrations in and migrations out.

Screen 5.7.3, Available Accessions

Purpose: Displays the current entries of available personnel by mental category, sex and education for each selected MOS and year.

Comments: It is not clear whether these values are the result of running the projection model or are the default model parameters. The sequence of "amounts" shown in the last column is a repetitive pattern that is most surprising. If these "data"

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Available MOS Inventory

ears

o
o
o
o
o
o
o

W A R N I N G

You have choosen a VERY complex option!

It's possible to change parameters in such a manner that the model output will be meaningless.

If you are not sure what you are doing, press 'N' to continue.

(Y/N)

Screen 5.6.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Detailed mode
1. Adjust Army Endstrength 2. Adjust Transition Rates 3. Adjust Accessions
Select

] to highlight [Enter] to edit [Esc] when finished
[F1] for help

Screen 5.7.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Edit EndStrength

SYSTEM: FACS VERSION: 1.0 PROJ

YEAR	EndStrength
1989	600000
1990	600000
1991	600000
1992	600000
1993	600000
1994	600000
1995	600000
1996	600000
1997	600000

More

Edit

] to highlight [Enter] to edit [Esc] when finished
[F1] for help [P] to print

Screen 5.7.1.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0
P R O T O T Y P E

Promotion Rates

SYSTEM: FACS — YEAR: 1995 — VERSION: 1.0 PROJ

MOS	E 1-3	E 4	E 5	E 6	E 7	E 8-9
19K	0.0000	0.5065	0.2202	0.0438	0.0540	0.0000
29E	0.0000	0.7660	0.0000	0.0000	0.0000	0.0000
31V	0.0000	0.5089	0.2465	0.0000	0.0000	0.0000
35H	0.0000	0.7058	0.2079	0.0000	0.1041	0.0705
41C	0.0000	0.3355	0.1825	0.0000	0.0000	0.0000
44B	0.0000	0.2046	0.1366	0.0000	0.0000	0.0000
45B	0.0000	0.9384	0.0834	0.0000	0.0000	0.0000
45E	0.0000	0.6437	0.4138	0.0000	0.0000	0.0000

More

Edit

] to highlight — [Enter] to edit — [Esc] when finished

[F1] for help — [P] to print

Screen 5.7.2.

are intended to serve as a temporary place holder pending availability of better estimates, the intention should be indicated by display of an explanation warning or caution window.

Screen 5.8, Approach for Estimating Projected MOS Inventory.

Purpose: Permits choice of running projection model using default settings or changing model parameters prior to running projection.

Comments: Option 1 was chosen to initiate the projection model, without a change in the model parameters.

Screen 5.9, Approach for Estimating Projected MOS Inventory.

Purpose: Temporary display on initiation of the projection model.

Comments: This display serves as a background during execution of the projection model. Upon completion of the model execution, the model enters the dates covered by the model on the screen.

Screen 5.10, Loading MOS: XXX

Purpose: To advise the user of progress as the model parameters for each selected MOS are being retrieved from a database and loaded.

Comments: Upon initiation of the projection model this screen appears for the first MOS which was selected through use of previous steps. The screen advises when the loading of each of the parameters is complete. The MOS which is being loaded is displayed in the window to the left, as is the year being loaded. The year will be the base year upon which the projection will be based. When the loading of the parameters for that MOS and year is complete, the next screen (5.11) appears to complete the loading, execution and saving for that MOS. When the loading process for the MOS is complete, the loading of the next MOS takes place and this screen (5.10) reappears to advise about the loading for that MOS. The alternation between screens 5.10 and 5.11 continues through the loading of all the selected MOS.

Screen 5.11, Loading

Purpose: To continue to advise about the loading of parameters.

Comments: As noted in conjunction with the previous screen,

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0
P R O T O T Y P E

Available Accessions
SYSTEM: FACS YEAR: 1995 VERSION: 1.0 PROJ

MOS	MenCat	Sex	Educ	Amount
29E	I,II,IIIa	Male	HS	129
29E	IIIb	Male	HS	102
29E	IV,V	Male	HS	325
29E	I,II,IIIa	Female	HS	129
29E	IIIb	Female	HS	102
29E	IV,V	Female	HS	325
29E	I,II,IIIa	Male	NHS	64
29E	IIIb	Male	NHS	62
29E	IV,V	Male	NHS	538

More

Edit

] to highlight [Enter] to edit [Esc] when finished
[F1] for help [P] to print

Screen 5.7.3.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

PROTOTYPE

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Available MOS Inventory

Approach for Estimating Projected MOS Inventory

1. Run Projection Model
*2. Change Model Parameters

Select

45B | from | | to |

More

Project

] to highlight [Space] to select [Enter] when finished
[F1] for help [ESC] to quit

Screen 5.8.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Available MOS Inventory				
MOS	Projected Years			
19K	from		to	
29E	from		to	
31V	from		to	
35H	from		to	
41C	from		to	
44B	from		to	
45B	from		to	
More				
Project				

Title: M1 Armor Crewmember

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 5.9.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0
PROTOTYPE

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS = 19K
YEAR = 1989

Please Wait

Loading MOS: 19K

Available Accessions	complete
Historical Accessions	complete
Initial Inventory	complete
Additional Migrations	complete
Migration In Rates	complete
Migration Out Rates	
Promotion Rates	
Seperation Rates	

] to highlight [Space] to select [Enter] when finished
[F1] for help [ESC] to quit

Screen 5.10.

the windows to the left of this screen advise about the loading of parameters for the MOS and the year shown in the upper left window. The window to the lower left displays the parameter which is being loaded. These are the same parameters listed on the preceding screen. This screen also has a window which advises about the percentage of the total data, over all MOS, which has been loaded. All of the years which have been selected previously for projection are executed, with the year and parameters shown in the respective windows. Upon completion of loading of all the parameters for a given year for the MOS, the results are saved. When one year is completed, the loading of the next year to be projected for that MOS is executed and saved. When the last projection year has been executed for an MOS, Screen 5.10 reappears and the initial loading of the parameters for the next MOS is executed.

Screen 5.12, Warning Screen

Purpose: To warn that data should be packed.

Comments: The meaning of packing data is not explained. A help screen is not presently available. "Y" was selected.

Screen 5.13, Warning Screen

Purpose: To warn that the packing process should not be interrupted.

Comments: When the process is completed, screen 5.14 appears. This process can take as long as running the projection model; some model runs, including packing, took four hours to complete. A percent complete indication such as in screen 5.11 and an audible tone to alert the user to completion of the process would be useful.

Screen 5.14, Adjusting.

Purpose: To advise that MOS data is being adjusted.

Comments: The window advises that the data for an MOS is being adjusted. The meaning of this adjustment is not clear, but presumably is associated with the preceding packing process. When the last MOS has been adjusted, screen 5.15 appears.

Screen 5.15 Approach for Estimating Projected MOS Inventory.

Purpose: Window indicates completion of the projection model.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS = 45K
YEAR = 1989

Projection Model

53% Complete

Please Wait

Loading.....
Migration Out Rates

] to highlight
[F1] for help

[Space] to select
[ESC] to quit

[Enter] when finished

Screen 5.11.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

```
SYSTEM = FACS
VERSION= 1.0 PROJ
MOS    =
YEAR   =
```

W A R N I N G

You should pack the data
after running the model.

Do you wish to pack(Y/N)

Screen 5.12.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

```
SYSTEM = FACS
VERSION= 1.0 PROJ
MOS     =
YEAR    =
```

```
********* Please Wait *********
 D O  N O T   I N T E R R U P T
         P A C K I N G
```

Screen 5.13.

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

```
SYSTEM = FACS
VERSION= 1.0 PROJ
MOS     =
YEAR    =
```

Please Wait

Adjusting 29E

Screen 5.14.

Comments: This is the same window used to initiate the model. The user was cautioned about changing the model parameters and the default options. The screen prompts are ambiguous; "when finished" and "to quit". The correct user response is "[ESC]to quit" which will permit selection of the "review" option as shown in screen 5.16. Selection of the default by pressing "[Enter] to finish", will reinitiate the model and redo the entire process that had been completed. The model adjustment factors are revised resulting in erroneous estimates of manpower availability. The next step in the step menu, i.e., Step 6, "Adjust Manpower Constraints", cautions the user against adjusting the constraints if the projection model has been run. Several trial runs demonstrated that this version (.91) of the program does not preclude enabling the adjustment factors more than once, running the projection model more than once as well as combining both in a single analysis. All test cases resulted in different manpower availability estimates.

Screen 5.16, Available MOS Inventory.

Purpose: Permits review of a previously executed projection.

Comments: The projected years listed are those selected in initiating the analysis before the step menu is accessed. The starting and ending years are entered after the name and version are entered as step 0 in running MCON. The selected years are not available to the user until the projection model has been completed. The cursor key was used to highlight "Review" and selected by pressing "Enter".

Screen 5.17, Characteristics Menu.

Purpose: To select characteristics of the MOS data to be displayed.

Comments: This screen permits the selection of the MOS characteristics to be displayed. For example, the projected availability of MOS of a particular AFQT level may be selected, as opposed to the default value of all levels. Options 1-3 permit specification of AFQT, Sex and Education parameters, while option 4 permits specification of year to be displayed. Options 5 and 6 permit selection of the two displays of the model results.

Selection of option 1 (AFQT) presents Screen 5.18, option 2 (Sex) gives Screen 5.19, and selection of option 3 (Education) gives Screen 5.20. Option 4 (Year) gives Screen 5.21 which was used to change the year to 1995.

Selection of Option 5 (Compare MOS) resulted in Report 5.1, while selection of Option 6 (Display MOS Inventory) resulted in Report 5.2. Report 5.3 was obtained by accessing step 8 (Print

PATH: projection model> Projecting MOSs Manpower> Projecting MOSs M-CON Ver 1.0

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.0 PROJ
MOS =
YEAR =

Available MOS Inventory

Approach for Estimating Projected MOS Inventory

1. Run Projection Model
*2. Change Model Parameters

Select

45B | from | | to |

More

Project

] to highlight [Space] to select [Enter] when finished
[F1] for help [ESC] to quit

Screen 5.15.

PATH:> Running projection model> Projecting MOSs Manpower M-CON Ver 1.Ø

P R O T O T Y P E

SYSTEM = FACS
VERSION= 1.Ø PROJ

Available MOS Inventory

MOS	Projected Years			
19K	from	1989	to	1995
29E	from	1989	to	1995
31V	from	1989	to	1995
35H	from	1989	to	1995
41C	from	1989	to	1995
44B	from	1989	to	1995
45B	from	1989	to	1995

Review Project

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 5.16.

of display reports) from the step menu and selecting the maintenance manpower constraints report.

Screen 5.18, AFQT Menu.

Purpose: Permit selection of AFQT characteristics to be displayed.

Comments: See Screen 5.17.

Screen 5.19, Sex Menu.

Purpose: Permit selection of Sex to be displayed.

Comments: See Screen 5.17.

Screen 5.20, Education Menu.

Purpose: Permit selection of education level to be displayed.

Comments: See Screen 5.17.

Screen 5.21, Year Menu.

Purpose: Permit selection of year to be displayed.

Comments: See Screen 5.17. The years are those which have been determined in the initialization step 0.

Screen 5.22, Wait.

Purpose: Advise that a report is being generated.

Comments: See Screen 5.17. The characteristics being included in the report are given in the window at the upper left.

REPORT DISCUSSION

Report 5.1, MOS Comparison Report.

Purpose: Present comparisons of the characteristics of the MOS.

Comments: See Screen 5.17. This report presents the profiles of various characteristics of the MOS. It presents the

```
PATH:jecting MOSs Manpower> Reviewing Projections> Comparing MOSs M-CON Ver 1.0
                              P R O T O T Y P E

 ═══════ CHARACTERISTICS ════════
 SYSTEM  : FACS
 VERSION : 1.0 PROJ
 AFQT : ALL
 Sex  : ALL
 Educ : ALL
 Year : 1989

                                          Characteristics

                                        1. AFQT
                                        2. Sex
                                        3. Education
                                        4. Year
                                        5. Compare MOS
                                        6. Display MOS Inventory
                                        7. Return Projection Menu

                                              Select

 ] to highlight          [Enter] to select          [Esc] when finished
[F1] for help
```

Screen 5.17.

PATH:ewing Projections> Comparing MOSs> Selecting Characteristics M-CON Ver 1.0

P R O T O T Y P E

CHARACTERISTICS

SYSTEM : FACS
VERSION : 1.0 PROJ
AFQT : ALL
Sex : ALL
Educ : ALL
Year : 1989

AFQT

All
I
II
IIIA
IIIB
IV

Select(s)

] to highlight [Space] to select [Enter] when finished
[F1] for help [ESC] to quit

Screen 5.18.

PATH:ewing Projections> Comparing MOSs> Selecting Characteristics M-CON Ver 1.0
P R O T O T Y P E

CHARACTERISTICS
SYSTEM : FACS
VERSION : 1.0 PROJ
AFQT : ALL
Sex : ALL
Educ : ALL
Year : 1989

Sex
All Male Female
Select(s)

] to highlight [Space] to select [Enter] when finished
[F1] for help [ESC] to quit

Screen 5.19.

PATH:ewing Projections> Comparing MOSs> Selecting Characteristics M-CON Ver 1.0

P R O T O T Y P E

```
═══════ CHARACTERISTICS ═══════
SYSTEM   : FACS
VERSION : 1.0 PROJ
AFQT : ALL
Sex  : ALL
Educ : ALL
Year : 1989
```

```
  Education
─────────────
All
HSG
Non HSG
─────────────
  Select(s)
```

] to highlight   [Space] to select   [Enter] when finished

[F1] for help   [ESC] to quit

Screen 5.20.

PATH:ewing Projections> Comparing MOSs> Selecting Characteristics M-CON Ver 1.0

P R O T O T Y P E

CHARACTERISTICS
SYSTEM : FACS
VERSION : 1.0 PROJ
AFQT : ALL
Sex : ALL
Educ : ALL
Year : 1989

YEAR
1989
1990
1991
1992
1993
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 5.21.

PATH:power> Reviewing Projections> Comparing MOSs> Viewing Report M-CON Ver 1.0
P R O T O T Y P E

CHARACTERISTICS

SYSTEM : FACS
VERSION : 1.0 PROJ
AFQT : ALL
Sex : ALL
Educ : ALL
Year : 1993

******* Please Wait *******
Generating a report for the
specified characteristics

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 5.22.

percentages falling at each level of the various characteristics. In this case, the year presented is 1995. In addition to AFQT, Sex and Education, information about standings in ASVAB, Vision, ability to lift, and reading grade level is presented.

Report 5.2, Projected MOS Inventory Report.

Purpose: Present projected availability by MOS and grade level.

Comments: See Screen 5.17. This report presents the projected total force inventory of MOS by grade level assigned to the M1A1. The characteristics included in the projection are given at the top of the table.

Report 5.3, Maintenance Manpower Constraint Report.

Purpose: Presents the number of each of the MOS available at the specified maintenance level and skill level.

Comments: This report was accessed from the Step menu, step number 8, "Display or print reports." The availability estimates have been adjusted for the projected values. The total availability for each MOS was calculated and included in Table 1 for 1995, the last year of the projection model run. This report reflects the final year only; estimates for previous years are not available. If all of the MOS were selected in initiating the projection model, then all of the MOS are projected values. However, if some but not all MOS are projected, there is ambiguity in the type of estimate, i.e. projected or adjusted values.

M-CON System: FACS   Version: 1.0 PROJ, Friday, November 23, 1990 6:43 pm

MOS Comparison Report

All Characteristics (values in Percentages)
Year : 1995

	AFQT					SEX		EDUCATION	
	I	II	IIIA	IIIB	IV	MALE	FEMALE	HSG	NON-HSG
19K	4.1	24.7	21.8	36.8	12.6	100.0	0.0	94.6	5.4
29E	8.9	38.8	16.1	28.2	8.0	82.1	17.9	98.3	1.7
31V	5.0	26.0	28.7	36.0	4.4	88.5	11.5	90.3	9.7
35H	20.4	47.0	9.1	16.2	7.3	78.8	21.2	97.3	2.7
41C	3.1	21.6	20.0	43.4	11.9	84.4	15.6	100.0	0.0
44B	3.7	14.9	25.1	45.0	11.3	95.6	4.4	98.6	1.4
45B	1.8	22.6	17.3	39.2	19.1	84.7	15.3	90.4	9.6
45E	5.7	18.5	20.6	37.5	17.6	100.0	0.0	82.9	17.1
45G	4.9	23.3	25.7	38.8	7.3	93.2	6.8	94.7	5.3
45K	3.4	28.0	26.1	35.0	7.5	95.7	4.3	98.3	1.7
45Z	8.9	25.3	20.3	25.9	19.6	98.7	1.3	100.0	0.0
52C	4.9	24.7	19.4	36.8	14.2	88.4	11.6	97.2	2.8
63E	3.4	14.0	20.4	30.0	32.2	100.0	0.0	83.9	16.1
63G	7.0	41.9	38.0	0.0	13.0	90.9	9.1	96.2	3.8
63H	3.9	18.1	21.8	40.2	16.0	96.7	3.3	97.0	3.0
63J	4.8	9.5	20.6	46.1	19.1	76.7	23.3	95.0	5.0
63Z	15.4	21.1	17.2	21.6	24.7	100.0	0.0	99.6	0.4

	ASVAB						
	<75	<85	<95	<105	<115	<125	<135
19K	0.6	7.0	18.2	26.1	28.4	15.6	4.0
29E	1.2	8.4	17.6	26.6	25.6	16.4	4.2
31V	1.0	7.9	20.6	31.6	23.9	11.6	3.2
35H	0.9	5.8	11.6	21.8	28.6	24.4	6.9
41C	3.1	12.4	21.8	27.6	21.5	10.6	3.0
44B	2.5	10.6	20.2	29.6	23.8	10.5	2.8
45B	4.0	14.5	22.4	26.1	20.3	10.1	2.5
45E	0.8	5.9	20.1	26.5	26.7	16.3	3.7
45G	1.5	9.8	20.6	29.7	23.6	11.7	3.1
45K	1.8	7.9	17.0	28.4	27.1	14.1	3.8
45Z	2.8	10.1	17.4	25.0	24.5	14.7	5.5
52C	2.8	11.0	20.3	27.5	22.9	12.0	3.4
63E	1.1	7.8	24.7	27.1	23.8	13.0	2.5
63G	0.6	3.2	13.2	23.2	30.0	24.3	5.5
63H	1.0	6.5	20.8	26.9	26.0	15.6	3.0
63J	1.5	10.5	28.6	27.6	20.6	9.6	1.7
63Z	3.2	11.0	17.2	22.6	22.9	15.5	7.5

Report 5.1.

	PULHES (Eyes) 1	2	>2	Weight Lift (MEPSCAT) Light	Medium	Heavy
19K	77.5	22.5	0.0	0.0	18.1	81.9
29E	75.4	24.6	0.0	5.4	26.2	68.4
31V	76.0	24.0	0.0	2.8	24.7	72.5
35H	74.6	25.4	0.0	8.3	25.7	66.0
41C	76.4	23.6	0.0	3.9	26.1	69.9
44B	77.6	22.4	0.0	1.1	20.9	78.0
45B	76.5	23.5	0.0	4.2	26.2	69.6
45E	77.5	22.5	0.0	0.0	19.0	81.0
45G	77.1	22.9	0.0	2.1	21.2	76.7
45K	77.1	22.9	0.0	1.1	20.1	78.7
45Z	77.3	22.7	0.0	0.4	17.4	82.2
52C	76.6	23.4	0.0	3.2	23.8	73.0
63E	78.2	21.8	0.0	0.0	18.6	81.4
63G	76.0	24.0	0.0	2.5	21.3	76.2
63H	77.7	22.3	0.0	0.9	19.9	79.2
63J	76.3	23.7	0.0	6.4	30.7	62.9
63Z	77.1	22.9	0.0	0.0	16.2	83.8

	Reading Grade Level <7	7-9	9-11	11-12	>12
19K	2.0	34.1	20.8	38.4	4.7
29E	1.2	26.3	17.4	44.5	10.6
31V	0.7	27.4	23.4	42.7	5.8
35H	1.2	18.7	11.6	46.1	22.5
41C	1.9	38.1	21.9	34.4	3.8
44B	1.8	37.4	23.3	33.5	4.1
45B	3.1	41.4	18.8	33.9	2.8
45E	2.8	37.5	20.5	33.6	5.6
45G	1.2	31.6	21.7	40.0	5.4
45K	1.2	29.5	21.9	43.3	4.2
45Z	3.1	33.6	17.3	36.6	9.4
52C	2.3	35.5	20.1	36.3	5.8
63E	5.2	44.4	18.0	28.8	3.6
63G	2.0	14.7	16.6	58.5	8.1
63H	2.5	38.6	21.0	33.6	4.3
63J	3.0	44.9	21.5	25.6	4.9
63Z	3.9	34.7	14.9	30.8	15.7

Report 5.1 Continued.

Projected MOS Inventory Report

System: FACS
AFQT : ALL
Educ : ALL

Version: 1.0 PROJ
Sex : ALL
Year : 1995

MOS	E1/3	E4	E5	E6	E7	E8/9	Total
19K	6208	4133	3119	1670	1438	0	16568
29E	467	477	504	326	1	0	1775
31V	2077	1377	1278	14	8	0	4754
35H	156	202	180	102	101	69	810
41C	111	81	77	51	0	0	320
44B	693	383	366	0	0	0	1442
45B	244	241	170	0	0	0	655
45E	433	276	250	0	0	0	959
45G	65	61	37	43	0	0	206
45K	702	480	148	269	11	0	1610
45Z	0	0	0	0	157	1	158
52C	1003	912	414	233	6	0	2568
63E	1493	1088	586	260	61	79	3567
63G	313	252	174	0	0	0	739
63H	1875	1488	1040	879	916	1	6199
63J	680	662	520	0	0	0	1862
63Z	0	0	0	0	0	227	227

Report 5.2.

Maintenance Manpower Constraint Report

System: FACS   Version: 1.0 PROJ

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
29E	1	0.00	12.37	0.00	12.37
29E	2	0.00	6.92	0.00	6.92
29E	3	0.00	5.23	0.00	5.23
31V	1	18.83	0.00	0.00	18.83
31V	2	6.37	0.00	0.00	6.37
35H	1	0.00	0.00	2.01	2.01
35H	2	0.00	0.00	0.95	0.95
35H	3	0.00	0.00	0.73	0.73
35H	4	0.00	0.00	0.62	0.62
35H	5	0.00	0.00	0.19	0.19
41C	1	0.00	42.52	30.24	72.77
41C	2	0.00	17.56	12.49	30.05
41C	3	0.00	9.31	6.62	15.93
45B	1	0.00	2.92	2.07	4.99
45B	2	0.00	0.99	0.70	1.69
45E	1	418.64	0.00	0.00	418.64
45E	2	161.73	0.00	0.00	161.73
45G	1	0.00	68.10	0.00	68.10
45G	2	0.00	34.68	0.00	34.68
45G	3	0.00	22.70	0.00	22.70
45K	1	0.00	352.26	238.14	590.40
45K	2	0.00	133.25	90.08	223.33
45K	3	0.00	140.03	94.66	234.70
63E	1	471.33	0.00	0.00	471.33
63E	2	252.26	0.00	0.00	252.26
63E	3	153.42	0.00	0.00	153.42
63E	4	118.81	0.00	0.00	118.81
63E	5	19.62	0.00	0.00	19.62

Report 5.3.

Maintenance Manpower Constraint Report

System: FACS Version: 1.0 PROJ

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
63G	1	0.00	60.37	2.88	63.24
63G	2	0.00	12.66	0.60	13.26
63H	1	0.00	355.43	187.04	542.46
63H	2	0.00	141.14	74.27	215.41
63H	3	0.00	208.79	109.87	318.66
63H	4	0.00	149.14	78.48	227.61
63J	1	20.70	6.57	13.76	41.04
63J	2	5.63	1.79	3.75	11.17

Report 5.3 Continued.

Central Division

ASA
We Improve Performance

Design Specification for a MANPRINT Training Characteristics Estimation Aid (TCEA)

Prepared by:

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Contract Number MDA903-86-C-0414
CDRL Sequence Number 0004AC

31 December 1987

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Working Paper MSG-88-08

DESIGN SPECIFICATION FOR A

MANPRINT TRAINING CHARACTERISTICS

ESTIMATION AID (TCEA)

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31 December 1987

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ACKNOWLEDGMENTS

The authors wish to gratefully acknowledge the assistance provided by numerous individuals and organizations in the development and evolution of Product Four to this point. From our subcontractor, Science Applications International Corporation (SAIC), special thanks for their participation and efforts go to Dr. Eleanor Criswell (SAIC's Project Director), Dr. Joseph Peters, Mr. Steven Eschholz, and Mr. Stephen Masterson. Each of these individuals played an important role in the evolution of Product Four, particularly in this phase of the effort. Thanks also go to Ms Betty Landee-Thompson of SAIC, whose ideas and concepts form the basis for the User Acceptance Plan presented in this document. We wish also to acknowledge Dr. Thomas Sicilia and his staff at the Training and Performance Data Center, Orlando, FL for their assistance in investigating the databases developed by that organization. As well, we must acknowledge the assistance of the U.S. Army Field Artillery School and Center, Fort Sill, Oklahoma; the U.S. Army Ordnance School and Center, Aberdeen Proving Ground, Maryland; the Soldier Support Center-National Capitol Region, Alexandria, Virginia; and Headquarters, U.S. Army Materiel Command, Alexandria, Virginia. Many people in these organizations took time from their busy schedules to provide data or assistance that were of material value. Finally, we would like to acknowledge Dr. Jonathan Kaplan of the Army Research Institute, the progenitor of the overall MANPRINT Methods effort, for his advice and guidance.

LIST OF ABBREVIATIONS AND ACRONYMS

ARI	Army Research Institute
CBP	Comparison-Based Prediction
DBMS	Database Management System
DCD	Directorate(s) of Combat Developments
DOTD	Directorate(s) of Training and Doctrine
MANPRINT	Manpower and Personnel Integration
MPT	Manpower, Personnel, and Training
PMCS	Preventive Maintenance Checks and Services
POI	Program of Instruction
SAIC	Science Applications International Corporation
SME, SMEs	Subject Matter Expert(s)
TCEA	Training Characteristics Estimation Aid
TM	Technical Manual
TPDC	Training and Performance Data Center

DESIGN SPECIFICATION FOR A MANPRINT TRAINING CHARACTERISTICS ESTIMATION AID

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DESIGN SPECIFICATION FOR A MANPRINT TRAINING CHARACTERISTICS ESTIMATION AID

INTRODUCTION

The Army has recently established the Manpower and Personnel Integration (MANPRINT) initiative to ensure that continuous attention is paid to Manpower, Personnel, Training, Human Factors Engineering, System Safety, and Health Hazards Assessment during system acquisition. In the past, there has been a tendency in system design to focus narrowly on engineering, cost, and battlefield mission goals. This led to situations where weapon systems place unreasonable demands on the capabilities of operator and maintainer personnel, require excessive, costly training for such personnel, or both. The overall result has been systems that are difficult to support from the perspectives of manpower, personnel, and training (MPT). The goal of MANPRINT is to maintain control over characteristics and aspects of system design that influence MPT demands, and to minimize MPT demands of new systems to the maximum extent possible.

To assist combat, materiel, and training developers performing MANPRINT functions, the Army Research Institute (ARI) has undertaken to develop a group of six tools, or estimation aiding products. These tools are designed to assist early estimation of MPT requirements and continuous evaluation of the impacts of system design on MPT demands. Product One will enable the precise definition of system performance requirements in a structured and logical fashion. Products Two, Three, and Four, respectively, will aid the estimation of likely Manpower, Personnel, and Training characteristics of proposed new systems, partly based on system performance requirements defined through use of Product One. Product Five will enable prediction of operator and maintainer job requirements, and numbers of personnel required for each job per copy of a system, based on initial system design information and performance requirements. Product Six will support identification of significant personnel characteristics required for performance of each operator and maintainer job implied by a system design.

This document presents the design specification for Product Four, the MANPRINT Training Characteristics Estimation Aid (TCEA).

Statement of Product Philosophy

The approach that Applied Science Associates, Inc. and Science Applications International Corporation (ASA/SAIC) have adopted for the

TCEA is an extension, with great modification, of the Comparison-Based Prediction (CBP) technique.

The premise behind the choice of this approach (modified CBP) is the availability of data on the characteristics of training provided by the Army for many types of systems. It is assumed that what the Army presently does in the way of training is a reasonably valid basis for estimating what will be done for training for new systems. It is also assumed that changes in training will, for the most part, be gradual, rather than revolutionary, even if the system changes themselves are revolutionary (e.g., the use of a laser-rifle does not imply an entirely new mode of training for rifle handling and marksmanship). What is known about the characteristics of training systems that now exist will be used to project what training systems for new-acquisition systems will be like.

Current Status of the TCEA and Content of This Report

The first phase of development of the MANPRINT products called for a concept definition. For the TCEA, the concept is documented in Roth et al. (April 1987). In the second (current) phase, the goal is to produce software and human interface specifications for the TCEA. These specifications must be clear and detailed enough to allow independent coding during Phase 3, such that all intentions of the Phase 2 developers can be achieved.

Accordingly, there are four specific requirements for this Phase 2 Product:

1. An exact specification of the interface design must be produced, with every screen state shown in detail. All program flow from each screen state must be shown.

2. The data sources external to the Product must be identified, and the mechanisms by which these data are to be accessed must be specified.

3. Internal algorithms and data for the Product must be produced. Those that are to come from outside must be specified and described. Mechanisms for producing or finding these external data or algorithms must be specified.

4. The software architecture must be specified in detail.

To satisfy the first requirement, we have produced an exact specification of the interface design. The interface design is discussed in the second section of this document and presented, screen-by-screen, in Appendix A. This section includes a discussion of user interface conventions and standard interface characteristics that perpetuate across interface screens. Appendix A presents screen states for each transaction of the user with the Product. Certain screen states (notably menu choice responses) are presented in a generic fashion, since their implementation is similar or identical with respect to many different transaction situations.

The concept paper for this Product discussed in detail the data sources to be used to develop the TCEA. Once developed, the TCEA requires the use of no external data sources, except user inputs. All databases required for the operation of this Product are considered an integral part of the Product. Since the Product's databases will have to be developed from external sources, the proposed methods for data development were exercised on a trial basis in this Phase. We used the methods appropriate to our "fallback" position of generating data from Program of Instruction (POI) and Technical Manual (TM) data in this exercise. This is discussed in the section on Database Content.

Investigation of databases developed by the Training and Performance Data Center (TPDC) revealed that these databases contain much of the information regarding system and training system characteristics that would have to be otherwise developed from this "fallback" method. It is our intent to utilize TPDC database sources to the maximum extent possible in developing the TCEA databases. A preliminary investigation of TPDC databases has shown that significant useful information (e.g., MOS-equipment relationships) is available. However, we do not expect that any direct "pipelining" from TPDC databases to the TCEA will be possible without additional data gathering and analysis. Ultimately, it may be possible for TPDC to gather additional data to supplement what is already present in their databases. This possibility will be explored at the beginning of Phase Three.

Further exploration of these databases will take place immediately after the initiation of Phase Three of the effort. A comprehensive Data Dictionary for the TCEA databases is found in Appendix B. Appendix C contains a database size estimate for the Product.

The processing logic discussed in the Software Design section and Appendix D satisfies the third and fourth requirements above. Using psuedocode as a method for documenting the processing logic for the TCEA will simplify code development in Phase Three. This specification is suitable for use in writing code in a high-level programming language such as C, or a database management system (DBMS) control language. The processing logic and pseudocode completely specifies all algorithms and processes required to implement the TCEA.

The last section of this document discusses the issue of user acceptance for the TCEA, and presents a user acceptance plan that is expected to assist in institutionalization of this Product.

USER INTERFACE

Overview

The MANPRINT Training Characteristics Estimation Aid presents a series of screens to the user. These highly interactive screens gather information about the new system from the user, and return information about the estimation process and results. The estimation process is functionally subdivided into five steps:

Step	Activity/Name
1	Initial Data Entry
2	Operator Profile
3	Maintenance Profile and Data Input
4	Comparison Systems
5	Training Characteristics Estimate

The potential paths through the Aid are shown in Figure 1, which shows the functional steps. There are options to move around between steps and to use stored data, but the figure is aimed at the functional process of training estimation, so it does not show these options. At the end of Step 1 the user is prompted to take Step 2, to establish a functional profile for operator training estimation. However, if the user wishes he/she may go directly to step 3, to establish a subsystem profile for maintenance training estimation and input data for this profile. Steps 4 and 5 are performed autonomously by the Aid. User input is required in these Steps only to change the decisions made by the automated Aid. Either or both Steps 2 and 3 must be complete before proceeding to Steps 4 and 5.

Step 1: Initial Data Entry

This step begins a session. The user indicates in this step whether to use prior data or to begin from scratch.

Step 2: Operator Profile

To support a training estimate for operator training, a profile of the operator functions to be trained is created. This profile can use an existing system as a model. Operator training estimation requires only this function, which establishes a comparison basis for the specified functions.

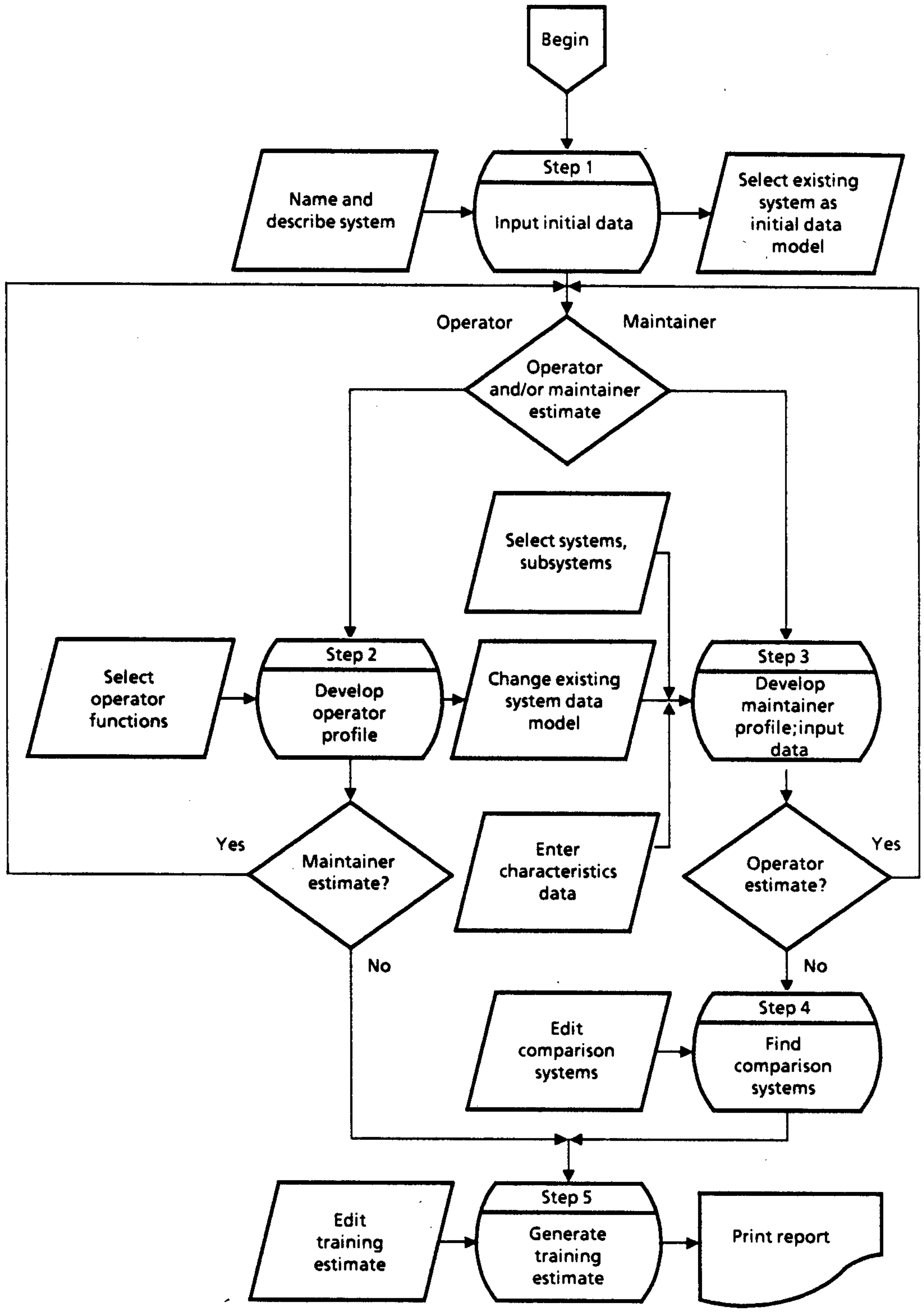

Figure 1. Overview of TCEA operation logic.

Step 3: Maintenance Profile and Data

This step establishes the profile and data for comparison analysis for maintenance training. The maintenance comparison process is based on the equipment subsystems to be included in the new system. The user develops a profile of the system that projects equipment characteristics of the expected hardware. This profile can use an existing system as a model. A comparison analysis (Step 4) follows this step.

Step 4: Find Comparison Systems

Once the maintenance profile is built, the TCEA automatically selects appropriate comparison systems. No user input is required for this step, but the selections made by the TCEA can be modified by the user, if desired.

Step 5: Generate Training Estimate

The comparison systems are used to build the training estimate. The TCEA performs this operation automatically, but the user can edit the results, if desired. This facility is provided to facilitate the use of the output in reports and presentations.

General User Interface Features

This section presents features found throughout the user interface. This is followed by a discussion of the operation of each of the five steps.

The user interface allows for both typed input and menu selection. All command operations that direct the software to take an action are menu selected, but once the menu is called up, the first letter of the choice can be typed and the cursor will go to that choice. When there are multiple fields, either for menu selection or for fill-in, and when the user is not constrained by an order of completion, the four arrow cursor keys control cursor movement through fields.

Titles

The name of the current step is shown at the top left of every screen. At the top right is a short label for the activity taking place on the screen, for example, "Introduction," or "Add Subsystem."

Prompting

The general approach is to utilize a "Lotus-type" (Lotus is a trademark of Lotus Development Corp.) menu. The "hot-key" for this menu is the escape key ("ESC"). This key can be easily changed if the various product developers decide on a different choice. Menus appear at the bottom of the screen. The user calls for a prompt by pressing "ESC".

The user then sees a menu of choices for the field marked by the cursor when the selection began.

On every screen a prompt message tells the user what actions are available. Possibilities are:

1. Press "Return" to continue to the next screen after viewing the current screen.

2. Press the "ESC" key for a menu.

3. Press "PgUp" or "PgDn" to page through more data or choices.

4. Move the cursor to a choice and press "Return" for that choice.

Input Methods

The user must make a typed keyboard entry only to generate a new system name. All other inputs can be made by menu selection. The user may type inputs, but the system will give a general error message if the input does not fit one of the acceptable choices (e.g., a subclass name is entered that is not a member of the subclass set for the specified class of system). When the user has a screen in front of him/her, he/she may type data directly.

The preferable mode of operation is menu selection, because the user cannot make a menu input that is meaningless to the TCEA.

Some operations allow the user to cycle through a large amount of information by varying the parameters defining what is displayed. The user operates the cursor keys to put the cursor in the field to be varied, and then uses the "grey" plus (+) and minus (-) keys to cycle through the alternatives. Information associated with these parameters, shown elsewhere on the display, changes as these operations are performed.

Whenever the user can make a typed input, the input field is highlighted in a specific color. When the user is to make a selection from a number of choices, a different highlight color is used.

Coordination of colors to be used will be made with developers of other Products, to ensure consistency. In cases where a text input is allowed, but menu selection is also available, the user will be shown the input field but prompted to enter "ESC" to see a menu of inputs from which to choose.

Menus

In Step 1, where typed input is a possibility, the user can bring up a menu by pressing the "ESC" key. This key was selected because it is currently ubiquitous in application software as a "hot key." Alternatives such as slash (/) or an ALT-key combination can be implemented easily.

In all other steps, the menu comes up automatically in each screen display, since the user has no other input choice. One exception to this rule is in Steps 4 and 5, where a user may wish to interactively edit information generated algorithmically by TCEA operation. In many situations, the user must make two decisions: (1) which subsystem or function shall be the object of the next activity; and (2) what shall the next activity be (e.g., add, delete, change). The subsystems or functions are presented in one or two columns in the middle of the display. The menus are presented in a row on the bottom (24th) line.

Invoking an activity requires specifying the activity and the function or subsystem on which to act by moving a highlight bar and/or a cursor to the desired positions. Pressing the up or down cursor keys (i.e., up or down arrows on the numeric pad) changes the subsystem or function selection. The actual choice is highlighted in reverse video. Pressing the right or left cursor keys (i.e., right or left arrows on the numeric pad) changes the activity to take place. As the activity changes, a blinking cursor highlights the capitalized letter of each choice. At the same time, a message appears on line 23 of the display describing the activity to take place. The activity is invoked when the user presses "Return." In all cases, however, pressing "Return" brings up a second screen, either for more specific data or for confirmation. The user cannot irrevocably cause an action to take place simply by pressing "Return" one time.

Some activities do not operate on specific functions or subsystems. For instance, "Add function" does not change an existing function; "Other," "End step," and "eXit" also do not have function-specific effects. When these activities are invoked, the result is the same no matter where the function/subsystem cursor bar is located.

There are three special menu-choice functions available from many screens: "Other," "End step," and "eXit." "Other" brings up a menu that allows saving a file, going to a "Print" menu, jumping to another step, or ending the session. The "Print" menu is generic and allows printing the current screen or a formatted output of current data.

"End step" stops data entry and allows the user to save, leave the program, print, or go to another step. "eXit" moves back to the screen from which the current screen was called.

Each choice has a key letter. This letter can be typed directly to initiate the action, instead of moving to the choice via cursor movement. The key letter will be both capitalized and highlighted in color. It is usually, but not always, the first letter in the word (e.g., "Print," "End step," "eXit").

Multiple Screens

Some displays (particularly browsing-type selection of functions or subsystems) require more display space than can fit on one display screen. In such cases, the PgUp and PgDn keys are used to page through multiple screens. At present, very few of these situations exist, due to an attempt to minimize this situation.

Sequencing and Interruptions

At any point the user may print the output of the current or previous steps, or save the results and status of the current version of the estimation process. The user may also exit at any time, and will be prompted to save the data.

Once the user has been prompted to save data he may begin another estimation process for another system or for a different version of the same system.

Explicit User Interface Specification

Appendix A contains a set of printouts of the display screens that will comprise the user interface for the TCEA. This set of screens illustrates information displays, input fields, and menus. The screens do not illustrate total fidelity with the operational software as presented, because it is not possible to show highlighting and color, which give information to the user. This set of displays is complete in implementing the TCEA design at this time, but modifications may become evident as the software is developed and debugged.

Step 1: Initial Data Entry

The user must begin at Step 1: Initial Data Entry. The user enters the following information:

1. System name
2. System class
3. System subclass
4. Data model

The system name identifies the file (if any) containing data and results of processing. If the same name is used more than once, then a version number is added by the TCEA. System class and subclass are descriptors that enable the TCEA to present a list of existing systems to serve as data models.

The data model corresponds to a system already in the database, or it may be a generic model. The data model is used to structure the input format (by selecting subsystems or functions). If an existing system is selected as the model (as opposed to the generic model), data from the existing system will be available as default input data for the maintenance estimate. The data model can be changed on a subsystem or function basis; the initial decision may be revised for any part of the two profiles (operator or maintainer).

Once the above four items have been entered, the TCEA generates an initial list of comparison systems to be used in the maintenance estimation process.

If the user calls for a prompt at the system name field, a menu of initial data descriptions corresponding to previous uses of the TCEA appears, along with name and version. More than one version of a TCEA input data description can exist for a particular system, as a result of repeated TCEA uses.

If the user calls for a prompt at the system class field, the full list of system classes supported by the TCEA is presented.

If the user calls for a prompt at the system subclass field, the full list of subclasses for the already specified system class is presented.

If the user calls for a prompt at the data model field, the list of existing systems in the database, corresponding to the specified system class and subclass, is presented.

The next requirement is to determine whether the estimation includes training characteristics for operators, maintainers, or both. It does not matter which model (Step 2 or Step 3) is prepared first.

Step 2: Operator Profile

To generate the estimate for operator training the user must specify the functions that the operator(s) will perform. These comprise the operator profile. Functional data for each system in the

TCEA databases can be used as defaults, or the user can add, delete, or modify functions (with respect to the operator functions data model) to suit the circumstances of the system for which the estimate is being made.

The user inputs the following data in step 2:

1. Functions to be included in the operator profile.

2. Operator class and subclass to allow selection of other operator functions.

Step 3: Maintenance Profile and Data Input

To perform the estimate for maintenance training, the user first structures the data model, then fills in data required by the model. The data describe the characteristics of the hardware system. The approach involves building a performance profile of the system, based on data models of one or more comparison systems. Data from the comparison systems are also available as default values. The user can accept these default values or change them to reflect the proposed new system.

Profile building consists of four steps, which can be performed iteratively:

1. Select a system to serve as the data model. This establishes a starting point that can be modified as desired. For example, for a new howitzer an older howitzer would be a logical data model, but every aspect of the profile can be modified.

2. Review the subsystems that make up the profile and delete those that are inappropriate to the new system.

3. Add appropriate new subsystems from other data models in the database. The user can select from a series of menus that inform him/her of all the alternative subsystems.

4. Review the subsystems that make up the profile and change the data model for each subsystem (if desired or appropriate). The user can select from a series of menus that inform him/her of all the alternative data models.

Data input consists of reviewing the data in each subsystem profile (data that come from the overall data model), and accepting or changing each data value. This step can be performed iteratively with profile building. For example, the user may bring a new subsystem into the profile, immediately review the data in the accompanying subsystem model, and change data as desired. After these two activities are complete, the user may move to another subsystem.

Step 4: Find Comparison Systems

During Step 4, the TCEA reviews the database to find comparison systems that match the data input. This match is performed only for maintainer models. If the user has elected to use only default data, then the TCEA will probably select the systems that were used as the models. If changes (from default data) were made, then the TCEA will seek those systems that most closely match the actual input data.

In some cases, more than one existing system will fit the data equally well for a given subsystem. The primary decision rule in this case will be to select the existing system that fits the largest number of subsystems.

The user may choose to alter the selected matching systems. That is, the user may override the results of the match and tell the TCEA to perform Step 5 using a manually selected model, rather than the one the TCEA determined was the best fit to the input data.

Step 5: Generate Training Estimate

During Step 5 the TCEA generates data for a training estimate. First the user sees a brief overview of estimated training time, training devices, other training equipment, and MOSs associated with the system (MOSs are derived from comparison systems and are not the result of any MOS estimation performed by the TCEA). The user may then look more closely at the training characteristics estimate for operators, by function, or at the estimate for maintenance training, by subsystem.

The data for each operator function are:

1. Comparison system used in the match to derive the data for this function.
2. Hands-on training time.
3. Academic training time.
4. Total training time.
5. Total training difficulty, a rating of the difficulty of achieving satisfactory training goals for this function.
6. Training devices required.

7. Other training equipment associated with training for this function.

8. MOSs trained on this function.

The data for each subsystem, for maintainer training, are:

1. Comparison system used in the match to derive the data or this subsystem.

2. Troubleshooting training time.

3. Repair training time.

4. Total training time.

5. Total training difficulty, a rating of the difficulty of achieving satisfactory training goals for this subsystem.

6. Training devices required.

7. Other training equipment associated with training for this subsystem.

8. MOSs trained to troubleshoot or repair this subsystem.

SOFTWARE DESIGN

This section contains:

1. A description of the language (pseudocode) used in TCEA design.

2. Discussion of the data dictionary contained in Appendix B.

3. A discussion of the database size estimate in Appendix C.

4. A brief discussion of the processing logic contained in Appendix D.

Software Description Language (Pseudocode)

The description of the processing logic for Product Four is accomplished by the use of pseudocode. The syntax used in the pseudocode is described below. The structure of the pseudocode has been designed to allow for easy translation into the C programming language.

Variables

The only variable names used in the pseudocode are those that represent record types within the database or fields within a record. All such names exist in the data dictionary. It is implied by the use of looping techniques in the psuedocode that variables will be needed to count all the cases, or test for boundary conditions. Also, variables will be needed to remember information within the program which is not stored in the database. To avoid clutter and complexity in the pseudocode, no such variables are used. Instead, the phrasing of the expressions used in the looping structure of the pseudocode is such that the boundaries are clear. The detailed variable needs are to be implemented in phase 3 of Product Four.

Examples :

dataModelForSubsystem - in the data dictionary

IF (the user asked to edit subsystems) - a variable that records whether the user asked to edit subsystems is implied

Action Statement

This is an English sentence that describes a simple action. When the text of such a statement is too long for one line, the remaining text is indented, to differentiate the carry-over text from the next action statement.

Examples :

```
ask the user to enter name

here we are specifying some action that is too wordy to fit on
   one line so we indent the second line

display time
```

Assignment

This is a special case of an action statement that assigns a value to a variable. The operator <- is used to represent the direction of assignment (i.e., the item on the left receives the value of the item on the right.

Examples :

```
systemIsDefined <- TRUE

subSystem <- the subsystem that the user selected from the
screen
```

Expression

This is an English phase that describes a condition used to control a processing loop. Algebraic expressions are intermixed when they are more concise than words. The expression is enclosed in parentheses.

Examples :

```
FOR ( each subsystem that belongs to the model system )

IF ( systemIsDefined = TRUE )
```

Comments

Since the statements in the pseudocode are mostly English sentences and phrases, comments are rare. When needed, they are specified between the two strings '/*' and '*/'.

Example :

```
/* here is a comment */
```

The following statements are all flow of control statements. They control the logical flow of the pseudocode. Each flow of control statement has a set of commands under its control. The indication of this control is through the use of indenting and the '¦' symbol. The string '--------' acts as a terminator for the scope of the flow of control statement. Each flow of control statement is printed in upper case.

Call Statement

```
CALL subProgramName
```

This statement causes processing to continue in the section of pseudocode labeled with 'Function name : subProgramName'. The subprogram is terminated with 'End subProgramName'. In addition, each subprogram is separated from surrounding pseudocode by a line of asterisks (*). Since these conventions clearly define the scope of a subprogram, the '¦' character and the string '--------' are not used for subprograms. Upon completion of a subprogram, processing continues with the next statement following the CALL statement.

If statement

```
IF ( expression1 )
¦   statements that are executed when expression1 is true
ELSEIF ( expression2 )
¦   statements that are executed when expression1 is true
ELSE
¦   statements that are executed when expression(s) are false
--------
```

The ELSEIF is not required. Multiple ELSEIF statements may exist. The ELSE is not required.

For Statement

```
FOR ( expression )
|   statements that are executed for each item described in
|   expression
--------
```

While Statement

```
WHILE ( expression )
|   statements that are executed as long as expression is true
--------
```

Switch Statement

```
SWITCH ( data item whose value we are testing )
|
CASE phrase describing data value1 :
|   statements that are executed when the data item's value =
|    value1
CASE phrase describing data value2 :
|   statements that are executed when the data item's value =
|    value2
CASE phrase describing data value3 :
|   statements that are executed when the data item's value =
|    value3
CASE phrase describing data valueN :
|   statements that are executed when the data item's value =
|    valueN
DEFAULT :
|   statements that are executed when the data item's value matches
|       none of the preceding cases
--------
```

Data Dictionary

The data dictionary is a collection data items that represent the information stored by the proposed software. Each discrete data item is listed alphabetically and briefly described. In addition to the discrete data items, the collection of discrete items into groups and the relationships between groups of data are represented. All data names referenced by the processing logic pseudocode (see Appendix D) are included in the data dictionary.

The majority of the data described by the data dictionary are disk-resident. Routine program variables are not specified in the processing logic and do not exist in the data dictionary. However, the comparison engine requires substantial manipulation of data which, if manipulated on disk, would degrade performance significantly. To manipulate these data in memory requires two tables and a series of linked lists. Since these structures are more sophisticated than simple variables, they are included in the data dictionary to clarify the actions required by the processing logic.

Disk Resident Data

The format used to described all disk-resident data pictorially displays the relationships among data items without specifically requiring a particular database model. A relational, hierarchical, or network database model can be used to represent the data relationships described by the data dictionary. The data dictionary is represented in a fashion that facilitates integration with the chosen DBMS.

Terminology used in the data dictionary and the processing logic to reference the structure of data on disk is meant to be interpreted in a generic sense. Most of these terms have specific meaning to a given DBMS or file system. Once a data base management system has been selected for this product, the correct terms for that environment will be used. In the context of this document these terms are defined as follows.

field - a discrete data item

segment - a group of fields which occur multiple times

key - a field whose value can uniquely identify a segment

record - a single occurrence of the highest level segment of a file and all occurrences of related segments

file - a collection of records

The purpose of defining a segment is to provide a vehicle for describing a "one to many" relationship between groups of fields. For example, in one system class there are may subclasses. Different database models handle such relationships in different fashions. This data dictionary merely displays the fact that such a relationship exists. It is not intended that the data dictionary imply how that relationship should be constructed.

A segment is shown as a set of vertical (¦) and horizontal (-) bars enclosing the fields which make up that segment. Whenever the horizontal bars attach a segment to a higher level segment, the lower level segment occurs multiple times for each key of the higher level segment.

In many cases an identifier (ID) field is specified within a segment. For example, the sysClassID field in the system file is an identifier field. Such a field is used to access a separate file. In the above example, the systemClass file can be searched by matching the sysClassID field to the systemClassID field. A given DBMS may automatically provide the indexing necessary to retrieve the desired field (in the above example systemClassName) by directly referencing that desired name in the original file. The use of ID's in the data dictionary demonstrates the understanding that duplication of data will be reduced or eliminated by a full featured DBMS.

To assist in database size estimates, the size of each field is given after the field name. The size of the segment is given in parentheses following the field length of the first field in the segment.

The purpose of the various files in the data dictionary is described below.

System file. This file contains all data generated in support of a user's definition of a new system for which training estimates are to be produced.

Comparison system file. This file contains the historical data on existing systems' subsystem makeup, characteristic values, training characteristics, and training difficulty estimates. The systems described in this file are the source for the formation of a new system's characteristics, and for generation of a comparison composite system which best reflects the characteristics of the new system.

systemClass file. This file contains the entire set of system classes and the relationships showing which subclasses are associated with each given system class.

subClass file. This file contains each subclass that exists.

subSystem file. This file contains the entire set of subsystems and the relationships showing which characteristics are associated with each given subsystem.

characteristic file. This file contains each characteristic that exists.

Memory Resident Data

Memory resident data structures are used by the comparison engine. They exist only for the duration of comparison case determination.

The "in-memory subsystem table" is an in-memory copy of each subsystem name within a system. Each table entry points to the beginning of a doubly linked list of "comparison subsystem candidates."

Each candidate contains the name of the comparison system which contains the desired subsystem, the score achieved by the candidate subsystem, and pointers to the next and previous candidate. When the comparison engine has completed its comparisons, the list will be in order with the best candidate first, followed by the second, etc.

The "comparison system scoring table" contains the names of each comparison system which has a subsystem that is in one of the "comparison subsystem candidate" lists. Each table entry also contains the number of subsystems for that comparison system that are comparison subsystem candidates, and the comparison system score. The comparison system score is the sum of all subsystem scores within that comparison system. The values in this table are used as tie breakers in determining the rank of subsystems which achieve identical scores. For any such subsystems, we look to the parent comparison systems and check the number of subsystem candidates and the comparison system score to determine the final ranking of the subsystems.

Database Size

The database size estimates indicate whether the aid can be expected to run properly on the target hardware. The estimates are built from the bottom up. We started with the estimates stated in the concept paper, and added to these where necessary. Following the establishment of these estimates, we reviewed the validity of the assumptions. The final database size estimates are presented in Appendix C.

The overall disk requirement is estimated to be four megabytes, a figure that is well within the capacity of the projected Bernoulli Box (TM) hardware. Memory requirements are set entirely by the database management system (R:Base System V).

Note that most of the projections result from a multiplication of numbers of records and bytes per record. This means that all records are of equal importance in the generation of sizing requirements.

The total number of comparison systems is estimated as 165 (11 classes x 6 subclasses/class x 2.5 systems/subclass). We also estimate five (5) characteristics per subsystem, based on our work with the howitzer.

We estimate that users may want to keep data on four (4) developing systems and 25 versions of each system. The availability of more disk storage than projected for these requirements means that more developing systems may be stored.

Processing Logic and Software

The processing logic is found in Appendix D. The logic is presented in a relatively formal fashion, using the pseudocode already defined in this report. Figure 2 shows an overview of the processing logic for TCEA operation, as related to the steps of TCEA operation.

Overview of Logic

A look at the first function, entitled "main," gives an overview of the process of the program. The first step is to call the module "getCommandLineParameters," which is concerned with the processes of Step 1 of the human interface. The Main Menu, discussed in the User Interface section, is presented next. It is represented in the logic flow as a SWITCH statement served by a series of CASE statements for the choices.

It may be noticed that the user is prevented from running the comparison until he has completed all the required information. This is done by an IF test that checks to see if all subsystem data are present.

It can be seen that the functions define most of the required algorithms. For example, the logic by which we intend to add subsystems to the profile can be seen in the addSubSystems function. Part of this function includes the display of potential subsystems.

Commercial Software

The processing logic was defined for a relational DBMS, and R:Base System V, which is part of the target software suite, fills this requirement. The human interface design was established prior to the decision to use R:Base. However there will be no problem in implementing the interface in a combination of the C Programming Language and R:Base command language. The C Programming Language is also part of the target software suite.

The actual implementation of the data dictionary in R:Base may cause some changes to the data dictionary. These changes are simply part of the development process, and the current dictionary defines all the database properties that must be known to structure the database in R:Base.

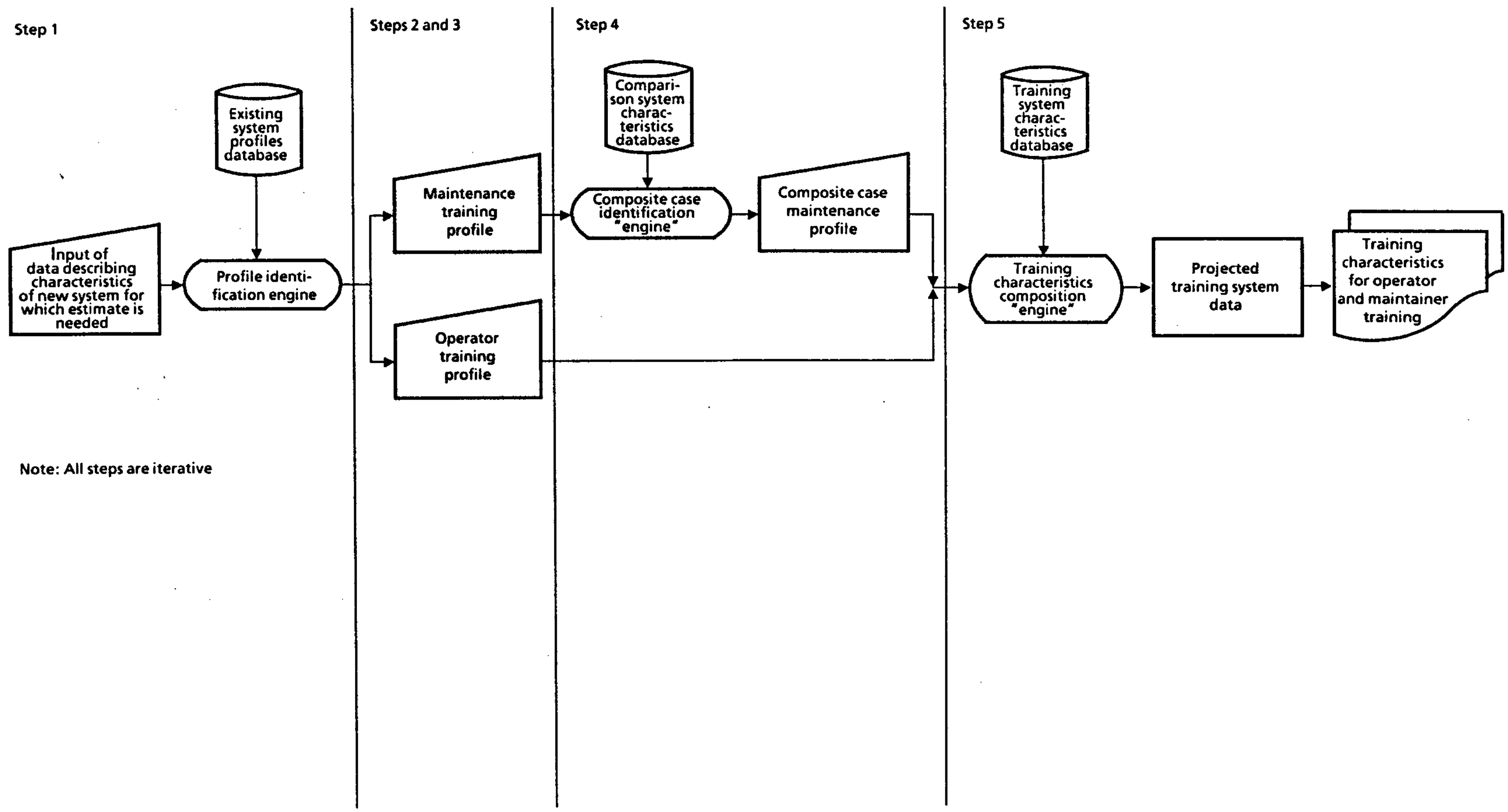

Figure 2. TCEA processing logic overview.

DATABASE CONTENT

This section illustrates the development of database resident data associated with the M109A2 self-propelled Howitzer. This system will be one of approximately 165 systems comprising the comparison system file within the database for the TCEA. The remainder of this section addresses the following topics concerning the M109A2 example:

1. Database Content
2. Sources of Data
3. M109A2 Data and Data Collection Method
4. Reliability of Data

Each of these topics is discussed in turn. Following this discussion is a discussion of two taxonomies that have been developed to assist in structuring TCEA operator and maintainer training profiles.

M109A2 Database Content

The comparison system database contains two basic types of data:

1. The operations and maintenance characteristics of existing systems which are used to identify characteristics of the new system.
2. The training times and devices required to train: (a) specific functions of an operational system; (b) troubleshooting and fault isolation for subsystems; and, (c) repair or service of subsystems in the existing Army inventory.

Inherent in each of these classes of data is the separation of system aspects into two categories: operator-specific and maintainer-specific. Database content is therefore driven by two separate taxonomies which amplify on each of these categories. One taxonomy consists of crew functions--in this example those associated with the M109A2. The other taxonomy consists of those subsystems which must be maintained--in this case M109A2 subsystems.

Table 1 lists the crew functions for the M109A2. This list of functions is taken directly from the taxonomy specified in Product One. The functions in this list are shared by all systems in the same class (Fire Support - Field Artillery) and subclass (Self-Propelled Howitzers). Table 2 lists M109A2 subsystems as broken down into three groups: turret, hull, and communications. The next subsection discusses in greater detail the sources of subsystem and training characteristics data related to these tables.

Table 1

M109 Operator Functions

- Prepare for March Order
- Drive/Move Cannon
- Navigate
- Emplace Cannon
- Displace Cannon
- Prepare Cannon for Firing
- Fire Cannon
- Fire Cannon at Direct Fire Targets
- Fire Crew Served Weapons
- Communicate
- Defend Against Attack
- Compensate for Equipment Malfunctions and Emergencies
- Perform Post-Mission Tasks

Sources of M109A2 Data

The M109A2 comparison system file was built by using the following information sources:

1. Subject Matter Experts (SMEs);

Table 2

M1Ø9A2 Subsystems

- o HULL
  - Engine
  - Fuel
  - Exhaust
  - Cooling
  - Electrical
  - Transmission
  - Transfer and Final Drive
  - Brakes
  - Movement Mechanism/Locomotion
  - Steering
  - Frame/Hull
  - Suspension
  - Accessories

- o COMMUNICATIONS
  - Intercom

- o TURRET
  - Cab
  - Race Ring
  - Main Armament
  - Secondary Armament
  - Power Pack
  - Cupola
  - Traversing Mechanism
  - Door Assemblies
  - Sight
  - Ammo Storage
  - Electrical

2. MANPRINT Product Four Expert;

3. Organizational Maintenance Manuals;

4. Operator's Manual; and

5. Programs of Instruction.

Use of these sources for developing a prototype data set afforded numerous insights regarding Phase Three implementation. For example, filling in the training characteristics database can be accelerated by focusing on POI analysis instead of system analysis. As POI files are reviewed, each system and associated subsystem specifically addressed by each training file can be allocated respective training hours. Once the POI has been analyzed, it can be excluded from further review. As a more specific example, a review of the 13B10, Cannon Crewman, POI will render system-specific training data not just for the M109A2 but also for the M110, the M102, and the M198.

Subject matter experts for the M109A2 consisted of an ex-ordnance officer, supplemented by very brief telephone support by the Ordnance School at Aberdeen Proving Ground, MD. A TCEA expert worked closely with the SME. The entire M109A2 database was developed jointly by these two individuals. Reference material included the following documents:

1. POIs for:

    a. 13B10, "Cannon Crewman" (October 1983)

    b. 63H10, "Track Vehicle Repairer" (September 1985)

    c. 63D10, "Self-Propelled Field Artillery System Mechanic" (May 1986)

    d. 45B10, "Small Arms Repairer" (August 1983)

    e. 45D10, "Self-Propelled Field Artillery Turret Mechanic" (January 1985)

    f. 63G10, "Fuel and Electrical Systems Repairer" (September 1985)

    g. 31V10, "Tactical Communications Systems Operator/Mechanic", (August 1983)

2. TM9-2350-303-10. Operator's Manual for Howitzer, Medium, Self- Propelled: 155MM, M109A2 (2350-01-031-0586). September 1980.

3. TM9-2350-267-20. Organizational Maintenance Manual For Hull, Powerpack, Drive Controls, Tracks, Suspension and Associated Components; Carrier, Ammunition, Tracked. M992, (NSN 2350-01-110- 4660). July 1984.

4. TM9-2350-267-20P. Organizational Maintenance Repair Parts and Special Tools List for Carrier, Ammunition, Tracked. M992, (2350- 01-110-4660). March 1986.

A call was made to the Ordnance School to ensure that those POIs listed above covered the gamut of training which was specific to the operation and maintenance of the M109A2.

M109A2 Data and Data Collection Methods

The TCEA approach employs a comparison-based prediction algorithm. Therefore, training projections for a new weapon system are based upon the summation of training hours and devices for existing subsystems which, in the composite, have characteristics and attributes resembling those of the desired new system. The first step in projecting training is determining which subsystems should constitute the composite. Accordingly, the first M109A2 database lists all of the subsystems, as well as the characteristics and attributes of each.

Table 3 itemizes a number of characteristics and attributes associated with self-propelled howitzers. Those attributes which apply to the M109A2 are designated either by a check mark by the appropriate attribute or by a "fill-in-the-blank" value. This table was developed based on SME experience aided by a content analysis of the M109A2 maintenance manuals. Non-M109A2 attributes were based on SME experience and a generalization of categories across systems which share the M109A2 mission.

If one were to presume that the newly desired system had turret specifications which were most closely matched by the M109A2, the next database needed would be one which identifies how many training hours are dedicated to troubleshooting and repairing the M109A2 turret. Because no such database exists, the TCEA approach will be to identify such training at the subsystem level for each of the existing systems in the database.

Table 4 presents an analysis of all of the maintenance training associated with the M109A2. This table allocated training hours to the appropriate subsystems addressed within each course. In addition, training hours for each subsystem are further broken down to troubleshooting versus repair training times. Training devices required to support subsystem training are also identified. For each course, the

Table 3

Characteristics and Attributes of M109 Subsystems

CHARACTERISTICS	ATTRIBUTES	
HULL		
ENGINE		
Single Fuel/Multi-Fuel	Gasoline	
	Diesel	X
	Mixture	
	Other	
Type	Turbine	
	Reciprocal	X
	Other	
Cylinders/Rotors/Turbines	Number	8
Horsepower	Horsepower	
Turbo-Charged?	Yes	X
	No	
FUEL		
Storage Capacity	No. of Gallons	135
Carburetion	Fuel Injected	
	Aspirated	X
	Other	
EXHAUST	N/A	
COOLING		
Method	Air	
	Water	X
	Other	
ELECTRICAL		
Voltage	Volts	24
APU?	Yes	
	No	X
Separate Battery Pack?	Yes	
	No	X

Table 3 (Continued)

CHARACTERISTICS	ATTRIBUTES	
TRANSMISSION		
Activation Mode	Manual	X
	Automatic	
	Other	
Number of Forward Gears	Number	4
Number of Reverse Gears	Number	2
Number of Gear Range Options	Number	1
TRANSFER AND FINAL DRIVE		
Number of Axles Engagable	Number	1
BRAKES		
Primary Activation Mode	Hydraulic	X
	Air	
	Mechanical	
	Other	
Engaging Mechanism	Disk	X
	Drum	
	Combination	
	Other	
MOVEMENT MECHANISM/LOCOMOTION		
Configuration	Wheels	
	Tracks	X
	Combination	
	Air Cushion	
	Other	
STEERING		
Level of Assistance	None (Manual)	X
	Power Assist	
	Full Power	
	Other	
Control Interface	Pedal	
	Wheel	X
	Levers	
	Other	

Table 3 (Continued)

CHARACTERISTICS	ATTRIBUTES	
FRAME/HULL		
Construction	Unit	X
	Frame	
	Other	
Materials	Steel	
	Aluminum	X
	Composite	
	Combination	
	Other	
SUSPENSION		
Function	Independent	X
	Non-independent	
	Other	
Main Suspension	Springs	
	Torsion Bars	X
	Other	
Shock Absorption	Hydraulic	X
	Air	
	Other	
ACCESSORIES		
Hoist		X
Winch		X
Capstan		X
Bilge Pumps		X
Winterization Kit		X
Towing Attachments		X
Fording		X
Fire Fighting		X
Tools and Test Equipment		X
Other		
COMMUNICATIONS		
INTERNAL	Radio	
	Low frequency	
	High frequency	
	Very high frequency	
	Ultra high frequency	
	Wire	X

Table 3 (Continued)

CHARACTERISTICS	ATTRIBUTES	
EXTERNAL	Radio	
	Low frequency	
	High frequency	
	Very high frequency	
	Ultra high frequency	
	Wire	X
TURRET		
CAB		
Construction	Unit	X
	Frame	
	Other	
Materials	Steel	
	Aluminum	X
	Composite	
	Combination	
	Other	
RACE RING		
Construction	Point Bearing	X
	Wire Race	
	Other	
MAIN ARMAMENT		
Main Weapon Purpose	Direct	
	Indirect	X
Main Weapon Size	Bore Diameter	155 mm
	Tube Length	?
Main Weapon Range	Range	18 km
Main Weapon Rate of Fire	Cyclic	4 /min
	Sustained	1 /min
Main Weapon Loading Mechanism	Manual	
	Part. Auto	X
	Auto	

Table 3 (Continued)

CHARACTERISTICS	ATTRIBUTES	
MAIN ARMAMENT (Continued)		
Recoil Mechanism	Recoilless	
	Hydraulic	X
	Pneumatic	X
	Spring	
	Gas	
SECONDARY ARMAMENT		
Secondary Armament Purpose	Direct	X
	Indirect	
Secondary Armament	Bore Diameter	.50 cal
	Tube Length	
Secondary Armament Range	Range	1500 m
Secondary Armament ROF	Cyclic	
	Sustained	
Secondary Armament Load Mechanism	Manual	X
	Part. Auto	
	Auto	
Recoil Mechanism	Recoilless	
	Hydraulic	
	Pneumatic	
	Spring	X
	Gas	X
	Blowback	
POWER PACK		
Sources	Main Engine	X
	Main Batteries	X
	APU	
	Aux Batteries	
CUPOLA		
Mobility	Fixed	X
	Moving	
TRAVERSING MECHANISM		
Function	Manual	
	Power	X

Table 3 (Concluded)

CHARACTERISTICS	ATTRIBUTES	
DOOR ASSEMBLIES		
Function	Manual	X
	Power Assist	
SIGHT		
Indirect	Collimator	X
	Stakes	
	Other	
Direct	Visual	X
	Laser	
	Thermal/IR	
AMMO STORAGE		
Capacity	Number of Fuzes	40
	No. of Projectiles	34
	No. of Powders	40
Rack Type	No. of Open Proj.	12
	No. of Closed Proj.	22
ELECTRICAL		
Voltage	Volts	24
APU	Yes	
	No	X
Separate Battery Pack	Yes	
	No	X

Table 4

M109-Specific Maintainer Training Hours

M109 SUBSYSTEMS/COMPONENTS	Maintainer Courses: 63H10 Track Vehicle Repairer T/S	63H10 Track Vehicle Repairer Repair	63D10 SPFA System Mechanic T/S	63D10 SPFA System Mechanic Repair
HULL				
Engine			.5	7.1
Fuel	5		.5	.1
Exhaust			.5	2.1
Cooling			.5	.1
Electrical	6		11.0	6.4
Transmission			.5	.1
Transfer and Final Drive			.5	2.4
Brakes			.5	.1
Movement Mechanism/Locomotion			.5	4.9
Steering			.5	.1
Frame/Hull			.5	.1
Suspension			.5	2.6
Accessories			.5	.1
COMMUNICATIONS				
TURRET				
Cab			.5	.1
Race Ring			.5	.1
Armament			.5	.1
Powerpack and Hydraulics			.5	.1
Cupola			.5	.1
Traversing Mechanism			.5	.1
Door Assemblies			.5	.1
Sight			.5	.1
Ammo Storage			.5	.1
Electrical			2.5	.1
Total M109 Specific Hours	11		51.2	
Total Hours in POI	593.5		242.6	
% M109 Specific	2		21	

Table 4 (Continued)

	Maintainer Courses			
	45B10 Small Arms Repairer		45D10 SPFA Turret Mechanic	
M109 SUBSYSTEMS/COMPONENTS	T/S	Repair	T/S	Repair
HULL				
N/A				
COMMUNICATIONS				
N/A				
TURRET				
Cab			.8	.1
Race Ring			.8	.1
Armament	9.5	14.5	.8	20.7
Powerpack and Hydraulics			5.9	11.9
Cupola			.8	.1
Traversing Mechanism			.8	.1
Door Assemblies			.8	.1
Sight			1.7	25.7
Ammo Storage			.8	.1
Electrical			22.4	13.2
Total M109 Specific Hours	24.0		107.7	
Total Hours in POI	362.0		223.2	
% M109 Specific	7		48	

Table 4 (Concluded)

M109 SUBSYSTEMS/COMPONENTS	Maintainer Courses: 63G10 Fuel/Elect. Sys. Repairer T/S	63G10 Fuel/Elect. Sys. Repairer Repair	31V10 Tac. Comm. Sys. Op./Mech. T/S	31V10 Tac. Comm. Sys. Op./Mech. Repair
HULL				
Engine				
Fuel				
Exhaust	3	3		
Cooling				
Electrical				
Transmission				
Transfer and Final Drive				
Brakes				
Movement Mechanism/Locomotion				
Steering				
Frame/Hull				
Suspension				
COMMUNICATIONS			43.3	1.2
TURRET				
N/A				
Total M109 Specific Hours	6		44.5	
Total Hours in POI	667.0		428.9	
% M109 Specific	1		10	

Notes:

1. 8V 71T engine training device used for 63D10, hull exhaust and electrical training.
2. M-2 machine gun cutaway and dummy cartridge, 50 caliber training devices used for 45B10, turret armament training.
3. Field artillery maintenance training device #6-54 used for 45D10, all turret training except cab.
4. No other training devices used in M109 specific training.

total number of hours is listed as well as that subset of hours which is specific to the M109A2. A percentage of M109A2 hours to total training hours is also given per course.

The method for allocating training hours was developed by a SME/TCEA expert team. Each POI file was content analyzed to determine:

1. Is training M109A2-specific in content?

2. What subsystems apply?

3. How many hours pertain to troubleshooting versus repair?

As we performed the content analysis, we developed a set of general rules to assist in future work. These rules were used by another independent expert team that analyzed the POIs as a check on reliability. These rules and the reliability analysis are presented in the next subsection.

Our analysis of operator training was similar to that done for maintenance. The taxonomy, however, was based on operator functions, instead on subsystems as used for maintenance training. The 13B10 POI was content analyzed to determine:

1. Is it M109A2 specific in content?

2. What operator functions apply?

The results of this analysis are provided in Table 5. The reliability of this analysis was also checked by another, independent team and the results are discussed in the following subsection.

Reliability of M109A2 Data

The ASA/SAIC approach to the development of the TCEA is heavily dependent upon the building of a comparable system database. This database development process is rather labor intensive and, for each POI, involves the cooperation between a TCEA expert and a POI expert. The large number of POIs and systems to be analyzed will require the use of numerous teams to establish the database. Associated with the use of numerous teams is the question of the reliability by which these teams identify system specific and sub-system specific course hours.

To facilitate the development of a uniform process for determining subsystem specific training hours, the ASA/SAIC Product Four/M109A2 SME team constructed a list of rules for analyzing POIs. These rules are provided in Table 6.

Table 5

M1Ø9-Specific Operator Training Hours for MOS 13B1Ø (Cannon Crewman)

OPERATOR FUNCTION	M1Ø9-SPECIFIC TRAINING HOURS
Prepare for March Order	1Ø.7
Drive/Move Cannon	9.5
Navigate	6.4
Emplace Cannon	14.7
Displace Cannon	11.2
Prepare Cannon for Firing	14.9
Fire Cannon	1Ø.9
Fire Cannon at Direct Fire Targets	6.8
Fire Crew Served Weapons	9.7
Communicate	1Ø.5
Defend Against Attack	6.2
Compensate for Equipment Malfunctions and Emergencies	7.7
Perform Post-Mission Tasks	9.3
M1Ø9 Hours	128.5
Total Hours in POI	551.5
Percentage M1Ø9 Hours	.23

Table 6

Rules for Determining M109-Specific Training Hours

1. Only peacetime hours should be counted.

2. If a POI file covers the M109 separately from the M110, do not count M110 hours.

3. If POI file covers the M109 and M110 as a single vehicle family (i.e. 109/110) count hours indicated as M109 related.

4. Count only course hours specific to the M109 or the M109/M110 system (e.g., general instruction on "the functioning of diesel engines" would not be counted; instruction on "the functioning of the 8V71T diesel engine" would be counted).

5. M109 introductory course hours are divided among all pertinent subsystems (i.e. hull, turret, and communications).

6. Introductory maintenance courses identified as M109 specific which serve only to describe the system/subsystems will have their hours recorded as "troubleshooting."

7. If a maintenance course description indicates the assembly, disassembly, repair, replace or any other word(s) that indicate efforts exclusive of diagnosis/troubleshoot actions, the hours are allocated to "repair."

8. If a POI file description mentions both diagnosis/troubleshoot and disassembly, assembly, etc., the hours will be halved between "troubleshoot" and "repair."

9. Preventive Maintenance Checks and Services (PMCS) are considered as "troubleshoot."

10. Hours for examinations and field exercises are divided among pertinent functions or subsystems.

To test the rules in Table 6 and the reliability that could be obtained between teams, we selected two courses for an independent team to analyze, 45D10 and 13B10.

The results of this test showed that for the 45D10 maintenance course, the first team estimated that 118.6 hours of the 45D10 total hours (223.2) were M109A2-specific, and the second team estimated that 127.9 of the hours were M109A2-specific.

The reliability for operator training was less than that for maintenance. The first team estimated that M109A2-specific training accounted for 128.5 of the total course hours (551.5). The second team estimated that 87.0 of the total course hours were M109A2 specific. Because the second team's calculations were accomplished merely through the use of the rules written by the first team, we anticipate that such scores can be improved with minimal training by making all rating teams "walk through" a simple analysis.

Taxonomies

Two taxonomies were developed to simplify the operation of the aid. The first is a class/subclass taxonomy of the types of systems that will comprise the database. The second is a taxonomy of operator functions used to structure the operator profile. Both taxonomies are found in Appendix E.

The class/subclass taxonomy is derived from the mission area taxonomy being developed for Product 1. This taxonomy was expanded into areas that were determined to be of importance which were not part of the Product 1 taxonomy at the time our team reviewed it. The original taxonomy had six missions which were expanded into system types, which are roughly equivalent to our subclasses. The taxonomy presented here consists of nine classes, subdivided into a total of 37 subclasses.

The class/subclass taxonomy is used in both operator and maintainer profiles. For operators establishing class and subclass is the first step in developing a list of functions. The operator function taxonomy then comes into play. For maintainers, the selection of a class and subclass simplifies the selection of a data model to use as a profile for data entry.

To generate the operator function taxonomy, a list of operator functions associated with systems in each subclass was generated. The expansion was derived from examination of the operational functions taxonomy for Product 1, along with the Kaplan and Crooks (1980) taxonomy. This expansion was performed by personnel at ASA with knowledge of Army systems and missions. In a small number of cases (Countermeasure Systems and Surveillance Systems), the expansion was not performed due to a lack of sufficient knowledge about operator functions. This taxonomy will be verified by Army SMEs in Phase 3 as part of the data collection effort.

USER ACCEPTANCE

In order to promote the use of the TCEA by its intended users, it is necessary to identify and, in Product implementation, overcome factors that could work against its acceptance. This is a special case of a general problem in introducing automated systems. Individuals who are provided with an automated system that either replaces or supplements functions previously performed by other means tend to question the automated system. Such questions generally fall into two categories: (1) introductory questions ("How do I learn to use this thing?"); and (2) functional questions ("What's going on in there?"; "Will this take more time than it would by hand?"; "Will using this system increase (or decrease) my productivity?"; etc.).

Users tend to evaluate and question both "start-up" costs associated with automated methods or aids and "benefit" costs associated with ongoing use of an automated method. If such principally subjective evaluations result in negative (or even neutral) perception of the method, the likelihood of acceptance and use of the method is significantly reduced. In the case of the TCEA and related MANPRINT methods Products, this would be disastrous.

Gaining acceptance for the TCEA requires several specific activities:

1. Identifying user groups who will utilize the TCEA;
2. Characterizing each distinct group of users (if there is more than one);
3. Identifying concerns and potential problems on the part of all user groups; and
4. Involving users in visible (both in process and in TCEA implementation) initiatives to overcome identified concerns and problems on the part of users.

Collectively, these activities will give users some "ownership" in the TCEA and help to optimize its design to account for the abilities and limitations of the user population.

User Group Identification

The user group identification process was begun during Phase I of TCEA development process. At that time, the most likely users of this Product were determined to be analysts in the Directorates of Training and Doctrine (DOTD) at the various TRADOC schools. There is also a potential user population in the Directorates of Combat Developments (DCD) at the TRADOC schools, and possibly a third population among the staffs of system support contractors to various AMC and TRADOC elements (e.g., Project Manager's organizations, PM TRADE, readiness commands, Combined Arms Center, etc.).

Early in Phase Three, representatives of each of these potential populations will be contacted by ASA/SAIC staff members for two purposes. The first purpose is to confirm that our present assumptions about each suspected user population are valid (i.e., they are in fact user populations for the TCEA, in that they currently make training estimates for proposed new materiel systems). The second purpose is to identify any additional user groups known to members of the groups already identified. Any potential additional user groups that are identified will be contacted, in turn, to validate that they are in fact user populations for the TCEA.

User Group Characterization

Once user groups have been identified and validated, we will next attempt to determine and validate user group characteristics. This activity will immediately follow user group identification.

Our present conception of the characteristics of the identified user groups above includes the following elements:

1. Users who presently make training estimates for new systems are not well trained in the process of training estimation.

2. There are few if any systematic procedures available to the user groups to support training estimation, particularly very early in the acquisition process.

3. User groups are unlikely to be sophisticated with respect to automated methods of any sort and are also likely not highly computer literate.

4. The primary user group (DOTD personnel) is largely composed of Subject Matter Experts (SMEs), rather than individuals with background in analytic methods or estimation techniques.

5. Many members of the primary user group hold temporary (normally one-year) appointments in their positions. This group is, therefore, likely to experience a relatively high degree of turnover.

Each of these characteristics has significant implications for the design of the TCEA, which we believe has been taken into account thus far in design. However, it is both desirable and necessary to validate these characteristics and discover other important characteristics of user populations to ensure acceptance and use of the TCEA.

Validation of the characteristics listed above, as well as identification of other characteristics of user populations, will be performed by telephone interviews with no fewer than five representative members of each identified user group. A structured interview format will be developed which explores the issues listed above (in an innocuous and non-challenging manner), as well as other potential user group characteristics (to be identified).

Members of each user group will be identified through discussions with MANPRINT points of contact in their respective organizations, and telephone interview dates and times pre-arranged. The interviews will then be conducted as scheduled. Responses to interview items will be compiled and content-analyzed by item, as well as overall, for each user group. From the results of the content analyses, a concept of user group characteristics for each identified group will be developed and examined for implications to TCEA design. This will also be performed for the overall population of user groups collectively.

Results of the user group characterization will be used, in conjunction with user involvement inputs (see below) to modify the characteristics of the human interface of the TCEA, as well as associated training (both external and embedded in the Product).

Identifying Concerns and Involving Users

In addition to the relatively passive involvement of users in the characterization process (see above), we believe that it is also necessary to involve selected users in the evolution of the TCEA. This will have beneficial effects on user acceptance through giving at least some representatives of user groups "ownership" in the characteristics of the Product. We intend to cause this to happen by means of two or more user design reviews. One user design review will take place soon after characterization of user groups is complete; the second will occur after the results of the first review have been implemented. We expect to involve a minimum of ten user representatives in the review panels for the TCEA. The same user representatives should participate in both reviews, to assure an understanding within the user community that response to their concerns and suggestions has in fact been made in the form of changes to TCEA interface and training design.

User design reviews will consist of presentations of the Product's human interface to one or more panels of representatives from the user groups, preceded by an explanation of the purposes and functional characteristics of the TCEA. The Product will be placed in context of the overall Products set and the MANPRINT process during the explanation, to ensure that users have an appropriate context for their review of the human interface. The human interface will be demonstrated by means of a rapid prototyping program (already developed), and user comments and suggestions will be solicited from users. A maximum of one day will be required for each review panel meeting.

After the first review panel meetings are complete, user suggestions and comments will be combined with the user group characterization data. The joint data will be explored for implications and ideas for design changes to the TCEA. In this process, we will concentrate on the human interface and on training and aiding needs expressed by the user population. Once implications are fully identified, these will be expressed as design changes to appropriate elements of the TCEA, and implemented.

After initial implementation of the TCEA software and some subset of the databases is complete, a second user design review will take place. This review should ideally involve the same review panel members that participated in the initial review. Essentially the same format will be used for the second review as for the first. And, again, user inputs regarding the TCEA will be solicited and used to implement design changes in the final version of the Product.

Using this approach, we believe that gaining user acceptance for the TCEA will be a straightforward matter. The initiatives of characterizing important features of user groups and of getting users involved in the design of the Product are essential to this acceptance. The processes we propose above will accomplish these goals.

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APPENDIX A

USER INTERFACE SCREENS

Step 1: Initial Data Entry   Description

The first step is to enter data describing the system for which you want an estimate.

1. You may start from scratch, with no prior data describing your new system. In this case, you must type in the New system name, and make selections or type in other data.

2. You may have already started data entry, or have a system description that you used previously for training estimation, but which you now wish to modify for another pass at estimation. In this case, you may choose to begin with a defined system description and revise it to reflect different assumptions about the system.

If you type a new name, you are in situation 1. If you choose from existing system names then you are in situation 2. You may keep more than one version of a system estimate and its descriptive data.

Press Return to continue

Name [Number]: Intro Step 1   [0001]

Step 1: Initial Data Entry   Initial Data

System name:
System class:
System subclass:
Data model:

1. To start from scratch, type in a system name. When you save the new data you may overwrite the old version, or you may create a new version.

2. To start with a system or version that you have already worked on, put the cursor in the System name field and press ESC for a menu of actions. Choose Select for a menu of system and version names.

3. Choose Other to Print, Save,or End Step 1.

Type the information or press ESC for a menu of actions for each field

----

Name [Number]: Intro 3 Step 1   [0002]

Step 1: Initial Data Entry Select System Name

System name:
System class:
System subclass:
Data model:

	System	Version	Date	Description
1.	HIP	1	5/6/87	No autoloader
2.	HIP	2	5/18/87	Autoloader

Select a system name from existing files
Select Other End step

Name [Number]: Name 1 [ØØØ3]

Step 1: Initial Data Entry SELECT System Name

System name:
System class:
System subclass:
Data model:

	System	Version	Date	Description
1.	HIP	1	5/6/87	No autoloader
2.	HIP	2	5/18/87	Autoloader

```
Select a system name from existing files
Select    Other  eXit   End step
---------------
Name [Number]: Name 2          [0004]
---------------
```

Step 1: Initial Data Entry

SELECT System Class

System name: HIP (2)
System class:
System subclass:
Data model:

1. Air Defense
2. Aviation
3. Close Combat Light (Infantry)
4. Close Combat Heavy (Armor)
5. Combat Service Support
6. Combat Support--Engineering and Mine Warfare
7. Command, Control, Communications
8. Fire Support (Field Artillery)
9. Intelligence and Electronic Warfare

Type in system class or press ESC for menu

Name [Number]: Class 1 [0005]

```
Step 1:  Initial Data Entry                             SELECT System Class

System name:  HIP (2)
System class:
System subclass:
Data model:

1.  Air Defense
2.  Aviation
3.  Close Combat Light (Infantry)
4.  Close Combat Heavy (Armor)
5.  Combat Service Support
6.  Combat Support--Engineering and Mine Warfare
7.  Command, Control, Communications
8.  Fire Support (Field Artillery)
9.  Intelligence and Electronic Warfare




Select a system class
Select    Other  eXit   End step
---------------
Name [Number]: Class 2          [0006]
---------------
```

```
Step 1:  Initial Data Entry                                    SELECT System Subclass

System name:  HIP (2)
System class: Fire Support
System subclass:
Data model:

1.  Medium Range Missiles
2.  Long Range Missiles
3.  Towed Howitzers
4.  Self-propelled Howitzers
5.  Rocket Systems
6.  Resupply Vehicles




Type in system subclass or press ESC for menu
---------------
Name [Number]: Subclass 1       [0007]
---------------
```

```
Step 1:  Initial Data Entry                                SELECT System Subclass

System name:  HIP (2)
System class: Fire Support
System subclass:
Data model:

1.  Medium Range Missiles
2.  Long Range Missiles
3.  Towed Howitzers
4.  Self-propelled Howitzers
5.  Rocket Systems
6.  Resupply Vehicles




Select a system subclass
Select    Other  eXit   End step
---------------
Name [Number]: Subclass 2       [0008]
---------------
```

Step 1: Initial Data Entry　　　　　　　　　　　　　　　　　　Select Data Model

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model:

Select one system candidate to specify the data model:

1. M109
2. M109A2/A3
3. Generic Template

Select a data model
Select　Other　eXit　End step

Name [Number]: Model　　　　[0009]

Step 1: Initial Data Entry   Select Data Model

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model: Generic Template

The above parameters will be carried through for the rest of the system estimation. The next screen is the Main Menu.You may choose to continueor go back and change the above data.

Press Return to continue

Name [Number]:   [0010]

Step 2: Develop Operator Profile   HIP(2)   Introduction

In Step 2 you will develop an operator profile. This consists of selecting the operator functions you want in your operator profile and deciding on the existing systems that will serve as models for the estimation process.

Press Return to continue

Name [Number]: Intro   Step 2   [0011]

Step 2: Develop Operator Profile   HIP (2)   Add Function

Here are the operator functions in the operator profile. You may now modify the profile for each individual function.

1 Prepare for march order
2. Drive/move cannon
3. Navigate
4. Emplace cannon
5. Displace cannon
6. Prepare cannon for firing
7. Fire cannon
8. Fire cannon at direct fire targets
9. Fire crew served weapons
10.Navigate
11.Communicate
12.Defend against attack
13.Displace system
14.Compensate for emergencies
15.Perform post-mission tasks

```
Add a function to the list of operator functions
Add function  Delete function  Change model   Other   eXit    End step
---------------
Name [Number]: Add func 1       [0012]
---------------
```

Step 2: Develop Operator Profile   HIP (2)   Add Function

Class:Fire SupportSubclass:Self-propelled Howitzers
Change fields with cursor. Cycle through options in a field with + and - keys.

1 Prepare for march order
2. Drive/move cannon
3. Navigate
4. Emplace cannon
5. Displace cannon
6. Prepare cannon for firing
7. Fire cannon
8. Fire cannon at direct fire targets
9. Fire crew served weapons
10.Navigate
11.Communicate
12.Defend against attack
13.Displace system
14.Compensate for emergencies
15.Perform post-mission tasks

Select this function to be added to the function list
Select function   eXit without adding function

Name [Number]: Add func 2   [0013]

```
Step 2: Develop Operator Profile     HIP (2)          Delete Function

Here are the operator functions in the operator profile. You may now modify
the profile for each individual function.

1  Prepare for march order
2. Drive/move cannon
3. Navigate
4. Emplace cannon
5. Displace cannon
6. Prepare cannon for firing
7. Fire cannon
8. Fire cannon at direct fire targets
9. Fire crew served weapons
10.Navigate
11.Communicate
12.Defend against attack
13.Displace system
14.Compensate for emergencies
15.Perform post-mission tasks


Delete a function from the list of operator functions
Add function  Delete function  Change model   Other   eXit    End step
---------------
Name [Number]: Delete func 1    [0014]
---------------
```

Step 2: Develop Operator Profile   HIP (2)   Delete Function

Put cursor on function to be deleted.

1 Prepare for march order
2. Drive/move cannon
3. Navigate
4. Emplace cannon
5. Displace cannon
6. Prepare cannon for firing
7. Fire cannon
8. Fire cannon at direct fire targets
9. Fire crew served weapons
10.Navigate
11.Communicate
12.Defend against attack
13.Displace system
14.Compensate for emergencies
15.Perform post-mission tasks

Select this function to be deleted from the function list
Select function   eXit without adding function

Name [Number]: Delete func 2   [0015]

Step 2: Develop Operator Profile   HIP (2)   Change Model

Here are the operator functions in the operator profile. You may now modify the profile for each individual function.

1 Prepare for march order
2. Drive/move cannon
3. Navigate
4. Emplace cannon
5. Displace cannon
6. Prepare cannon for firing
7. Fire cannon
8. Fire cannon at direct fire targets
9. Fire crew served weapons
10.Navigate
11.Communicate
12.Defend against attack
13.Displace system
14.Compensate for emergencies
15.Perform post-mission tasks

Change the data model for this function
Add function   Delete function   Change model   Other   eXit   End step
----
Name [Number]: Change model 1   [0016]

Step 2: Develop Operator Profile   HIP (2)   Change Model

Function: Prepare for march order
Function model: M109A2/A3
Class: Fire Support
Subclass: S-P Howitzer

To cycle through models, classes, or subclasses, put the cursor in the corrct field and press + or -. In this way you may select the data model you want for the function.

Some functions will not be represented in every data model. If the function is not present then the data model will not appear.

Change the model for this function to the one specified above
Select model for function   View function list   eXit without changing model

----

Name [Number]: Change model 2   [0017]

Step 2: Develop Operator Profile   HIP (2)   Change Model

Function: Prepare for march order
Function model: M1Ø9A2/A3
Class: Fire Support
Subclass: S-P Howitzer

To cycle through models, classes, or subclasses, put the cursor in the corrct field and press + or -. In this way you may select the data model you want for the function.

Some functions will not be represented in every data model. If the function is not present then the data model will not appear.

Change the model for this function to the one specified above
Select model for function   View function list   eXit without changing model

----

Name [Number]: Change model 3   [ØØ18]

Step 2: Develop Operator Profile HIP (2) Change Model

Function: Prepare for march order

Here are all data models with this function. Select a new data model, put the cursor on the desired model, specify Select.

1. M109A1
2. M1A
3. M10
4. M60A1
5. M60A3
6. M88
7. M113
8. M901
9. M528
10. M2/M3
11. AH1S
12. AH1T
13. AH64
14. UH1
15. UH60
16. UH58C
17. OH58D
18. CH47
19. CH53
20. HMMWV

Select this existing system as the data model
Select model eXit

Name [Number]: Change/select [0019]

Step 3: Develop Maintainer Profile HIP (2) Introduction

In Step 3 you will develop a profile for maintenance training and put data into that profile. The profile will consist of the subsystems that make up the new system, and the data will describe that system. The data model provides default and sample data for the characteristics that describe a system.

You can add or delete subsystems from the maintainer profile, and you can change the data model for each subsystem.

Once you have a maintainer profile you can change the data in it, or accept the default inputs provided by the data model. For convenience, you may develop a profile for a subsystem and then enter data immediately, or you may complete all subsystems before entering data.

Press Return to continue

Name [Number]: Intro Step 3 [0020]

```
Step 3: Develop Maintainer Profile    HIP (2)          Add Subsystem

Here are the subsystems in the maintainer profile.  You may now modify the
model for each individual subsystem.

1. Engine                                  16.Turret movement and hydraulics
2. Fuel                                    17.Traversing mechanism
3. Cooling                                 18.Door assemblies
4. Electrical                              19.Sight
5. Transmission                            20.Ammunition storage
6. Transfer and final drive                21.Turret electrics
7. Brakes
8. Locomotion mechanism
9. Steering
10.Frame/hull
11.Suspension
12.Accessories
13.Cab
14.Race ring
15.Armament


Add a subsystem to the list of subsystems
Add          Delete             Change model   Other    eXit    End step
---------------
Name [Number]: Add Subsystems 1 [0021]
---------------
```

Step 3: Develop Maintainer Profile   HIP (2)   Add Subsystem

Class: Subclass:

Change fields with cursor. Cycle through options in a field with + and - keys.

1. Engine
2. Fuel
3. Cooling
4. Electrical
5. Transmission
6. Transfer and final drive
7. Brakes
8. Locomotion mechanism
9. Steering
10. Frame/hull
11. Suspension
12. Accessories
13. Cab
14. Race ring
15. Armament
16. Turret movement and hydraulics
17. Traversing mechanism
18. Door assemblies
19. Sight
20. Ammunition storage
21. Turret electrics

Select this subsystem to be added to the subsystem list

Select   eXit

Name [Number]: Add Subsystems 2 [0022]

Step 3: Develop Maintainer Profile   HIP (2)   Delete Subsystem

Here are the subsystems in the maintainer profile. You may now modify the model for each individual subsystem.

1. Engine
2. Fuel
3. Cooling
4. Electrical
5. Transmission
6. Transfer and final drive
7. Brakes
8. Locomotion mechanism
9. Steering
10. Frame/hull
11. Suspension
12. Accessories
13. Cab
14. Race ring
15. Armament
16. Turret movement and hydraulics
17. Traversing mechanism
18. Door assemblies
19. Sight
20. Ammunition storage
21. Turret electrics

Delete this subsystem from the list of subsystems

Add   Delete   Change model   Other   eXit   End step

Name [Number]: Delete subsys 1 [0023]

```
Step 3: Develop Maintainer Profile    HIP (2)            Delete Subsystem

Put cursor on subsystem to be deleted.

1. Engine                                 16.Turret movement and hydraulics
2. Fuel                                   17.Traversing mechanism
3. Cooling                                18.Door assemblies
4. Electrical                             19.Sight
5. Transmission                           20.Ammunition storage
6. Transfer and final drive               21.Turret electrics
7. Brakes
8. Locomotion mechanism
9. Steering
10.Frame/hull
11.Suspension
12.Accessories
13.Cab
14.Race ring
15.Armament


Select this subsystem to be deleted from the subsystem list
Select            eXit
---------------
Name [Number]: Delete subsys 2  [0024]
---------------
```

Step 3: Develop Maintainer Profile   HIP (2)   Change Model

Here are the subsystems in the maintainer profile. You may now modify the model for each individual subsystem.

1. Engine
2. Fuel
3. Cooling
4. Electrical
5. Transmission
6. Transfer and final drive
7. Brakes
8. Locomotion mechanism
9. Steering
10. Frame/hull
11. Suspension
12. Accessories
13. Cab
14. Race ring
15. Armament
16. Turret movement and hydraulics
17. Traversing mechanism
18. Door assemblies
19. Sight
20. Ammunition storage
21. Turret electrics

Change the data model and/or data for this subsystem

Add   Delete   Change model   Other   eXit   End step

Name [Number]: Change/enter 1   [0025]

```
Step 3: Develop Maintainer Profile    HIP (2)            Change Model

Subsystem: Transmission
Subsystem model: M1Ø9A2/A3
Class: Fire Support
Subclass: S-P Howitzer

Characteristic                                                Attribute

Activation mode   [Manual (M)  Automatic (A)  Other (O)]       M
Number of forward gears                                        4
Number of reverse gears                                        2
Number of gear range options                                   1




Change the model and data for this subsystem as specified above
Select              View model list          eXit
---------------
Name [Number]: Change/enter 2   [ØØ26]
---------------
```

Step 3: Develop Maintainer Profile   HIP (2)   Change Model

Subsystem: Transmission
Subsystem model: M109A2/A3
Class: Fire Support
Subclass: S-P Howitzer

Characteristic	Attribute
Activation mode [Manual (M) Automatic (A) Other (O)]	M
Number of forward gears	4
Number of reverse gears	2
Number of gear range options	1

Change the model and data for this subsystem as specified above
Select   View model list   eXit

Name [Number]: Change/enter 3 [0027]

Step 3: Develop Maintainer Profile   HIP (2)   Change Model

Subsystem: Transmission

Here are all data models with this subsystem.

1. M109A1
2. M1A
3. M10
4. M60A1
5. M60A3
6. M88
7. M113
8. M901
9. M528
10.M2/M3
11.AH1S
12.AH1T
13.AH64
14.UH1
15.UH60
16. UH58C
17. OH58D
18. CH47
19. CH53
20. HMMWV

Select this existing system as the data model
Select   eXit

Name [Number]: Change/select   [0028]

Step 4: Find Comparison Systems HIP (2) Introduction

The comparison can now take place for the maintenance profile. This process will compare the profile of subsystems and characteristics for the new system with the profiles for all existing systems. When the comparison is complete the Aid will specify one existing system as a model to use for each subsystem when the Aid performs Step 5, Generate Training. You may change the model for each subsystem if you wish.

The comparison process will take some time, so if you do not want to perform the comparison at this time, select End step.

Continue with Step 4
Continue End step

Name [Number]: Intro Step 4 [0029]

Step 4: Find Comparison Systems HIP (2) Subsystems and Models

The comparison is complete. You may now review the results of the comparison and you may change the model if you wish.

1. Engine
2. Fuel
3. Cooling
4. Electrical
5. Transmission
6. Transfer and final drive
7. Brakes
8. Locomotion mechanism
9. Steering
10. Frame/hull
11. Suspension
12. Accessories
13. Cab
14. Race ring
15. Armament
16. Turret movement and hydraulics
17. Traversing mechanism
18. Door assemblies
19. Sight
20. Ammunition storage
21. Turret electrics

```
Select subsystem for review and change
Select               Other      End step
---------------
Name [Number]: Compar complete  [0030]
---------------
```

Step 4: Find Comparison Systems HIP (2) Change model/Enter data

Here are results of the comparison. The quality of fit is Good, Fair, Poor. You may change the model by putting the cursor in the model field and pressing +/-. You may also look at models in other classes and subclasses. Your selection will affect the results of Step 5, the Training Estimate.

Subsystem: Transmission
Subsystem model: M109A2/A3 Class: Fire Support Subclass: S-P Howitzer

Characteristic	Attribute		Fit
	Model	New System	
Activation mode [Manual (M) Automatic (A) Other (O)]	M	M	G
Number of forward gears	4	4	G
Number of reverse gears	2	2	G
Number of gear range options	1	1	G

Select the above model for the subsystem
Select Review another subsystem eXit End step

Name [Number]: Results menu [0031]

Step 5: Training Characteristics Estimate HIP (2) Introduction

In Step 5 the Aid will generate the training characteristics estimate. You can review and edit the results of the estimate. If you wish, you can return to steps 2 and 3, enter different descriptive data, and rerun the estimate.

First you will see a brief overview of the whole training estimate. You may then look more closely at operator or maintainer training.

The training estimate is directed at initial technical training in an institutional environment.

Press Return to continue

Name [Number]: Intro Step 5 [0032]

Step 5: Training Characteristics Estimate HIP (2) Overview

Operator		Maintainer
Academic time:		Troubleshoot time:
Hands-on time:		Repair/service time:
Training devices:		
Other training equipment:		
MOSs:		

Review data for individual operator functions

Operator functions Maintenance subsystems End step

Name [Number]: chars overview [0033]

Step 5: Training Characteristics Estimate HIP (2) Operator functions

Operator functions Total time: Function	Time Academic	Hands-on
1. Prepare for march order		
2. Drive/move cannon		
3. Navigate		
4. Emplace cannon		
5. Displace cannon		
6. Prepare cannon for firing		
7. Fire cannon		
8. Fire cannon at direct fire targets		
9. Fire crew served weapons		
10. Navigate		
11. Communicate		
12. Defend against attack		
13. Displace system		
14. Compensate for equipment malfunctions & emerg.		
15. Perform post-mission tasks		

View data for this function and edit if desired
View/edit Delete Add Other eXit End step

Name [Number]: Function menu 1 [0034]

Step 5: Training Characteristics Estimate HIP (2) Operator functions

Operator functions Total time:	Time	
Function	Academic	Hands-on

1. Prepare for march order
2. Drive/move cannon
3. Navigate
4. Emplace cannon
5. Displace cannon
6. Prepare cannon for firing
7. Fire cannon
8. Fire cannon at direct fire targets
9. Fire crew served weapons
10. Navigate
11. Communicate
12. Defend against attack
13. Displace system
14. Compensate for equipment malfunctions & emerg.
15. Perform post-mission tasks

View data for this function and edit if desired

View/edit Delete Add Other eXit End step

Name [Number]: Function menu 2 [0035]

Step 5: Training Characteristics Estimate HIP (2) Edit/Delete Function

Function:
Comparison system for this function:
Training

	Time	Difficulty	Highlighted areas can be edited.
Hands-on:			
Academic:			
Total:			

Training devices:

Other training equipment:

MOSs:

Change the data for this function to that shown above
Edit Delete Other Print eXit End step

Name [Number]: Edit function [0036]

```
Step 5:  Training Characteristics Estimate    HIP (2)    Edit/Delete Function

Function:
Comparison system for this function:
Training
            Time        Difficulty     Highlighted areas can be edited.
Hands-on:
Academic:
Total:

Training devices:



Other training equipment:



MOSs:


Delete this function
Edit      Delete      Other    Print    eXit    End step
---------------
Name [Number]: Delete function  [0037]
---------------
```

Step 5: Training Characteristics Estimate HIP (2) Edit/Delete Function

Function:
Comparison system for this function:
Training

	Time	Difficulty	Highlighted areas can be edited.
Hands-on:			
Academic:			
Total:			

Training devices:

Other training equipment:

MOSs:

Add a new function and enter data
Add Other Print eXit End step

Name [Number]: Add function [0038]

```
Step 5:  Training Characteristics Estimate    HIP (2)    Maintenance subsystems

Maintenance subsystems Total time:                                 Time
                    Subsystem                               Trouble     Repair

1. Engine
2. Fuel
3. Exhaust
4. Cooling
5. Electrical
6. Transmission
7. Transfer and final drive
8. Brakes
9. Locomotion
10.Steering
11.Frame/hull
12.Suspension
13.Hull accessories
14.Cab
15.Race ring
16.Main armament
[PgDn for more]

View data for this subsystem and edit if desired
View/edit     Delete     Add     Other     eXit    End step
---------------
Name [Number]: Subsys menu 1    [0039]
---------------
```

Step 5: Training Characteristics Estimate HIP (2) Maintenance subsystems

Maintenance subsystems Total time:

Subsystem	Time Trouble	Time Repair
17.Secondary armament		
18.Power pack		
19.Cupola		
20.Traversing mechanism		
21. Door assemblies		
22. Sight		
23. Ammunition storage		
24. Electrical		

[PgUp for more]

View data for this subsystem and edit if desired
View/edit Delete Add Other eXit End step

Name [Number]: Subsys menu 2 [0040]

```
Step 5:  Training Characteristics Estimate    HIP (2)    Edit/Delete Subsystem

Subsystem:
Comparison system for this subsystem:
                    Training
                Time        Difficulty     Highlighted areas can be edited.
Troubleshoot:
Repair:
Total:

Training devices:



Other training equipment:



MOSs:


Change the data for this subsystem to that shown above
Edit          Delete    Add     Other    eXit   End step
---------------
Name [Number]: Edit subsys      [0041]
---------------
```

```
Step 5:  Training Characteristics Estimate    HIP (2)    Edit/Delete Subsystem

Subsystem:
Comparison system for this subsystem:
                    Training
                Time        Difficulty     Highlighted areas can be edited.
Troubleshoot:
Repair:
Total:

Training devices:



Other training equipment:



MOSs:


Delete this subsystem
Edit          Delete    Add     Other    eXit   End step
---------------
Name [Number]: Delete subsys    [0042]
---------------
```

```
Step 5:  Training Characteristics Estimate    HIP (2)    Edit/Delete Subsystem

Subsystem:
Comparison system for this subsystem:
                         Training
                    Time        Difficulty    Highlighted areas can be edited.
Troubleshoot:
Repair:
Total:

Training devices:



Other training equipment:



MOSs:


Add a new subsystem and enter data
Add                    Other   Print    eXit    End step
---------------
Name [Number]: Add subsys       [0043]
---------------
```

Step 1: Initial Data Entry OTHER

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model:

Save under this system name (a new version may be required)
save (New version) save (Replace old version) Print eXit End step

----

Name [Number]: Other- save new [0044]

Step 1: Initial Data Entry OTHER

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model:

Save under this system name (current version will be replaced)
save (New version) save (Replace old version) Print eXit End step

----

Name [Number]: Other-save repla [0045]

Step 1: Initial Data Entry OTHER

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model:

Go to print menu
save (New version) save (Replace old version) Print eXit End step
----
Name [Number]: Other- Print [0046]

Step 1: Initial Data Entry   OTHER

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model:

Return to previous step
save (New version) save (Replace old version) Print eXit   End step
----
Name [Number]: Other- exit   [0047]

Step 1: Initial Data Entry OTHER

System name: HIP (2)
System class: Fire Support
System subclass: Self-propelled Howitzers
Data model:

Stop at this point and go to a menu of activities
save (New version) save (Replace old version) Print eXit End step

----

Name [Number]: Other- end step [0048]

PRINT MENU

Print the current Screen

Print the results of:

Step 1

Step 2

Step 3

Step 4

Step 5

All steps

eXit

Name [Number]: Print [0049]

System name: HIP (2)   Class: Fire Support   Subclass: S-P Howitzer
Data model:

Go to Step 1: Initial Data Entry

Go to Step 2: Develop Operator Profile

Go to Step 3: Develop Maintainer Profile

Go to Step 4: Find Comparison Systems

Go to Step 5: Training Characteristics Estimate

Save the current data (new version)

Replace old version

Print data

End Session

eXit

Put the cursor on your choice and press Return

Name [Number]: End step   [0050]

APPENDIX B

DATA DICTIONARY

APPENDIX B

DATA DICTIONARY

The data dictionary presents three pieces of information: (1) data that are to be contained in a disk-resident database; (2) in-memory data structures; and (3) and alphabetic listing of fields along with their descriptions.

(1) The following data are contained in a disk-resident database. The lines and indentation indicate hierarchical relationships among data elements.

```
system file
-----------
| systemName (key) - 15       (82 for segment)
| version - 5
| date - 8
| sysDescription - 30
| sysClassID - 4
| sysSubClassID - 4
| dataModelForMaint - 4
| dataModelForOpFun - 4
| systemIsDefined - 4
| maxCompCases - 4
----------------------------------------------------------------------
   | sysSubSysID (key) - 4  (44)         |         | compSysCandid - 4
   | dataModelForSubSystem - 4           |         --------------------
   | subSysIsDefined - 4                 |
   | maxCompSubSys - 4                   | sysOpFunctID (key) - 4 (16)
   | sysOccSpec - 12                     | sysOpHandsOn - 4
   | sysTroubleTime - 4                  | sysOpAcademic - 4
   | sysTroubDiffEst - 4                 | sysOpDiffEst - 4
   | sysRepairTime - 4                   -----------------------
   | sysRepairDiffEst - 4                   |   | sysOpOtherEqp - 10
   -----------------------------------      |   -------------
      |   |   |   | sysMnOtherEqp - 10      |
      |   |   |   ---------------           | sysOpDevice - 10
      |   |   |                             ------------------
      |   |   | sysMnDevice - 10
      |   |   ------------------
      |   |
      |   | rankOfSubSysCandid (key) - 4 (8)
      |   | compSysHavingSubSys - 4
      |   -------------------------
      |      | candidCharactID - 4 (12)
      |      | comparability - 8
      |      ---------------
      |
      | sysCharactID - 4  (16)
      | charactIsDefined - 4
      | sysCharactValue - 8
      ---------------
```

```
comparison system file
----------------------
| compSystemName (key) - 15 (53)
| compDescription - 30
| compSysClassID - 4
| compSubClassID - 4
-----------------------------------------------------------------
   | compSubSysID (key) - 4 (24)       | compOpFunctID (key) - 4 (16)
   | compOccSpec - 4                   | compOpHandsOn - 4
   | compTroubleTime - 4               | compOpAcademic - 4
   | compTroubDiffEst - 4              | compOpDiffEst - 4
   | compRepairTime - 4                ---------------------
   | compRepairDiffEst - 4                 |   | compOpOtherEqp - 10
   -----------------------------           |   -------------
      |   |   | compMnOtherEqp - 10        |
      |   |   ---------------              | compOpDevice - 10
      |   |                                -----------------
      |   | compMnDevice - 10
      |   ------------------
      |
      | compCharactID - 4 (12)
      | compCharactValue - 8
      ---------------
```

```
systemClass file
----------------
| systemClassID (key) - 4 (34)
| systemClassName - 30
---------------
   | systemSubClassID - 4
   ---------------


subClass file
-------------
| subClassID (key) - 4 (34)
| subClassName - 30
---------------


OperatorFunction File
---------------------
| opFunctID - 4  (34)
| opFunction - 30
--------


subSystem file
--------------
| subSysID (key) - 4 (34)
| subSystemName - 30
---------------
   | charactID - 4
   ---------------


characteristic file
-------------------
| characteristicID (key) - 4 (64)
| characteristicName - 30
| valueType - 4
| valueUnit - 10
| strictTolerance - 8
| relaxTolerance - 8
---------------
```

(2) The following are in-memory data structures.

```
 in-memory
 subsystem
   table                comparison subsystem candidates list

 ---------------        -------------------------------------
| memSubSysID-1 |---> | memCompSysHavingSubSys | subSysScore |<---> ...

| memSubSysID-2 |--->   -------------------------------------
| memSubSysID-3 |--->
|     ...       |
| memSubSysID-n |--->
 ---------------


              comparison system scoring table

      ---------------------------------------------------
     | memCompSys-1 | numberSubSysCandid-1 | compScore-1 |
     | memCompSys-2 | numberSubSysCandid-2 | compScore-2 |
     | memCompSys-3 | numberSubSysCandid-3 | compScore-3 |
     |      .       |          .           |      .      |
     |      .       |          .           |      .      |
     |      .       |          .           |      .      |
     | memCompSys-m | numberSubSysCandid-m | compScore-m |
      ---------------------------------------------------
```

(3) The following is an alphabetic list of fields and descriptions.

candidCharactID	-	identifier of the desired characteristic record
charactIsDefined	-	indicates that a chracteristic has been defined for the system
characteristicID	-	identifier of the desired characteristic record
characteristicName	-	name of a characteristic of a subsystem
charactID	-	identifier of the desired characteristic record
compOpAcademic	-	number of weeks spent in classroom for operator training
compOpDiffEst	-	difficulty estimate for operator training
comparability	-	percentage difference between desired value and comparison value
compCharactID	-	identifier of the desired characteristic record
compCharactValue	-	value of the characteristic
compDescription	-	description of the comparison system
compMnDevice	-	maintenance training device
compMnOtherEqp	-	other maintenance training equipment
compOccSpec	-	Military Occupational Specialty needed for maintenance
compOpDevice	-	operator training device
compOpFunctID	-	identifier for an operator function
compOpHandsOn	-	number of weeks spent in hands-on training for an operator course
compOpOtherEqp	-	other operator training equipment
compRepairDiffEst	-	repair training difficulty estimate
compRepairTime	-	number of weeks spent in maintenance repair training
compScore	-	score for a comparison system
compSubClassID	-	subclass of the comparison system
compSubSysID	-	identifier of the desired subSystem record
compSysCandid	-	name of a comparison system candidate
compSysClassID	-	system class of the comparison system
compSysHavingSubSys	-	comparison system which contains the candidate subsystem
compSystemName	-	name of the comparison system
compTroubDiffEst	-	trouble shooting training difficulty estimate
compTroubleTime	-	number of weeks spent in maintenance trouble shooting training
dataModelForSubSystem	-	comparison system from which the subsystem was modeled
dataModelForMaint	-	comparison system initially used for modeling the maintenance profile
dataModelForOpFun	-	comparison system initially used for modeling the operator profile
date	-	date of the current version of the system

maxCompCases	-	maximum number of comparison case systems for the system
maxCompSubSys	-	maximum number of comparison subsystems for the system subsystem
memCompSys	-	in-memory copy of compSysCandid
memCompSysHavingSubSys	-	in-memory copy of compSysHavingSubSys
memSubSysID	-	in-memory copy of sysSubSysID
numberSubSysCandid	-	number of subsystem candidates contained by a comparison system
opFunctID	-	identifier for an operator function
opFunction	-	name of an operator function
rankOfSubSysCandid	-	best fit rank assigned to comparison subsystem candidate
relaxTolerance	-	relaxed percentage tolerance for a characteristic
strictTolerance	-	restrictive percentage tolerance for a characteristic
subClassName	-	system subclass name
subClassID	-	identifier of a specific record in the subclass file
subSysID	-	identifier of a specific record in the subSystem file
subSysIsDefined	-	indicator of whether the subsystem has been defined
subSysScore	-	best fit score for a comparison subsystem
subSystemName	-	subsystem name
sysCharactID	-	identifier of the desired characteristic record
sysCharactValue	-	value of the characteristic
sysClassID	-	system class of the system
sysDescription	-	description of the specified version of the system
sysMnDevice	-	maintenance training device
sysMnOtherEqp	-	other maintenance training equipment
sysOccSpec	-	Military Occupational Specialty needed for maintenance
sysOpAcademic	-	number of weeks spent in classroom for operator training
sysOpDevice	-	operator training device
sysOpDiffEst	-	difficulty estimate for operator training
sysOpFunctID	-	identifier for an operator function
sysOpHandsOn	-	number of weeks spent in hands-on training for an operator course
sysOpOtherEqp	-	other operator training equipment
sysRepairDiffEst	-	repair training difficulty estimate
sysRepairTime	-	number of weeks spent in maintenance repair training
sysSubClassID	-	subclass of the system
sysSubSysID	-	identifier of the desired subSystem record
systemClassID	-	identifier of a specific record in the systemClass file

systemClassName	-	system class name
systemIsDefined	-	indicator of whether the system has been defined
systemName	-	name of the system
systemSubClassID	-	identifier of a specific record in the subClass file
sysTroubleTime	-	number of weeks spent in maintenance trouble shooting training
sysTroubDiffEst	-	trouble shooting training difficulity estimate
valueType	-	type of value of the characteristic
valueUnit	-	unit of measurement to be associated with a characteristic value
version	-	version number of a system

APPENDIX C

DATABASE SIZE ESTIMATE

APPENDIX C. DATABASE SIZE ESTIMATE

The database size estimate is based on the size of each of the files in the database. Those file sizes are listed below. The addition of those sizes results in a raw data requirement of 1 Megabyte. Database overhead for such items as hash tables, indexes, and b-trees adds .3 Megabytes of additional disk space. Allowing for some expansion of the estimates, the total disk requirement for the database is 1.5 Megabytes. Disk space will be required by MS-DOS, the database management system, application executables, and source code for the application. These items increase disk requirements to 4 Megabytes.

Each value is given as a rounded approximation, followed by the computation, followed by a description of the constituents of the computation.

* Number of comparison systems = 11 * 6 * 2.5 = 165
  number of classes = 11
  number of subclasses = 6
  comparison systems per class/subclass = 2.5

* size of comparison system file = .4 Megabytes

  342,375 = 165 * (53 +
  (10 * (24 + 5*12 + 3*10 + 1.5*10)) +
  (12 * (16 + 3*10 + 1.5*10)))

  number of comparison systems = 165
  data space per comparison system = 53

  number of subsystems per comparison system = 10
  data space for subsystem info = 24
  characteristics per subsystem = 5
  data space for characteristic = 12
  training device for subsystem maintenance = 3
  data space for training device = 10
  other training equipment for subsystem maintenance = 1.5
  data space for training approach = 10

  operator functions per comparison system = 10
  data space per operator function = 16
  training devices for operator function = 3
  data space for training device = 10
  other training equipment for operator function = 1.5
  data space for other training equipment = 10

```
* size of system file = .6 Megabytes

    606,400 = 4*25 * (82 + 40*4 +
    10 * (44 + 5*16 + 5*(8 + 5*12) + 3*10 + 1.5*10) +
    12 * (16 + 3*10 + 1.5*10) )

    number of systems = 4
    number of versions per system = 25
    data space for system info = 82
    comparison systems candidates per system = 40
    data for comparison system candidate = 4

    number of subsystems per system = 10
    data for subsystem info = 44
    characteristics per subsystem = 5
    data space per characteristic = 16
    number of comparison subsystem candidates per subsystem = 5
    data space for comparison subsystem candidate = 8
    number of characteristics per comparison subsystem candidate = 5
    data space per characteristic = 12
    training device for subsystem maintenance = 3
    data space for training device = 10
    other training equipment for subsystem maintenance  = 1.5
    data space for other training equipment = 10

    operator functions per comparison system = 12
    data space per operator function = 16
    training devices for operator function = 3
    data space for training device = 10
    other training equipment for operator function = 1.5
    data space for other training equipment = 10
```

* size of systemClass file = 1 Kilobytes

  638 = 11 * (34 + 6*4)

  number of system classes = 11
  data space for system class info = 34
  number of subclasses per class = 6
  data space for subclass info = 4

* size of subclass file = 3.5 Kilobytes

  3,400 = 100 * 34

  number of subclasses = 100
  data space for subclass info = 34

* size of operatorFunction file = 7 Kilobytes

  6,800 = 200 * 34

  number of functions = 200
  data space for operator function info = 34

* size of characteristic file = 64 Kilobytes

  64,000 = 1000 * 64

  number of characteristics = 1000
  data space for characteristic info = 6

APPENDIX D

PROCESSING LOGIC

APPENDIX D

PROCESSING LOGIC

This document specifies the processing logic of Product Four. The main program is presented first, and the subprograms follow in alphabetic order. Each subprogram is separated from the next by a line of asterisks.

```
**********************************************************************
Function name : main

CALL getCommandLineParameters
WHILE ( TRUE )
|   tell user that (s)he may perform initial data entry, develop
|       a maintenance profile, develop an operator profile, run the
|       comparison engine, run training estimate engine,
|       select reports, or quit
|   SWITCH ( on user's choice )
|   |
|   CASE initial data entry:
|   |   CALL initialDataEntry
|   CASE develop maintenance profile:
|   |   CALL developMaintProfile
|   CASE develop operator profile:
|   |   CALL developOpProfile
|   CASE run comparison engine:
|   |   IF ( systemIsDefined = FALSE )
|   |   |   give error, telling user to define all subsystems
|   |   |       before attempting to initiate comparison
|   |   |   continue with next iteration of WHILE loop
|   |   --------
|   |   CALL findComparisonCase
|   |   CALL reviewComparisons
|   CASE run training estimation engine:
|   |   find first occurrence of rankOfSubSysCandid
|   |   IF ( no occurrences of rankOfSubSysCandid exists )
|   |   |   give error, telling user that the comparison engine must
|   |   |       run before the training estimate can be generated
|   |   |   continue with next iteration of WHILE loop
|   |   --------
|   |   CALL findTrainingEstimate
|   |   CALL reviewTraining
|   CASE select reports:
|   |   CALL selectReports
|   CASE quit:
|   |   CALL safelyQuit
|   |   exit
|   --------
--------
End main
```

```
***********************************************************************
    Function name : activation

    ask user whether (s)he wishes to enter embedded training
    read response from screen
    IF ( user wants embedded training )
    |   CALL embeddedTraining
    --------

    /* determine system name and version on which user wants to work */
    display initial data entry screen
    WHILE ( systemName has not been selected and verified )
    |   IF ( user wishes to select from a list )
    |   |   FOR ( each system record )
    |   |   |   display each systemName
    |   |   |   prompt user to select a system name
    |   |   --------
    |   --------
    |   read systemName
    |   /* here we are finding an existing system */
    |   IF ( systemName exists in system file )
    |   |   IF ( user has not specified a version number )
    |   |   |   FOR ( each version of systemName )
    |   |   |   |   display version, date, & sysDescription
    |   |   |   --------
    |   |   |   ask user to select the version desired
    |   |   --------
    |   |   find system record with selected systemName and version
    |   |   find systemClass record with systemClassID = sysClassID
    |   |   find subClass record with subClassID = sysSubClassID
    |   |   display systemClassName, subClassName, dataModelForMaint
    |   |   FOR ( each compSysCandid )
    |   |   |   display compSysCandid
    |   |   --------
    |   |
    |   |   /*
    |   |   Create a temporary copy of system on which we shall
    |   |   perform all updates. This will allow the user to decide,
    |   |   when (s)he exits, to save the updates under the old version
    |   |   number, or keep the old version, and save all updates
    |   |   under a new version number.
    |   |   */
    |   |   copy selected system record to a new system record with
    |   |       systemName = "temporary"
    |   ELSE
    |   |   /* here we are creating a new system */
    |   |   ask user if (s)he wishes to create a new system
    |   |   IF ( user wants new system )
    |   |   |   create a new system record
    |   |   |   ask user for a description of this version of the system
    |   |   |   sysDescription <- user's description of new system
```

```
|    |    |    IF ( user types in the system class directly )
|    |    |    |   read the system class name that the user has typed
|    |    |    ELSE
|    |    |    |   FOR ( each systemClass record )
|    |    |    |   |   display systemClassName
|    |    |    |   --------
|    |    |    |   ask user to select a system class
|    |    |    --------
|    |    |    sysClassID <- user's selected system class
|    |    |    IF ( user types in the sub class directly )
|    |    |    |   read and verify the subClassName that user has typed
|    |    |    ELSE
|    |    |    |   FOR ( each systemSubClassID of the selected
|    |    |    |          system class )
|    |    |    |   |   find subClass record with subClassID =
|    |    |    |   |       systemSubClassID
|    |    |    |   |   display subClassName
|    |    |    |   |   ask user to select a subClassName
|    |    |    |   --------
|    |    |    |   sysSubClassID <- user's selected sub class
|    |    |    --------
|    |    |    FOR ( each comparison system record )
|    |    |    |   IF ( compSysClassID = sysClassID and
|    |    |    |         compSubClassID = sysSubClassID )
|    |    |    |   |   compSysCandid <- compSystemName
|    |    |    |   |   display compSysCandid
|    |    |    |   --------
|    |    |    --------
|    |    ELSE
|    |    |    inform user that the system name does not already exist
|    |    |    prompt user to re-enter a system name
|    |    --------
|    --------
--------
End activation
```

```
***********************************************************************
     Function name : addSubSystems

     /* add any systems from other class/subclass to the comparison list */

     ask user if (s)he wishes to add comparison systems from another
         class/subclass to the comparison list for this system
     IF ( user wants systems from other class/subclass )
     |   FOR ( each systemClass record )
     |   |   IF ( systemClassID = sysClassID and
     |   |        systemSubClassID =sysSubClassID )
     |   |   |   continue next iteration of FOR loop
     |   |   --------
     |   |   find subClass record with subClassId = systemSubClassID
     |   |   display systemClassName and subClassName
     |   --------
     |   ask user to select new class and subclass
     |   FOR ( each comparison system record )
     |   |   IF ( new class = compSysClassID and
     |   |        new subclass = compSubClassID )
     |   |   |   display modelSystemName
     |   |   --------
     |   |   WHILE ( the user does not ask to quit )
     |   |   |   ask user to select system to add to the comparison list
     |   |   |   compSysCandid <- selected system
     |   |   --------
     |   --------
     --------

     /* display a list of subsystems that can be added to the system */
     FOR ( each compSysCandid  )
     |   find the comparison system record with modSysName = compSysCandid
     |   FOR ( each compSubSysID in the comparison system record )
     |   |   IF ( compSubSysID is not in the current set of subsystems )
     |   |   |   display subSystemName on the screen in red
     |   |   --------
     |   --------
     --------
```

```
/* let the user select the subsystems to add */
WHILE ( user does not ask to quit )
|   prompt user to select subsystem for addition to the system
|       data template
|   read user's selection
|   sysSubSysID <- the selected subsystem
|   subSysIsDefined <- FALSE
|   FOR ( each compSysCandid )
|   |   find the comparison system record with compSystemName =
|   |       compSysCandid
|   |   IF ( compSubSysID matches the selected subsystem )
|   |   |   display the compSystemName as template candidate
|   |   |       for the selected subsystem
|   |   --------
|   --------
|   ask user to select comparison system name to be used as
|       subsystem template
|   dataModelForSubSystem <- comparison system name
|   FOR ( each compCharactID in the comparison system record )
|   |   sysCharactID <- compCharactID
|   |   charactIsDefined <- FALSE
|   --------
--------
End addSubSystems
```

```
************************************************************************

     Function name : changePrimary

     /* change the subsystem makeup of the primary comparison case */
     WHILE ( user does not choose to quit )
     |   prompt user to enter a subsystem name to be replaced
     |   read the subsystem name
     |   find the system's subsystem with sysSubSysID = selected subsystem
     |   display subSystemName
     |   FOR ( each compSysHavingSubSys  )
     |   |   display compSysHavingSubSys
     |   |   FOR ( each candidCharactID  )
     |   |   |   display characteristicName, sysCharactValue,
     |   |   |       comparability, and valueUnit
     |   |   --------
     |   --------
     |   ask user to select the comparison system which contains the
     |       desired subsystem
     |   read selected comparison system name (thereby
     |       indicating which subsystem)
     |
     |   /*
     |   renumber all comparison subsystems which have better rankings
     |   than the selected subsystem
     |   */
     |   FOR ( each compSysHavingSubSys )
     |   |   IF ( rankOfSubSysCandid >= 1 and
     |   |        rankOfSubSysCandid < selected subsystem's
     |   |                             rankOfSubSysCandid )
     |   |   |   rankOfSubSysCandid <- rankOfSubSysCandid + 1
     |   |   --------
     |   --------
     |   newly selected subsystem's rankOfSubSysCandid <- 1
     --------
     End changePrimary

************************************************************************

     Function name : deleteSubSystems

     WHILE ( user does not ask to quit )
     |   prompt user to select subsystem for deletion from the template
     |   read user's selection
     |   find the sysSubSysID that matches the selected subsystem
     |   delete that sysSubSysID and all associated sysCharactID's
     |   remove that subsystem name from the monitor
     --------
     End deleteSubSystems
```

```
***********************************************************************

     Function name : developMaintProfile

     WHILE ( TRUE )
     |   FOR ( each sysSubSysID in the system record )
     |   |   systemIsDefined <- TRUE
     |   |   IF ( subSysIsDefined = TRUE )
     |   |   |   display subSystemName on screen in green (already defined)
     |   |   ELSE
     |   |   |   display subSystemName on screen in red (yet to be defined)
     |   |   |   systemIsDefined <- FALSE
     |   |   --------
     |   --------
     |
     |   tell user that (s)he may ADD or DELETE subsystems, EDIT
     |       characteristics, or accept the current set of subsystems
     |       and characteristics
     |   SWITCH ( on user's choice )
     |   |
     |   CASE add:
     |   |   CALL addSubSystem
     |   CASE delete:
     |   |   CALL deleteSubSystem
     |   CASE edit:
     |   |   CALL editCharacteristics
     |   CASE accept current subsystems
     |   |   return
     |   --------
     --------
     End developMaintProfile
```

```
*************************************************************************

    Function name : developOpProfile

    WHILE ( TRUE )
    |   tell user that (s)he may add a function, delete a function,
    |       change class/subClass, change data model, or quit
    |   SWITCH ( on user's choice )
    |   |
    |   CASE add a function:
    |   |   display dataModelForOpFun
    |   |   find comparison system record with compSystemName =
    |   |      dataModelForOpFun
    |   |   FOR ( each compOpFunctId )
    |   |   |   sysOpfunctId <- compOpFunctId
    |   |   |   sysOpHandsOn <- compOpHandsOn
    |   |   |   sysOpAcademic <- compOpAcademic
    |   |   |   FOR ( each compOpDevice )
    |   |   |   |   sysOpDevice <- compOpDevice
    |   |   |   --------
    |   |   |   FOR ( each compOpOtherEqp )
    |   |   |   |   sysOpOtherEqp <- compOpOtherEqp
    |   |   |   --------
    |   |   --------
    |   CASE delete a function:
    |   |   FOR ( each sysOpFunctID )
    |   |   |   display sysOpFunctID
    |   |   --------
    |   |   ask user to select the function to be deleted
    |   |   delete sysOpFunctID = specified function
    |   CASE class/subClass:
    |   |   WHILE ( user  wants to cycle through class )
    |   |   |   WHILE ( user still wants to cycle through subClass )
    |   |   |   |   find the next comparison system record with
    |   |   |   |      sysClassID = desired class and
    |   |   |   |      sysSubClassID = desired subClass
    |   |   |   |   display the new compSysClassID and compSubClassID
    |   |   |   --------
    |   |   --------
    |   |   record the comparison system as a temporary data model
```

```
|   CASE change data model:
|   |   FOR ( each comparison system record )
|   |   |   display compSystemName
|   |   --------
|   |   ask user to select the desired data model
|   |   dataModelForOpFun <- selected data model
|   |   FOR ( each sysOpFunctID )
|   |   |   delete sysOpFunctID
|   |   --------
|   |   find comparison system record with compSystemName =
|   |      dataModelForOpFun
|   |   FOR ( each compOpFunctId )
|   |   |   sysOpfunctId <- compOpFunctId
|   |   |   sysOpHandsOn <- compOpHandsOn
|   |   |   sysOpAcademic <- compOpAcademic
|   |   |   FOR ( each compOpDevice )
|   |   |   |   sysOpDevice <- compOpDevice
|   |   |   --------
|   |   |   FOR ( each compOpOtherEqp )
|   |   |   |   sysOpOtherEqp <- compOpOtherEqp
|   |   |   --------
|   |   --------
|   CASE quit:
|   |   return
|   --------
--------
End developOpProfile
```

```
************************************************************************

     Function name : editCharacteristics

     ask user to select the subsystem whose characteristics (s)he wishes
         to edit
     read subsystem
     find the sysSubSysID that matches the selected subsystem
     find the comparison system record that matches dataModelForSubSystem

     /* get the characteristic value from the user */
     FOR ( each sysCharactID )
     |   display characteristicName, compCharactValue, and valueUnit
     |   ask user for sysCharactValue
     |   charactIsDefined <- TRUE
     --------

     subSysIsDefined <- TRUE
     FOR ( each sysCharactID )
     |   IF ( charactIsDefined = FALSE )
     |   |   subSysIsDefined <- FALSE
     |   --------
     --------
     End editCharacteristics

************************************************************************

     Function name : embeddedTraining

     To be supplied
     End embeddedTraining
```

```
**********************************************************************
     Function name : findComparisonCase
     /* determine the comparison subsystems for each subsystem within
     the system */
     FOR ( each sysSubSysID )
     |   find the entry in in-memory subsystem table with memSubSysID =
     |       sysSubSysID
     |   IF ( entry cannot be found )
     |   |   /* create a new in-memory subsystem table entry */
     |   |   memSubSysID <- sysSubSysID
     |   --------
     |   FOR ( each compSysCandid )
     |   |   find the comparison system record with compSystemName =
     |   |       compSysCandid
     |   |   IF ( compSubSysID != sysSubSysID )
     |   |   |   continue next iteration of nearest FOR loop
     |   |   --------
     |   |
     |   |   /* create each comparison case for the current subsystem */
     |   |   rankOfSubSysCandid <- a unique arbitrary number (over 1000)
     |   |   compSysHavingSubSys <- compSystemName
     |   |   FOR ( each sysCharactID )
     |   |   |   candidCharactID <- sysCharactID
     |   |   |   find the characteristic record with characteristicID =
     |   |   |       sysCharactID
     |   |   |
     |   |   |   /* determine a score for each characteristic */
     |   |   |   IF ( sysCharactValue is within plus or minus the
     |   |   |        strictTolerance percentage of compCharactValue )
     |   |   |   |   record a score of 2
     |   |   |   |   comparability <- ( ((sysCharactValue -
     |   |   |   |      compCharactValue) / minimum of the 2 values)
     |   |   |   |      * 100% )
     |   |   |   ELSEIF (sysCharactValue is within plus or minus the
     |   |   |            relaxTolerance percentage of compCharactValue)
     |   |   |   |   record a score of 1
     |   |   |   |   comparability <- ( ((sysCharactValue -
     |   |   |   |      compCharactValue) / minimum of the 2 values)
     |   |   |   |      * 100% )
     |   |   |   ELSE
     |   |   |   |   record a score of 0
     |   |   |   |   comparability <- "no match"
     |   |   |   --------
     |   |   |   sum the score for each characteristic into a
     |   |   |       subsystem score
     |   |   --------
     |   |   CALL recordScores
     |   --------
     --------
     CALL rankScores
     End findComparisonCase
```

```
**********************************************************************

     Function name : findTrainingEstimate

     FOR ( each sysSubSysID )
     |   find rankOfSubSysCandid = 1
     |   find comparison system record with compSystemName =
     |       compSysHavingSubSys
     |   find compSubSysID = sysSubSysID
     |   sysOccSpec <- compOccSpec
     |   sysTroubletime <- compTroubleTime
     |   sysTroubDiffEst <- compTroubDiffEst
     |   sysRepairTime <- compRepairTime
     |   sysRepairDiffEst <- compRepairDiffEst
     |   FOR ( each compMnDevice )
     |   |   sysMnDevice <- compMnDevice
     |   --------
     |   FOR ( each compMnOtherEqp )
     |   |   sysMnOtherEqp <- compMnOtherEqp
     |   --------
     --------
     End findTrainingEstimate

**********************************************************************

     Function name : getCommandLineParameters

     /* record all command line parameters */
     FOR ( each command line parameter )
     |   IF ( parameter = systemClassName )
     |   |   record systemClassName for automatic display later in program
     |   ELSEIF ( parameter = subClassName )
     |   |   record subClassName for automatic display later in program
     |   --------
     --------
     End getCommandLineParameters
```

```
***********************************************************************

     Function name : initialDataEntry

     CALL activation
     CALL selectModelForSystem
     End initialDataEntry

***********************************************************************

     Function name : makeAltPrimary

     /*
     make an alternate comparison system the primary comparison case,
     by setting each of the subsytem rankings to 1 */
     FOR ( each sysSubSysID )
     |   /* find each subsystem in the selected alternate case */
     |   IF ( selected alternate rankOfSubSysCandid > maxCompSubSys )
     |   |   find compSysHavingSubSys with rankOfSubSysCandid =
     |   |       maxCompSubSys
     |   ELSE
     |   |   find compSysHavingSubSys with rankOfSubSysCandid = selected
     |   |       alternate rankOfSubSysCandid
     |   --------
     |
     |   /*
     |   renumber all comparison subsystems which have better rankings
     |   than the selected alternate subsystem
     |   */
     |   FOR ( each compSysHavingSubSys )
     |   |   IF ( rankOfSubSysCandid >= 1 and
     |   |        rankOfSubSysCandid < selected alternate's
     |   |                             rankOfSubSysCandid )
     |   |   |   rankOfSubSysCandid <- rankOfSubSysCandid + 1
     |   |   --------
     |   --------
     |   newly selected alternates's rankOfSubSysCandid <- 1
     --------
     End makeAltPrimary
```

```
***********************************************************************
     Function name : MnProfileRpt

     To be supplied
     End MnProfileRpt

***********************************************************************

     Function name : OpProfileRpt

     To be supplied
     End OpProfileRpt

***********************************************************************

     Function name : rankScores

     /*
     Use tie breakers to determine final ranking of comparison subsystems.
     Move comparison subsystem candidate list entries around, so that
     their order represents their rank.
     */
     FOR ( each memSubSysID in the in-memory subsystem table )
     |   FOR ( each memCompSysHavingSubSys in comparison subsystem
     |         candidates list )
     |   |   WHILE ( subSysScore for current memCompSysHavingSubSys =
     |   |           subSysScore for next memCompSysHavingSubSys )
     |   |   |   IF ( current memCompSysHavingSubSys is not the same
     |   |   |        class/subclass as the system, but the next
     |   |   |        memCompSysHavingSubSys is the same class/subclass )
     |   |   |   |   swap positions in the candidate list
     |   |   |   ELSE
     |   |   |   |   find scoring table entry memCompSys =
     |   |   |   |       memCompSysHavingSubSys of the current candidate
     |   |   |   |       list entry
     |   |   |   |   find scoring table entry memCompSys =
     |   |   |   |       memCompSysHavingSubSys of the next candidate
     |   |   |   |       list entry
     |   |   |   |   IF ( numberSubSysCandid for current entry <
     |   |   |   |        numberSubSysCandid for next entry )
     |   |   |   |   |   swap positions in the candidate list
     |   |   |   |   ELSEIF ( compScore of current entry < compScore of
     |   |   |   |                                          next entry )
     |   |   |   |   |   swap positions in the candidate list
     |   |   |   |   --------
     |   |   |   --------
     |   |   |   increment to the next memCompSysHavingSubSys down the list
     |   |   --------
     |   --------
     --------
```

```
/*
save the calculated rank of each comparison subsystem candidate
into the system file
*/
maxCompCases <- 0
FOR ( each memSubSysID in the in-memory subsystem table )
|   maxCompSubSys <- 0
|   FOR ( each memCompSysHavingSubSys in comparison subsystem
|         candidates list )
|   |   find system record with sysSubSysID = memSubSysID
|   |   select comparison case with compSysHavingSubSys =
|   |       memCompSysHavingSubSys
|   |   rankOfSubSysCandid <- current position in comparison
|   |                         candidate list
|   |   maxCompSubSys <- maxCompSubSys + 1
|   --------
|   IF ( maxCompSubSys > maxCompCases )
|   |   maxCompCases <- maxCompSubSys
|   --------
--------
End rankScores
```

```
***********************************************************************

    Function name : recordScores

    /* create comparison subsystem candidate list entry */
    memCompSysHavingSubSys <- compSysHavingSubSys
    subSysScore <- the score achieved for the current comparison subsystem

    /* insert new entry into the list */
    FOR ( each entry of the candidate list for memSubSysID = sysSubSysID )

    |   IF ( subSysScore for the new entry >= subSysScore for the
    |                                         existing entry )
    |   |   insert new entry before the existing entry
    |   --------
    --------
    IF ( subSysScore for the new entry was smaller than all existing
         entries )
    |    add the new entry to the end of the list
    --------

    find comparison system scoring table entry with
        memCompSys = memCompSysHavingSubSys
    IF ( no such entry exists )
    |   /* create a new scoring table entry */
    |   memCompSys <- memCompSysHavingSubSys
    |   numberSubSysCandid <- 0
    |   compScore <- 0
    --------

    numberSubSysCandid <- numberSubSysCandid + 1
    compScore <- compScore + subSysScore
    End recordScores
```

```
**********************************************************************

    Function name : reviewComparisons

    WHILE ( True )
    |   /* display the primary comparison case */
    |   FOR ( each sysSubSysID )
    |   |   find comparison case with rankOfSubSysCandid = 1
    |   |   display sysSubSysID and compSysHavingSubSys
    |   |   FOR ( each candidCharactID )
    |   |   |   find characteristic record with characteristicID =
    |   |   |       candidCharactID
    |   |   |   display characteristicName, sysCharactValue,
    |   |   |       comparability, and valueUnit
    |   |   --------
    |   --------
    |   display maxCompCases
    |
    |   tell user that (s)he may accept the primary comparison case,
    |       change the comparison case, or view alternative comparison
    |       cases
    |   SWITCH ( on user's choice )
    |   |
    |   CASE accept primary comparison case:
    |   |   return
    |   CASE change primary comparison:
    |   |   CALL changePrimary
    |   CASE view alternative comparison:
    |   |   IF ( maxCompCases > 1 )
    |   |   |   CALL viewAlternates
    |   |   ELSE
    |   |   |   display message indicating that there are no alternates
    |   |   --------
    |   --------
    --------
    End reviewComparisons
```

```
*********************************************************************

Function name : reviewTraining

display sysOccSpec, sysTroubletime, sysTroubDiffEst, sysRepairTime
   sysRepairDiffEst
FOR ( each sysMnDevice )
|   display sysMnDevice
--------
FOR ( each sysMnOtherEqp )
|   display sysMnOtherEqp
--------
FOR ( each sysOpFunctID )
|   display sysOpFunctID, sysOpHandsOn, sysOpAcademic, sysOpDiffEst
|   FOR ( each sysOpDevice )
|   |   display sysOpDevice
|   --------
|   FOR ( each sysOpOtherEqp )
|   |   display sysOpOtherEqp
|   --------
--------

WHILE ( True )
|   tell user that (s)he may accept the training estimate, or
|       change the training estimate
|   SWITCH ( on user's choice )
|   |
|   CASE accept training estimate:
|   |   return
|   CASE change training estimate:
|   |   tell user to modify sysOccSpec, sysTroubletime,
|   |      sysTroubDiffEst, sysRepairTime, sysRepairDiffEst,
|   |      sysMnDevice, sysMnOtherEqp, sysOpFunctID, sysOpHandsOn,
|   |      sysOpAcademic, sysOpDiffEst, sysOpDevice, or sysOpOtherEqp
|   |   read values modified by user
|   |   record the modifications in the appropriate fields
|   --------
--------
End reviewTraining
```

```
**********************************************************************

     Function name : safelyQuit

     ask user if current system should be saved under the old
         version number or a new version number
     IF ( save under old version )
     |   delete system record with the old version number
     |   change systemName from "temporary" to the actual system name
     ELSE
     |   change systemName from "temporary" to the actual system name
     |   version <- new version number
     |   ask user for a description of the new version
     |   sysDescription <- user's description of new version
     --------
     End safelyQuit
```

```
**********************************************************************

     Function name : selectModelForSystem

     /*
     determine comparison system name to be used as data model for
     this system
     */
     IF ( dataModelForMaint has not been selected )
     |   FOR (each comparison system record )
     |   |   IF ( compSysClassID = sysClassID and compSubClassID =
     |   |        sysSubClassID )
     |   |   |   display the compSystemName and compDescription
     |   |   --------
     |   --------
     |   prompt user to select a comparison system name
     |   dataModelForMaint <- selected comparison system name
     |   dataModelForOpFun <- selected comparison system name
     |   find the comparison system record with compSystemName =
     |       dataModelForMaint
     |   FOR ( each compSubSysID within the comparison system record  )
     |   |   sysSubSysID <- compSubSysID
     |   |   dataModelForSubSystem <- compSystemName
     |   |   subSysIsDefined <- FALSE
     |   |   FOR ( each compCharactID in the comparison system record )
     |   |   |   sysCharactID <- compCharactID
     |   |   |   charactIsDefined <- FALSE
     |   |   --------
     |   --------
     --------

     ask user if (s)he wishes to exclude comparison systems from
         consideration
     IF ( user wants to exclude comparison systems )
     |   WHILE ( user does not ask to quit )
     |   |   prompt user to select a comparison system name from the
     |   |       previously displayed comparison list
     |   |   delete the compSysCandid field containing the selected
     |   |       system name
     |   |   erase the selected comparison system name from the monitor
     |   --------
     --------
     End selectModelForSystem
```

```
**********************************************************************

     Function name : selectReports

     prompt user to choose report formats
     record user format preferences
     prompt user to select the System Model Report, Operator Profile
         Report, Maintenance Profile Report, or Training Estimate Report
     SWITCH ( on user's choice )
     |
     CASE System Model Report:
     |   CALL sysModelRpt
     CASE Operator Profile Report:
     |   CALL OpProfileRpt
     CASE Maintenance Profile Report:
     |   CALL MnProfileRpt
     CASE Training Estimate Report:
     |   CALL trainingEstRpt
     --------
     End selectReports
**********************************************************************
     Function name : sysModelRpt

     To be supplied
     End sysModelRpt

**********************************************************************
     Function name : trainingEstRpt

     print systemName, version, date
     FOR ( each sysSubSysID )
     |   find subsystem record with subSysID = sysSubSysID
     |   print subSysName, sysOccSpec, sysTroubletime, sysTroubDiffEst,
     |      sysRepairTime, and sysRepairDiffEst
     |   FOR ( each sysMnDevice )
     |   |   print sysMnDevice
     |   --------
     |   FOR ( each sysMnOtherEqp )
     |   |   print sysMnOtherEqp
     |   --------
     --------
     FOR ( each sysOpFunctID )
     |   print sysOpFunctID, sysOpHandsOn, sysOpAcademic, sysOpDiffEst
     |   FOR ( each sysOpDevice )
     |   |   print sysOpDevice
     |   --------
     |   FOR ( each sysOpOtherEqp )
     |   |   print sysOpOtherEqp
     |   --------
     --------
     End trainingEstRpt
```

```
************************************************************************

    Function name : viewAlternates

    record that we desire comparison subsystems with a rank of 2
    WHILE ( True )
    |   /* select the next alternate comparison case system */
    |   FOR ( each sysSubSysID )
    |   |   IF ( desired rank > maxCompSubSys )
    |   |   |   find compSysHavingSubSys with rankOfSubSysCandid =
    |   |   |       maxCompSubSys
    |   |   ELSE
    |   |   |   find compSysHavingSubSys with rankOfSubSysCandid =
    |   |   |       desired rank
    |   |   --------
    |   |   display sysSubSysID and compSysHavingSubSys
    |   |   FOR ( each candidCharactID )
    |   |   |   find characteristic record with characteristicID =
    |   |   |       candidCharactID
    |   |   |   display characteristicName, sysCharactValue,
    |   |   |       comparability, and valueUnit
    |   |   --------
    |   --------
    |   display maxCompCases
    |
    |   SWITCH ( on user's choice )
    |   |
    |   CASE view next alternate:
    |   |   increment desired rank by 1
    |   |   IF ( desired rank > maxCompCases )
    |   |   |   tell user we have seen all comparison cases and are
    |   |   |       starting over
    |   |   |   reset desired rank to 1
    |   |   --------
    |   CASE change alternate to primary comparison:
    |   |   CALL makeAltPrimary
    |   |   return
    |   CASE quit:
    |   |   return
    |   --------
    --------
    End viewAlternates

************************************************************************
```

APPENDIX E

TAXONOMIES

APPENDIX E

TAXONOMIES

There are two taxonomies in this Appendix. The first is a taxonomy of classes and subclasses of systems.

Class/subclass

Close Combat Light (Infantry)
Infantry Fighting Vehicles
Antitank Vehicles
Medium Antitank Weapons
Heavy Antitank Weapons
Man-portable Weapons

Close Combat Heavy (Armor)
Tanks
Cavalry Fighting Vehicles

Fire Support (Field Artillery)
Medium Range Missiles
Long Range Missiles
Towed Howitzers
Self-Propelled Howitzers
Rocket Systems
Resupply vehicles

Air Defense
Gun Systems
Line of Sight Missile Systems
Non-Line of Sight Systems
Man-Portable Air Defense Systems

Aviation
Attack Helicopters
Cargo Helicopters
Scout Helicopters
Utility Helicopters
Fixed Wing Aircraft
VTOL Aircraft

Combat Service Support
Light Cargo Trucks
Heavy Cargo Trucks
Recovery Vehicles

Intelligence and Electronic Warfare
- Countermeasures Systems
- Surveillance Systems
- Interpretation and Analysis Systems

Command, Control, Communications
- Fire Control Systems
- Battlefield Management Systems
- Communication Systems

Combat Support--Engineering and Mine Warfare
- Demolition Detection Equipment
- Combat Engineer Vehicles
- Recovery Vehicles
- Bridging Equipment
- Mines and Explosives

OPERATOR FUNCTIONS TAXONOMY

Close Combat Light (Infantry)
<u>Infantry Fighting Vehicles</u>

Plan and prepare mission

Drive vehicle

Navigate

Communicate

Detect/locate/acquire target

Attack target

Defend against attack

Perform reconnaissance

Call for fire support

Transport combat troops and supplies

Perform post-mission tasks

Compensate for equipment malfunctions and emergencies

Close Combat Light (Infantry)
<u>Antitank Vehicles</u>

Plan and prepare mission

Drive vehicle

Navigate

Communicate

Detect/locate/acquire target

Attack target

Defend against attack

Perform reconnaissance

Call for fire support

Perform post-mission tasks

Compensate for equipment malfunctions and emergencies

Close Combat Light (Infantry)
<u>Man-portable Weapons</u>

Conduct pre-operational inspection

Prepare weapon for firing

Emplace weapon/Get into firing position

Detect/locate/acquire targets

Fire weapon

Perform post-firing tasks

Clear/recover from misfire

Close Combat Light
<u>Medium Antitank Weapons</u>

Conduct pre-operational inspection

Prepare weapon for firing

Emplace weapon/Get into firing position

Detect/locate/acquire targets

Fire weapon

Clear/recover from misfire

Perform post-firing tasks

Close Combat Light
<u>Heavy Antitank Weapons</u>

Conduct pre-operational inspection

Prepare weapon for firing

Emplace weapon/Get into firing position

Detect/locate/acquire targets

Fire weapon

Perform post-firing tasks

Clear/recover from misfire

Close Combat Heavy (Armor)
<u>Tanks</u>

Plan and prepare mission

Drive vehicle

Navigate

Communicate

Detect/locate/acquire target

Attack target

Defend against attack

Perform reconnaissance

Call for fire support

Perform post-mission tasks

Compensate for equipment malfunctions and emergencies

Close Combat Heavy (Armor)
<u>Cavalry Fighting Vehicles</u>

Plan and prepare mission

Drive vehicle

Navigate

Communicate

Detect/locate/acquire target

Attack target

Defend against attack

Perform post-mission tasks

Perform reconnaissance

Call for fire support

Compensate for equipment malfunctions and emergencies

Transport combat troops

Fire Support (Field Artillery)
<u>Medium Range Missiles</u>

Prepare for march order

Move to firing point

Navigate

Communicate

Emplace system

Prepare weapon for firing

Fire weapon

Conduct post-firing inspections

Execute "failure to fire" procedures

Compensate for equipment malfunctions and emergencies

Perform emergency destruction of warhead

Displace system

Fire Support (Field Artillery)
Long Range Missiles

Prepare for march order

Move to firing point

Navigate

Communicate

Emplace system

Prepare weapon for firing

Fire weapon

Conduct post-firing inspections

Execute "failure to fire" procedures

Compensate for equipment malfunctions and emergencies

Perform emergency destruction of warhead

Displace system

Fire Support (Field Artillery)
Towed Howitzers

Prepare for march order

Drive/move cannon

Navigate

Emplace cannon

Displace cannon

Prepare cannon for firing

Fire cannon

Fire cannon at direct fire target

Navigate

Communicate

Defend against attack

Compensate for equipment malfunctions and emergencies

Perform post-mission tasks

Fire Support (Field Artillery)
Self-Propelled Howitzers

Prepare for march order

Drive/move cannon

Navigate

Emplace cannon

Displace cannon

Prepare cannon for firing

Fire cannon

Fire cannon at direct fire targets

Fire crew served weapons

Navigate

Communicate

Defend against attack

Displace system

Compensate for equipment malfunctions and emergencies

Perform post-mission tasks

Fire Support (Field Artillery)
Rocket Systems

Prepare for march order

Move to firing point

Navigate

Communicate

Emplace system

Prepare weapon for firing

Fire weapon

Conduct post-firing inspections

Execute "failure to fire" procedures

Compensate for equipment malfunctions and emergencies

Perform emergency destruction of warhead

Displace system

Fire Support (Field Artillery)
<u>Resupply Vehicles</u>

Prepare for march order

Drive/move to weapon site

Drive/move to supply stores site

Navigate

Load/unload stores

Communicate

Defend against attack

Compensate for equipment malfunctions and emergencies

Perform post-mission tasks

Air Defense
Gun Systems

Prepare for march order

Move vehicle

Navigate

Emplace system

Prepare weapon for engagement

Load/reload weapon

Detect/locate/acquire target

Engage aircraft targets

Engage ground targets

Communicate

Defend against attack

Displace system

Perform post-mission tasks

Compensate for equipment malfunctions and emergencies

Air Defense
<u>Line of Sight Missile Systems</u>

Prepare for march order

Move vehicle

Navigate

Emplace system

Prepare weapon for engagement

Detect/locate/acquire target

Engage aircraft targets

Navigate

Communicate

Reload missile launchers

Replenish missile load

Defend against attack

Displace system

Perform post-mission tasks

Compensate for equipment malfunctions and emergencies

Air Defense
Non-Line of Sight Systems

Prepare for march order

Move vehicle

Navigate

Emplace system

Prepare weapon for engagement

Detect/locate/acquire target

Engage aircraft targets

Engage ground targets

Communicate

Reload missile launchers

Replenish missile load

Defend against attack

Displace system

Perform post-mission tasks

Compensate for equipment malfunctions and emergencies

Air Defense
<u>Man-Portable Air Defense Systems</u>

Conduct pre-operational inspection

Prepare weapon for firing

Emplace weapon/Get into firing position

Detect/locate/acquire target

Fire weapon

Clear/recover form misfire

Perform post-firing tasks

Aviation
<u>Attack Helicopters</u>

Plan and prepare for mission

Taxi and takeoff

Fly aircraft to/from mission area

Fly during night conditions

Fly during weather conditions

Manage weight and balance

Navigate

Communicate

Approach and land aircraft

Perform after-landing tasks

Compensate for in-flight equipment malfunctions and emergencies

Detect/locate/acquire targets

Attack target

Defend against ground attack

Defend against air attack

Perform reconnaissance

Call for fire support

Perform post-mission tasks

Aviation
Cargo Helicopters

Plan and prepare for mission

Taxi and takeoff

Fly aircraft to/from mission area

Fly during night conditions

Fly during weather conditions

Manage weight and balance

Navigate

Communicate

Approach and land aircraft

Perform after-landing tasks

Compensate for in-flight equipment malfunctions and emergencies

Defend against ground attack

Defend against air attack

Load/unload internal loads

Raise/lower external loads

Perform paradrop

Rappel troops

Call for fire support

Perform post-mission tasks

Aviation
Utility Helicopters

Plan and prepare for mission

Taxi and takeoff

Fly aircraft to/from mission area

Fly during night conditions

Fly during weather conditions

Manage weight and balance

Navigate

Communicate

Approach and land aircraft

Perform after-landing tasks

Compensate for in-flight equipment malfunctions and emergencies

Detect/locate/acquire targets

Attack target

Defend against ground attack

Defend against air attack

Load/unload internal loads

Raise/lower external loads

Perform paradrop

Rappel troops

Perform reconnaissance

Call for fire support

Perform post-mission tasks

Aviation
Scout Helicopters

Plan and prepare for mission

Taxi and takeoff

Fly aircraft to/from mission area

Fly during night conditions

Fly during weather conditions

Navigate

Communicate

Approach and land aircraft

Perform after-landing tasks

Compensate for in-flight equipment malfunctions and emergencies

Detect/locate/acquire targets

Attack target

Defend against ground attack

Defend against air attack

Perform reconnaissance

Call for fire support

Perform post-mission tasks

Aviation
<u>Fixed Wing Aircraft</u>

Plan and prepare for mission

Taxi and takeoff

Fly aircraft to/from mission area

Fly during night conditions

Fly during weather conditions

Navigate

Communicate

Approach and land aircraft

Perform after-landing tasks

Compensate for in-flight equipment malfunctions and emergencies

Manage weight and balance

Defend against ground attack

Defend against air attack

Perform paradrop

Perform reconnaissance

Perform post-mission tasks

Aviation
<u>VTOL Aircraft</u>

Plan and prepare for mission

Taxi and takeoff

Fly aircraft to/from mission area

Fly during night conditions

Fly during weather conditions

Navigate

Communicate

Approach and land aircraft

Transition between vertical and forward modes

Perform after-landing tasks

Compensate for in-flight equipment malfunctions and emergencies

Acquire targets

Attack target

Manage weight and balance

Defend against ground attack

Defend against air attack

Raise/lower internal loads

Perform paradrop

Rappel troops

Perform reconnaissance

Call for fire support

Perform post-mission tasks

Combat Service Support
<u>Light Cargo Trucks</u>

Plan and prepare mission

Prepare load

Drive vehicle

Navigate

Defend against attack

Compensate for equipment malfunctions and emergencies

Load/unload vehicle

Perform post-mission procedures

Combat Service Support
<u>Heavy Cargo Trucks</u>

Plan and prepare mission

Prepare load

Drive vehicle

Navigate

Defend against attack

Compensate for equipment malfunctions and emergencies

Load/unload vehicle

Perform post-mission procedures

Combat Service Support
<u>Recovery Vehicles</u>

Plan and prepare mission

Drive vehicle to recovery site

Navigate

Position and prepare recovery vehicle

Prepare system to be recovered

Perform recovery

Perform post-recovery procedures

Tow disabled vehicle/equipment

Perform post-mission procedures

Intelligence and Electronic Warfare
Countermeasures Systems

Intelligence and Electronic Warfare
<u>Surveillance Systems</u>

Intelligence and Electronic Warfare
Interpretation and Analysis Systems

Identify key environmental features

Identify key elements of threat force

Identify/select routes

Identify hazards to movement

Identify early warning of enemy threat

Predict enemy vulnerability/strength

Identify targets

Report map changes; update sitmap

Prepare briefings

Fuse multi-source intelligence

Command, Control, Communications
<u>Fire Control Systems</u>

Represent battlefield conditions

Acquire targets

Gather and interpret target information

Predict target behavior

Select and order targets

Select friendly units to engage targets

Manage weapon functions

Compensate for equipment malfunctions and emergencies

Communicate

Prepare briefings

Command, Control, Communications
Battlefield Management Systems

Represent battlefield conditions

Represent status of forces

Project battlefield operations

Project weather conditions

Select and order targets

Manage weapon functions

Plan personnel

Plan logistics

Select friendly units to engage targets

Control friendly forces for offense and defense

Prepare briefings

Command, Control, Communications
Communication Systems

Assemble equipment and antennas

Establish/enter communications network

Transmit and receive messages

Encode/decode messages

Apply transmission/reception security procedures

Apply anti-jamming procedures

Route information

Combat Support--Engineering and Mine Warfare
<u>Demolition Detection Equipment</u>

Plan and prepare mission

Operate detection equipment

Mark danger areas

Perform post-mission operations

Combat Support--Engineering and Mine Warfare
Combat Engineer Vehicles

Plan and prepare mission

Drive vehicle to obstacle removal/breaching site

Navigate

Plan exact approach to accomplish mission

Prepare system hardware for obstacle removal/breaching

Remove/breach obstacle

Perform post-removal/breachment procedures

Compensate for equipment malfunctions and emergencies

Perform post-mission procedures

Combat Support--Engineering and Mine Warfare
<u>Recovery Vehicles</u>

Plan and prepare mission

Drive vehicle to recovery site

Navigate

Position and prepare recovery vehicle

Position and prepare system to be recovered

Perform recovery

Perform post-recovery procedures

Perform post-mission procedures

Combat Support--Engineering and Mine Warfare
<u>Bridging Equipment</u>

Plan and prepare mission

Prepare bridge site

Excavate foundations

Construct bridge abutments

Construct bridge span

Construct/assemble bridge

Prepare bridge and transporter for launching

Launch bridge

Connect bridge

Recover bridge

Disassemble bridge

Perform post-mission tasks

Combat Support--Engineering and Mine Warfare
<u>Mines and Explosives</u>

Plan mission

Conduct pre-operational inspection

Transport explosive or mine

Emplace explosive or mine

Prepare diagram of layout

Arm weapon

Perform post-mission tasks

Working Paper

WP MSG 90-03

HANDBOOKS, GUIDES AND METHODOLOGICAL AIDS FOR THE MANPRINT PRACTITIONER

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Working Paper MSG 87-01

A VISUAL DISPLAY INTERFACE TO MEET COGNITIVE REQUIREMENTS IN TACTICAL OPERATIONS

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(MSG 01-87)

June 1987

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A VISUAL DISPLAY INTERFACE TO MEET COGNITIVE REQUIREMENTS IN TACTICAL OPERATIONS

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Problem Area

The complexity of the modern battlefield has grown enormously, and the amount of information the commander has need for, and can obtain, taxes his cognitive capacity. In addition, the military commander may have to operate in a small mobile environment with information provided him from distributed sources. Under these conditions, how best can his display interface be designed to aid him in conducting effective tactical operations?

The older, classical human factors literature has enabled computer system display designers to attend efficaciously to visual sensory requirements; and some of the more recent literature has enabled them to begin attending to human cognitive requirements. Well organized discussions of such literature are provided by Boff, Kaufman and Thomas (1986), Kantowitz and Sorkin (1983), and Salvendy (1987). As yet, however, the display designers have not addressed comprehensively some important broader aspects of the cognitive domain (e.g., organization of subdisplays for maximum cognitive aiding). This hold-back may have been governed in part by the absence of needed hardware and software state-of-the-art developments. But technology has advanced now to the point where display system hardware/software capability need no longer be a limiting factor. The time has come to make the display system interface cognitively more friendly.

Previous Research

As a starting point for addressing the above problem, a search was conducted of the recent literature relating to the display of information. Because the number of publications dealing with displays (as a general category) is so very vast, this search was restricted to documents that were concerned with visual displays suitable for the presentation of high-density information, and with cognitive aspects associated with the display of such information. Those documents which were judged to touch directly on this problem area have been listed in Appendix A. They have been grouped into five sections. The first (Display Design) is comprised of reports and books which relate in a general or comprehensive way to display design. Aspects receiving major attention include human factors, graphic presentation and overlays, formatting, coding, symbols, and multiwindow and multidisplay presentation. The second section (Tactical Operations) lists publications heavily concerned with the visual display of information in tactical operations and battlefield management. The third section (Decision Support Systems) lists publications dealing with the problem of aiding a user with computer supported programs which utilize aspects such as artificial intelligence, expert systems, and rule-based systems. The fourth section (Cognition and Models) includes publications primarily concerned with human memory. The fifth section (Organization of Information and Data Bases) deals with software concerns in display presentation. While a number of the publications have aspects that relate to more than one of the above five categories, each has been listed only once (in the section which was judged to be most representative of its thrust).

An examination of the literature listed in Appendix A reveals a very comprehensive data base for the sensory aspects of display design, and a good grounding for many of the cognitive aspects. The evolvement of display designs in high-density information environments seems, however, to be modeled too much in terms of computer system organization and too little in terms of human cognitive requirements. Perhaps a display interface can be developed which helps to reduce in a greater measure the short-term or working memory demands made of a stressed battlefield commander, and also permits him to readily reformulate his hypotheses when needed for redirection of military action.

Perceptual and Cognitive Limitations and Strengths

Before proposing a generic tactical display design for military commanders, let us examine briefly some cognitive and perceptual factors involved. Since human information processing requires memory, every effort must be made to avoid overloading it, particularly during emergency and threat situations. In its simplest form, human memory has been modeled as being comprised of three subsystems: sensory memory, short-term or working memory, and long-term memory. (For a more detailed overview of human information processing and cognition see Wickens (1987).) The sensory storage system holds information provided by the sense organs. This information is stored for a brief time (in the case of vision it is less than one second) after which if it doesn't enter short-term or working memory, it is totally lost. Information which has been transferred to working memory, however, can be retained for a longer period (about 15 seconds depending on circumstances). Also, working memory can be refreshed by rehearsing the information originally transferred to it. Thus effort and capacity is required for maintaining information in the working memory. On the other hand, when information is transferred to long-term memory, it is there forever; but retrieving it may become a problem. Furthermore, information in long-term memory must be transferred back into working memory before it can be utilized. Attention is another aspect which interacts with the operation of the working memory. On the basis of this model for human memory and the research supporting it, one would infer that a battlefield commander's performance could be improved if his tactical display interface were designed to reduce the capacity requirement for his short-term or working memory.

Addressing display interface design from another direction, we note that at the present time there are a number of tasks which the human can perform better than the computer. For example, after examining the human factors literature, Shneiderman (1987) developed a list of capabilities in which the human excelled the machine. He judged the human to be better at:

Sensing low level stimuli

Detecting stimuli in noisy background

Recognizing constant patterns in varying situations

Sensing unusual and unexpected events

Remembering principles and strategies

Retrieving pertinent details without a prior connection

Drawing upon experience and adapting decisions to the situation

Selecting alternatives if the original approach fails

Reasoning inductively and generalizing from observations

Acting in unanticipated emergencies and novel situations

Applying principles to solving varied problems

Making subjective evaluations

Concentrating on important tasks when overload occurs

Adapting physical responses to changes in situation.

But to utilize his superior capabilities, the human must be provided with a suitable display interface, one in which the configuration and organization of the presentation permits ready and direct access to the information. In addition, this information needs to be given at a time period and in a manner that enables the human to obtain a rapid understanding and use of it.

Some Current Display Design Approaches

Of necessity, the development of display interfaces has been constrained by what hardware and software can provide. Initial displays were low-resolution, primitive alphanumeric presentations of computer processing. With progress in the state-of-the-art, human interfaces to computer displays could be made more friendly. Color graphics were developed to integrate information presentation and to provide spatial orientation where needed. Then complex symbolic graphic and alphanumeric overlays were introduced. Cluttered displays of inadequate resolution resulted; and thus where much data were needed, sequential call-up of alternative and additional "pages" were provided. This mode of presentation heavily taxed the user's memory. Another development was windowing, the grouping of related information in a specific display area so there could be a simultaneity of presentation for several groupings. Also, decision support systems were developed to automate selected tasks, in order to aid the user and/or reduce his workload.

The direction of these developments shows a primary concern with memory overload of the user. However, a bias of the computer systems designer remains. Regarding parsimony of presentation, he develops his display interface with an unconscious modeling of the human as if he had the capabilities of a machine. The inclusion of coherent redundancy may be of great utility in human information processing.

Proposed Enhancement of the Display Interface

Developments in displays and associated computer hardware/software state-of-the-art has reached the point where full color displays of extended visual area can be provided at near video rates. Using multiple screens, a visual subtense of 120 degrees by 90 degrees can be presented with resolution approaching 4,000 by 3,000 pixels. (This is compatible with an eye resolution of about 2 arc minutes.) Such display interfaces could be miniaturized, when so required, and viewed with optical aiding; in which case it is estimated that they would be no larger than about 12 inches wide, by 9 inches high, by 12 inches deep (i.e., less than one cubic foot in volume). They could thus be integrated into an armored vehicle, or even placed in a jeep. To support such an expanded display configuration, the electronic cabling and computer processors planned for military vehicles that are currently on the drawing boards need also to be designed now, so they will be potentially capable of meeting this type of requirement.

The major reasons for proposing this display interface concept are: to reduce the demand on the military commander's short-term or working memory capacity; and to permit him to perform readily and easily such key functions as monitoring, using his stand-by skills, overriding automated recommendations, and signing-off on instructions and orders.

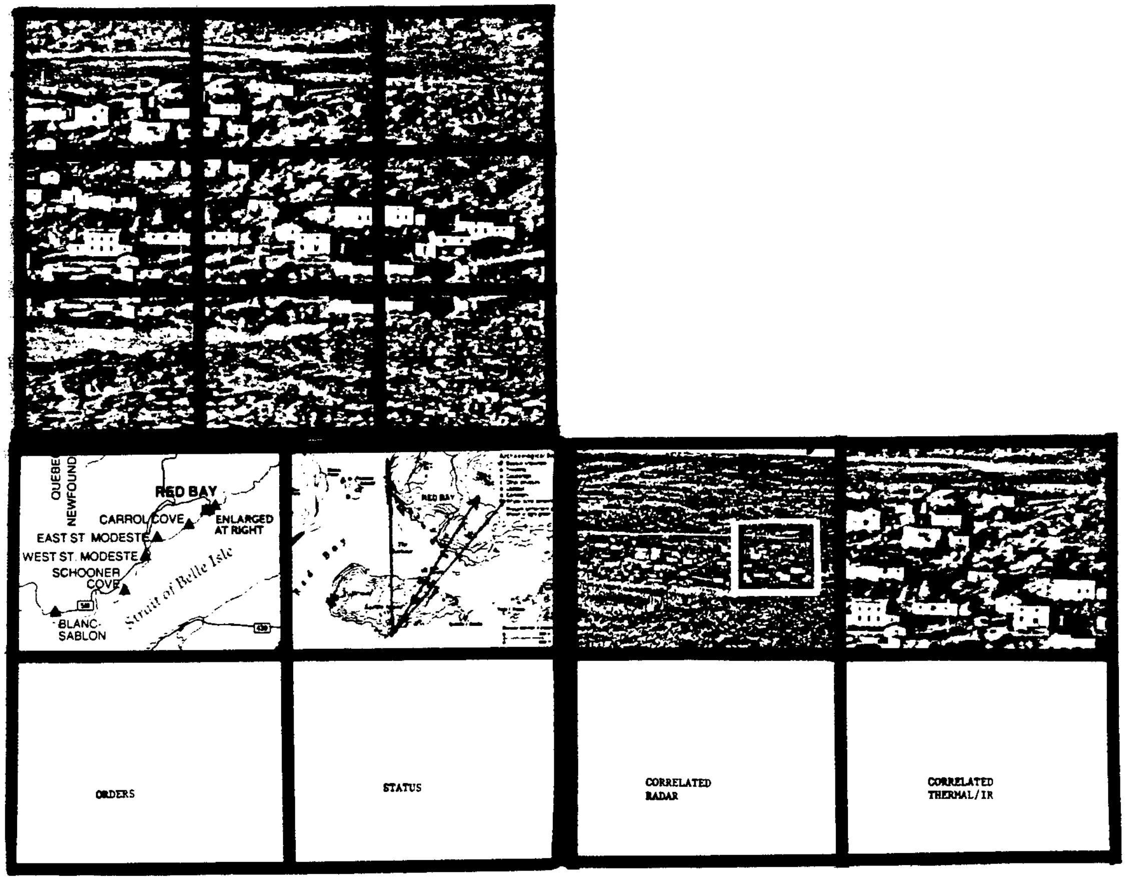
Using only one mode to provide information may not suffice. A human often needs to combine redundant and complementary information, sometimes obtained from several modes of presentation. For example, in an office environment people working at their desks "simultaneously" examine different kinds of information (images, data and text) in order to arrive at their decisions or accomplish their task. To emulate this in a computer supported system requires a display interface which simultaneously presents multiple images from various data bases. So too in the military environment a display configuration is required which permits a "natural" acquisition and processing of information, in order that there be timely, comprehensive situation understanding and decision making. Processor and sensor advances have created an overload of such magnitude that users have become unable to directly cope with the information provided. Computer supported real-time advisory systems can help, as can the integration of the critical information in a display window. But when the volume of related information becomes vast, color graphics, spatial organization, overlays, highlighting, coding and similar procedures for the integration of information in a single window may not be practical. In addition, in the distributed battlefield where the commander may be operating in an isolated work environment, he needs display outputs that can stimulate his development of alternative courses of action.

The amount of information which needs to be presented simultaneously and the manner in which it is presented should be governed by such factors as human comprehension rate, display access time and the characteristics of human perception. If the user is permitted to view at will the aspects of interest to him in a visually expanded multidisplay presentation by merely directing his gaze, the capacity requirement for his working memory is greatly decreased. He need do no rehearsing for retention and may even reduce the amount of information that he must transfer to his long-term memory. The human may also be helped in situation understanding and in performing tasks such as those listed on page 5 if the presentation includes partially redundant, coherent subdisplays.

The concept of an expanded visual display interface comprised of a number of partially redundant and cognitively coherent subdisplays which can be visually accessed at will is generic. Specific display content, however, is task and situation dependent. An illustration of what can be provided to a military commander is shown and described in Figure 1. (Please note that for the situation presented in this figure, the display subtense is even less than that proposed in the first paragraph of this section.)

In summary, this paper outlines a generic concept for a technologically feasible, expanded, computer supported, tactical display interface that is judged to be capable of reducing the memory workload of the military leader (whether he commands a small or a large unit) and aids his thinking and problem solving skill, has utility as an adaptive information system interface, and can potentially be mounted in a small, isolated working environment.

STORED IMAGERY DISPLAY



TACTICAL OPERATIONS DISPLAY

REAL-TIME DISPLAY

Figure 1
A Concept for a Display Interface for the Battlefield Commander

The total display is comprised of three sections, each subtending 40° horizontally and 30° vertically. The presented displays are meant to be illustrative only. The upper left section presents previously obtained reconnaissance imagery of an area of interest, selected by the commander, plus the surrounding eight neighboring images. These scenes have a 25% overlap. The lower left section is concerned with tactical operations. Starting at the upper left and going clockwise: the first sub-display provides input to the commander, using maps and graphics to give him processed combat information; the second is commander generated, also uses maps and graphics, and concentrates on the commander's sector of responsibility; the third lists the status of equipment and personnel; and the fourth presents incoming and outgoing orders. The lower right section presents real-time sensor information. Starting at the upper left and going clockwise: the first sub-display shows live video of his sector of responsibility and outlines a portion of the scene which he selects to view in magnification on the second sub-display; the third shows correlated thermal/IR imagery; and the fourth presents a correlated radar display.

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APPENDIX A

RECENT LITERATURE RELATING TO THE DISPLAY OF TACTICAL INFORMATION

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Working Paper

WP MSG 91-01

CONSIDERING WORKLOAD PROBLEMS FOR OPERATIONAL CREWS OF A TWO-MAN TANK

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OCTOBER 1990

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CONSIDERING WORKLOAD PROBLEMS FOR OPERATIONAL CREWS OF A TWO-MAN TANK

by
Jonathan Kaplan

This paper considers some issues related to workload problems for operational crews of a two-man tank. Among them are:

+ Determining the functions of each member of two-man tank crew.

+ Identifying the tasks required by each of these functions.

+ Identifying the types controls and displays required by each task.

+ Identifying the type of hardware and software that is appropriate for each control and display.

It is the position of this paper that the logical first element is to allocate functions and tasks on some reasonable basis to each of the two members of the crew. Such allocation can be made using a workload analysis. However, workload itself is dependent upon the way the two-man tank is expected to be used. Therefore, more than one type of workload analysis would have to be made. The following is a description of issues to be considered in such analyses.

The worst operational workload problems of a two-man tank will take place <u>during</u> combat, not between combat events.

In combat the most basic performance division for a tank is stationary vs. on-the-move. Stationary combat is likely to produce more accurate gunnery, but it requires higher quality armor. Combat on the move will exacerbate workload problems of limited crew sizes, because the driver will be fully engaged in driving and will not be available for other significant duties. No automatic driving technology can be predicted in the reasonably near future.

If one assumes combat from a <u>stationary</u> tank, then a relatively low technology situation becomes possible. That is, the driver can assume the tasks of a 3- and 4-man crew's tank commander. Thus problems of radar and computer assistance move. It is unlikely that a platoon commander could perform command and control tasks adequately in the highly focused environment of case (b). This further suggests case (a) as the preferable alternative. However, if the workload in case (a) is critically high when the platoon commander tasks are added, it may be necessary to call for special equipment in the form of a platoon commander's computerized assistant. This leads to the conclusion that some or all of the following situations be modelled: a two-man tank that engages the enemy -

(1) only while stationary and with no additional computerized aids.

(2) on the move and with no additional computerized aids.

(3) on the move, according to case (a).

(4) on the move, according to case (b).

(5) on the move, with no additional computerized aids and while serving as the platoon commander's tank.

(6) on the move, according to case (a) and while serving as the platoon commanders tank.

(7) on the move, according to case (b) and while serving as the platoon commander's tank.

Both HEL and ARI have methods (CREWCUT and MAN-SEVAL) that should be of some use in doing a workload-based allocation. Both methods are based upon simulation modelling. Both methods require the development of a model of the two-man tank that includes task identification, task sequences, probabilities of task sequences, and task performance measures. It appears to be plausible for either or both methods to be used. If both methods are used, their outputs can be compared. However, it is suggested that MAN-SEVAL is less stringent in its requirements and perhaps should be used at the concept design stage, while CREWCUT is used following the development of a detailed design. Both methods should share a common model of the two-man tank to the extent that the methods allow this. To do modelling, relatively detailed data must be available. However, it is not certain at this writing where these data will come from.

There are at least <u>some</u> possible data sources:

1- Subject Matter Experts filling in forms or being interviewed.

2- Similar systems.

Working Paper

WP MSG 90-11

A CONCEPT FOR THE INSTITUTIONALIZATION OF HARDMAN III

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Background

HARDMAN III is a family of six software modules created for the purpose of helping the Army plan, forecast and manage manpower, personnel, and training resources during the acquisition of new weapon systems. The modules are designed to be used together and will be distributed in a single package of six Bernoulli cartridges (or in a box of 312 diskettes). However, each module has its own purpose, and the anticipated using organizations are likely to employ some of the modules far more frequently than others. The six modules are named below, and their relationship is illustrated schematically in Figure 1.

1. SPARC: System Performance and RAM Criteria

2. M-CON: Manpower Constraints Aid

3. P-CON: Personnel Constraints Aid

4. T-CON: Training Constraints Aid

5. MAN-SEVAL: Manpower System Evaluation

6. PER-SEVAL: Personnel System Evaluation

Objectives

The overall objective of the proposed effort is to get HARDMAN III methods (as embodied in ARI software) used in the Army. Supporting objectives are to minimize the time required for the institutionalization, and to make the process of institutionalization as painless as possible.

Applicable General Principles

To get people to use your products, you have to understand what is likely to motivate them to do so. People are

HARDMAN III

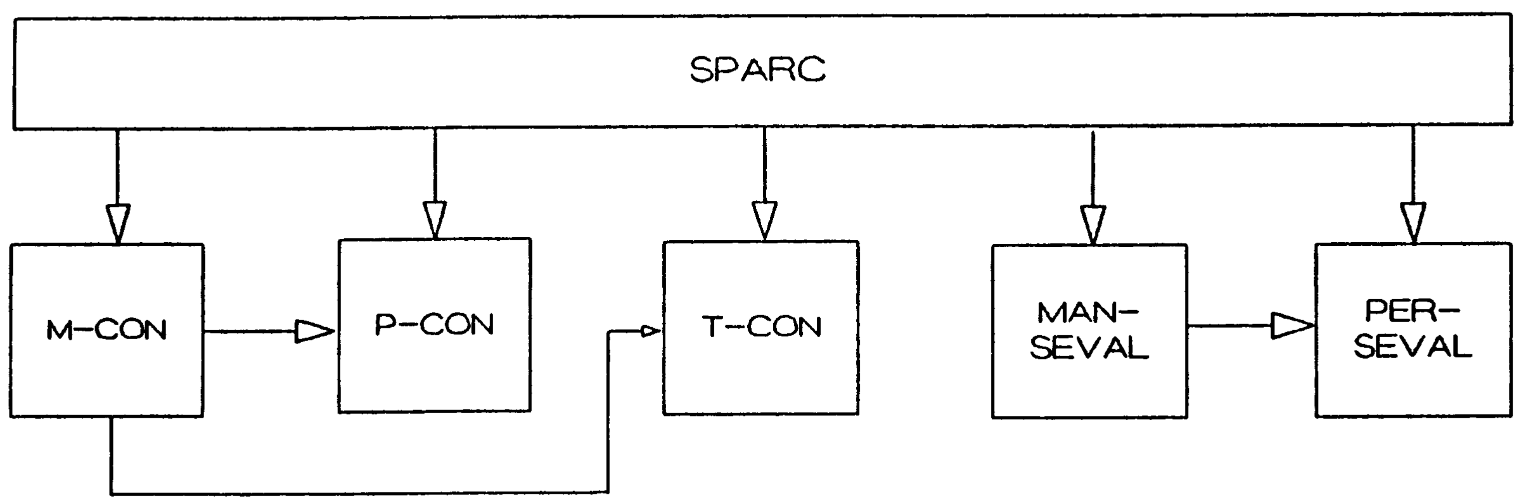

Figure 1. Schematic of Modules in HARDMAN III

motivated to use a new method for one or more of the following reasons:

1. The output of the method is required for them to do as part of the job that they must do, and is:

   a. more accurate;
   b. more justifiable;
   c. more nearly what their job requires;
   d. easier to produce;
   e. quicker to produce;

than that currently available to them.

2. The output of the method is interesting to them and enables them to do something they wanted to do, but they could not do before in an adequate way.

3. Using the method is intrinsically interesting, or has some reinforcing qualities.

4. They are ordered to use it by their manager(s) and cannot easily get out of it.

Managers order people to use a new analytical method for one or more of the following reasons:

1. They believe that the method's output leads to success of their project and, therefore, reward for them. This means that the method must produce output that looks like the type of material that the manager, himself, believes is related to project success.

2. Using the method does not use up time and dollar assets that are thought to be better spent elsewhere in the project (i.e., the costs of using the software are outweighed by the benefits flowing from its use).

3. They were ordered to do so by their manager(s) or by a regulation that is enforced.

In the ideal situation, the method to be marketed would be able to provide most of the above motivators. However, even if this were the case, different users and managers are rewarded by different subsets of motivators. Therefore, the marketing approach to each organization should be influenced by an understanding of:

1. The relationship between the method's output and the function of that organization.

2. The set of motivators that is likely to apply to the organization and individual being briefed.

Identification of Potential Users

In general user organizations fall into two categories:

1. Weapon system oriented;
2. Functional analysis oriented.

Weapon system-oriented organizations that are potential users of the Hardman III methods include:

1. TRADOC Combat Development Centers at individual schools.
2. PERSSOs working for ODCSPER.
3. PM staffs working for AMC.

Analysis-oriented organizations that are potential users of HARDMAN III methods include:

1. TRAC
2. TEXCOM
3. OTEA
4. ARI
5. HEL
6. CSERIAC
7. USAPIC
8. CAA
9. LOG Center
10. ODCSPER MANPRINT Office
11. AAMSA
12. Hq DA Office of Chief of Staff for Plans, Analysis and Evaluation (PA&E).
13. MRSA

Analysis of Requirements of Potential Users

1. General Principles.

The weapon system oriented organizations tend to be motivated by orders from managers plus ease and cheapness of use in concert with passing over required hurdles. The analysis-oriented organizations tend to be more motivated by accuracy, justification, and interest; but they also are motivated by ease, cheapness and orders. The common elements here are ease, cheapness and orders. That suggests that in marketing any organization at any level, ease, cheapness and orders from authority should be emphasized.

Ease and cheapness are related to how much time is required to produce desired outputs, and how much difficult cognitive work is required during that time. During marketing, if it appears to users or managers that unacceptable amounts of time or cognitive difficulty are required, negative decisions can be expected. If users or managers see that HARDMAN III does many things in which they are not interested, they are likely to assume they will have to do these additional things. This will raise their estimate of time and complexity to an unrealistic level.

Therefore, it is desirable to market those parts of HARDMAN III that produce the specific outputs desired by a given organization, and to refer to the other parts, but not market them unless significant interest is shown.

In addition, ease and cheapness are partly a function of easy availability of data. HARDMAN III methods come with data libraries, but they do not come with data libraries for all Army systems. <u>Only those organizations, for which HARDMAN III has applicable data should be marketed.</u>

In its developmental phase, data bases are incomplete. Potential users of HARDMAN III methods are likely to respond in an unfavorable way if data for their class of Army systems is not present, even if told that it will be available in the near future. <u>It is hard to recover from unfavorable attitudes.</u>

Therefore, the nature of the marketing of HARDMAN III methods should be affected by both the requirement for the output of specific methods and the presence of applicable data in those methods in the following manner:

a. Determine the output of interest for the given organization.

b. Market only the method(s) that produce that output.

c. Determine whether the method(s) to be marketed have data appropriate to the specific organization to be marketed at the time of marketing.

d. If adequate, appropriate data are present, discuss the immediate use of the method(s) and negotiate immediate sending of the method(s).

e. If adequate, appropriate data are not present, show the method(s); provide probable date(s) for data base completion. Discuss what users and ARI could do with the method(s). Do not leave the method(s). <u>Do not make offers that cannot be fulfilled.</u>

2. The Top-Down Approach.

The necessity for orders from authority within the Army suggests that general officers will have to issue the orders. This suggests that high level members of their staffs will have to be marketed, and convinced of the desirability of using HARDMAN III (or the parts of it that pertain to their organization) instead of whatever their present procedures are. To be convincing, it will be necessary to show them that switching to HARDMAN III will lead to success, as they define it, without unacceptable costs. The definition of success is specific to the organization being marketed. This suggests the following strategy.

a. Identify a target general officer. The ideal general officer is one who controls the largest number of target organizations and is known to be open to new ideas.

b. Determine what that officer and his staff consider to be success. This may be different from one organization to the other, if that officer and staff control more than one target organization.

c. Prepare a briefing. If the state of data and software development allows, this should include a demonstration of one method (per briefing) that is thought to be of the greatest interest to this organization. This briefing should include an example that is specific to the interests of that general officer, if possible. However, using an example has great dangers that are as great as rewards. If any data or outcomes are shown that are plainly wrong, the audience will focus on these errors and will have great difficulty separating the utility and goodness of the method from the errors of the users of the method. Therefore, never do a realistic demonstration for this type of audience without having all aspects of the example studied and agreed to by military subject matter experts with specific knowledge of this domain.

3. The Bottom-Up Approach.

Once you have orders from above to use a method, the bottom up audience will want to be briefed to find out the extent of the damage that will be done to them. They will assume the worst. If you can show them that a method they are being ordered to use is more useful to them, the difference be-tween their expectation and reality will have a very posi-tive impact on the chances that they will use it. This means, that you have to know what it is they do at a fairly high level of detail so that you can show them that the method can do it: faster, cheaper, better, more justifiably, in a more interesting way, etc.

It is very unlikely that the first version of any method will be without significant flaws, or that it will do everything that its users want of it. That is why all successful software goes through multiple versions. When software only goes through one version, it is because nobody bought it, and it died. The best source of this improvement information is the user community. Further, if users believe that there will be multiple versions, and that their input will have an effect on future versions, they will be more likely to want to use the version they have. Therefore, this should be explained to them in any briefing or demonstration.

The kind of demonstration that one gives users usually is different from that given to a manager. Users want to know what they will have to do to use a method, in detail. Managers usually focus on the output and costs, but not on the specific work required. This means that significant amounts of time have to be allocated for demonstrations to potential users. It also means that one should probably not demonstrate more than one method per session. If more than one method is demonstrated to users in a given session, they will confuse the methods later on. They will think the level of required work is higher than it is, and they will forget how the methods work. This suggests the following strategy:

a. Identify an organization that has been ordered to use one or more HARDMAN III methods.

b. Identify that part of the organization that is supposed to output the same sort of material that one or more HARDMAN III methods output. Then, identify the manager in charge of that part of the organization.

c. If possible, get a member of the staff of the signer of the order to contact the identified manager to tell him or her to prepare for one or more required briefing(s) and demonstration(s). If this is not possible, contact the manager. Refer to the order (if possible), and set up the briefing(s) and demonstration(s). It may be necessary to offer to brief some staffers first. However, when scheduling the briefing and demonstration for users, make sure to leave at least one full session for any given method. One session should be at least half a day. No more than one session should be attempted in any given day. If users are to be given hands on access, a full day is likely to be needed per session.

d. Do not attempt a demonstration of software for users unless you have data that is applicable to their function. Some users will be able to see that the method is useful apart from the absence of data. Many others will not be able to do this, and you will lose them.

e. If possible demonstrate a realistic example of the use of a method that these users would do, themselves. Be very careful to make sure that you don't say anything in this example that appears to be "incorrect". Some of the user audience will fasten on it, and you will lose them. To avoid this problem, it is best to have a military subject matter expert scrub the example before you give it.

f. Many of the HARDMAN III methods have two modes of operation--an easy one and a detailed, harder one. Always start off with the easy one. Do not show the harder one until the audience understands what the easy one is, and that the harder one is an option. If the audience confuses the two modes of operation, they will think they will have to do more work, and you will lose many of them. With most users audiences, it is vital to stress the ease of use (especially as compared to their present procedures). In almost all audiences, there will be a few individuals who are interested in how the method works, internally, and any more rigorous version of the method. Unless this represents the majority view, hold answers to such questions until after you have finished briefing the easiest version. Do not talk about the more rigorous method until you are reasonably sure that the audience understands the easy version.

Proposed General Strategy

We can respond to the above analysis by -

a. Releasing prototype software (minus data bases) to ARI field units. Train the field unit personnel to be able to train personnel at the post they are supporting.

b. Developing a training plan and schedule (see below) for MSG personnel to train personnel in organizations not supported by an ARI field unit.

c. Releasing replacement disks for the various software modules as the prototypes are improved and data bases are added (Fall, 1990).

d. Scheduling refresher training in Alexandria periodically for personnel who have been trained on the original prototype software.

e. Training potential users of HARDMAN III modules outside of ARI only after the data bases in which they would logically be interested have been added.

Administrative and Logistical Requirements

If an audience cannot see what is being demonstrated, there is little purpose in the demonstration. If HARDMAN III method demonstrations are to be performed for an audience of more than three people, there must be some mechanism for them to read the screens. The only such mechanism known is an appropriate computer plus an appropriate monitor that can be attached in some manner to a projection device.

In general, it is unsafe to assume that a working, appropriate computer will be available. Further, last minute loading of software into strange computers often results in failure. It would be greatly preferable to take a fully-loaded and tested portable computer to the demonstration site. Such a computer should have the following characteristics:

1. Portable.
2. Full screens can be displayed.
3. Enhanced graphics capability.
4. At least an 80286 processor installed.
5. A math coprocessor installed.
6. At least one 30MB hard disk installed. However, if more than one method is to be demonstrated during a given marketing trip, the computer must have a Bernoulli interface card (and associated software) installed. In this relatively high probability case, a 40MB Bernoulli Box must be taken as well.
7. All config.sys, autoexec.bat, and Bernoulli software drivers installed and tested.
8. All HARDMAN III software and data to be demonstrated installed and tested.
9. The capability of connecting to an available projector (or, if we doubt one will be available on-site, taking one of our own).

It is even less likely that an appropriate projector will be available at the demonstration site. This means that one should be taken that is known to function adequately with the computer being taken. The projector should have the following characteristics:

1. Portable.
2. Capable of interfacing with computer to be used.
3. Capable of projecting full screen.
4. Capable of projecting in true color.
5. If possible, capable of projecting enhanced graphics.
6. Two extra light bulbs and an extension cord.

Proposed Personnel

Effort Coordinator:	Charles Holman
Trainers:	Ray Sidorsky (Lead for SPARC, MAN-SEVAL, PER-SEVAL)
	Judah Katznelson (Lead for M-CON, P-CON, T-CON)
Technical Adviser:	Jonathan Kaplan

Proposed Schedule

1. General Considerations.

For scheduling to be supportive of the Institutionalization of HARDMAN III rather than undermining it, it must be credible; that is, consistent with the realities of the contracts which are providing the products to be marketed:

a. The HARDMAN III (six products) program is scheduled for completion at the end of September, 1990. There is much understandable desire for early marketing and use of these products. As a result of this desire, it is possible to estimate a delivery of useful prototypes in June, 1990. (This estimate is not without risk: Typically, software is not really in good shape until 3-6 months after its final delivery date which, in this case, is the end of September 1990. It must be assumed that, in June, some software bugs and database errors will be present in some or all of the six products. It is also possible that some functionality will not have been completed for PER-SEVAL.)

b. All HARDMAN III products have been designed to be self-training to the extent possible. The training medium is detailed context-sensitive help screens. These screens are under development, but they will not be available before June. Therefore, development of any training materials focused on use of the modules themselves (as opposed to audience preparation) before the delivery of the help screens is premature and is likely to result in significant user frustration.

c. Some data have already been entered into the first five modules of HARDMAN III for the purpose of exercising the software and aiding MSG in performing a limited number of analyses in support of the original PEO-HFM efforts. Comprehensive, checked databases will not be available prior to June. It is assumed that they will be available in June, but that errors will continue to be discovered until the final delivery date. Therefore, marketing and training that require the existence of completed, checked databases will not be possible until Fall, 1990. However, some top-down marketing and familiarization (rather than training) will be possible prior to June.

d. Current status.

(1) The SPARC, M-CON, P-CON and T-CON modules have completed function testing. However, in their present form, they cannot exchange data, read data from other sources, copy analyses to diskettes, or be updated.

(2) The MANSEVAL and PERSEVAL modules are still under original development.

2. Proposed Schedule for Top-Down Marketing Events.

Objective: Getting order(s) requiring the use of HARDMAN III methods in the accomplishment of established functions.

Date	Event
22-26 Jan	Staff draft MoA's at TRADOC Hq and ODCSPER
29 Jan - 2 Feb	Prepare and deliver briefings as required to support attainment of MoAs.
5-9 Feb	Identify appropriate organizations from whom to get orders requiring methods use.
12-16 Feb	Make contacts with appropriate staff officers, and make dates to brief them.

20-23 Feb	Determine exactly what ARI wants general officers' orders to their subordinates to say, and prepare a briefing to persuade them to issue those orders.
26 Feb - 2 Mar	Brief staff officers and make appointments to brief general officers.
5 Mar - ?	Brief general officer(s) as to what we will provide, and the nature of the order(s) we need from them in order for their use of HARDMAN III to be successful.

3. Proposed Schedule for Bottom-Up Marketing Events.

Objective: Excite the interest of user personnel in trying out specific modules of HARDMAN III in the normal conduct of their present duties.

Date	Event
29 Jan - 16 Feb	Prepare procurement document for two demonstration portable PCs, Bernoulli boxes, interface cards, projectors and 150 Bernoulli cartridges (25 users x 6 cartridges each).
20-23 Feb	Identify which SRL organizations (MSG or FUs) will have responsibility for briefing and training each of the users identified on page 4 above. Identify the individuals within each identified SRL organization who will be primarily responsible for the briefing and training of each user.
5-9 Feb	Software familiarization for MSG Trainers (Prototype M-CON)
12-16 Feb	Software familiarization for MSG Trainers (Prototype P-CON)
20-23 Feb	Software familiarization for MSG Trainers (Prototype T-CON)
26 Feb - 2 Mar	Software familiarization for MSG Trainers (Prototype SPARC)
5-9 Mar	Software familiarization for MSG Trainers

(Prototype MAN-SEVAL)

12-16 Mar	MSG Trainers prepare briefings on capabilities of HARDMAN III
18 Jun	Receive initial version of completed software and data bases for SPARC, M-CON, P-CON, T-CON and MAN-SEVAL
19-29 Jun	Exercise completed software and data bases in MSG; identify and correct errors
5-13 Jul	Trainers prepare lesson plans for training users in SPARC, M-CON, P-CON, T-CON and MANSEVAL
16-20 Jul	MSG review of proposed training
23-27 Jul	Training Trip: Ft Bliss FU (Sidorsky)
23-27 Jul	Training Trip: Ft Rucker FU (Katznelson)
30 Jul - 3 Aug	Training Trip: Ft Knox FU (Sidorsky)
30 Jul - 3 Aug	Training Trip: Ft Sill (Katznelson)
6 Aug	Receive initial version of completed software and data bases for PER-SEVAL
7-10 Aug	Exercise completed software and data bases for PER-SEVAL in MSG; identify and correct errors
8 Aug	Training Trip: MANPRINT Office, ODCSPER (Holman, Sidorsky)
8 Aug	Training Trip: USAPIC (Holman, Kaplan)
13-17 Aug	Trainers prepare lesson plans for PER-SEVAL
20-24 Aug	Training Trip: Ft Leavenworth FU (Sidorsky)
20-24 Aug	Training Trip: TRAC-BH (Katznelson)
27-31 Aug	Training Trip: Ft Hood FU (Sidorsky)
27-31 Aug	Training Trip: MRSA (Katznelson)
4-7 Sep	Training Trip: CAA (Holman, Kaplan)
4-7 Sep	Training Trip: LogCen & ALMC [Include summary of MANCAP II] (Katznelson, Maisano)

10-14 Sep	Training Trip: AMSAA (Holman, Kaplan)
17-21 Sep	Training Trip: OTEA (Holman, Katznelson)
24-28 Sep	Training Trip: PA&E, HqDA (Holman, Sidorsky)
2 Nov	Receive final versions of all software and data bases
5-9 Nov	Proof-test final versions of HARDMAN III in MSG
15 Nov	Mail replacement Bernoulli cartridges or sets of diskettes to HARDMAN III users

Working Paper

WP MSG 90-01

USING BLUEPRINT OF THE BATTLEFIELD TO ASSIST THE MATERIEL DEVELOPERS

JUDAH KATZNELSON

JANUARY, 1990

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Introduction and Background

The Army uses lists of functions and tasks as a starting point for evaluating and developing doctrine, training, organizations, and materiel as parts of the Concept Based Requirements System (CBRS). These lists describe the combat activities performed by Army soldiers, systems, or units. As a result, these lists provide a basis for establishing the performance requirements necessary for the successful execution of Army missions or operations. While many such lists have been prepared to support specific analytic efforts, no common framework of combat functions and generic tasks has been established to aid these efforts.

The Blueprint of the Battlefield (Blueprint, for short) is a comprehensive hierarchical listing of Army battlefield functions and generic tasks. The Blueprint serves as a common reference system for field commanders, combat developers, analysts, and planners to analyze and integrate the actions the Army performs in combat. Each element has been defined and arranged hierarchically according to seven major functions occurring on the battlefield, performed by the force, to execute operations. These seven functions called "Battlefield Operating Systems" (BOSs) are: maneuver, fire support, air defense, command and control, intelligence, mobility and survivability, and combat service support (See Figure 1). BOSs should not be confused with Army branches or proponents. Despite the familiar branch-oriented terminology of the seven BOSs, each BOS includes functions performed by many segments of the force. Elements of the force are responsible for performing functions in several or all of the BOSs in the execution of assigned missions. The BOSs are areas of responsibility a force has with respect to accomplishing its mission. The Blueprint, while originally designed for use in combat development studies, is applicable to materiel development studies and to other types of analyses as well. Since the Blueprint provides standard definitions for battlefield functions, it can be used to assist in the development of materiel, doctrine and training. (See Appendix A for a graphic representation of Blueprint.)

Discussion

This paper will discuss the use of Blueprint of the Battlefield as a tool to assist the materiel developer during the weapon system acquisition life cycle. By using Blueprint, Army managers can increase the probability of understanding potential performance trade-offs and ramifications early in the development cycle, thereby saving resources and insuring a better product for our soldiers in the field.

The focus of this paper will be restricted to discussing some (and by no means all) of the design characteristics of the

BLUEPRINT OF THE BATTLEFIELD

HOW IT'S ORGANIZED -

The Blueprint is arranged according to seven Battlefield Operating Systems (BOSs)

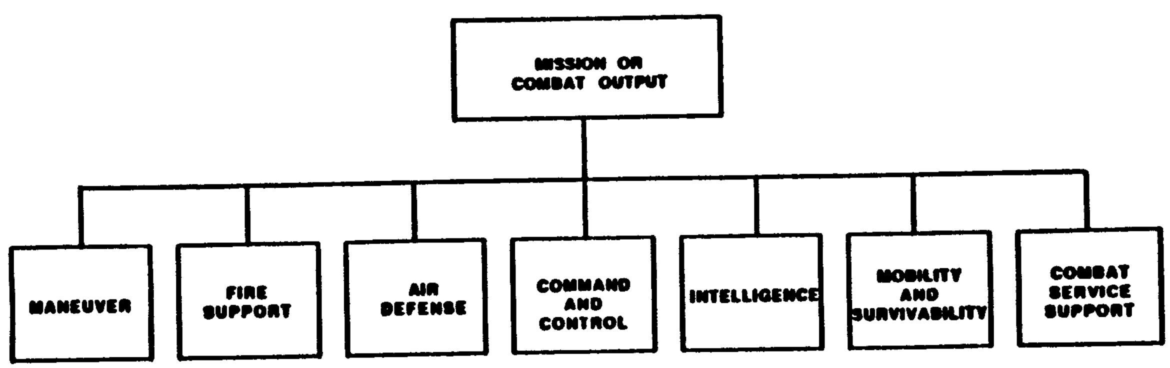


Figure 1

Non-Line of Sight (NLOS) Fiber Optic Guided Missile System (FOG-M) and Future Armored Combat System (FACS). As a variant of the Heavy Force Modernization program, FACS is intended to be the Army's main battle tank and the follow-on to the Abrams tank.

The use of Blueprint by the materiel developer provides a number of advantages in the early and mid-stages of a weapon system's life cycle:

a. The functional structure of the Blueprint provides a means for examining all types of missions and operations in terms of the same basic elements. This promotes a combined arms perspective for the integration of battlefield requirements and capability issues. That is, the analysis of each battlefield function can consider alternative means (i.e., weapon systems, units) for achieving the same result on the battlefield.

b. The Blueprint maintains its functional character for several levels of detail below the BOSs. These functions specify what the force does on the battlefield. Battlefield functions can, in turn, be decomposed into generic tasks.

c. The hierarchical format of the Blueprint in a straight-forward way of breaking the BOSs down into more specific functions and eventually into tasks. This provides its own subset of advantages:

(1) At the upper levels, the Blueprint provides a concise picture of the major combat activities of the force. At the lower levels, the Blueprint provides increasingly greater detail on what the force must do to accomplish its missions.

(2) The meaning of each function in the Blueprint is elaborated by the functions subordinate for it.

(3) By design, each function in the Blueprint appears only once. While the titles of some functions from different BOSs do resemble one another (e.g., Process Direct Targets - Maneuver BOS and Process Air Targets - Air Defense BOS), the definitions of these functions clearly distinguish them.

(4) The hierarchical structure is modular. If the unit or force being analyzed does not perform a given function within a particular scenario, that function is discarded without disrupting the rest of the structure.

(5) The hierarchical structure supports prioritization of functions at all levels of the Blueprint. This is due to the fact that each function in the hierarchy helps define the functions immediately above it. As a result, any function or generic task can be traced vertically through the hierarchy to

determine its contribution to higher level functions and to mission success.

Ideally, and for maximum benefit, Blueprint should be accomplished as a two-step process (See Figure 2). Initially, an analysis of each function and task under each BOS should be undertaken to understand the "intra-action" between that particular function or task and whether it is applicable to the particular weapon system being developed. The analysis should be conducted simultaneously with design of hardware components of a manned system so that the system performance requirements for operations, maintenance and support occasioned by that design can be identified. For example, one of the features being considered for FACS is the use of embedded training which would build into the operational system the capacity to enhance and maintain the skill proficiency to operate and maintain the weapon system. The materiel developer would begin with the first BOS (Maneuver) and review the definition of this BOS and the definitions of each function and task under this BOS. As the analyst moves through the Maneuver BOS, he would come across "Move Through Air" (1.1.1.3), realize that this particular event is not applicable to the FACS, and discard this item from embedded training considerations (See Figure 3). When all of the functions and tasks under that BOS have been accounted for, the analyst would go on to the next BOS. Upon reaching the Combat Service Support BOS and considering the Fix (7.3) function and the Fix/Maintain Equipment (7.3.2) task, the relationship of embedded training to these events should cause the analyst to consider the implications that arise when these three factors play against one another. Since the embedded training delivery system will use the FAC's actual displays, controls, power sources, etc., the wear-out rates will rise, causing increased maintenance times, system down time and supply requirements (See Figure 4). At this point, the consideration of embedded training for the FACS has produced logistical and maintenance issues that need to be fully addressed so as to provide Army management as complete a picture as possible of design alternative implications. These events can be specified using the Blueprint and should be specified down to a level of detail no greater than is necessary to meet the requirements of the users of that report. Where reasonable, each interactive cycle of the hardware and software design, should have corresponding changes made to the Blueprint report.

Secondly, an "inter-BOS" analysis should be completed so that each BOS function and task is grouped with each other BOS function and task (See Figure 5). After discarding those functions and tasks that are not appropriate to the particular weapon system, a list should be prepared of all functions and tasks within these particular BOSs that operator, maintenance and support personnel must perform. By pairing and grouping the various BOS elements, certain potential implications may surface and highlight additional concerns that should be addressed.

BLUEPRINT METHOD OVERVIEW

BLUEPRINT was Applied in a Two Step Process:

1. **Intra-BOS Analysis -** pairs each function and task within a particular BOS with the new design feature or technological change in the weapon system being developed.

2. **Inter-BOS Analysis -** groups each new design feature or technological change with each BOS function and task and then with each other BOS function and task.

Figure 2

INTRA-BOS ANALYSIS

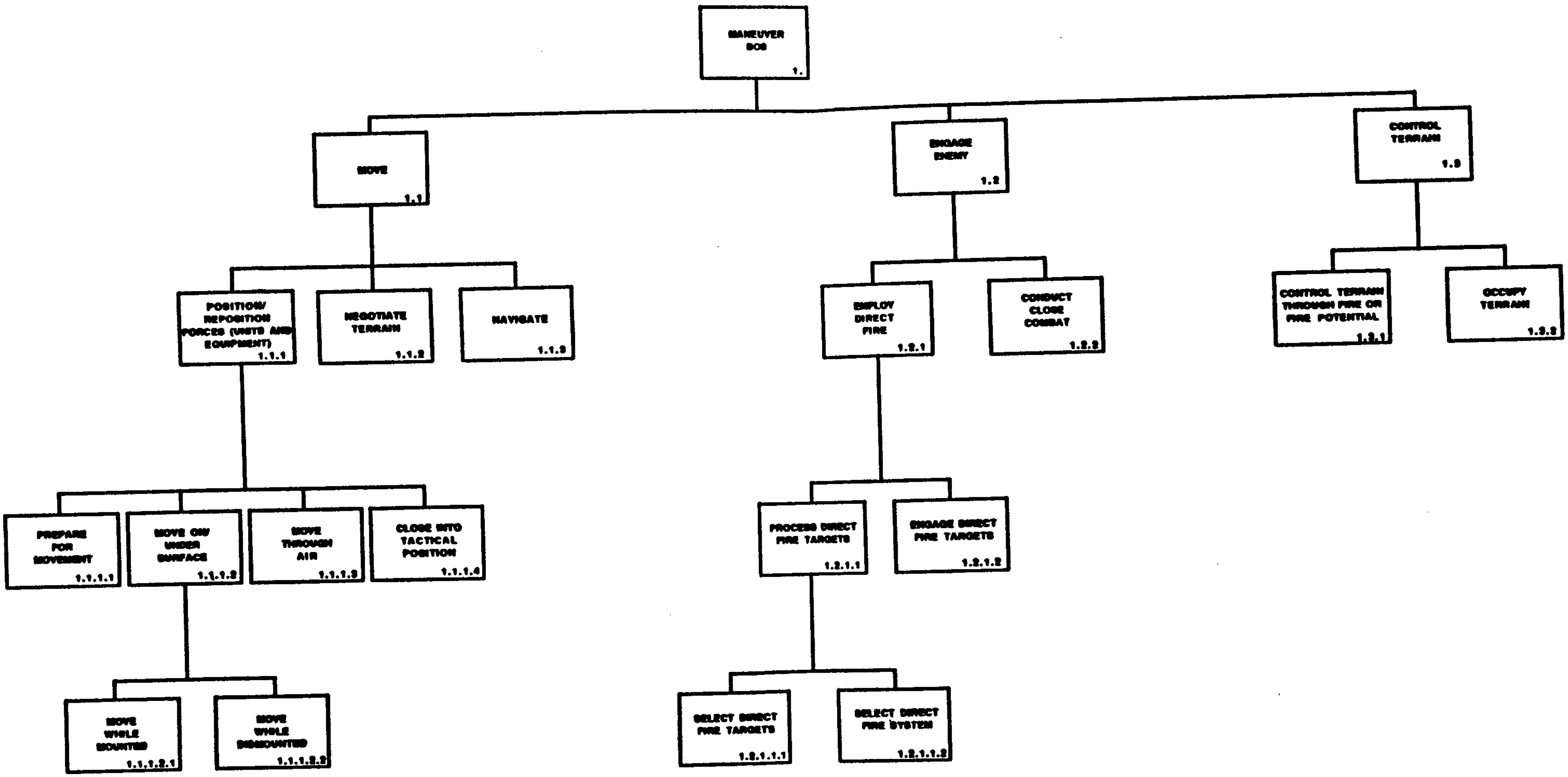


Figure 3 **Maneuver BOS.**

BLUEPRINT METHOD OVERVIEW

INTRA-BOS ANALYSIS

Method	Example
1. Choose design feature or technological change.	1. Embedded training
2. Determine whether a particular function or task is applicable.	2. Use of the "Arm" function (7.1) under The Combat Service Support BOS is not applicable.
3. Systematically pair features or changes with each function and task within a particular BOS.	3. The embedded training feature and the Fix/Maintain Equipment function (7.3.2) have a direct and mutual effect upon each other.
4. Perform analysis to ascertain implications for materiel developer.	4. Since the embedded training delivery system will use the FACS actual displays, controls, power sources, etc., the wear out rates of the components will rise causing increased maintenance times, system down times and supply requirements.

Figure 4

BLUEPRINT METHOD OVERVIEW

INTER-BOS ANALYSIS

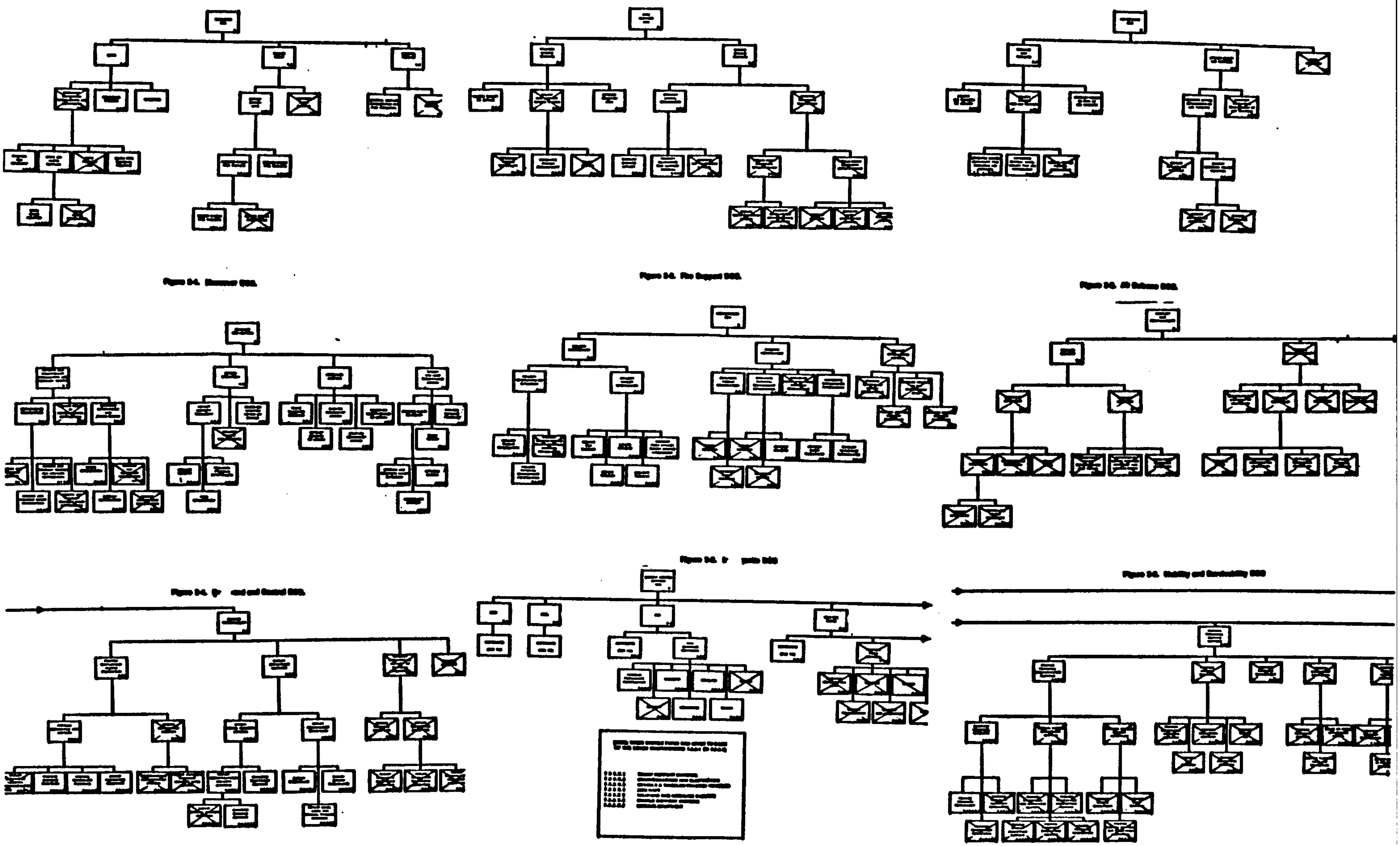


Figure 5

For example, as we are focusing on the Combat Service Support BOS and its Provide Personnel Service Support (7.4.3) function as it relates to the other BOS elements during a FACS analysis, we are introducing additional elements into the equation, examining them, discarding them if they are inappropriate, or noting them if they raise legitimate issues. When we pair the Mobility and Survivability BOS function entitled "Provide Battlefield Hazard Protection" (6.3.1) with Provide Personnel Service Support and relate both of them to embedded training, we are left with a concern that may have been overlooked had not Blueprint been used. Personnel service support includes the skills and aptitudes that the soldiers bring with them to the job. The intensity of training, the length of training, the difficulty of assigned tasks, etc. all bear upon the choice of which soldiers should be assigned to which weapon systems. Battlefield hazard protection includes protecting friendly forces and equipment from enemy fire. One obvious way to accomplish this is to arm them and allow friendly forces to return fire. When we combine these two elements with embedded training we need to keep in mind that our soldiers will be using the very same equipment to fight and train. The soldier will have the capability of using the FACS in the training mode via computer display simulation or the battle mode firing live rounds. Therefore, it becomes imperative that the soldier chosen for that system be able to switch easily from one mode to the other as directed by changing battlefield conditions and that a fail-safe system be developed that guarantees the soldier's awareness of which mode the FACS was employing (See Figure 6). Once again, the consideration of embedded training for the FACS has produced an issue that needs to be fully addressed to provide Army management as complete a picture as possible of design alternative implications. (NOTE: A chart of additional FACS concerns can be found in Appendix B.)

Another example of this type of interactive BOS analysis can be shown using the NLOS FOG-M system. The NLOS FOG-M is a fiber optic cable guided missile system that can engage stationary and moving line and non-line of sight targets. It has a moduler, vehicular mounted, precision guided, light and heavy anti-armor and anti-helicopter missile system design (See Figure 7). The missile is launched vertically and then programmed to pitch over to level flight (See Figure 8). The low cost seeker mounted in the nose of the missile sends pictures of the battlefield to the gunner via a bi-directional fiber optic data link. A bobin located in the rear allows the fiber optic cable to play out like a fishing line off of a spinning reel. The gunner can survey the battlefield, select a target and activate the automatic tracker, or, if preferred, manually fly the missile to the target. Built-in flight recording devices allow the gunner to perform reconnaissance and damage assessment as well (See Figure 9).

By using the same procedure as first demonstrated for the FACS, Army managers can increase the probability of understanding

BLUEPRINT METHOD OVERVIEW

INTER-BOS ANALYSIS

Method	Example
1. Choose design feature or technological change.	1. Embedded training.
2. Determine whether a particular function or task is applicable.	2. Use of "Provide Field Services" (7.4.2) under Combat Service Support BOS is not applicable.
3. Systematically pair features or changes with each function and task within a particular BOS.	3. The "Provide Personnel Service Support" function (7.4.3) includes the skills and aptitudes of soldiers which influences the required level of embedded training.
4. Pair features or changes with one BOS and then systematically group these elements with each other BOS function or task.	4. Grouping the two elements above with "Provide Battlefield Hazard Protection (6.3.1) task causes a new concern to surface.
5. Perform analysis to ascertain implications for materiel developer.	5. Soldiers will use same equipment to train and fight. It is imperative that soldier be able to switch easily from training mode to battle mode and vice versa. Fail-safe system must guarantee soldier's awareness of which mode was being employed.

Figure 6

CONCEPT OF FOG-M SYSTEM

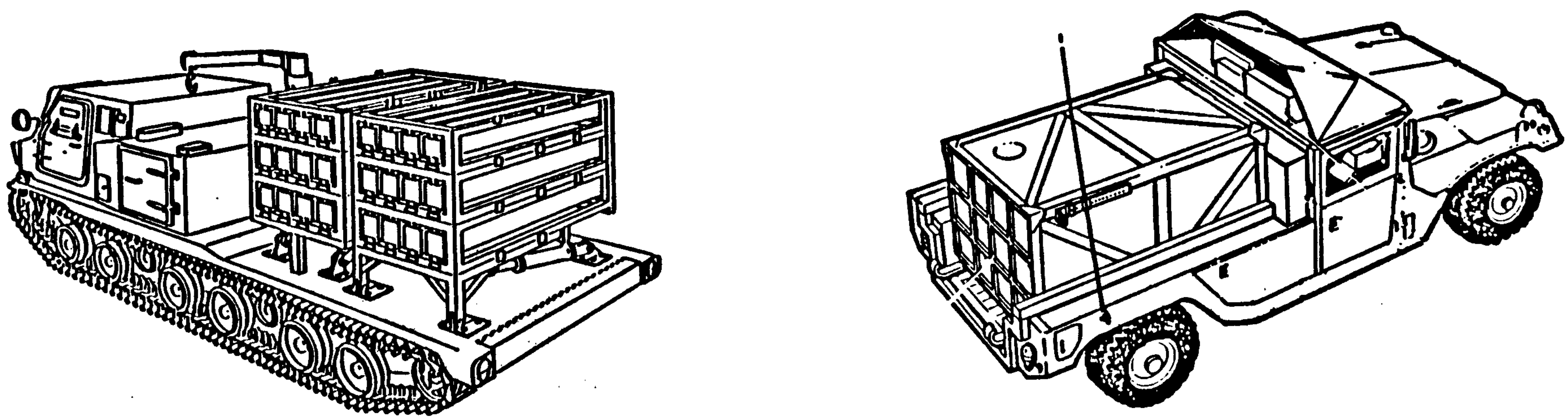


Figure 7

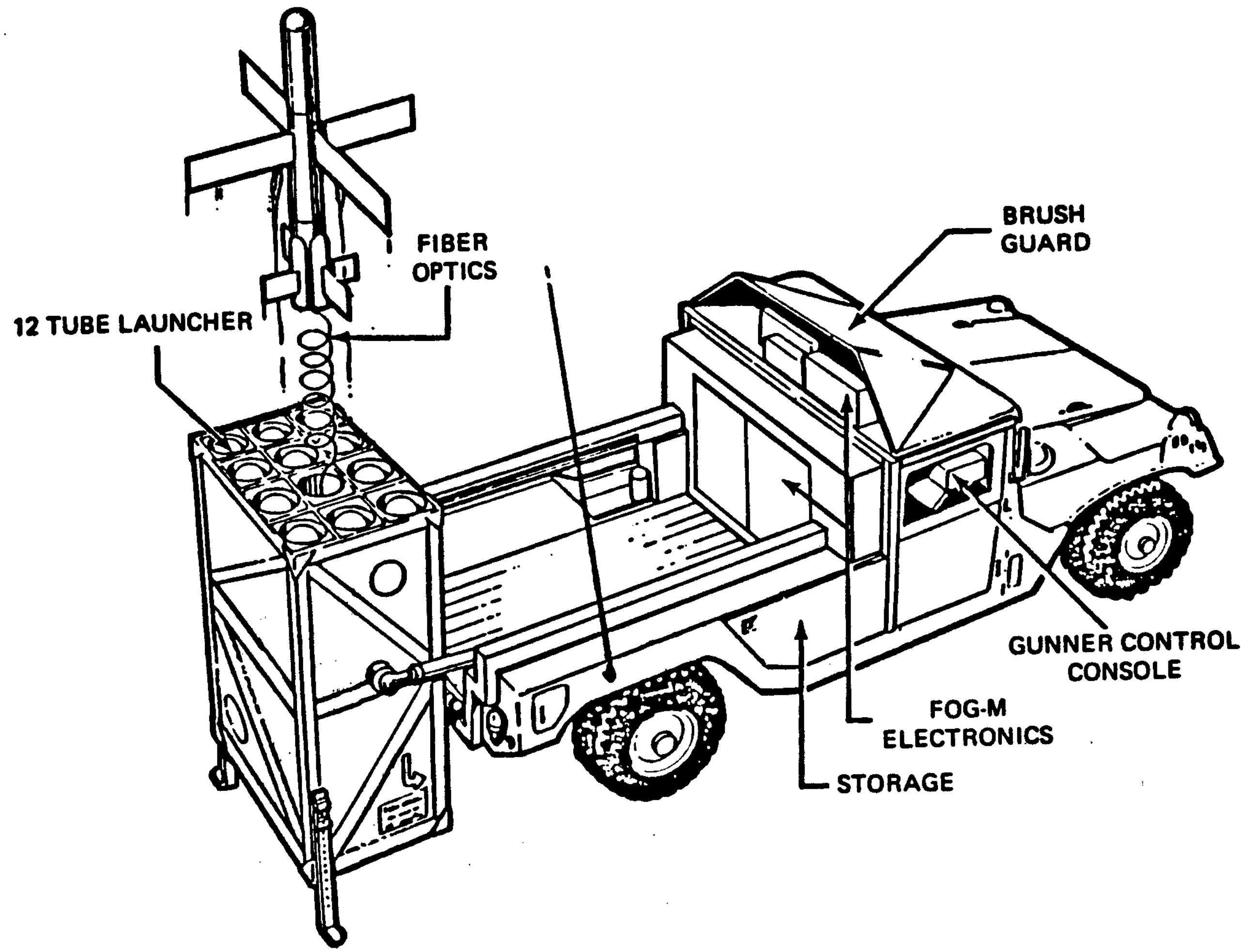

FIBER OPTICS
12 TUBE LAUNCHER
BRUSH GUARD
GUNNER CONTROL CONSOLE
FOG-M ELECTRONICS
STORAGE

Figure 8

FOG-M System Generic Mission

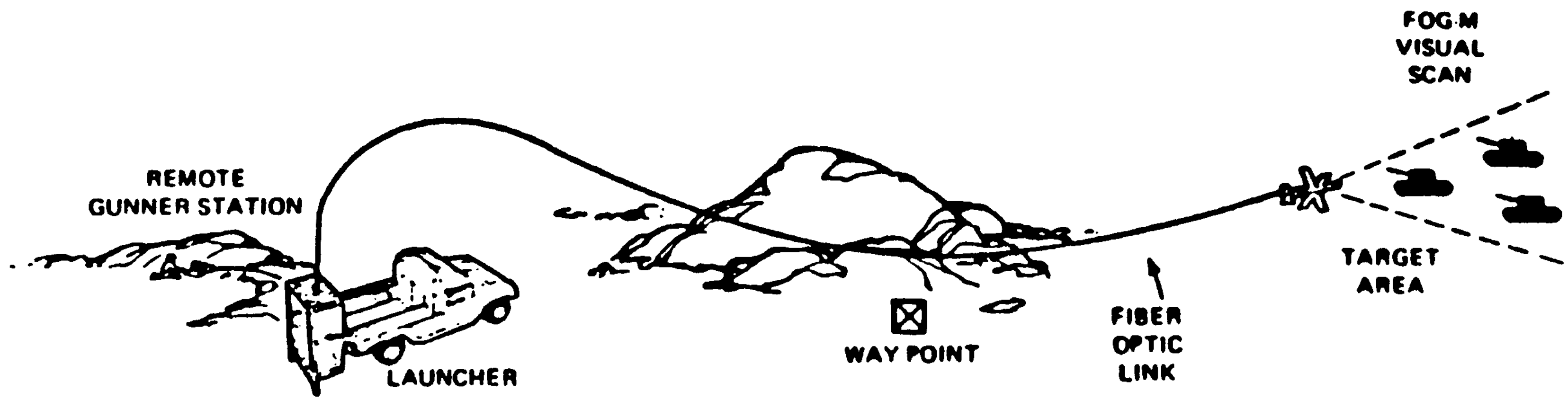


Figure 9

potential performance trade-offs and ramifications early in the development cycle. (See Appendix C: Implications for the FOG-M as a Result of Blueprint of the Battlefield Analysis.)

The product of these analytic efforts can be used in the system acquisition process in support of equipment design, testing and evaluation planning, training requirements identification, manning and workload assessment, and other documentation and reporting. In addition, it will support a wide range of Logistic Support Analyses (LSA) requirements.

Summary

The Army, in order to accomplish its mission of preparing for war, must conduct studies to assess the capability of the Army to execute its missions. Analyses performed by the materiel developer should begin with the functions and tasks performed by a force or unit that pertain to the problem under consideration.

The hierarchical structure of the Blueprint permits a top-down prioritization of functions with respect to a mission. This structure provides a rational basis for making comparisons of Blueprint elements, supports mathematical methods for assigning relative weights to functions and tasks, and eliminates overlooking critical capabilities or double counting others. The Blueprint supports the analysis of competing solutions to operational effectiveness issues by providing a linkage between capabilities or means (i.e., candidate solutions) and ends (i.e., mission success). Functions do not imply a specific means for meeting battlefield requirements and therefore do not bias the search for the best solution.

Major studies, like mission area analyses, involve multiple branches or proponents. An important goal is to integrate the capabilities of the participants during the course of a study. This integration is important because, whereas the capabilities of an individual branch or proponent may be inadequate, the collective capabilities of the Army may be sufficient to support the execution of the Army's missions. Capabilities that enable the performance of a given battlefield function are identified from all contributing branches or proponents and linked to the Blueprint at the generic task or subfunction level. While one branch or proponent may identify a battlefield weakness in performing a function, an Armywide weakness cannot be confirmed until the capabilities of the entire force are aligned with that function. The force's capabilities can then be examined to verify the existence of battlefield weaknesses, identify opportunities to exploit threat vulnerabilities, and offer alternative solutions (existing, planned, or feasible). When used, the Blueprint can assist materiel developers in their efforts to put quality equipment into the hands of our soldiers.

APPENDIX A:

BATTLEFIELD OPERATING SYSTEMS (BOS)

IN

BLUEPRINT OF THE BATTLEFIELD

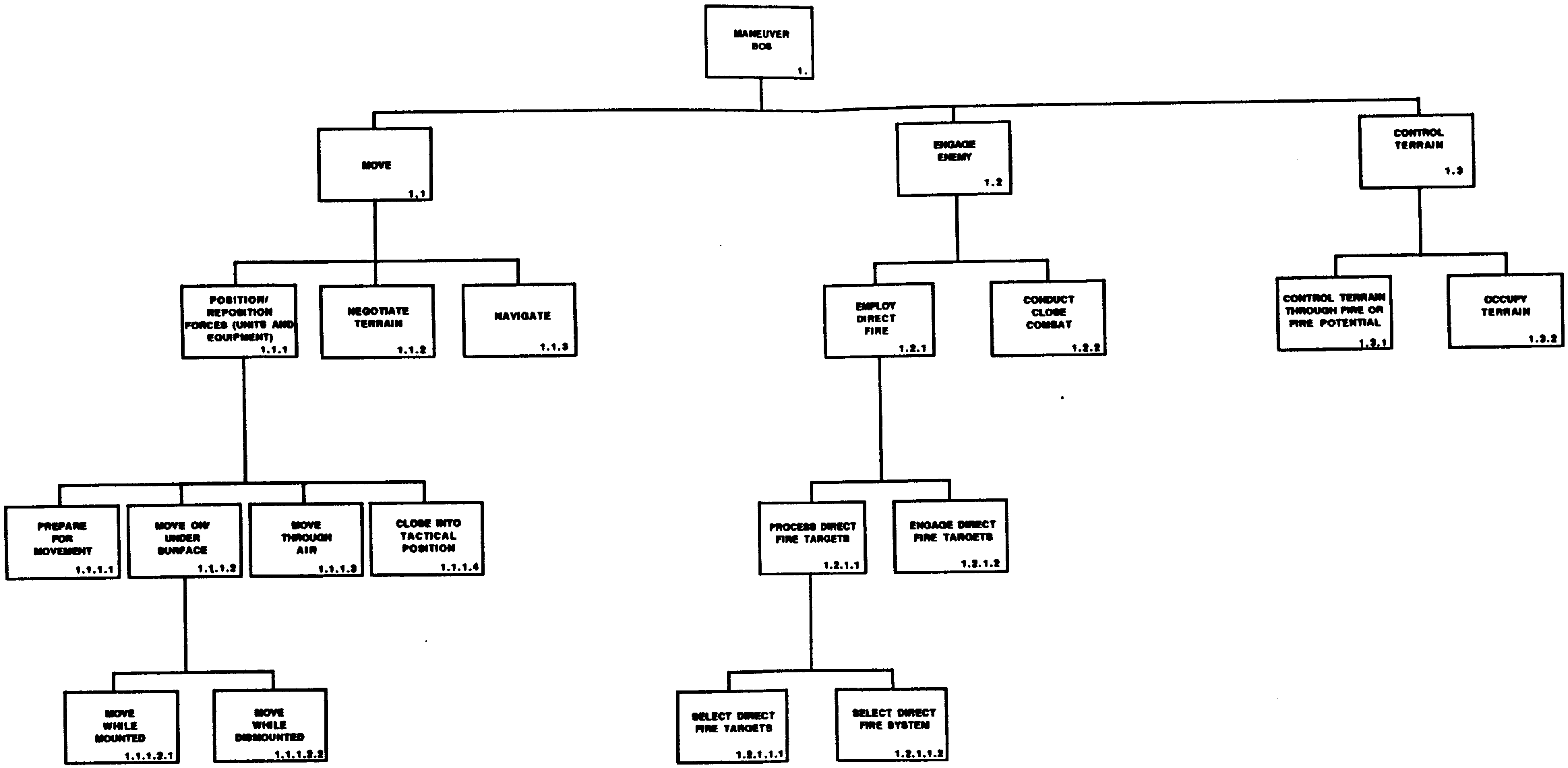


Figure A-1 **Maneuver BOS**

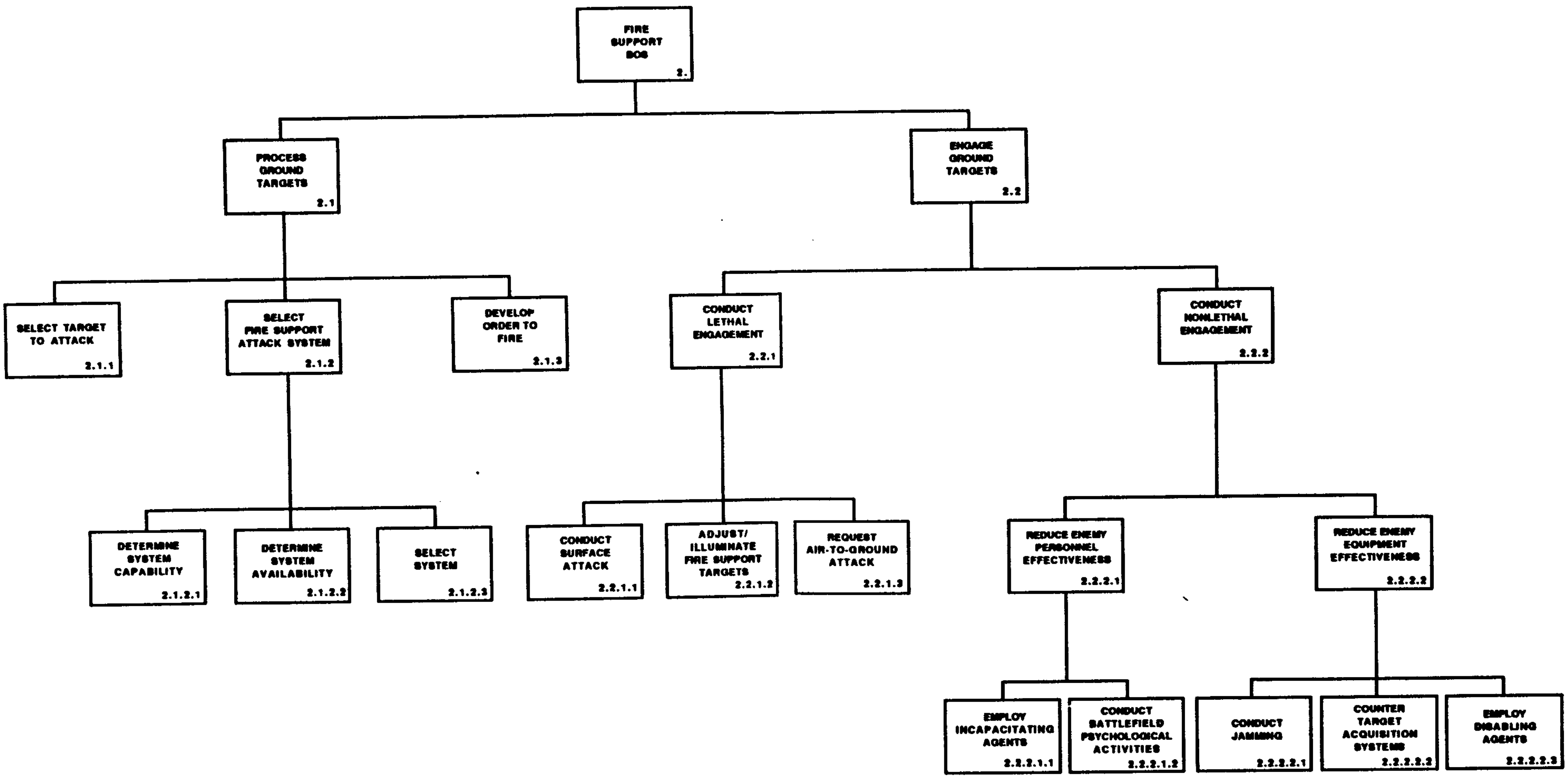


Figure A-2 Fire Support BOS

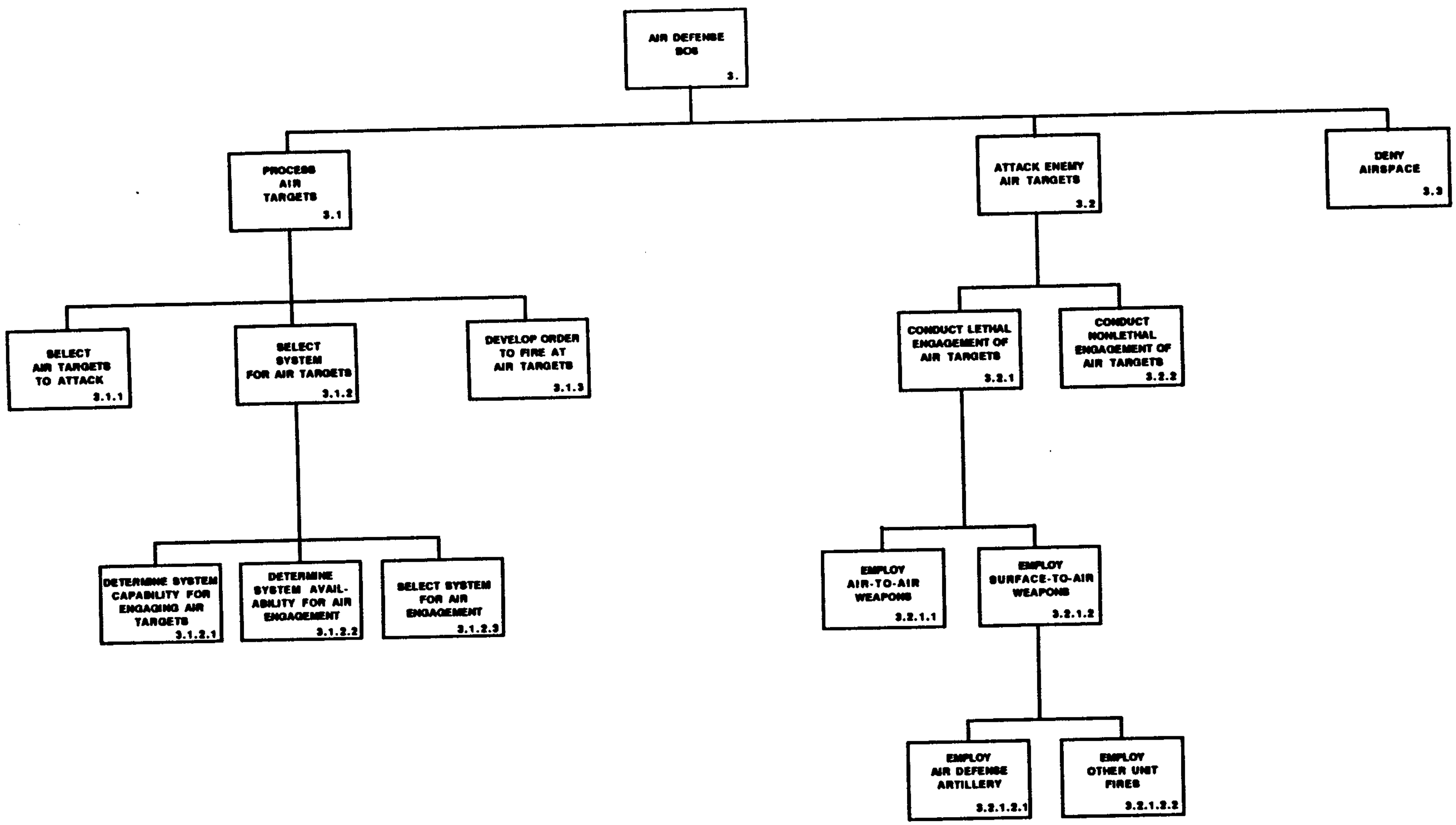


Figure A-3 Air Defense BOS

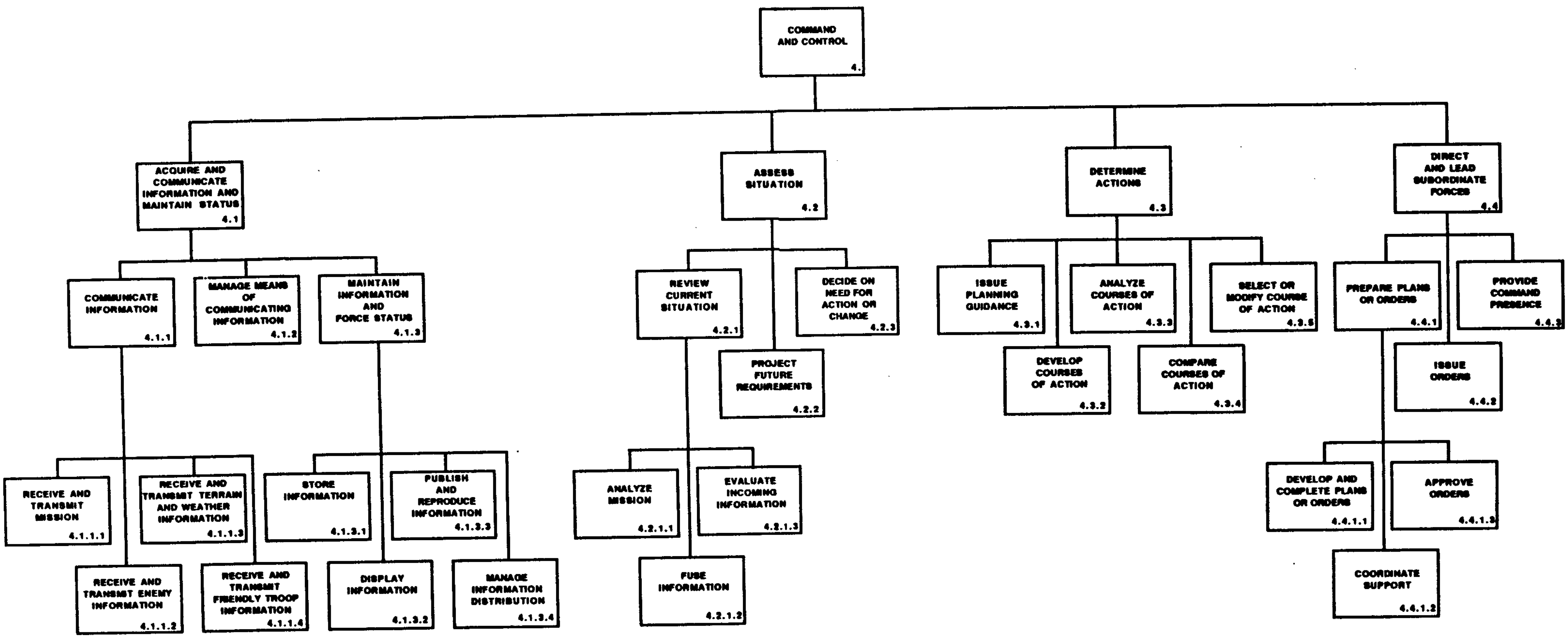


Figure A-4 Command and Control BOS

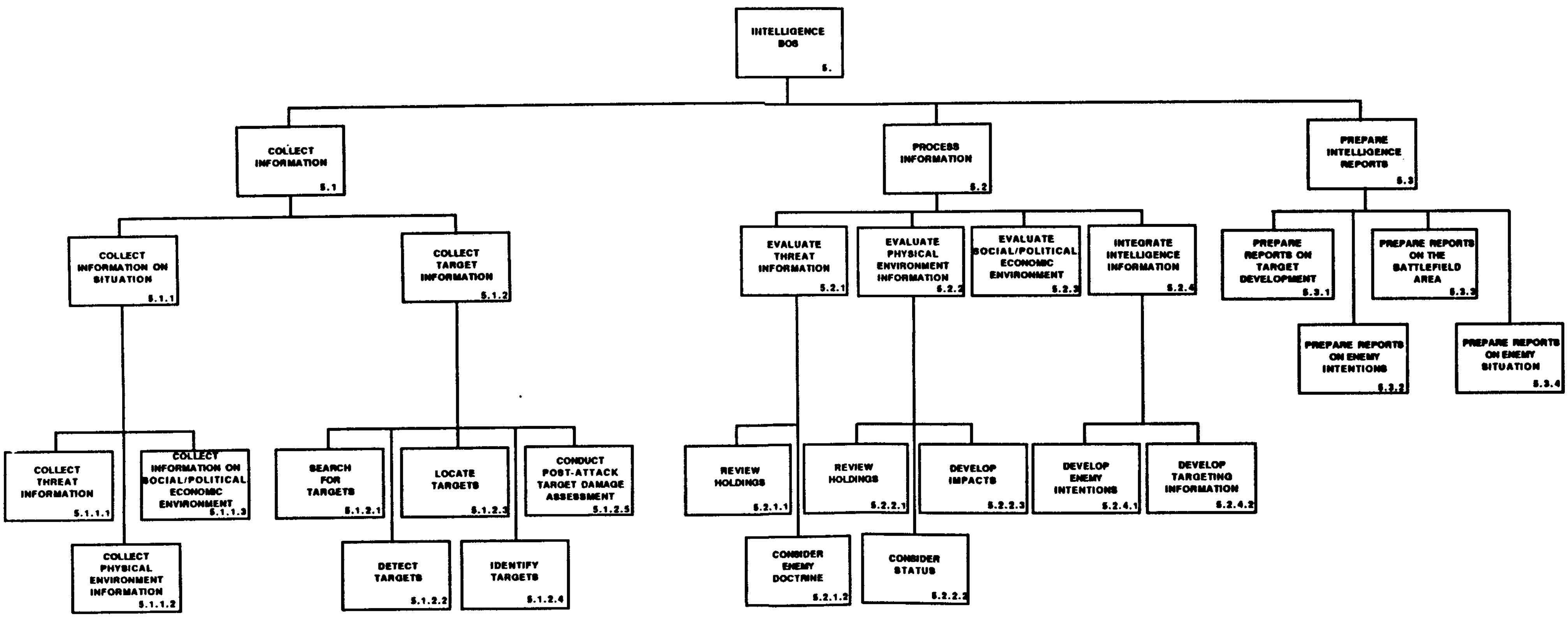


Figure A-5 Intelligence BOS

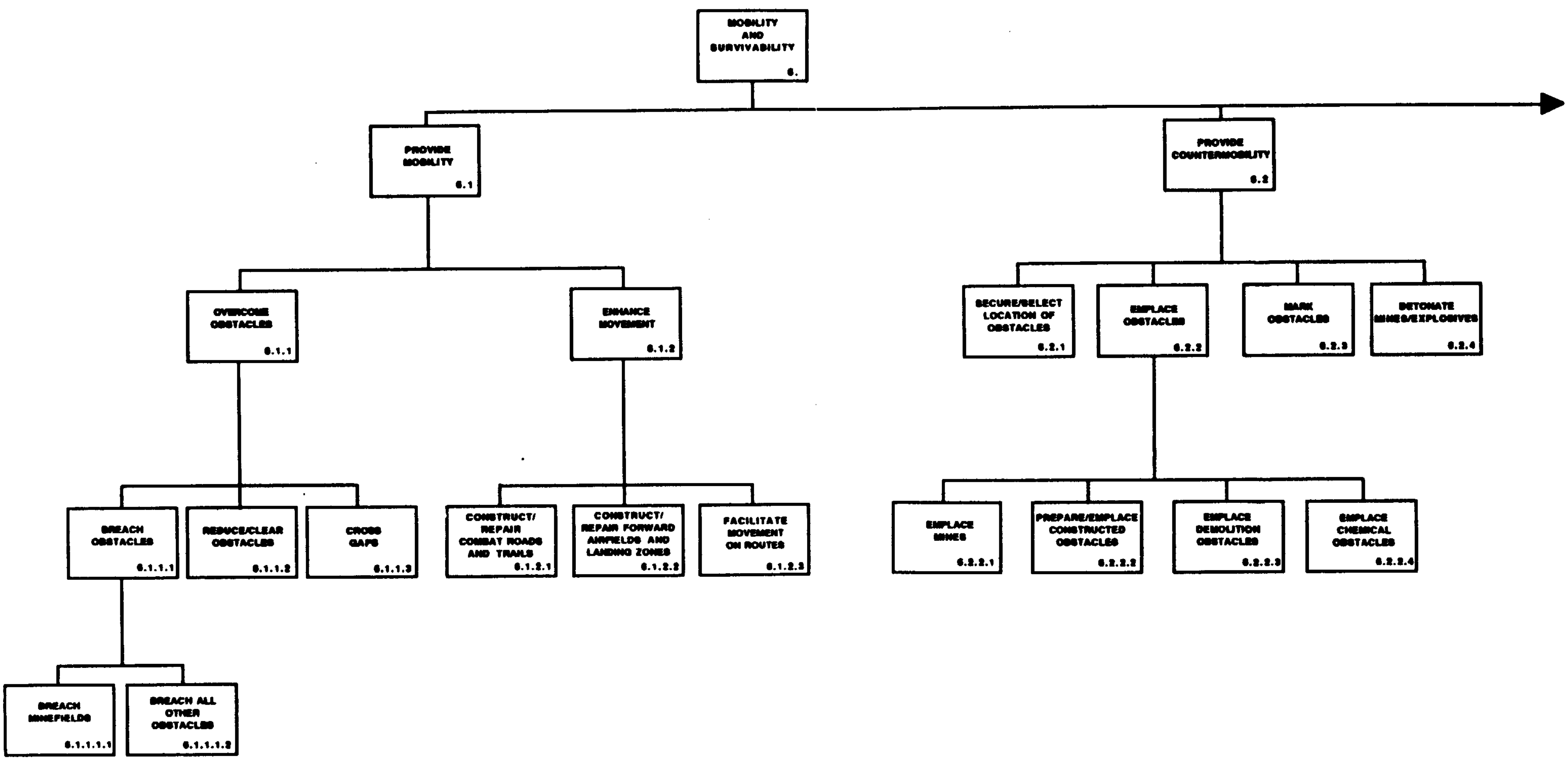


Figure A-6a Mobility and Survivability BOS

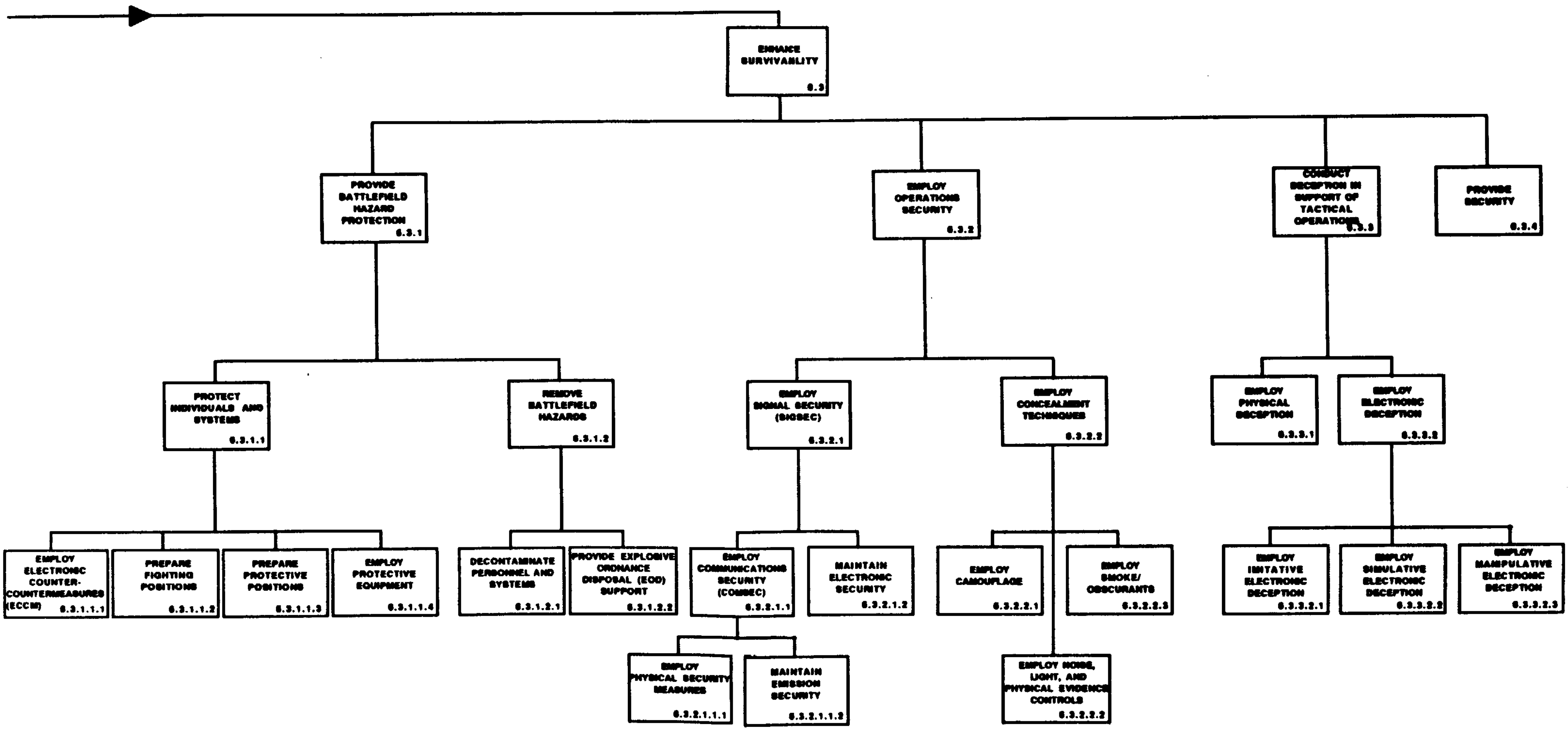
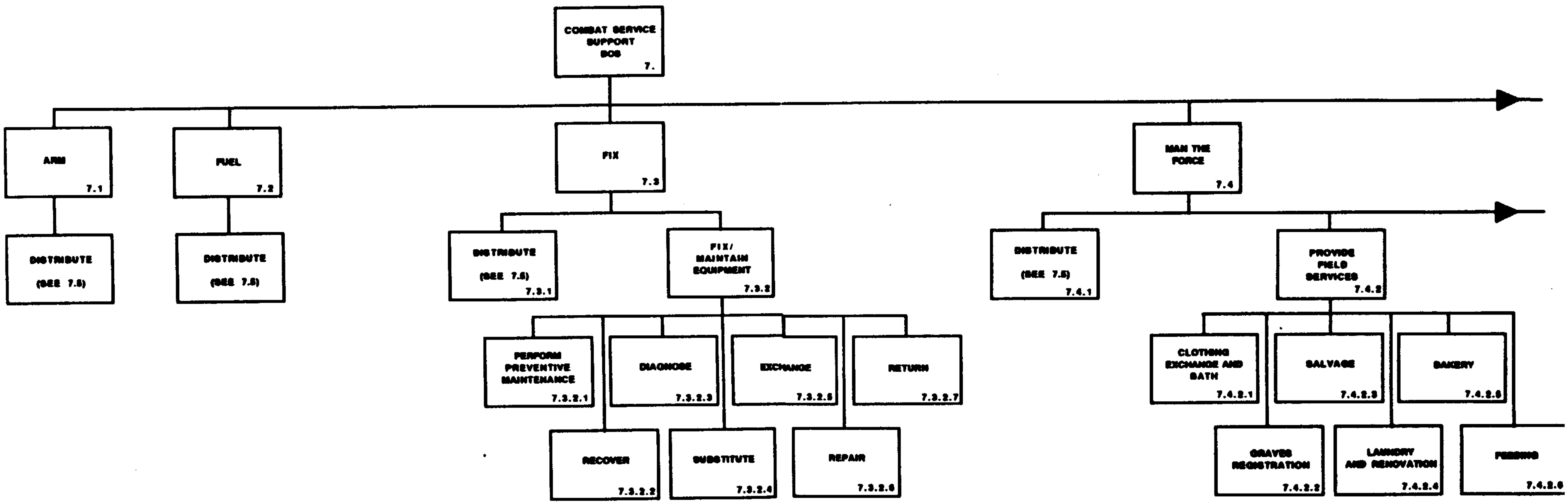


Figure A-6b **Mobility and Survivability BOS (Continued)**



[NOTE: THESE SYSTEM TYPES CAN APPLY TO EACH OF THE SEVEN SUBFUNCTIONS 7.3.2.1 TO 7.3.2.7]

7.3.2.X.1	TROOP SUPPORT MATERIEL
7.3.2.X.2	COMMUNICATIONS AND ELECTRONICS
7.3.2.X.3	VESSELS & WHEELED/TRACKED VEHICLES
7.3.2.X.4	AIRCRAFT
7.3.2.X.5	WEAPONS AND GUIDANCE SYSTEMS
7.3.2.X.6	MISSILE SUPPORT SYSTEMS
7.3.2.X.7	MEDICAL EQUIPMENT

Figure A-7a Combat Service Support BOS (Part 1)

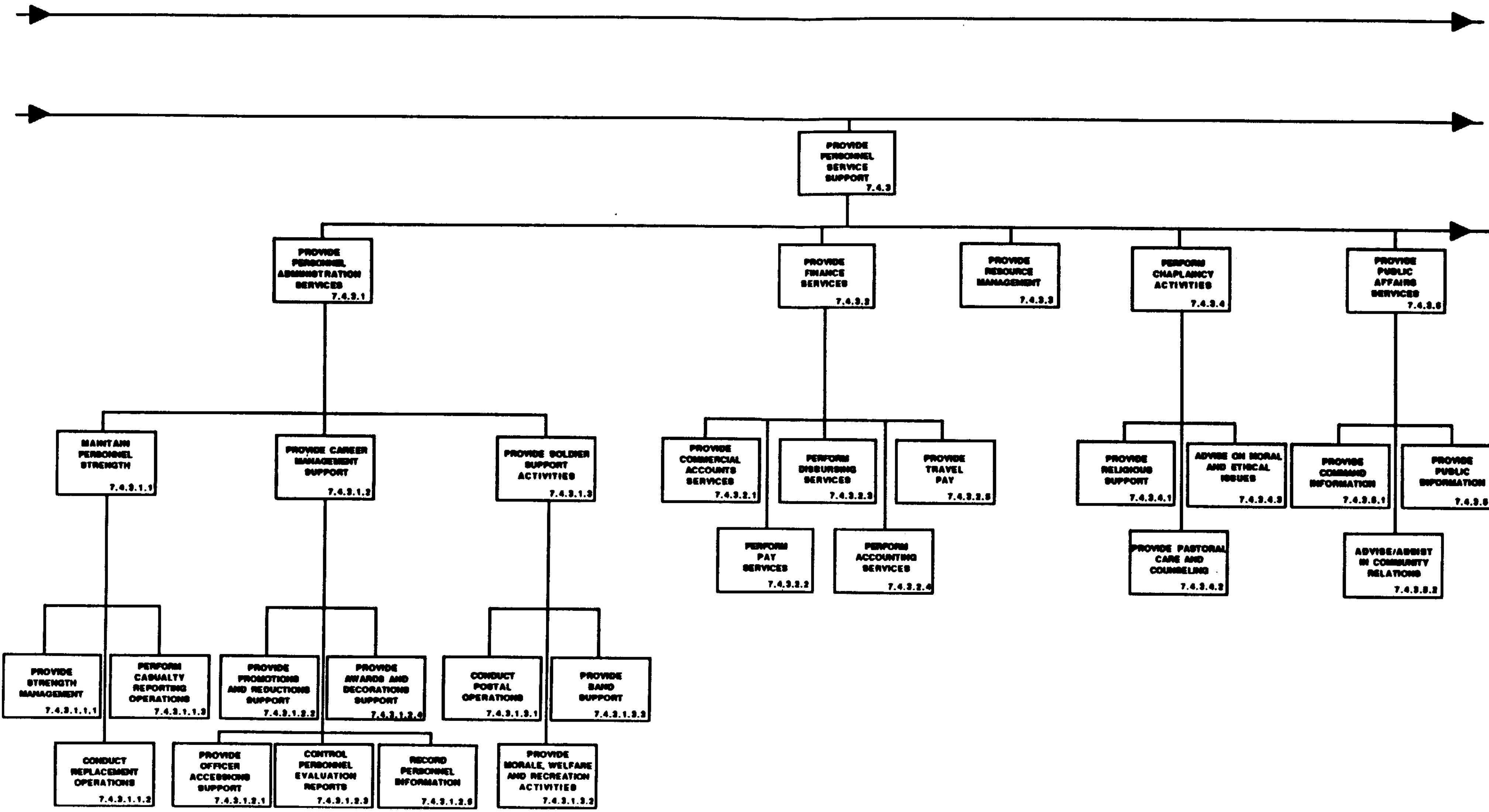


Figure A-7b Combat Service Support BOS (Part 2)

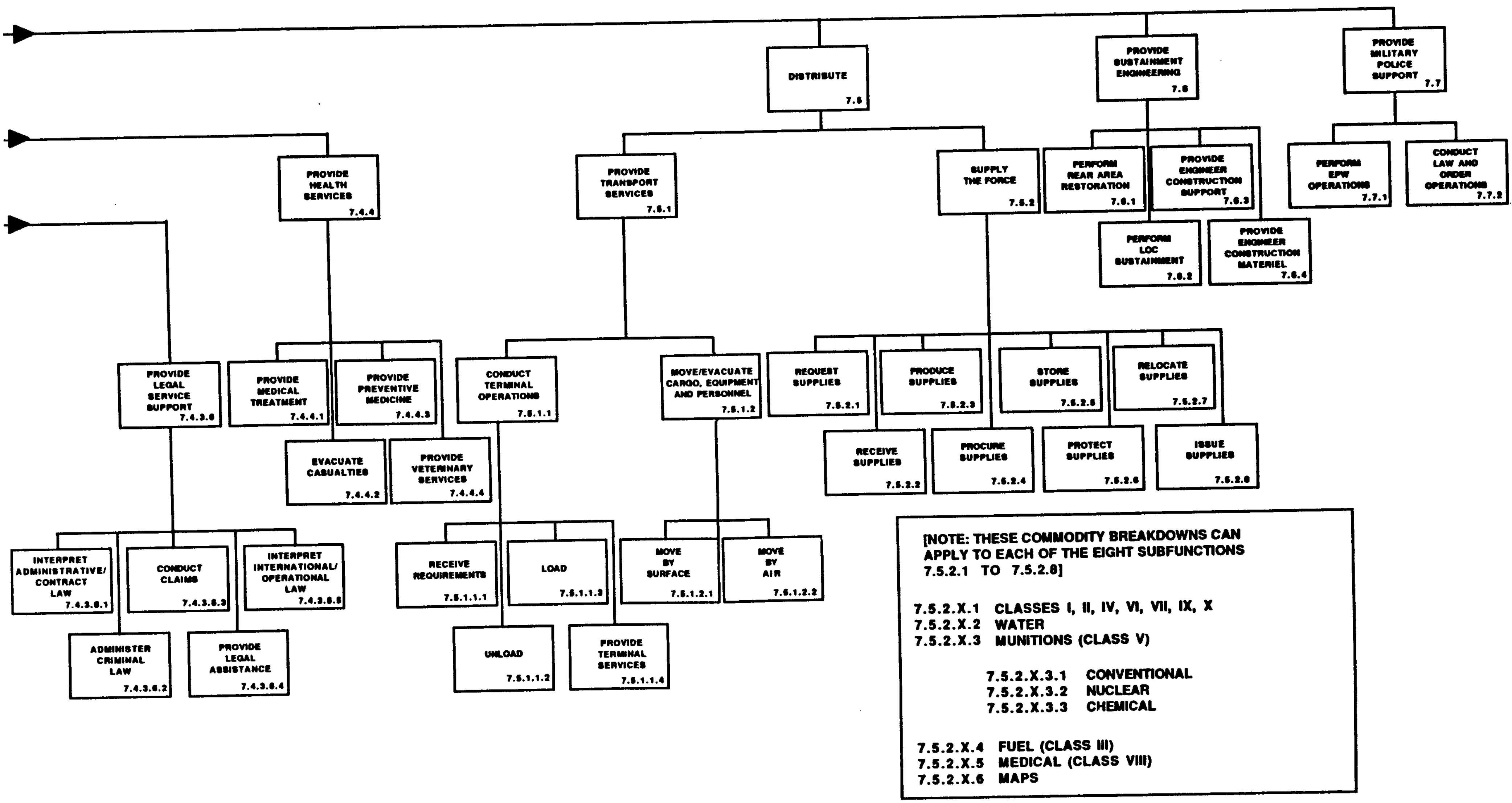


Figure A-7c Combat Service Support BOS (Part 3)

APPENDIX B:

IMPLICATIONS FOR THE FACS

AS A RESULT OF

BLUEPRINT OF THE BATTLEFIELD ANALYSIS

FACS CONCERNS

TECHNOLOGY OR CHANGE	BOS FUNCTION LINKAGE	IMPLICATIONS
Embedded Training	7.3.2 Fix/Maintain System	Increased use of actual weapon system for training results in faster wear out rates for system and components which increases maintenance times, system down time, and replacement needs.
	7.4.3 Provide Personnel Service Support 6.3.1 Provide Battlefield Hazard Protection	Use of actual weapon system for training purposes increases the emphasis on development of a fail-safe system to prevent operators from employing the training mode when in a battle mode or vice versa.
Increased Track Life	6.1 Provide Mobility	Increased capability for continuous operations for weapon requires work-rest plans, cross-training of tasks for crew, and increased supplies for personnel and weapon. (This concern also relates directly to the implications of reduced crew size mentioned below.)
Reduced Crew Size	7.4.3.1.1 Maintain Personnel Strenght	Probable increase in continuous operations capability if fourth crewmember's functions are automated. Can the reduced crew accomplish all tasks in the event of equipment failure? What does reduced crew size do to maintenance times and requirements? Ex: If past procedure requires a crew of four to change a track, can changing to a crew size of three result in a track redesign that does not result in increased repair time?

FACS CONCERNS

TECHNOLOGY OR CHANGE	BOS FUNCTION LINKAGE	IMPLICATIONS
Autoloader	7.1 Arm	An autoloader will result in faster rearm times. A greater rate of fire will result in a faster expenditure of ammunition resulting in increased rearming and resupply needs.
Individual Crew Compartments	4.1.1 Communicate Information	Degraded ability for intra-weapon system communication and crew coordination decreases total system performance.
	6.3 Enhance Survivability	Individual crew stations will increase survivability from hostile fire.
	7.4.4.3 Provide Preventive Medecine	Physical isolation may lead to psychological isolation and cause a degradation in battle performance.
Increased Firepower	7.5.2 Supply the Force	New binary round is larger than present projectile and will require more space for stowage, supply and rearming capacity. Does FACS provide enough space to assemble the round into firing configuration or must it be done outside the tank? How does this affect personnel exposure to enemy fire? What doed this do to combat support services? Increased requirements should increase resupply vehicle needs and the attendant maintenance of those vehicles.

FACS CONCERNS

TECHNOLOGY OR CHANGE	BOS FUNCTION LINKAGE	IMPLICATIONS
Multiple Target Acquisition System	2.1 Process Ground Targets	Increased target identification capabilities lead to increased targets at which to shoot. This results in a faster expenditure of ammunition and increases rearm requirements.
	5.2 Process Information 7.4 Man the Force	Increased target identification and processing requirements could affect human performance as soldier not only has to process more bits of information at once, but has to do so over a wider battlefield area.
Increased Weight Improved Modular Armor Larger Main Gun	7.5.1 Provide Transport Services	Increased weapon system size may decrease transportability and deployability resulting in longer supply times and increased service support requirements.
Seat Design	6.1.2 Enhance Movement	Seat must not only provide enough space in a closed hatch environment while wearing MOPP gear, but allow for the crew to rest during in-vehicle, closed hatch missions. This may require an increase in interior space requirements.
Increased Health Design	7.4.4 Provide Health Services	Continuous operations in a dirty battlefield environment will require a larger waste disposal and supply system which may require increased interior space and supply support.

FACS CONCERNS

TECHNOLOGY OR CHANGE	BOS FUNCTION LINKAGE	IMPLICATIONS
Advanced Technology Transition Demonstration (ATTD)	4.3.2 Develop Courses of Action	ATTD is a hardware demonstration that is usually done piecemeal, but needs to be done in an integrated fashion with the other components. Resources need to be allowed for feasibility studies that address this integration aspect during the development phase.
Placement and Positioning of Main Gun in Relation to Gunner	1.1.3 Negotiate Terrain 2.2.1.1 Conduct Surface Attack	There has been much discussion of decreasing the tank's profile so as to increase its survivability. Until now, all gunner positions have been in the turret which has the gunner pointing the gun in much the same direction as the tank is traveling. Placement of the gunner's station down low in the hull of the tank with an elevation of the gun tube will certainly reduce the tank's profile, but will, at times, force the gunner to aim the gun in one direction while he and the tank are traveling in another. This will effect the gunner's balance, coordination, accuracy and performance.

APPENDIX C:

IMPLICATIONS FOR THE FOG-M

AS A RESULT OF

BLUEPRINT OF THE BATTLEFIELD ANALYSIS

ILLUSTRATING BLUEPRINT USING FOG-M

FEATURE	BOS LINKAGE	CONCERN
Operator MOS	Move Through Air (1.1.1.3) Search For Target (5.1.2.1) Man The Force (7.4)	The designated MOSs have missile systems experience but no requirement for guiding, hovering or searching (as can be found in the remotely piloted vehicle operator MOS). Will this cause a critical difference in performance and accuracy?
Night, Obscurants	Search for Target (5.1.2.1) Engage Ground Targets (2.2) Attack Enemy Air Targets (3.2) Employ Smoke, Obscurants (6.3.2.2.3)	FOG-M uses its TV capacity search and identify targets. Will FOG-M be useless during night or obscurant conditions? Will the use of infra-red cameras cause an unacceptably high loss of monitor resolution?
Command and Control	Engage Enemy (1.2) Review Current Situation (4.2.1) Collect Information (5.1) Man The Force (7.4)	Studies indicate that the operator needs approximately 110 seconds to identify an enemy target in a generic scenario. However, enemy helicopter can be over 10 kilometers away and out of range before FOG-M can engage it.

Working Paper

WP MSG 90-07

Application of Early Comparability Analysis (ECA) to
the Advanced Field Artillery System (AFAS)

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Working Paper

APPLICATION OF EARLY COMPARABILITY ANALYSIS (ECA) TO THE ADVANCED FIELD ARTILLERY SYSTEM (AFAS)

March 1989

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APPLICATION OF EARLY COMPARABILITY ANALYSIS (ECA) TO THE ADVANCED FIELD ARTILLERY SYSTEM (AFAS)

SUMMARY

This report presents the findings from a comprehensive application of Early Comparability Analysis (ECA) performed in support of the weapon system development process for the Advanced Field Artillery System (AFAS). ECA is a technique developed by the Soldier Support Center-National Capital Region (SSC-NCR) to systematically examine tasks now being performed on existing weapon systems that also will be required for a planned new system. Tasks that make heavy demands on manpower, personnel, or training (MPT) resources are identified through surveys of subject-matter experts (SMEs) and other sources. These "high driver" tasks are then further analyzed to determine likely sources of the problem and to propose solutions that will reduce the burden of these tasks for the new system.

In this study, portions of which are still in progress, more than 400 tasks performed on components of predecessor and reference systems that also would be required for AFAS have been examined. These tasks are now the responsibility of operators and maintainers in 14 military occupational specialties (MOSs). SMEs were asked to rate each task along six dimensions: percent performing, task learning difficulty, task performance difficulty, frequency rate, decay rate, and time-to-train. Based on these SME surveys, 15 tasks were determined to be high drivers. All are maintenance tasks. Subsequent task analyses plus an examination of other sources of deficiencies and solutions to overcome them have been completed on 11 of these tasks.

The results obtained so far point to a variety of problems in the seven areas that were considered: manpower, personnel, training, equipment design, task procedures, tools-manuals-job aids, and performance conditions. No individual step or group of steps in any of the procedures were identified as unusually difficult and, in most instances, there was no outstanding deficiency in the qualifications of MOS incumbents who perform these tasks. Instead, the main difficulties seem to be associated with the unusual length of many of these tasks, deficiencies in Technical Manuals covering some of these tasks, and the broad scope of tasks that soldiers in certain MOSs are expected to master. Most of the high drivers identified by this study are mechanical or electronic troubleshooting tasks. These appear to be particularly difficult because they rarely

are practiced in their entirety during training and because of the tendency to adopt troubleshooting approaches that depend on analytic abilities and skills in reading schematics that may be beyond the capabilities of soldiers entering the MOSs that perform these tasks.

APPLICATION OF EARLY COMPARABILITY ANALYSIS (ECA) TO THE ADVANCED FIELD ARTILLERY SYSTEM (AFAS)

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APPLICATION OF EARLY COMPARABILITY ANALYSIS (ECA)
TO THE ADVANCED FIELD ARTILLERY SYSTEM (AFAS)

INTRODUCTION

Early Comparability Analysis (ECA) is a methodology developed by the Soldier Support Center-National Capital Region (SSC-NCR) as a tool to assist combat developers in the timely and effective introduction of manpower, personnel, and training information early in the weapon system acquisition process. A complete description of the ECA methodology is available in Early Comparability Analysis (ECA): Procedural Guide prepared and distributed by SSC-NCR.

Background

ECA is one of an array of manpower and personnel integration (MANPRINT) techniques that can be used to insure that a new weapon system can be operated and maintained in a way that will achieve its full design potential. An ECA examines operator and maintainer tasks performed on components of existing weapon systems that are similar to components proposed for the new system. The technique identifies any "high drivers" present in existing systems, tasks that are resource intensive with respect to manpower, personnel, or training requirements. These tasks may require more personnel than the unit can support, may require special knowledge or abilities not now requisite for entry to the particular military occupational specialty (MOS) responsible for them, or may require an inordinate amount of training. The "lessons learned" approach implemented using an ECA focuses attention on prevailing problems so they can be overcome for the new system.

An ECA is conducted in two stages. In the first stage, lists are prepared of tasks now performed on predecessor or reference system components that are similar to those that will be performed on components of the new system. A separate list is developed for each MOS participating in the operation or maintenance of these predecessor or reference system components. The tasks on each list are rated by subject matter experts (SMEs) from that MOS along six dimensions: percent performing, task learning difficulty, task performance difficulty, frequency rate, decay rate, and time-to-train. The results then are combined with any other information available on the tasks to identify those tasks that are human resource intensive, or high drivers. In the second stage of an ECA, a task analysis is performed on each high driver and, together with information obtained from instructors and relevant documentation, the results are used to identify deficiencies that cause the task to be a high driver.

Solutions to eliminate the deficiencies then are proposed.

Scope of Study

In this study, a comprehensive ECA was performed on operator and maintenance tasks similar to those that will be required when a new self-propelled howitzer (SPH), the Advanced Field Artillery System (AFAS), is fielded to replace the current M109A2/A3 (M109). Although several revisions have been made in the implementation plan and schedule for AFAS since this study began, its results continue to be applicable not only to AFAS but to the interim Howitzer Improvement Program (HIP) as well.

Altogether, relevant tasks performed on nine groups of existing equipment by incumbents in 14 MOSs were examined. The equipment groups studied were track and suspension, engine and transmission, driver operating components, automatic fire control, radio communications, turret, cannon and gun mount, nuclear-biological-chemical (NBC) collective, and ammunition handling. The MOSs included those responsible for relevant operator tasks (MOSs 13B, 13M and 19K), organizational maintenance tasks (MOSs 45D, 63E, 63T and 31V) and Direct Support (DS) and General Support (GS), or intermediate, maintenance tasks (MOSs 45L, 63H, 63G, 29E, 39L, 37M and 29S).

This study, undertaken as part of a larger MANPRINT effort, had two primary objectives. The first was to provide AFAS combat developers at U.S. Army Field Artillery School (USAFAS), Fort Sill, with the manpower, personnel, and training information they needed to assist them during the their planning for AFAS. The second was to examine the applicability of the ECA methodology very early in the concept exploration stage of the weapon system acquisition process, and determine whether an ECA can be readily performed by a contractor.

Three reports have been prepared based on this study. This report, emphasizing the study's findings, summarizes the results obtained when over 400 tasks relevant to AFAS were examined using the ECA approach. A second report, <u>Methodological Considerations in Applying Early Comparability Analysis (ECA)</u>, describes our experiences in carrying out the ECA and suggests various refinements in the SSC-NCR procedure based on these experiences. The report also considers such issues as the dimensions considered when determining which tasks are high drivers, the way total ECA scores are computed for a task, the number of SMEs required to rate tasks reliably, and the range of solutions to be considered when high drivers are identified. The third report, <u>Alternative Procedural Guide for Early Comparability Analysis (ECA)</u>, is an elaboration of the procedural guide prepared by SSC-NCR. It recommends various refinements to steps in the procedure, such as how to cope with the generic task lists now being adopted for many maintenance MOSs, and expands the range of deficiencies underlying high drivers to be considered.

The present report does not include the results from all of the 14 MOSs selected for examination in this study. Because some MOSs were identified as pertinent to AFAS only well after the study was underway, because of difficulties experienced in generating the needed basic lists for a few of these MOSs, and because of delays in scheduling the SME surveys of those tasks, a portion of this work is still in progress. Also, information about a few tasks that were surveyed is designated "For Official Use Only" and therefore these tasks are not considered in detail in this report. More specifically, this report does not include survey data for three MOSs: 39L (Field Artillery Digital Systems Repairer), 27M (Multiple Launch Rocket System Repairer), and 29S (Field Communications Security Equipment Repairer). Similarly, the report does not include the specific results of the task analyses and subsequent remedial recommendations for two tasks identified as high drivers for MOS 29E (Communications-Electronics Radio Repairer).

Study Focus

The conceptual new weapon that was the focus of this study is the Advanced Field Artillery System (AFAS). It is representative of the newly emerging weapon systems the ECA methodology was designed to support. AFAS is planned as a new crew-served self-propelled howitzer (SPH) to succeed the M109 SPH currently in inventory. It is intended to provide the advanced capabilities needed to meet the threat for the year 2000 and beyond, and to operate under the dispersed battlefield concept envisioned by Army 21. Compared with the M109, AFAS will have a considerably greater range and rate of fire, the communications and automatic position determining equipment needed to allow it to operate independently of a battery position, improved mobility to defend itself against counterfire, a capability for sustained operations over a period as long as 96 hours, and a substantially reduced crew size.

Largely because this study was begun at a very early point in the weapon system acquisition process, its scope intentionally was focused on only those tasks that would be required to sustain AFAS operations under a 96-hour battle scenario. Supply and other support tasks, such as transporting fuel, obtaining meteorological data, or operating a battery command post, were excluded. Certain other tasks also were excluded by the USAFAS combat developers, particularly special weapons tasks and those pertaining to airborne operations. The combat developers, in addition, decided at its beginning that the study should include only organizational level maintenance functions. However, as the work proceeded, selected intermediate DS-GS maintenance functions were added. As a result, groups of tasks were examined successively during this study rather than all concurrently.

<u>Organization of Report</u>

The remainder of this report describes the findings from the ECA study organized by the sequence of steps in the ECA methodology. As will be pointed out, the project staff attempted to follow the ECA procedure presented in the SSC-NCR guide as closely as possible. In some instances, particularly in the later steps, it appeared desirable to modify or augment the SSC-NCR procedure. When this occurred, a description of both the original and the modified approach is included along with the rationale for making the change.

The report of what was accomplished in each step is divided into several segments. These are:

- <u>title</u> of the step and a succinct statement of its purpose;

- <u>procedure</u> for carrying out the step, summarized from the SSC-NCR <u>Procedural Guide</u>;

- <u>activities</u> actually performed in carrying out this step, including any modifications in the procedure; and

- <u>findings</u> from the step in summary form, with illustrations referring to particular MOSs or tasks in accompanying tables and figures.

Because of the scope of this effort, only summaries of the results are presented within the body of the report. The task lists used when surveying the SMEs in Step 4, and the survey findings for each task included in the lists, are presented by MOS in Appendix A. Samples of the on-site task analyses of high driver tasks performed in Step 8 of the ECA are presented in Appendix B. The deficiencies analysis for MOS 31V is reported in the results for Step 10; more complete and detailed analyses covering both deficiencies and possible solutions for the high drivers in MOSs 63T, 31V and 63H are provided in Appendix C.

During the course of this study, an opportunity arose to consider how maintenance support could be provided to AFAS sections under the conditions of a 96-hour battle scenario. The USAFAS combat developers responsible for planning AFAS tentatively had proposed adopting a mobile maintenance contact team (MMCT) approach in which maintenance personnel in a specially equipped vehicle would rendezvous with a disabled howitzer to restore the howitzer to combat capability. No information was then available, however, on the MOSs that should be represented on the MMCT. In order to address this question, a small substudy was conducted to define the scope of repairs that might be undertaken by the team and to consider the personnel who should comprise it. The results of this substudy are presented in Appendix D.

STEP PROCEDURES AND FINDINGS

Step 1. Study Initiation

Decide whether an ECA is appropriate, which predecessor and reference systems should be considered, and who largely will be responsible for performing the ECA.

SSC-NCR Procedure

An ECA presumes most new weapons are evolutionary, having similar components and performing largely the same functions as the predecessor system the new weapon will replace. The conceptual system also may incorporate other components or features not found on the predecessor system. These components can be studied by identifying reference systems that already include them. An ECA is appropriate when there is a suitable predecessor system in the Army inventory and there is no vast technological gap between existing predecessor systems or their components and those envisioned for the new system under development.

Predecessor systems and components from reference systems are selected for the study by determining whether the tasks performed on those systems are similar to ones that will be required to operate and maintain the new system.

Personnel resources are needed to carry out an ECA. In addition to identifying how these requirements will be met, the proponent school for the study should take responsibility for coordinating the effort with other affected service schools, preferably through the MANPRINT Joint Working Group (MJWG).

Activities

The decision to conduct an ECA for AFAS was made by the combat development team responsible for AFAS within the office of the TRADOC System Manager for Cannon (TSM-Cannon), Directorate of Combat Developments (DCD), USAFAS. The team sought assistance from the Army Research Institute in the Behavioral and Social Sciences (ARI) which, in turn, arranged the participation of a contractor to work on this study as well as some companion MANPRINT studies focusing on AFAS.

The AFAS combat development team, ARI representatives and contractor project staff all concurred that an ECA was appropriate, that an existing system, the M109, was a logical predecessor system, and that other reference systems could be identified to match most of the components not present on the predecessor system but planned for the new system. The principal exception was the expected employment of some new technology for the AFAS cannon. In order to achieve the intended increase in range of fire, compared with the current range of the M109 cannon, some new technology was required. Three possibilities being examined during concept exploration for AFAS were electromagnetic propulsion, liquid propellants, and rocket-assisted projectiles. No reference systems currently in inventory which employ any of these technologies in the same way as envisioned for AFAS could be identified.

Findings

Several iterations were required to identify the predecessor and reference systems appropriate to an ECA study for AFAS. The primary problems that emerged during this process were deciding how to divide up the conceptual system, selecting which of several possible reference systems to use, and determining whether certain basic, equipment-related tasks should be included. For example, the initial version of the predecessor and reference system breakdown considered the chassis as a whole, with the Multiple Launch Rocket System (MLRS) as the most comparable existing system. The second version of the breakdown divided the chassis into a track-suspension segment similar to the track and suspension of the M109, an engine-transmission segment similar to that used on MLRS, and a "driving" (meaning operator interface while driving) segment similar to that used on the M109. The third and final version of the breakdown specified MLRS for both the track-suspension and engine-transmission segments, and the M109 for the driving segment.

Other components were added, deleted or changed between versions. For example, a decision was reached to include maintenance test equipment such as the Standard Test Equipment-Internal Combustion Engine (STE-ICE) along with the engine-transmission segment, and to exclude the M-2 50-cal machine gun because, although it was planned for AFAS, it would not be considered by the AFAS design program. The final breakdown is shown in Table 1.

Step 2. Identify Relevant MOS(s)

Identify the MOSs responsible for operating and maintaining the designated predecessor and reference system components.

Table 1

Predecessor and Reference System Components for AFAS

	Component	Existing Item
1.	Chassis	
	a. Track and Suspension	MLRS
	b. Engine and Transmission (incl. maintenance test equipment)	MLRS
	c. Driving Controls	M109A2/A3
2.	Automatic Fire Control System (AFCS) (incl. fire control computer, inertial reference and navigational system, and communications processor)	MLRS
3.	Radio (voice and digital)	MLRS
4.	Turret (incl. all fire control equipment other than AFCS)	M109A2/A3
5.	Cannon and Gun Mount	M109A2/A3
6.	Nuclear-Biological-Chemical (NBC) Collective System	M1A1 Tank
7.	Ammunition Handling Equipment	M109A2/A3

SSC-NCR Procedure

The MOSs of soldiers who operate and maintain the systems and components that were selected for study in Step 1 are identified. If it is not clear which MOSs are to be included, the service schools most knowledgeable about the existing system should be contacted. Information about relevant MOSs also can be obtained from a Qualitative and Quantitative Personnel Requirements Information (QQPRI) report if one is available.

Activities

Both the scope of the ECA for AFAS and the identity of the MOSs involved with the predecessor and reference systems and components selected for examination emerged as significant issues at this stage of the study. Specifying the operator MOSs for the M109 and MLRS components identified in the breakdown was readily accomplished by the AFAS combat developments team. An M109 section is manned by MOS 13B, and MLRS operations are performed by MOS 13M. Both are field artillery MOSs. The team also had no difficulty identifying MOS 19K as the armor MOS responsible for operating the NBC collective system for the M1 tank, chosen because no field artillery platform currently has NBC protection equipment comparable to that provided for the M1.

Specifying the appropriate maintenance MOSs turned out to be more difficult for two reasons. One was that the combat developers were not altogether familiar with the distribution of responsibilities among maintenance MOSs. Organizational maintenance on the MLRS chassis, for example, is performed by an MOS 63T Bradley Fighting Vehicle System (BFVS) Mechanic. The second was that no decision as to the scope of the ECA with respect to maintenance tasks had yet been made. When this latter issue was discussed, the combat developers determined that, for their purposes, emphasis should be given to organizational level maintenance and that DS, GS and depot levels of maintenance should be excluded. The organizational level maintenance MOSs identified for inclusion in the study were MOSs 63T, 31V (Unit Level Communications Maintainer), 45D (Self-Propelled FA Turret Mechanic), and 63E (M1 Tank Systems Mechanic).

Seven MOSs were therefore identified at this stage of the study for inclusion in the ECA. Several months later, the decision limiting the scope of the study to organizational level maintenance tasks was reexamined, and it was determined that four DS and GS maintenance MOSs should be added. These were MOS 29E covering communications electronics, MOS 39L covering field artillery computers, MOS 45L covering the cannon and gun mount, and MOS 63W covering the tracked vehicle chassis. As the task lists for these MOSs were being developed, it became apparent that certain additional chassis maintenance tasks performed by MOS 63G should be included, as should some position determining system (PDS) tasks now performed by MOS 27M. Finally, certain communications electronics tasks thought to be performed by MOS 29E turned out to be the responsibility of MOS 29S. These additions brought the total number of MOSs identified as relevant to the ECA for AFAS to 14.

Findings

The final list of the 14 MOSs identified as performing operator or maintenance tasks on predecessor and reference system components similar to those proposed for AFAS is shown in Table 2.

Step 3. Prepare Task Lists

> Obtain task inventories for each MOS, if available, and prepare a task list containing all tasks performed on the predecessor and reference components(s) by that MOS.

SSC-NCR Procedure

An existing, complete list of tasks performed by an MOS usually can be obtained from the Directorate of Training Development (DOTD) at the proponent school. If one is available, the tasks performed by the MOS on the predecessor and reference system components can be extracted to develop a task list for use in conducting an ECA. If no comprehensive task inventory is available for the MOS, the tasks that should be included on the ECA task list can be generated from the Soldier's Manual (SM), Logistic Support Analysis Records (LSARs), Technical Manuals (TMs), and other sources. It is important to insure that the ECA task list for each MOS is complete.

Activities

Only a few minor problems emerged in preparing the ECA task lists for the operator positions. These problems resulted primarily from the breadth of these three MOSs (13B, 13M and 19K). Soldiers Manuals for these MOSs typically allocate tasks performed on any of several systems operated by the MOS to just one system. Thus, tasks from several systems may have to be assembled to obtain a complete task list covering the components of any designated predecessor or reference system. Some selectivity also was required to eliminate tasks not applicable to the new system or ones that specifically were excluded from the ECA, such as special weapons tasks.

Two very substantial problems arose during the preparation of the ECA task lists for the maintenance MOSs, however. First, comprehensive task inventories were available for only three of the 11 maintenance MOSs included in the study (27M, 31V and 45L). Preparing ECA task lists for these three MOSs required only a careful review of the source task inventory to select those that were applicable to the identified predecessor and reference

Table 2

Relevant Operator and Maintenance MOSs

MOS	Title	Function
13B	Cannon Crewmember	Operator, Cannon
13M	MLRS Crewmember	Operator, Chassis
19K	M1 Armor Crewman	Operator, NBC
31V	Unit Level Communications Maintainer	Org. Maint., Radios
45D	Self-Propelled FA Turret Mechanic	Org. Maint., Cannon
63E	M1 Tank Systems Mechanic	Org. Maint., NBC
63T	BFVS Mechanic	Org. Maint., Chassis
27M	MLRS Repairer	DS-GS Maint., PDS
29E	Communications-Electronics Radio Repairer	DS-GS Maint., Radios
29S	Field Communications Security Equipment Repairer	DS-GS Maint., KY-57
39L	Field Artillery Digital Systems Repairer	DS-GS Maint., AFCS
45L	Artillery Repairer	DS-GS Maint., Cannon
63G	Fuel and Electrical Systems Repairer	DS-GS Maint., Chassis
63H	Track Vehicle Repairer	DS-GS Maint., Chassis

components. Here, as with the operator tasks, tasks sometimes are described as if they are specific to only one of the systems maintained by that MOS even though the task also is performed on several other systems including the one that is being examined in the study. No task inventories were available for the remaining eight MOSs, nor could LSARs be obtained for these MOSs. Partly, this was due to ongoing efforts to restructure some of these MOSs. MOS 39L, for example, recently had been split into two MOSs but the division of functions and tasks between them had not been completed and no one was certain which tasks would be assigned to which MOS. When no task list was available, Maintenance Allocation Charts (MACs) were used as the primary source of task list information if a suitable TM could be found. When the TM was not sufficient, it was necessary to depend on obsolete task inventories, on Programs of Instruction (POIs), or on lists generated specifically for this purpose by the proponent school.

The second problem was even more difficult. The proponent schools for most of the maintenance MOSs selected for the study were the U.S. Army Ordnance Center and School (USAOC&S) at Aberdeen Proving Ground and the U.S. Army Signal Center (USASIGCEN) at Fort Gordon. Both schools recently elected to replace their existing equipment-specific task inventories with much simpler generic task inventories. Generic tasks, however, are much too broad to be useful for conducting an ECA. The difficulties we experienced in working from generic task lists can be illustrated by what happened during the preparation of a task list for MOS 29E. In the absence of a definitive task inventory, a list of 101 equipment-specific tasks was derived from applicable MACs. Examples of these were: "Test Amplifier Assy, IF (Audio and Squelch Amplifier) for assemblies A5000, A5000A" and "Test Semiconductor Device Assy for assemblies A9400, A9400A". The school rejected this list and proposed, in its place, a generic list of only six tasks. Examples of these were: "Repair Receiver-Transmitter RT-524/VRC" and "Troubleshoot Antenna GRA-50". These generic task descriptions, however, were either too all-encompassing to be evaluated accurately on an ECA survey form, or omitted some essential performance requirements such as replacing the GRA-50 antenna following troubleshooting. The project then generated a compromise list that preserved the generic description of the performance required while matching it to a specific unit or subsystem. An example of the 31 tasks on the resulting list is "Evaluate Recvr/Transmtr RT-841 (including mount, cabling and antenna)".

Findings

School-approved ECA task lists were developed for 12 of the 14 MOSs included in the study. Work on task lists for the remaining two MOSs is continuing. Table 3 indicates the number of tasks appearing on each list. Complete lists of all the tasks surveyed for each MOS are included in the tables in Appendix A.

Table 3

Numbers of Tasks on ECA Task Lists

MOS	Title	No. Tasks
13B	Cannon Crewmember	98
13M	MLRS Crewmember	53
19K	M1 Armor Crewman	2
31V	Unit Level Communications Maintainer	37
45D	Self-Propelled FA Turret Mechanic	24
63E	M1 Tank Systems Mechanic	2
63T	BFVS Mechanic	26
29E	Communications-Electronics Radio Repairer	36
29S*	Field Communications Security Equipment Repairer	5
45L	Artillery Repairer	27
63G	Fuel and Electrical Systems Repairer	60
63H	Track Vehicle Repairer	60
	TOTAL	430

* Survey administration not yet complete.

Step 4. Collect Task Data

Survey SMEs for their ratings and compile available data for each task on each task list concerning:

- Percent Performing
- Task Learning Difficulty
- Task Performance Difficulty
- Frequency Rate
- Decay Rate
- Time-to-Train.

SSC-NCR Procedure

Although the opinions of SMEs usually will be the primary source of data for an ECA, considerable amounts of other data on task dimensions may be available. These include information developed by the Army Occupational Survey Program, the Army Operational Test and Evaluation Agency, the Army Research Institute, the Army Human Engineering Laboratory, and various studies, analyses and publications prepared by the proponent school. An effort should be made to compile this information as a supplement to or, in some instances, as a replacement for data collected using an SME survey instrument.

The SME survey instrument consists of a six-column rating form. Each task appearing on the task list for that MOS is rated on a scale of 1 to 4 along each of the six dimensions, or criteria, used to differentiate problem tasks from non-problem tasks. Descriptions of the dimension and anchors for each scale value are provided to the SMEs to improve the consistency of their ratings. The six dimensions are:

a. Percent Performing: What proportion of the relevant MOS and skill level performs this task?

1 = 1-25%
2 = 26-50%
3 = 51-75%
4 = 76-100%

b. Task Learning Difficulty: How difficult is it for the average soldier, in the appropriate MOS and of the appropriate skill level, to learn this task?

1 = Not difficult
2 = Somewhat difficult
3 = Moderately difficult
4 = Very difficult

c. Task Performance Difficulty: How difficult is it, for the average soldier, of the proper skill level and in the proper MOS, to perform this task? Consider both cognitive and physical difficulty.

1 = Not difficult
2 = Somewhat difficult
3 = Moderately difficult
4 = Very difficult

d. Frequency Rate: On the average, how often is this task performed by the average soldier of the proper skill level and in the proper MOS?

1 = Seldom (Annually)
2 = Occasionally (Semi-annually or quarterly)
3 = Often (Monthly)
4 = Frequently (Daily or weekly)

e. Decay Rate: Given this task, how much proficiency is lost by the average soldier from the end of his formal training until he first performs the task in the field? (Assume that the task is performed within a reasonable period of time after training and is performed by an average soldier of the proper skill level and in the proper MOS.)

1 = Low
2 = Moderately low
3 = Moderately high
4 = High

f. Time-to-Train: How much time is required to train the average soldier, of the proper skill level and in the proper MOS, to perform this task to standard?

1 = Less than 3 hours
2 = 3 hours or more but less than 6 hours
3 = 6 hours or more but less than 9 hours
4 = 9 hours or more

Activities

At the time each proponent school was asked to approve the draft task list for an MOS, the school also was asked to supply, or at least identify, any information it had that could be used to complement the ECA survey results. Because we worked through the MANPRINT representative at each school, the kinds of information being sought was fairly clear. Yet, not a single study or analysis covering any of the 14 MOSs included in the ECA was identified for us in response to these requests.

Independently, we did obtain one report that might have been useful, a Computerized Occupational Analysis Data Program (CODAP) report on MOS 13B. However, three problems were encountered in trying to use the information in it for this ECA study. First, the tasks considered by the CODAP study did not coincide with those in the MOS 13B Soldier's Manual. Second, the CODAP tasks were almost exclusively garrison, and not battlefield, tasks. And, third, the dimensions of each task considered in the report emphasized task criticality rather than task difficulty. Although supplementary information sources such as lesson plans were helpful later in the ECA when high drivers were analyzed, SME ratings proved to be the most easily obtained and consistent source of information as to which tasks are problem tasks.

SME surveys have been administered for 11 of the 14 MOSs included in the ECA. Surveys for the remaining three MOSs currently are in progress. In several instances, obtaining access to groups of SMEs was quite difficult. Many of the maintenance MOSs addressed by the study are low density and their personnel are widely dispersed among operating units. SMEs for these MOSs, such as MOS 63T, were surveyed in groups of as few as two SMEs at a time. The cost, both in time to make arrangements and in travel expenses, to visit significant numbers of operating units in order to conduct SME surveys for low density MOSs was not practical within the scope of this study. Also, the schools preferred to have a role in identifying which supervisory and instructor personnel should be considered SMEs for the purposes of an ECA.

Conducting the surveys at school locations also led to some difficulties. Many maintenance tasks are not included in formal training programs and therefore school instructors may not be familiar with them. In several instances, we had to survey MOS 63T mechanics experienced only with the Bradley Fighting Vehicle System (BFVS) chassis instead of mechanics who have serviced the similar, but not identical, MLRS chassis. As a result, these SMEs were not familiar with certain tasks performed on the MLRS. In one case, for MOS 63G, we were unable to locate any SMEs. This MOS applies only up to the -20 skill level, and from that level on is subsumed under MOS 63H. Very few MOS 63H SMEs are familiar with MOS 63G fuel and electrical maintenance tasks, however.

Aside from these problems, no other major difficulties were encountered in conducting the actual surveys. Although the minimum number of 10 participating SMEs recommended by SSC-NCR was not always possible because of inaccessibility, "no shows", or lack of some participants' familiarity with reference systems such as the BFVS, the number seemed satisfactory in all but one instance. As explained above, the MOS 63H SMEs who are supposed to be familiar with MOS 63G tasks generally were not, and only one survey participant was able to rate most of the tasks. We were unable to locate groups of MOS 63H SMEs familiar with MOS 63G tasks or any groups of MOS 63G instructors.

Findings

The number of SMEs participating in the ECA survey, by MOS for each of the 11 MOSs surveyed, is shown in Table 4. As pointed out above, the survey of MOS 63G tasks was conducted with the same SMEs who participated in the MOS 63H survey. The lower number of participants cited in the table for MOS 63G resulted from the elimination of those MOS 63H SMEs who reported no knowledge of MOS 63G tasks at all. A sample page from the survey form used is shown in Figure 1.

Step 5. Assign Values to Data

Assign values to data other than SME survey results on a scale of 1 to 4, and combine the results with the survey data.

SSC-NCR Procedure

Data from sources other than SME surveys are transposed to correspond to the 1 to 4 scale applied to the survey data. This may require scaling raw data, converting the data so they match the scale values used for the surveys, or adjusting the scale used to a four-point scale. Data for each of the six dimensions are transposed separately. This information is then merged with the corresponding survey data by calculating the average SME rating for that dimension on each task and weighting each source of information, including the survey results, equally. The outcome will be a single composite score, ranging from 1 to 4, representing each dimension of each task.

Activities

Because we were unable to obtain any usable data on the task dimensions considered for an ECA other than the SME survey results, it was not necessary to create or transpose any scales. The raw SME survey ratings were entered into a spreadsheet computer program in order to calculate averages for each dimension for each task.

Findings

The findings for this step are included with the findings from the following steps, Calculate ECA Scores and Identify "High Drivers", and are presented in detail in Appendix A.

Table 4

Numbers of SMEs Participating in ECA Surveys

MOS	Proponent	No. SMEs
13B	USAFAS, Fort Sill	20
13M	USAFAS, Fort Sill	15
19K	USAACS, Fort Knox	7
31V	USASIGCEN, Fort Gordon	12
45D	USAOC&S, Aberdeen P.G.	8
63E	USAOC&S, Aberdeen P.G.	7
63T	USAOC&S, Aberdeen P.G.	12
29E	USASIGCEN, Fort Gordon	9
45L	USAOC&S, Aberdeen P.G.	9
63G	USAOC&S, Aberdeen P.G.	9
63H	USAOC&S, Aberdeen P.G.	14
	TOTAL	122

ECA

QUESTIONNAIRE

MOS:

COMPONENT:

MLRS Chassis

	A. PERCENT PERFORMING 1 = 1% - 25% 2 = 26% - 50% 3 = 51% - 75% 4 = 76% - 100%	B. TASK PERFORMANCE DIFFICULTY 1 = Not Difficult 2 = Somewhat Difficult 3 = Moderately Difficult 4 = Very Difficult	C. FREQUENCY RATE 1 = Seldom (annually) 2 = Occasionally (semi-annually) 3 = Often (monthly) 4 = Frequently (weekly/daily)	D. TASK LEARNING DIFFICULTY 1 = Not Difficult 2 = Somewhat Difficult 3 = Moderately Difficult 4 = Very Difficult	E. TIME TO TRAIN 1 = Less than 3 hours 2 = 3 up to 6 hours 3 = 6 up to 9 hours 4 = 9 hours or more	F. DECAY RATE 1 = Low 2 = Moderately Low 3 = Moderately High 4 = High
Repair Hull-bolted Assembly						
Repair Hull, machined						
Repair Track Adjuster						
Repair Lockout Support						
Repair Pumping Unit, Hydraulic						
Adjust Diesel Engine						
Remove/Install Diesel Engine						
Repair Diesel Engine						
Repair Engine Turbo-charger						
Replace Flywheel Assembly						
Repair Flywheel Assembly						
Adjust Fuel Injector						
Replace Fuel Injector						
Repair Centrifugal Pump						
Repair Cooler Fluid Transmission						
Replace Cylinder Head						
Repair Cylinder Head						
Repair Cooler, Engine Oil						
Replace Lubricating Pump						

Figure 1. Sample Page of an ECA Survey Form

Step 6. Calculate ECA Scores

Compute an ECA score for each task by multiplying together the composite scores for each of the dimensions of the task.

SSC-NCR Procedure

The composite scores in the form of scale values between 1 and 4 for each dimension of each task are multiplied together to obtain a total ECA score for each task. In other words, the ECA task score is equal to:

(Percent Performing) x (Task Learning Difficulty) x (Task Performance Difficulty) x (Frequency Rate) x (Decay Rate) x (Time-to-Train)

Information on Percent Performing will not be available if the predecessor or reference system has not been fielded for a sufficiently long time to permit reliable estimates. When this occurs, the total ECA score will be based on only five dimensions.

Activities

The computer spreadsheet developed for calculating the average of SME survey ratings for each task dimension also was programmed to multiply together the average scores across the six dimensions for each task in order to calculate an ECA score for the task.

Findings

The results of this step, used to determine which tasks are high drivers, are presented in Appendix A for each MOS.

Step 7. Identify "High Drivers"

Evaluate each calculated ECA score to identify any that are "high drivers", those with scores of 216 or more (if subscores on 6 dimensions were used) or 90 or more (if subscores on only 5 dimensions were used).

SSC-NCR Procedure

The ECA scores calculated in Step 6 are inspected to identify those that are 216 or greater using six dimensions, or 90 or greater using five dimensions. These are problem tasks, those with high enough composite averages within each dimension to suggest the task is a "high driver" in its use of manpower, personnel, and training resources. These tentative high driver tasks are then reviewed by SMEs to verify that they are resource intensive. At the same time, tasks with ECA scores approaching the high driver cut-off value should be reviewed to determine if any are perceived as particularly resource intensive.

Activities

The total ECA score for each task was inspected to determine any that represented high driver tasks. Because all tasks were rated along all six dimensions, the single cut-off score of 216 was used throughout the study.

The complete set of ECA scores for each MOS were then sent to the proponent school for that MOS for review. Both high drivers and other tasks that scored within 20 percent of the cut-off, or a score of 173, specifically were noted as tasks the school should examine carefully. For each task, the school was asked to concur or not concur that the task was a high driver. In addition, the school was asked to identify any other tasks on the list that should be considered high drivers regardless of their scores.

Exceptions to the cut-off score emerged during these reviews of the ECA scores by two of the schools. First, one MOS 63G task received a score of 216, equal to the cut-off score. However, this particular task was among those rated by MOS 63H SMEs, and only one of these SMEs felt he knew enough about the task, an electrical troubleshooting task, to rate it. The school, USAOC&S, decided that this task should not be considered a high driver. At the same time, the school added a task, "Repair Diesel Engine Bradley-MLRS", that appeared on the MOS 63H survey form but received an ECA score of only 155.82. The other exceptions occurred in the designation of high driver tasks for MOS 31V. Although the original task list for this MOS had been assembled from the SM and had been approved by USASIGCEN, the school elected to eliminate one task, a supervisory task, that had been designated as a high driver. At the same time, the school requested that a task, one that was not surveyed because it did not appear in the SM and had not been added by the school when the task list was originally reviewed, be considered a high driver. This task involves troubleshooting one component of a typical communications equipment configuration.

Findings

The complete ECA scoring of every task from each MOS included in the study is contained in Appendix A. The number of tasks that were identified as high drivers, by MOS, is shown in Table 5. The table also indicates the number of tasks that had ECA scores within 20 percent of being a high driver, and the number of tasks determined by the proponent school to be high drivers. It should be noted that a prior ECA survey conducted on MOS 63H by the combat developments office at USAOC&S identified one high driver, a generic task covering repair of the hull electrical system. Component tasks included within this generic DS-GS maintenance task were surveyed twice in this ECA study. In the MOS 63T survey, an organizational level task on troubleshooting the hull electrical power system also turned out to be a high driver. In the MOS 63G survey, the same task was represented by a series of DS-GS repair-replace tasks covering electrical system components. These tasks presume troubleshooting already was accomplished at the organizational level, as specified in the MAC table. Although too few SMEs rated these tasks to consider the results entirely reliable, none of the MOS 63G hull electrical repair-replace tasks received scores in the high driver range.

Step 8. Conduct Task Analyses

> Perform a task analysis on each high driver that specifies its individual procedural steps, the tools and test equipment required, the conditions under which the task is performed, and the standard(s) that must be met.

SSC-NCR Procedure

A task analysis is required for each high driver. An already completed task analysis often will be available from DOTD at the proponent school. If one is not available, the task analysis must be developed. In most cases, sufficient information will be available from Field and Technical Manuals or other publications to prepare a task analysis sufficient for the purposes of an ECA.

Table 5

Number of ECA "High Drivers" Identified, by MOS

MOS	Title	ECA Score: 173-215	216 or More	# High Drivers
13B	Cannon Crewmember	0	0	0
13M	MLRS Crewmember	0	0	0
19K	M1 Armor Crewman	0	0	0
31V	Unit Level Communications Maintainer	2	8	8*
45D	Self-Propelled FA Turret Mechanic	0	0	0
63E	M1 Tank Systems Mechanic	0	0	0
63T	BFVS Mechanic	0	1	1
29E	Communications-Electronics Radio Repairer	0	4	4
45L	Artillery Repairer	0	0	0
63G	Fuel and Electrical Systems Repairer	0	1**	0
63H	Track Vehicle Repairer	1	1	2***
	TOTAL			15

* Includes one task with an ECA score over 216 deleted by the school, and one task not surveyed added by the school.

** ECA score of 216, but representing only one respondent and deleted as a high driver by the school.

*** Includes one task with an ECA score of 155.82 designated as a high driver by the school.

Activities

At the same time the high driver tasks identified on the basis of their ECA scores were verified by the schools, the schools were asked to supply any available task analyses covering these tasks. From among the 15 high drivers, the schools were able to supply task analysis information only for tasks in one MOS, 31V. This information, however, was limited to a Form 550, Task Analysis Worksheet, for each of the eight tasks. These analyses were extremely generic and, while they divided the task into functional segments, they lacked the specificity needed to document the individual steps in the task procedures.

Task analysis information may be available from other sources, however. For example, Applied Science Associates, Inc. and ARI prepared a comprehensive task breakdown of operator tasks for HIP. This breakdown is contained in Volume II of Embedded Training (ET) and Training Devices for the Howitzer Improvement Program (HIP). Although no MOS 13B operator tasks were identified as high drivers in our ECA study, the breakdown would have been very helpful in performing a task analysis had any high driver tasks emerged for this MOS.

In order to examine each of the high driver tasks in detail, observations of task performance were scheduled at the respective proponent schools. These on-site observation sessions proved very helpful in understanding the complexity of the procedure and the problems likely to be encountered by a soldier either when learning or when performing the task. The on-site visits also resulted in opportunities to conduct interviews with instructors, inspect test equipment and job aids, and determine how the task was presented during training. The value of these sessions fully outweighed the cost involved.

Various "levels" of task analysis may be used, reflecting the amount of detail and ancillary information desired. For the purpose of the ECA, every procedure was broken down into individual steps, each generally representing an action taken by the doer leading to some consequence or outcome. When possible, a draft of the task analysis was prepared beforehand using TMs. This considerably reduced the amount of on-site time required, and allowed the demonstration of task performance to proceed at a normal pace.

Findings

On-site observations of a soldier performing each of the high drivers were made at the proponent school for that MOS. A sample page from one of the task analyses completed to examine high drivers in this ECA study is shown in Figure 2. More comprehensive samples of the task analyses prepared during the study are contained in Appendix B.

As it turned out, nearly all of the high driver tasks uncovered through the SME surveys involved troubleshooting, usually of an electronic or electrical component. Because the procedures used to perform a troubleshooting task are highly dependent on each other, rarely, if ever, will all of the steps be employed before the "trouble" is identified. Therefore, it was not possible to observe every step in every procedure. Instead, some representative troubleshooting problem was inserted into the equipment, and the procedure was demonstrated to the extent required before the problem was located. Nevertheless, sufficiently large segments of each procedure were observed and documented to serve as a data base for examining task-related problems and their solutions in subsequent steps of the ECA.

The critique of observed task performance held with school representatives at the conclusion of the task analysis session proved extremely valuable. A summary of the qualitative findings obtained from on-site observations and interviews conducted along with the task analysis of a high driver for one MOS, MOS 63T, is reproduced in Figure 3.

STEP	ELEMENT	NORMAL INDICATOR	DIVERGENCE
95.	Verify no faults, steps 27-32		

--------------------------(FROM STEP 89)--------------------------

STEP	ELEMENT	NORMAL INDICATOR	DIVERGENCE
96.	Turn Master Power Switch OFF		
97.	Measure resistance between terminals 2 and 3 of Engine Accessory Switch	0 ohms	If resistance present, replace Engine Accessory Switch and verify no faults

NOTE: Use of Inspection Mirror required.

NOTE: Have helper assist.

STEP	ELEMENT	NORMAL INDICATOR	DIVERGENCE
98.	Remove plug 1W10P1 from jack 1A1J8		
99.	Measure resistance between plug 1W10P1 pin A and Engine Accessory Light positive terminal 54B	0 ohms	If resistance present, replace wiring harness 1W10 and verify no faults

NOTE: Have helper assist.

STEP	ELEMENT	NORMAL INDICATOR	DIVERGENCE
100.	Turn Engine Accessory Switch OFF		

Figure 2. Sample Page of an ECA Task Analysis

A task analysis was conducted September 17, 1987 at the U.S. Army Armor Center and School (USAACS), Ft. Knox, KY, on the 63T task, "Troubleshoot Power Distribution System of Bradley-MLRS Vehicle" identified as a high driver task by an ECA survey of SMEs.

Although the lesson plan for this task was provided to the project staff in advance, it contained only a "skeleton" of the procedure without the troubleshooting tree included in the TM. The staff was unable to obtain a copy of this TM until the time of the demonstration. Consequently, an outline of the troubleshooting steps in the lesson had to be prepared on site before actual performance was observed.

The instructor began the demonstration with a review of parts identification for the performing trainee who then carried out the troubleshooting procedure. The instructor inserted a "trouble" for the trainee to find. The demonstration did not include actual component replacement; these procedures are contain in other MOS 63T tasks.

A dismounted training station was used during task demonstration. The USAACS personnel, however, indicated that having the subsystem mounted on the vehicle would not significantly affect the ability of the soldier to perform the task. The observers also examined the appearance of the subsystem from the driver's seat of an actual M3 Bradley and experienced no added difficulty in locating components from how they appeared using the training station.

Approximately 2 1/2 hours were needed to perform the 26 steps required to complete this task, one of the more lengthy and comprehensive branches in this troubleshooting procedure. At the conclusion of the session, other branches of the tree were examined by the observers. None were judged to be significantly more difficult than the task segment that was demonstrated.

The soldier performing the task appeared to experience little, if any, difficulty except at the beginning of the task when he needed time to refamiliarize himself with the organization of the

Figure 3. Summary of Task Analysis Qualitative Findings, MOS 63T

troubleshooting chart in the TM. No coaching from the instructor was required. The performing soldier was a recent graduate of MOS 63T Advanced Individual Training (AIT) who was awaiting assignment.

During a discussion, the instructor advised that there had been errors in the TM which, although since corrected, may have contributed to apparent task difficulty when experienced SMEs were surveyed. Other USAACS personnel present at the demonstration also expressed the opinion that this task should not have been designated a high driver. The instructor specifically disputed the high rating on frequency rate obtained in the ECA survey. However, each of the subscores for this task exceeded the median subscores for all remaining tasks surveyed for this MOS and were at the top of the range of the subscores for all tasks with respect to Frequency Rate, Task Learning Difficulty, Time-to-Train and, particularly, Decay Rate.

The task analysis itself did not suggest any unique deficiency in equipment design, performance conditions, or training emphasis that would account for this task being rated a high driver. Although no one step or group of steps seemed difficult to learn or perform, the following more general factors were identified as possible sources of task learning or task performance difficulty:

1. Reading Dependency. With the many variations within the troubleshooting tree, the task is extremely TM dependent. A soldier with insufficient reading ability or one who is not adept at following written instructions could have difficulty performing this task. However, no individual step appears to depend on particularly complicated directions.

2. Electrical Familiarity. Qualification for MOS 63T is based on mechanical rather than electrical aptitude and interest. While the mechanic has been taught basic electricity and the operation of the Standard Test Equipment for the M1 Tank (STE-M1) in the common subject phase of AIT, this is one of only a handful of tasks performed by this MOS that depends on a knowledge of electrical instead of mechanical or hydraulic principles.

Figure 3. Summary of Task Analysis Qualitative Findings, MOS 63T (Continued)

3. Performance Environment. The mechanic performing the task on a vehicle is in a confined area (the driver's seat) where cable and connection labels are not as easily identified as they are when performing this type of work on a shop bench.

4. Inspection Mirror. Some steps may require the use of an inspection mirror to guide proper probe placement. While this appears to affect only a small number of the steps, a soldier without practice in using the mirror could have considerable difficulty. Use of the mirror was not required during the demonstration that was observed.

5. Test Equipment. The STE-series of equipment was not yet introduced when many senior MOS 63T personnel received their formal training and thus many personnel in the field may not routinely use the STE-M1.

6. Assistant Required. The mechanic must accurately direct an assistant (usually a crew member) and rely on that assistant to follow his directions. The need for an assistant was not observed since none is required when the task is performed on a bench.

7. Limited Training. As with most troubleshooting tasks, formal training on this task is limited to an explanation and subsequent practice on only the one branch of the troubleshooting tree covered by the school's lesson plan.

8. Complex Procedure. The task analysis identified 129 steps for this procedure. Although all generally will not be used, task performance probably includes many more steps than is typical of most other MOS 63T tasks.

9. Troubleshooting Charts. Performance of this task involves the use of complicated troubleshooting charts. Soldiers not familiar with these job aids may have difficulty following the procedure because it requires skipping from one section of the chart to another, depending on the results of each check performed.

Figure 3. Summary of Task Analysis Qualitative Findings, MOS 63T (Continued)

Step 9. Conduct Learning Analysis

Identify the knowledge, skills, and abilities (KSAs) needed to accomplish each high driver task, and determine the manpower, personnel, and training (MPT) requirements for performing each step of the high driver task.

SSC-NCR Procedure

The task analysis information generated in Step 8 is thoroughly reviewed to identify the knowledge, skills, and abilities (KSAs) a soldier must have to perform each high driver task to specified standards under expected conditions. These KSAs then are examined to determine the MPT requirements for each step of the high driver task, such as the number of personnel, the mental and physical attributes, and the scope of training required. An already completed learning analysis may be available from the proponent school DOTD.

Activities

The project's approach to this step differed somewhat from the one described by SSC-NCR, primarily because of the complexities of examining troubleshooting tasks. Also, we elected to change the title of this step to "Conduct Performance Analysis" to indicate it was more encompassing in that it considered KSAs affecting task performance as well as task acquisition. The substitute procedure adopted by the project consisted of the following steps:

a. Obtain a completed learning analysis from the proponent school DOTD, if available, and integrate the findings with those of the ECA study.

b. Assemble information on the relevant knowledge, skills and abilities (KSAs) specified or surmised as qualifications for entrance into the MOS, and on the content of Advanced Individual Training (AIT) common subjects that are taught to soldiers in this MOS as verified by instructors at the teaching school.

c. Identify the individual task steps, if any, that are responsible for the task being a high driver. Identify the KSAs required for successful performance of each of these steps and compare them with the KSAs presumed present based on the soldier's MOS. Note any discrepancies for attention in Step 10 of the ECA, "Identify Deficiencies".

d. Identify the generic steps comprising task performance. For this purpose, a "generic" step is one that is performed similarly across various equipments operated or maintained by that MOS, such as "change radio frequency" or "reconnect hose clamp". Generally, a soldier proficient at a step with several models of field radios or several models of vehicles can be expected to have little or no difficulty performing it on a new radio or vehicle. Steps in the procedure that cannot be subsumed under generic steps also should be listed. This analysis should be performed for the task as a whole whether or not an individual step has been identified as responsible for the task being a high driver.

e. Identify the KSAs required for successful performance of each of these generic steps, and thus for the task as a whole, and compare them with the KSAs presumed present based on the soldier's MOS. Note any discrepancies for attention in Step 10 of the ECA, "Identify Deficiencies".

The first two substeps, as already noted, were accomplished as part of the on-site task analysis visits. The third substep produced no relevant information in that none of the task analyses completed for this study revealed any individual steps or groups of steps that appeared to cause unusual difficulty. Extracting generic steps from the task analyses for the fourth substep was a useful approach for identifying the KSAs required to perform the task in the fifth substep. Checking back with the school instructors who were present during the task analysis allowed confirmation of the KSAs we identified.

Findings

The SME surveys so far completed resulted in the identification of 15 high drivers among four MOSs. These 15 high drivers are identified in Appendix A where the ECA survey results are presented by MOS. Task analyses and subsequent learning analyses were completed on 11 of these 15 tasks; this work currently is in progress for the four high drivers identified for MOS 29E. The following conclusions resulted from these analyses regarding the KSAs required by a soldier to perform the tasks successfully.

- MOS 63T (1 "high driver"): No individual steps in the task were identified as unusually difficult, either in the opinion of the instructors or on the basis of actual observation of task performance. The KSAs required for task performance, as derived from the component generic steps included in the task procedure, are all present in the capabilities of students completing AIT for MOS 63T according to the instructor. All of these KSAs were evident in the performance of the recent AIT graduate observed during the task analysis except for "use of an inspection mirror", a skill not required when the task is performed under bench conditions.

- <u>MOS 31V (8 "high drivers")</u>: No individual steps in the eight tasks were identified as unusually difficult, either in the opinion of the instructor or on the basis of actual observation of task performance. The KSAs required for task performance, as derived from the component generic steps included in the task procedures, are all present in the capabilities of students completing AIT for MOS 31V according to the instructor. All of these KSAs were evident in the performance of the recent AIT graduate observed during the task analysis even though that soldier performed only some of the eight tasks, with the remainder performed by the instructor.

- <u>MOS 63H (2 "high drivers")</u>: For these tasks, observations of task performance were made with a school instructor rather than a student performing the task. No individual steps or groups of steps seemed particularly difficult to perform, either in the opinion of school instructors or on the basis of actual observation of task performance. MOS 63H personnel should not have any difficulty performing these tasks considering the KSAs required as derived from the component generic steps included in the procedures. Although some proficiency in the use of special tools and gages is required for these tasks, these or similar tasks are taught in AIT. In the instructor's view, recent MOS 63H AIT graduates should have the KSAs needed to perform these tasks.

In order to illustrate the derivation of these conclusions, the findings from this step for one MOS, 63T, are described more fully in Figure 4.

No learning analysis (Form 550 or equivalent) for this task was available from the Directorate of Training Development (DOTD), USAOC&S. The analysis therefore was accomplished using the results of performance observations during the on-site task analysis at USAACS, Fort Knox (where AIT on this task occurs), and the KSA information on MOS 63T supplied by school personnel. The results of the analysis were:

a. No individual steps in this task, "Troubleshoot Power Distribution System of Bradley-MLRS Vehicle" could be identified as responsible for the task being identified as a high driver. The course instructor, the training branch chief, the branch supervisor of instruction, and a curriculum development representative from USAOC&S concurred in this conclusion. Also, all of these representatives except the one from curriculum development expressed doubt that this task should be considered a high driver.

b. The task as a whole consists of 26 segments identified on the basis of end items to be replaced, repaired or serviced. Only the first eight plus the last two are covered during training at Fort Knox. The segments are:

0. Select and use troubleshooting tree of TM9-2350-252-20-1-1
1. Hook up the STE-M1(BFVS)
2. Self-test the STE-M1(BFVS)
3. Troubleshoot the panel lights
4. Measure voltage (any step)
5. Measure resistance (any step)
6. Replace wiring harness 1W2
7. Replace electrical distribution box

(End of Fort Knox lessons)

8. Replace wiring harness 1W15
9. Replace battery shunt
10. Replace electrical lead 1W14
11. Replace battery jumper lead 1W33
12. Replace circuit breaker 1A2CB1
13. Replace wiring harness 1W4
14. Replace battery master switch relay
15. Replace relay diode

Figure 4. Performance Analysis Findings, MOS 63T

16. Replace wiring harness 1W10
17. Replace master power indicator light
18. Replace instrument panel indicator light
19. Replace engine accessory switch
20. Replace wiring harness 1W1
21. Replace electrical lead 1W16
22. Replace voltmeter
23. Service storage batteries

(Segments 8-23 are ends of other branches of the troubleshooting tree. Altogether, there are 18 possible components to replace or service.)

General Activities:
24. Follow safety precautions
25. Complete DA Form 2404

Total: 0-25 = 26 segments

c. The following common steps were identified as necessary to perform the task as a whole:

	Action	Tools and Procedures
1.	Select and use the correct trouble-shooting tree	Technical Manual
2.	Hook up the Test-Measurement-Diagnostic Equipment (TMDE)	Connect at quick disconnects
3.	Self-test the TMDE	Follow TM procedures, press keys, read displays
4.	Measure voltage	Use multimeter probes, read correct scale
5.	Measure resistance	Use multimeter probes, read correct scale
6.	Inspect on-off indicators, panel lights	Visual
7.	Operate electrical switches	Hand movement

Figure 4. Performance Analysis Findings, MOS 63T (Continued)

Action	Tools and Procedures
8. Identify test points on equipment	Visual
9. Remove and install cable connectors	Quick disconnects
10. Identify test points in cable connectors	Visual
11. Remove and replace access covers	Socket wrenches
12. Manually traverse turret	Hand movements
13. Remove and install floor plate	Socket wrenches
14. Notify supervisor as directed by TM troubleshooting tree	Refer identified problem to DS-GS maintenance for repair
15. Follow safety precautions	Observe all TM warnings and cautions
16. Complete DA Form 2404	Write up fault and action taken

d. The following KSAs were identified as necessary to learn or perform the task. According to instructor personnel, all students completing AIT for MOS 63T have these KSAs. All of these KSAs were observed in the performance of the 63T10 student who participated in the task analysis except for "use an inspection mirror". This skill was not required during the task analysis because the equipment had been removed from a vehicle and placed on a bench for easy access during training.

Knowledge
Basic electricity as taught in AIT

Figure 4. Performance Analysis Findings, MOS 63T (Continued)

Skills
- Use a STE-M1 (TMDE)
- Use a multimeter
- Use hand tools
- Connect and disconnect cables
- Identify test points
- Locate and inspect indicators
- Locate and operate switches
- Manually traverse turret
- Remove and replace cables and parts
- Use an inspection mirror
- Follow path in TM troubleshooting tree

Abilities
- Average reading ability
- Average dexterity and motor abilities

e. Based on these analyses, no KSA deficiencies that would lead to this task being designated a high driver were identified, either with respect to specific steps in the procedure or to the procedure as a whole.

Figure 4. Performance Analysis Findings, MOS 63T (Continued)

Step 10. Identify Deficiencies

Compare the KSAs required to perform each high driver task with the KSAs required by the MOS to identify any manpower, personnel, or training deficiencies.

SSC-NCR Procedure

Examine data such as unit manpower authorizations, personnel qualifications for the MOS, and the training given with respect to the results of the learning analysis in Step 9 to identify any manpower, personnel, or training deficiencies such as too few authorized personnel, personnel in the MOS who do not have the qualifications required to perform this task, or the omission of some key knowledge or skill from the training program.

Activities

The project staff elected to broaden this step to consider several possible areas of deficiency in addition to manpower, personnel, and training. These were equipment design, task procedures, supporting tools-manuals-job aids, and performance conditions. Most of the information needed for this step was obtained during the on-site task analyses or from the interviews and discussions with school personnel that took place during those visits. No effort was made in this step to focus on a single, or most prominent, deficiency. Instead, each high driver task, or group of tasks when they were closely related, was reviewed to determine if deficiencies in any of the seven areas could be impacting task learning or task performance. When a possible deficiency was identified, it was assessed in light of the pattern of subscore ratings obtained during the SME survey that originally identified the task as a high driver.

Findings

The examination of possible sources of deficiencies resulted in the following principal conclusions regarding the high drivers identified for the three MOSs on which the task analyses have been completed.

- MOS 63T (1 "high driver"): No prominent deficiencies were identified. This electrical troubleshooting task is dissimilar to most of the mechanical tasks performed by the MOS, however, and may represent a different aptitude than the mechanical aptitude specified for entry to the MOS, even though no aptitude deficiency was observed or reported. Training appears satisfactory except that steps early in the lengthy procedure are practiced far more often than those appearing later, and some portions of the task are never practiced during training. Tools-manuals-job aids appear satisfactory. It was learned that the school currently is rewriting the procedure to allow beginning the task at alternative entry points in the troubleshooting tree depending on the symptoms observed or reported. While this change is likely to reduce task performance time, it may increase task learning difficulty because of the need to match reported symptoms with those listed in the troubleshooting guide. The change also may increase the dependence of this task on the soldier's ability to understand the logic of electrical troubleshooting.

- MOS 31V (8 "high drivers"): These electronic checkout and troubleshooting tasks represent a major portion of the workload for MOS 31V. An evident problem affecting performance on these tasks was the inadequacy both of the procedures themselves and the way they are presented in the TMs. Although most of these procedures employ the symptom-based troubleshooting approach widely used at organizational maintenance levels, the necessary step-by-step troubleshooting charts are not provided for all tasks and those that are provided in the TMs contain numerous errors and omissions. As a result, a substitute system-based troubleshooting approach employing circuit schematics is used during training. This approach is considerably more difficult to master, and may be particularly difficult for soldiers holding MOS 31V qualifications. Although minimum levels of proficiency are achieved during training, the training program incorporating schematics may be considerably longer than necessary. Both approaches depend on the soldier having the necessary charts or schematics available during job performance to guide his work. However, because the steps to be followed are not explicit for system-based troubleshooting, use of these procedures in the field is likely to result in lengthy task performance times and a high rate of decay.

- MOS 63H (2 "high drivers"): The only outstanding deficiency identified for these particular transmission and engine repair tasks was that they are both very lengthy tasks. Because of the time required, each task is practiced only once during AIT. Yet, the tasks involve a large number of steps, are heavily dependent on the soldier's ability to select and read the appropriate TMs, and require the use of several specialized and sometimes delicate tools. Soldiers entering this MOS seem better qualified than those entering most other vehicle repair MOSs. Nevertheless, significant amounts of resources are consumed by these tasks during both training and performance because of their unusual length. Providing additional practice when these tasks are learned during AIT would lengthen training but probably would not result in a substantial reduction in performance time. Improvements in the reliability of the equipment, particularly the clutch assembly of the Bradley transmission may be the only effective long-term remedy.

A summary of the deficiency analysis for six of the eight MOS 31V high drivers is shown in Figure 5 to illustrate how this step was accomplished. Because information on the remaining two tasks is "For Official Use Only", the findings from the task analyses on those two tasks are not contained in this report. ECA score patterns for these tasks are included, however. The complete analyses for the high drivers from MOSs 63T, 31V, and 63H are contained in Appendix C.

Because of similar equipment and overlapping procedures, the six of eight high driver tasks from MOS 31V that can be described in detail are considered together. Many of the identified deficiencies and SME comments apply to most or all of these six tasks. The ECA subscores and their relative contribution to the total ECA score obtained for these tasks are shown in the table on the following page.

Each of the high drivers identified by the ECA survey contains very high subscores in Percent Performing and Frequency Rate. Because the primary job of 31V MOS is to troubleshoot radios, a high score in these categories for organizational radio repairers should be expected. For comparison, the task of installing a radio in a tactical vehicle resulted in a frequency rate of only 2.08 in the survey. It should be noted that aside from the concurring judgment by school personnel that these tasks are high drivers, the reason for their high ECA rating may be a distortion imposed by the way an ECA score is determined. If the MOS were broader and included organizational maintenance on a greater range of equipment, these high ECA subscores would have lower values even if these tasks still had to be performed as frequently and required the same number of manhours.

Task performance was examined with respect to each of seven potential sources of difficulty:

1. Manpower. None of the tasks are individually manpower intensive but, in some units, the number of radios relative to the number of MOS 31V personnel could cause a heavy workload. With better procedures, increased access to maintenance kits, and simpler directions, more preventive maintenance checks and services (PMCS) and rudimentary checkout and troubleshooting procedures might be assumed by the vehicle crew.

2. Personnel. No specific physical or aptitude deficiencies could be identified. The qualifiers for this MOS are passing scores on electronics and on surveillance-communications. Discussions with the course instructors gave the impression that the top qualifiers in these aptitudes were being lost to more

Figure 5. Deficiency Analysis of High Drivers for MOS 31V

ECA Subscore	Eval. 12-ser	Sys TS 12-ser	Sys TS VRC-64	PMCS VIC-1	Eval. VIC-1	Sys TS V1C-1 +FM
A. Percent Performing	3.42	3.08	2.91	3.30	3.18	Not in ECA Survey
B. Task Performance Difficulty	1.83	2.33	2.27	2.50	2.00	
C. Frequency Rate	.75	3.33	3.09	3.30	3.27	
D. Task Learning Difficulty	2.17	2.50	2.45	2.44	2.27	
E. Time-to-Train	2.50	3.33	3.55	2.70	2.45	
F. Decay Rate	2.17	2.67	2.82	2.30	2.18	
TOTAL ECA SCORE	275.68	532.92	501.19	413.28	253.48	

ECA Subscore	Sys TS KY-57	Install KY-57 KT	Remaining 29 Tasks	Range 29 Tasks
A. Percent Performing	3.45	3.09	2.77	(1.60-3.36)
B. Task Performance Difficulty	3.00	2.45	1.82	(1.33-2.40)
C. Frequency Rate	3.18	2.64	2.74	(1.50-3.25)
D. Task Learning Difficulty	3.09	2.36	1.89	(1.27-2.18)
E. Time-to-Train	2.91	2.18	1.71	(1.27-2.25)
F. Decay Rate	2.73	2.18	2.00	(1.58-2.27)
TOTAL ECA SCORE	808.65	225.05	89.28	(22.95-147.75)

Figure 5. Deficiency Analysis of High Drivers for MOS 31V (Continued)

highly technical MOSs, and that some of their MOS 31V students are only marginally qualified. While the instructors do not report having many students with profound reading difficulties, the troubleshooting procedures contained in these tasks may depend on analytic abilities that are beyond the capacity of many MOS 31V soldiers.

3. Training. Formal task training on the equipment covers all common failures. Decay rate following training is high on the troubleshooting segments, however. This seems related to remembering the peculiarities of a large number of radios rather than intricacies of the procedures or complexities in equipment design.

Time-to-train is rated "high" or "very high" on every task analyzed. This likely is attributable to the instructional material. The TM troubleshooting charts are quite deficient, so training is done with wiring diagrams and schematics. While this method is very thorough, it is very time consuming given the ability of entrants to this MOS. Training time might be reduced considerably with better instructional and performance aids.

The planned replacement radio, SINCGARS, will have a profound impact on reducing the variety of radios and, consequently, on reducing task training time if the new TM procedures for organizational maintenance are well written and consistent with the capabilities of an MOS 31V soldier.

4. Equipment Design. The equipment related to these tasks is rugged and the probability of failure seems reduced as much as possible for radio equipment. Connectors are simple and sturdy. The project team did not observe any steps in these tasks in which characteristics of the equipment made operation, evaluation, or repair physically difficult, complex, or strenuous. The project team was advised that some vehicle installations of the VIC-1 have more complicated cabling than was observed. When cable installation or replacement is required, the task may be inherently difficult.

5. Task Procedures. "Task Performance Difficulty"

Figure 5. Deficiency Analysis of High Drivers for MOS 31V (Continued)

is not related to any individual steps of these tasks and this subscore was rated high only for tasks related to the VIC-1 intercom system. This system's installation can be somewhat complex on some vehicles.

The evaluation segment of these tasks and most of the troubleshooting segments are symptom-based and specify the circuit test points to be used to isolate faulty components. This procedure is usual for troubleshooting tasks at the organizational maintenance level for electrical and electronic equipment. However, weaknesses and deficiencies in the way these procedures are presented in the TMs make it necessary for students to use schematic diagrams and system-based troubleshooting techniques instead of simpler symptom-based troubleshooting procedures. Because of the analytic ability required, this may be difficult for some MOS 31V students.

6. Tools-manuals-job aids. TM procedures are poorly written and incomplete. Consequently, the school has designed its own job aids based on schematic diagrams. Practice with these diagrams is provided to students but their ability to use them may be limited. These job aids may not be available in the field, and the soldier then would have to relearn the task. The poor quality of the procedures in the TMs appears to be the primary source of difficulty for these tasks.

7. Performance conditions. No environmental conditions or factors such as cramped workspace or excess noise that would affect the difficulty of performance were noted.

Figure 5. Deficiency Analysis of High Drivers for MOS 31V (Continued)

Step 11. Suggest Solutions

Identify all possible manpower, personnel, and training solutions that will overcome the deficiency and eliminate the high driver status of the task.

SSC-NCR Procedure

During this step, changes in manpower, personnel, and training that will resolve the identified deficiencies are considered. These include, for example, increasing the authorized manpower in an MOS, modifying the qualifications of accessions into an MOS, or improving the current training program through the introduction of new training devices. Each suggested change must be evaluated with respect to its Army-wide implications. Reasonable manpower, personnel, or training solutions can be implemented by the proponent school. If there is no reasonable MPT solution, some materiel change may be proposed as a solution.

Activities

Based on the logic used in the preceding two steps, changes in equipment design, task procedures, supporting tools-manuals-job aids, and environmental conditions also were considered as possible solutions. Because AFAS was still in the concept development stage of the materiel acquisition cycle, materiel solutions could be introduced economically and therefore need not be considered with any different priority. Also, as many solutions as possible were devised to provide combat developers with a range of diverse alternatives that could be adopted singly or in combination depending on other issues that were beyond the scope of this ECA but may be significant considerations during the new system planning process.

Findings

The most direct solutions for resolving the high driver tasks identified during the study are summarized in the following paragraphs. Comprehensive summaries of the learning analyses, the identification of deficiencies, and the suggested solutions for all high driver tasks in each MOS on which task analyses were completed are presented in Appendix C.

- MOS 63T (1 "high driver"): No significant deficiencies could be identified that would account for the high driver status of this task. Also, proponent school personnel voiced some concern as to whether this task was, in fact, a high driver although a similar task at the DS-GS maintenance level also was identified as a high driver in an earlier, independent ECA survey. Nevertheless, the project's analysis of this task did suggest that electrical and electronic tasks may be particularly difficult for incumbents in MOSs concerned primarily with the operation or maintenance of mechanical equipment.

A variety of possible solutions were identified including improved test equipment, reassigning the task to a more suitably qualified MOS at the unit level, increasing the reliability of the equipment requiring maintenance, and the addition of a training device to enhance training. However, the most promising solution would be to reallocate this task to the DS-GS maintenance level where more qualified personnel could be available to perform it. As it is, a sizable proportion of the failures identified through the troubleshooting procedures constituting this task cannot be remedied at the organizational level because they require DS-GS level repairs.

If this change is implemented, consideration then would have to be given to strengthening the capabilities of MOS 63G, now responsible for the parallel DS-GS maintenance functions, in that the most closely related tasks at the DS-GS level also appears to be high drivers. Selection for that MOS also is based on mechanical aptitude even though the MOS is specifically responsible for fuel and electrical system repairs that likely depend heavily on electrical and electronic aptitudes. Despite the dependence of this task on electrical and electronic abilities, changing the criteria for entrance to MOS 63G may not be practical in that this MOS is absorbed at the -30 skill level by MOS 63H, which is almost exclusively concerned with mechanical tasks.

- <u>MOS 31V (8 "high drivers")</u>: The outstanding deficiency affecting all eight of these tasks was the poor quality of the TM procedures supplied to support learning and performance. Qualifications for entry to MOS 31V are modest. While these soldiers should be able to develop proficiency at organizational level checkouts and troubleshooting of communications equipment using an explicit, symptom-based step-by-step guide, they cannot be expected to fully master system techniques based on the use of schematics as they now are required to do. Significant improvements in the procedures and how they are presented in the TMs should substantially improve the quality of performance, reduce performance time, and shorten training time.

  The communication equipment currently maintained by MOS 31V is due to be phased out as more modern SINCGARS equipment enters the inventory. Nevertheless, an inexpensive investment in clearer, more accurate, and more easily used troubleshooting guides for currently fielded equipment would yield a worthwhile return. Also, the "lessons learned" with respect to these high driver tasks should be considered in the design of the TMs for organizational maintenance performed on SINCGARS.

- <u>MOS 63H (2 "high drivers")</u>: The only specific deficiency associated with these two high drivers that could be identified during the analysis was that, because of the length of these tasks, too little practice is provided during AIT. The underlying problem appears to be a result of the breadth of this MOS. It encompasses troubleshooting and repair assignments on virtually every component of any tracked vehicle currently in the Army inventory. Because of the number of components involved, and the substantial differences in the details of procedures for repairing similar components from one vehicle to the next, only the most universal or frequently needed tasks are likely to be mastered without substantial on-the-job experience with particular vehicles.

  Adding to this problem is the increasing complexity of newer systems, the tighter tolerances required for full performance capability of the equipment, and the increased stress this equipment experiences because of efforts to keep the weight of the power system low with respect to the weight of the armaments carried. The SMEs at USAOC&S anticipate, for example, that there will be many more transmission failures if the heavier AFAS turret is mounted on a current Bradley chassis. Considerable skill will be required to perform intermediate maintenance on the AFAS chassis, and it is not likely that this level of skill can be developed in the school setting given the variety of tasks a soldier in MOS 63H will have to learn.

  Perhaps the most effective long range solution would be to divide this MOS into two or more MOSs, each with a more limited scope of responsibility. Although some vehicle-specific MOSs have been created in the ordnance career field to respond to this problem, such as MOS 63E for the Abrams M1 Tank or MOS 63T for the Bradley Fighting Vehicle, these are at the unit rather than at the intermediate maintenance level. Similar specialization at the DS-GS level would be helpful but, instead of focusing on particular weapon systems, the division should be based on creating subsystem specialists concerned only, for example, with engines, with transmissions, or with suspensions and tracks.

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LIST OF ACRONYMS

AFAS	Advanced Field Artillery System
AFCS	Automatic Fire Control System
AIT	Advanced Individual Training
ARI	Army Research Institute for the Behavioral and Social Sciences
BFVS	Bradley Fighting Vehicle System
CODAP	Computerized Occupational Data Analysis Program
DCD	Directorate of Combat Developments
DOTD	Directorate of Training Development
DS	Direct Support (Maintenance)
ECA	Early Comparability Analysis
ET	Embedded Training
FA	Field Artillery
GS	General Support (Maintenance)
HIP	Howitzer Improvement Program
KSA	Knowledge, Skill, Ability
LSAR	Logistic Support Analysis Record
M109	M109A2/A3 Self-Propelled Howitzer
MAC	Maintenance Allocation Chart
MANPRINT	Manpower, Personnel Integration
MJWG	MANPRINT Joint Working Group
MLRS	Multiple Launch Rocket System
MOS	Military Occupational Specialty
MMCT	Mobile Maintenance Contact Team
MPT	Manpower, Personnel, Training
NBC	Nuclear-Biological-Chemical

LIST OF ACRONYMS (Continued)

PDS	Position Determining System
PMCS	Preventive Maintenance Checks and Services
QQPRI	Qualitative and Quantitative Personnel Requirements Information
SINCGARS	Single Channel Ground Airborne Radio System
SM	Soldier's Manual
SME	Subject Matter Expert
SPH	Self-Propelled Howitzer
SSC-NCR	Soldier Support Center-National Capital Region
STE-ICE	Standard Test Equipment, Internal Combustion Engine
STE-M1	Standard Test Equipment, M1 Tank
TM	Technical Manual
TMDE	Test-Measurement-Diagnostic Equipment
TSM-Cannon	TRADOC System Manager for Cannon
USAACS	U.S. Army Armor Center and School
USAFAS	U.S. Army Field Artillery School
USAOC&S	U.S. Army Ordnance Center and School
USASIGCEN	U.S. Army Signal Center

APPENDIX A

ECA SURVEY RESULTS

Note: Tasks with ECA composite scores within 20 percent of being a high driver (scores of between 173 and 215) are labeled "NEAR" in the High Driver column. These tasks are not included in the number of high drivers for the MOS reported at the bottom of the column, however.

ECA TASK SCORES
MOS 29E

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Evaluate RT-524 Configuration	9	2.89	2.00	3.33	1.89	2.22	2.33	188.63	NEAR
2	Troubleshoot RT-524 Config.	9	3.44	2.44	3.44	2.00	2.67	2.22	343.72	YES
3	Aline-Adust RT-524	9	3.33	1.78	3.56	2.00	2.44	2.33	240.35	YES
4	Repair RT-524	9	3.89	2.33	3.56	2.22	2.44	2.33	408.93	YES
5	Replace RT-524	9	2.89	1.33	2.44	1.22	1.44	1.11	18.47	no
6	Evaluate R-442 Configuration	9	2.33	1.78	3.00	1.89	1.89	1.89	83.87	no
7	Troubleshoot R-442 Config.	9	2.89	1.78	2.78	1.78	1.89	1.67	79.84	no
8	Aline-Adust R-442	9	2.44	1.67	3.00	1.89	2.00	1.89	87.22	no
9	Repair R-442	9	2.56	1.78	2.67	1.89	1.89	1.67	72.04	no
10	Replace R-442	9	2.56	1.22	2.11	1.22	1.22	1.22	12.04	no
11	Evaluate AM-1780 Configuration	9	2.11	1.89	2.11	1.56	2.00	2.11	55.29	no
12	Troubleshoot AM-1780 Config.	9	2.33	2.00	2.22	1.78	2.33	2.22	95.60	no
13	Repair AM-1780	9	2.44	1.78	2.22	1.89	1.78	2.11	68.46	no
14	Replace AM-1780	9	2.56	1.33	2.11	1.33	1.22	1.44	16.93	no
15	Evaluate C-2298/97/96 Config.	9	2.33	1.89	2.33	1.67	2.00	1.78	60.94	no
16	Troublsht C-2298/97/96 Config.	9	2.22	1.89	2.22	1.56	2.00	1.89	54.82	no
17	Repair C-2298/97/96	9	2.33	1.56	2.11	1.78	1.44	2.11	41.54	no
18	Replace C-2298/97/96	9	2.56	1.33	2.11	1.22	1.22	1.44	15.52	no
19	Eval Antennas, Matching Unit	8	2.63	1.88	2.63	1.63	1.50	1.88	59.05	no
20	Trblsht Antennas,Matching Unit	8	2.13	1.63	2.25	1.63	1.13	2.13	30.18	no
21	Replace Antennas,Matching Unit	8	2.38	1.25	2.13	1.50	1.00	1.88	17.74	no
22	Evaluate RT-841 Configuration	9	3.00	1.67	3.00	2.00	2.56	2.00	153.33	no
23	Troubleshoot RT-841 Config.	9	3.11	2.11	3.00	2.22	2.56	2.11	236.23	YES
24	Aline-Adust RT-841	9	2.89	2.00	3.22	2.33	1.89	2.00	164.11	no
25	Repair RT-841	9	3.22	1.89	3.22	2.11	2.33	2.00	193.21	NEAR
26	Replace RT-841	9	2.44	1.11	1.67	1.33	1.11	1.33	8.94	no
27	Evaluate AM-2060 Configuration	9	2.33	1.56	2.44	1.44	1.56	1.67	33.23	no
28	Troubleshoot AM-2060 Config.	9	2.11	1.67	2.56	1.33	1.89	2.00	45.29	no
29	Adust AM-2060	9	2.44	1.44	2.11	1.44	1.44	1.78	27.65	no
30	Repair AM-2060	9	2.56	1.56	2.44	1.56	1.89	1.67	47.59	no
31	Replace AM-2060	9	2.11	1.22	2.67	1.22	1.11	1.22	11.42	no
32	Evaluate KY-57 Configuration	3	2.33	2.33	1.67	2.33	2.00	1.67	70.58	no
33	Troubleshoot KY-57 Config.	2	2.00	2.00	2.00	2.50	1.50	1.50	45.00	no
34	Aline-Adust KY-57	2	2.00	2.00	2.00	2.50	1.00	1.50	30.00	no
35	Repair KY-57	2	2.00	2.00	2.00	2.50	1.00	1.50	30.00	no
36	Replace KY-57	2	2.00	2.00	2.00	2.00	1.00	1.00	16.00	no
		Mean	2.55	1.75	2.51	1.79	1.74	1.79	87.88	
		High	3.89	2.44	3.56	2.50	2.67	2.33	408.93	No. of HDs = 4
		Low	2.00	1.11	1.67	1.22	1.00	1.00	8.94	

ECA TASK SCORES
MOS 31V

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Sys Trblsht 12 Series Radio	12	3.08	2.33	3.33	2.50	3.33	2.67	532.92	YES
2	Sys Trblsht VRC-64;GRC-160	11	2.91	2.27	3.09	2.45	3.55	2.82	501.19	YES
3	Verify Install VRC-64;GRC-160	12	2.58	1.67	2.83	1.75	1.75	1.83	68.49	no
4	Install FM Radio Install Kit	12	2.67	2.17	2.08	2.08	2.25	1.83	103.44	no
5	Eval Operation 12 Series Radio	12	3.42	1.83	3.75	2.17	2.50	2.17	275.68	YES
6	Unit PMCS 12 Series Radio	12	3.25	1.83	3.17	1.50	1.83	1.83	95.13	no
7	Unit PMCS VRC-64;GRC-160	11	3.27	1.91	3.09	1.64	1.82	1.82	104.47	no
8	Check Unit PMCS VRC-64;GRC-16(	11	3.09	1.64	3.18	1.73	1.64	1.82	82.70	no
9	Check Unit PMCS 12 Series Rad	12	3.00	1.67	3.25	1.67	1.50	1.58	64.32	no
10	Check Install FM Radio	12	2.83	1.33	3.00	1.75	1.42	1.75	49.17	no
11	Check Maintenance Tact Radios	12	3.25	1.58	2.92	1.67	1.50	1.75	65.66	no
12	Evaluate Operation GRA-39	12	2.33	1.75	2.67	1.92	1.58	2.25	74.35	no
13	Sys Trblsht KY-57 with FM Rad	11	3.45	3.00	3.18	3.09	2.91	2.73	808.65	YES
14	Install KY-57 Install Kit	11	3.09	2.45	2.64	2.36	2.18	2.18	225.05	YES
15	Eval Operation KYK-13	11	2.64	1.91	3.00	2.00	1.82	2.09	114.80	no
16	Unit PMCS on KY-57	11	3.00	2.00	3.00	2.09	1.73	2.27	147.75	no
17	Check Install KY-57	11	3.09	1.82	3.20	1.73	1.55	2.00	96.01	no
18	Check PMCS on KY-57	11	3.00	1.73	3.00	1.91	1.73	1.91	97.86	no
19	Check Vinson with Radio	11	3.36	1.91	3.18	2.00	1.64	1.91	127.66	no
20	Check Maintenance of Vinson	11	3.18	2.00	3.09	2.09	1.73	1.91	135.62	no
21	Sys Trblsht GRA-39	12	2.33	1.83	2.50	2.00	1.83	2.17	84.96	no
22	Unit PMCS on VIC-1	10	3.30	2.50	3.30	2.44	2.70	2.30	413.28	YES
23	Evaluate Operation VIC-1	11	3.18	2.00	3.27	2.27	2.45	2.18	253.48	YES
24	Unit PMCS on GRA-39	12	2.42	1.83	2.67	1.92	1.67	2.00	75.48	no
25	Check Unit PMCS on GRA-39	12	2.33	1.75	2.67	1.92	1.67	2.00	69.57	no
26	Check PMCS on VIC-1	11	3.18	2.18	3.27	2.18	2.27	2.27	256.05	YES
27	Check Installed Field Wire	11	2.55	1.91	2.64	1.55	1.27	1.73	43.53	no
28	Check Op Field Expedient Ant	10	2.00	2.30	2.30	1.80	1.50	1.70	48.56	no
29	Check Unit PMCS OE-254 Ant	11	2.82	1.64	3.09	1.73	1.55	1.91	72.64	no
30	Unit PMCS on OE-254 Ant	11	2.82	1.64	3.09	1.73	1.55	1.91	72.64	no
31	Replace BNC on Coax Cable	11	2.00	2.36	1.91	2.18	1.64	2.09	67.37	no
32	Check Install RC-292 Ant	10	2.60	1.40	2.90	1.70	1.50	2.10	56.53	no
33	Check Install OE-254 Ant	11	2.73	1.55	3.09	1.73	1.45	1.91	62.49	no
34	Install-Replace Veh-Mount Ant	11	2.45	2.30	2.36	1.27	1.45	1.73	42.67	no
35	Set-Up Op Field Expedient Ant	10	1.60	2.40	1.50	1.90	1.70	2.20	40.93	no
36	Install-Maint DR-8 with GRA-39	11	1.73	1.73	2.00	1.45	1.45	1.82	22.95	no
37	Install-Replace Pwr Suply;VIC-1	7	2.14	1.43	2.14	2.14	1.57	2.14	47.33	no
		Mean	2.78	1.93	2.85	1.95	1.87	2.03	148.69	
		High	3.45	3.00	3.75	3.09	3.55	2.82	808.65	No. of HDs = 8
		Low	1.60	1.33	1.50	1.27	1.27	1.58	22.95	

ECA TASK SCORES
MOS 45L

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Replace 155mm Cannon Tube	9	1.78	2.11	1.11	1.11	1.78	1.67	13.73	no
2	Evaluate 155mm Cannon Tube	9	2.67	2.00	1.67	1.56	1.33	1.38	25.35	no
3	Repair 155mm Breech-block Assy	9	2.11	1.89	1.22	1.44	1.78	1.56	19.47	no
4	Repair Variable-Recoil System	8	2.38	2.50	1.75	2.50	2.50	1.88	121.77	no
5	Repair Main Accumulator	9	2.56	2.11	2.11	1.89	1.78	1.50	57.37	no
6	Repair Hydraulic Power Pack	8	2.38	2.50	1.50	2.00	2.00	1.75	62.34	no
7	Repair Rammer Cylinder Assy	9	2.00	1.67	1.56	1.67	1.67	1.67	24.01	no
8	Repair Elevating Cylinder	9	2.33	2.00	2.11	2.11	2.11	2.00	87.82	no
9	Repair Traversing Mechanism	9	2.67	2.44	1.67	2.22	2.56	1.89	116.54	no
10	Repair Hydraulic Components	9	2.22	1.78	2.56	1.56	1.67	1.56	40.72	no
11	Replace Manual Traverse Clutch	9	2.00	1.67	1.67	1.56	1.67	1.67	24.01	no
12	Repair Electrical Wiring	9	2.56	2.56	1.67	2.33	2.11	2.22	119.15	no
13	Conduct Checks & Services: Veh	9	2.78	1.56	3.33	1.33	1.67	1.44	46.23	no
14	Maintain Tool Kit	9	2.89	1.11	3.00	1.11	1.11	1.22	14.53	no
15	Prepare DA Form 2404	8	2.50	1.13	3.13	1.13	1.25	1.63	20.08	no
16	Replace Main Accumulator	9	2.11	1.67	1.11	1.78	1.63	1.78	20.08	no
17	Replace Hydraulic Power Pack	9	1.89	1.89	1.33	1.67	1.78	1.56	21.93	no
18	Replace Elevating Cylinder	9	2.22	1.67	2.00	1.67	1.56	1.67	32.01	no
19	Inspect Breech-block Assy	9	2.33	1.11	2.11	1.22	1.00	1.33	8.92	no
20	Inspect Main Accumulator	9	2.44	1.22	2.56	1.33	1.11	1.67	18.85	no
21	Inspect Hydraulic Power Pack	9	2.33	1.56	2.67	1.33	1.56	1.56	31.23	no
22	Inspect Elevating Cylinder	9	2.78	1.44	2.11	1.56	1.22	1.56	25.05	no
23	Inspect Manual Traverse Clutch	9	2.33	1.44	1.89	1.67	1.33	1.67	23.58	no
24	Inspect Electrical Wiring	9	2.67	2.11	2.33	2.00	2.11	2.11	117.09	no
25	Test Electrical Wiring	9	2.67	2.67	2.11	2.33	2.11	2.22	164.33	no
26	Replace Electrical Wiring	9	2.67	2.56	1.56	2.56	2.33	2.00	126.42	no
27	Repair Cab Power Relay Box	9	2.00	1.78	1.56	1.44	1.56	1.33	16.57	no
		Mean	2.38	1.86	1.98	1.71	1.71	1.68	51.82	
		High	2.89	2.67	3.33	2.56	2.56	2.22	164.33	No. of HDs = 0
		Low	1.78	1.11	1.11	1.11	1.00	1.22	8.92	

ECA TASK SCORES
MOS 63T

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Repair MLRS Road Wheel Housing	12	1.83	1.66	1.58	1.33	1.66	1.50	15.90	no
2	Replace MLRS Shock Absorber	12	2.50	1.30	1.80	1.10	1.30	1.30	10.88	no
3	Replace MLRS Road Wheels	12	2.50	1.00	2.30	1.00	1.00	1.30	7.48	no
4	Install Power Unit	12	3.50	2.20	2.30	2.20	2.20	1.70	145.72	no
5	Remove Power Unit	12	3.50	2.20	2.30	2.20	2.20	1.50	128.57	no
6	Ground Hop Power Unit	12	3.20	1.50	2.10	1.50	1.20	1.70	30.84	no
7	Adjust Right-Left Service Brak	12	2.80	1.60	1.80	1.60	1.30	1.80	30.19	no
8	Adjust Controll Steer, Neutral	12	3.10	2.40	2.00	2.10	1.60	1.80	89.99	no
9	Replace Engine Starter	12	2.60	1.60	1.50	1.40	1.30	1.40	15.90	no
10	Ajust Geer Shift & Clutch Link	11	2.70	1.50	1.70	1.40	1.00	1.70	16.39	no
11	Service Engine Gas Cylinder	9	2.50	1.50	1.80	1.40	1.10	1.20	12.47	no
12	Replace Crew Extinguisher	12	2.90	1.50	1.80	1.30	1.10	1.60	17.92	no
13	Replace Engine Fire Extnguish	12	2.30	1.50	1.30	1.30	1.30	1.40	10.61	no
14	Troublshoot Veh Power Dist Sys	12	3.30	2.40	2.80	2.30	2.30	2.50	293.28	YES
15	Troublshoot Veh Dome Light Sys	11	2.40	1.60	1.60	1.60	1.50	1.40	20.64	no
16	Troubleshoot Ramp System	12	2.30	1.70	1.40	1.30	1.30	1.70	15.73	no
17	Troubleshoot Bilge Pump System	12	2.30	1.30	1.40	1.20	1.10	1.70	9.39	no
18	Troublshoot Veh Ext Light-Horn	11	2.80	1.50	2.00	1.40	1.40	1.60	26.34	no
19	Troublshoot Fire Port Vent Fan	12	2.30	1.40	1.70	1.30	1.30	1.60	14.80	no
20	Troublshoot Hull Vent Fan Sys	12	2.30	1.60	1.80	1.40	1.40	1.60	20.77	no
21	Troubleshoot Steering System	12	2.10	1.90	2.30	1.80	1.70	1.70	47.74	no
22	Troubleshoot Brake System	12	2.70	1.60	2.00	1.60	1.70	1.80	42.30	no
23	Troublshoot Geer Selection Sys	12	2.40	1.60	1.80	1.40	1.60	1.80	27.87	no
24	Troublshoot Eng Air Intake Sys	11	2.80	1.50	1.80	1.50	1.50	1.60	27.22	no
25	Troublshoot Eng Lubrication	11	2.60	1.60	1.60	1.60	1.60	2.10	35.78	no
26	Troublshoot Fire Suppression	12	2.30	1.80	1.70	1.40	1.80	2.10	37.25	no
		Mean	2.64	1.65	1.85	1.52	1.48	1.66	44.31	
		High	3.50	2.40	2.80	2.30	2.30	2.50	293.28	No. of HDs = 1
		Low	1.83	1.00	1.30	1.00	1.00	1.20	7.48	

ECA TASK SCORES
MOS 19K

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Operate Gas Filter:M1 Tank	6	2.82	1.33	2.33	1.33	1.16	1.16	15.64	no
2	Perform PreOp Check-Servic:NBC	6	2.82	1.67	2.16	1.83	1.67	1.83	56.89	no
		Mean	2.82	1.50	2.25	1.58	1.42	1.50	36.26	
		High	2.82	1.67	2.33	1.83	1.67	1.83	56.89	No. of HDs = 0
		Low	2.82	1.33	2.16	1.33	1.16	1.16	15.64	

ECA TASK SCORES
MOS 63E

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Maintain M1 Gas Filter Sys	7	2.71	1.42	1.71	1.28	1.42	1.71	20.45	no
2	Perform PreOp Check-Servic:NBC	6	2.82	1.67	2.16	1.83	1.67	1.83	56.89	no
		Mean	2.77	1.55	1.94	1.56	1.55	1.77	38.67	
		High	2.82	1.67	2.16	1.83	1.67	1.83	56.89	No. of HDs = 0
		Low	2.71	1.42	1.71	1.28	1.42	1.71	20.45	

ECA TASK SCORES
MOS 45D

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Repair M109 Firing Mechanism	8	2.00	1.13	2.00	1.13	1.00	1.25	6.38	no
2	Adjust M109 Breech Mech (Cam)	8	2.13	2.13	2.00	2.25	1.75	2.38	85.03	no
3	Inspect Torque Key	8	2.38	1.25	1.75	1.25	1.13	1.50	11.03	no
4	Repair M109 Cannon Breech Mech	8	1.63	2.25	1.63	2.13	2.13	2.50	67.80	no
5	Repair M109 Breech Carrier	8	1.75	2.00	1.38	2.13	1.88	2.38	46.03	no
6	Inspect Variable Recoil Mech	8	2.38	1.75	2.00	1.50	1.38	1.75	30.18	no
7	Inspect Counterrecoil Buffer	7	2.29	1.71	1.71	1.43	1.43	2.29	31.36	no
8	Repair Loader-Rammer System	8	2.75	2.25	1.75	1.88	1.88	2.38	91.08	no
9	Repair Spade System	8	2.25	1.63	2.13	1.75	1.63	1.50	33.42	no
10	Trblsht Manual Traversing Syst	8	2.75	1.63	2.50	1.50	2.00	2.00	67.24	no
11	Trblsht Cannon Man'l Elevation	8	2.75	1.88	2.38	1.88	2.00	2.13	98.55	no
12	Service Equilibrated Elevation	8	2.00	1.88	1.75	2.25	1.88	2.25	62.63	no
13	Adjust Equilibrated Elevation	7	1.57	1.57	1.86	2.14	2.00	2.29	44.94	no
14	Repair Cab Slip Ring Arm	8	3.13	1.63	2.63	1.75	1.75	1.88	77.25	no
15	Trblsht Cab Pwr Pack Ckt	8	2.63	1.75	2.50	2.00	1.88	2.00	86.53	no
16	Test Cab Pwr Harness Assy	7	2.29	1.57	2.14	1.71	1.57	2.00	41.31	no
17	Service Cab Hydraulic Pwr Pack	8	2.38	2.13	2.25	2.13	2.00	2.13	103.50	no
18	Replace Pwr Pack-Main Tubes	8	1.75	2.75	1.38	2.50	2.50	2.50	103.77	no
19	Test Main Accum Nitro Pressure	8	2.50	1.75	2.38	2.00	1.63	2.13	72.30	no
20	Replace Telescope Mount	7	2.86	1.86	2.00	1.71	1.43	1.43	37.20	no
21	Synchronize Telescope Mount	7	2.57	2.14	2.14	2.00	2.00	1.71	80.50	no
22	Purge Telescope Mount	6	2.67	1.17	2.00	1.17	1.17	1.17	10.01	no
23	Trblsht Howitzer Mount	6	2.50	1.50	2.00	1.33	1.50	1.50	22.44	no
24	Repair Travel Locks	8	1.88	1.13	1.13	1.25	1.25	1.25	4.69	no
		Mean	2.32	1.77	1.97	1.78	1.70	1.93	54.80	
		High	3.13	2.75	2.63	2.50	2.50	2.50	103.77	No. of HDs
		Low	1.57	1.13	1.13	1.13	1.00	1.17	4.69	

ECA TASK SCORES
MOS 13M

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers = > 216
1	Position MLRS Launcher Fire Pt	15	2.50	1.20	2.70	1.30	1.50	1.30	20.53	no
2	OM Crew Equipment Containers	15	2.10	1.40	3.00	1.30	1.30	1.10	16.40	no
3	Perform Gunner Reload Op	15	2.70	1.60	3.20	1.90	2.50	1.30	85.36	no
4	Interpret Fault Messages-Ind	15	2.00	1.50	2.80	1.50	2.20	1.30	36.04	no
5	Recon-Select Platoon Positions	15	2.00	1.70	2.80	1.90	2.50	1.30	58.79	no
6	Select Firing Positions	15	1.60	1.40	3.40	1.70	2.10	1.20	32.63	no
7	Measure Mask Data	15	1.30	1.70	2.70	1.90	1.90	1.80	38.77	no
8	Perform Sect Chief Reload Op	15	2.30	1.30	3.40	1.20	1.70	1.30	26.96	no
9	Direct Hangfire Procedures	15	1.70	1.50	2.00	1.70	1.90	1.30	21.41	no
10	Perform Emergency Destruction	15	1.90	2.00	1.70	1.90	1.90	1.50	34.98	no
11	PMCS MLRS Carrier M993 (Org)	15	2.90	1.50	3.70	1.50	2.20	1.30	69.05	no
12	Replace Track Shoe	15	2.30	1.80	1.50	1.10	1.70	1.30	15.10	no
13	Prepare Disabled Veh:Towing	15	1.50	1.60	2.00	1.40	1.40	1.30	12.23	no
14	Perform Hydraulic Sys Maint	15	1.70	1.90	2.30	1.90	1.90	1.80	48.27	no
15	Perform Diagnostic Test:FCS	14	1.90	1.80	2.40	2.00	1.90	1.60	49.90	no
16	Perform Maint LLM Batteries	14	2.30	1.20	3.20	1.30	1.30	1.20	17.91	no
17	Perform Maint Electronics Box	14	1.50	1.70	2.20	1.50	1.80	1.60	24.24	no
18	Perform LLM PMCS (Org)	14	2.60	1.40	3.10	1.60	1.80	1.40	45.50	no
19	Perform Maint Fire Cont Unit	14	1.90	1.70	2.90	1.60	1.60	1.50	35.97	no
20	Perform Maint Fire Cont Panel	14	1.50	1.70	2.00	1.50	1.80	1.50	20.66	no
21	Perform Maint Sht No-Volt Test	14	2.10	1.30	2.20	1.20	1.10	1.20	9.51	no
22	Perform Maint Electronics Unit	14	1.40	1.50	2.30	1.60	1.60	1.60	19.78	no
23	Install-Replace PDS	14	1.80	1.60	2.00	1.60	1.40	1.60	20.64	no
24	Perform Maint SRP/PDS (Org)	14	1.50	1.70	2.00	1.60	1.80	1.60	23.50	no
25	Startup-Shutdown FCS	14	2.60	1.30	3.00	1.20	1.50	1.40	25.55	no
26	Interpret Fault Mssgs-Ind Mech	13	1.80	1.50	2.70	1.50	1.60	1.70	29.74	no
27	Replace Communicat's Processor	13	1.80	1.80	2.10	1.60	1.50	1.50	24.49	no
28	Perform FCS After Maint Test	13	2.10	1.30	3.10	1.40	1.50	1.50	26.66	no
29	Remove-Replace Encoder Adapter	14	1.30	2.10	1.90	1.90	1.80	1.60	28.38	no
30	Perform Startup-Shutdown FCS	15	2.60	1.30	3.10	1.20	1.70	1.10	23.51	no

ECA TASK SCORES
MOS 13M

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
31	Update PDS	15	2.70	1.40	3.30	1.50	1.80	1.30	43.78	no
32	Calibrate PDS	15	2.50	1.50	3.50	1.50	2.00	1.50	59.06	no
33	Perform a Fire Mission	15	2.60	1.30	3.40	1.50	1.90	1.30	42.58	no
34	Edit-Input FCS Data	15	2.20	1.50	3.40	1.70	2.10	1.60	64.09	no
35	PMCS Cable Commun Components	12	2.40	1.90	2.50	2.20	1.90	2.00	95.30	no
36	Install PLDMD: Pltn Leader Veh	12	2.00	1.90	2.60	1.80	2.00	2.10	74.69	
37	Startup-Shutdown PLDMD	12	1.80	1.80	3.30	1.90	2.10	1.80	76.79	no
38	Compose-Xmit Mssgs: PLDMD	12	2.10	1.90	2.70	1.80	2.10	1.90	77.37	no
39	Review-Edit Rcvd Message	12	2.80	1.30	3.40	1.70	2.30	1.70	82.26	no
40	Review-Edit Database Info	10	2.20	1.60	3.30	1.60	2.00	1.40	52.04	no
41	Request Ammunition	14	2.50	1.30	3.10	1.30	1.60	1.40	29.34	no
42	Est-Enter-Leave Radio Net	14	2.60	1.20	3.50	1.30	1.70	1.30	31.37	no
43	Encode-Decode Msg:KTC 600 Code	13	2.90	1.70	3.20	1.80	2.10	1.80	107.34	no
44	Use KTC 1400 Cipher System	13	2.90	1.70	3.20	1.80	2.20	1.80	112.45	no
45	Recognize ECM:Implement ECCM	13	2.20	2.00	2.30	2.00	2.30	1.80	83.79	no
46	Prepare-Submit Op MIJI Report	14	2.10	1.80	2.20	1.80	1.80	1.90	51.19	no
47	Mount Radio Set AN/VRC-46	14	2.60	1.20	2.90	1.30	1.50	1.30	22.94	no
48	Oper Radio Set VRC-64/GRC-160	13	2.80	1.10	3.00	1.30	1.50	1.50	27.03	no
49	Operate Radio Set VRC-46	14	2.80	1.10	3.10	1.10	1.60	1.30	21.85	no
50	Install Radio Set VRC-64	14	2.40	1.20	2.80	1.30	1.40	1.60	23.48	no
51	Perform PMCS 12-Series Radios	13	2.90	1.20	2.80	1.20	1.60	1.30	24.32	no
52	Op KY-57 & 12 Series Radio Set	14	2.70	1.50	3.00	1.60	1.90	1.50	55.40	no
53	Place into Opts VIC-1	13	2.50	1.50	2.80	1.50	1.70	1.60	42.84	no
		Mean	2.20	1.54	2.77	1.57	1.80	1.50	42.34	
		High	2.90	2.10	3.70	2.20	2.50	2.10	112.45	No. of HDs = 0
		Low	1.30	1.10	1.50	1.10	1.10	1.10	9.51	

ECA TASK SCORES
MOS 63H

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Repair MLRS Hull-Bolted Assy	8	1.75	2.00	1.38	1.50	1.50	1.75	18.95	no
2	Repair MLRS Hull, Machined	8	1.13	1.86	1.29	1.71	2.29	1.71	18.04	no
3	Repair MLRS Track Adjuster	12	2.08	1.33	1.67	1.00	1.33	1.58	9.77	no
4	Repair MLRS Lockout Support	5	2.00	2.00	1.80	2.00	1.60	2.00	46.08	no
5	Repair Pumping Unit,Hydraulic	5	1.80	1.40	1.20	1.40	2.20	1.60	14.90	no
6	Adjust Diesel Engine	14	2.43	1.71	2.07	1.86	1.71	2.14	58.83	no
7	Remove-Install Diesel Engine	14	2.50	1.79	2.64	1.50	2.14	2.14	81.26	no
8	Repair Diesel Engine	14	2.36	2.21	2.29	2.29	2.86	2.00	155.82	no
9	Repair Engine Turbocharger	13	1.31	1.92	1.31	1.77	1.62	1.92	18.07	no
10	Replace Flywheel Assy	14	1.43	1.43	1.36	1.50	1.21	1.43	7.21	no
11	Repair Flywheel Assy	7	1.14	1.86	1.43	1.86	1.29	1.57	11.38	no
12	Adjust Fuel Injector	14	2.07	1.71	2.00	1.86	1.64	1.71	37.15	no
13	Replace Fuel Injector	14	2.21	1.71	1.93	1.64	1.57	1.71	32.40	no
14	Repair Centrifugal Pump	6	1.50	2.83	1.33	2.83	2.33	2.17	81.17	no
15	Repair Cooler Fluid Xmission	8	1.50	1.50	1.13	1.50	1.25	1.25	5.93	no
16	Replace Cylinder Head	13	1.92	1.92	1.50	1.85	2.31	2.08	49.09	no
17	Repair Cylinder Head	11	1.45	1.82	1.45	1.91	2.36	2.00	34.72	no
18	Repair Cooler, Engine Oil	11	1.60	1.55	1.64	1.45	1.55	1.45	13.23	no
19	Replace Lubricating Pump	11	1.50	1.45	1.45	1.27	1.36	1.36	7.51	no
20	Repair Lubricating Pump	9	1.33	1.78	1.33	1.56	1.22	1.67	10.01	no
21	Remove-Install Xmission XDR	13	2.69	1.77	2.54	1.69	2.00	2.08	85.00	no
22	Replace Xmission XDR:HMPT 500	13	3.00	1.69	2.85	1.54	1.77	1.92	75.64	no
23	Repair Xmission XDR:HMPT 500	13	2.38	2.46	2.46	2.46	2.77	2.92	287.90	YES
24	Remove-Instal-Disconnct Clutch	11	1.55	2.36	1.27	2.18	1.91	2.00	38.73	no
25	Repair HSG, Piston Disc CL	7	1.14	2.86	1.14	2.86	2.57	2.29	62.67	no
26	Repair Main Housing Assy	7	1.29	3.14	1.14	2.86	3.14	2.57	106.63	no
27	Repair Housing Intermediate,RT	7	1.14	3.14	1.14	2.86	3.29	2.57	99.09	no
28	Remove-Install Hous Intmed,RT	7	1.14	2.57	1.14	2.43	2.71	2.14	47.44	no
29	Remove-Install Left Int Housng	7	1.14	2.57	1.14	2.43	2.71	2.14	47.44	no
30	Repair Left Interim Housing	7	1.14	3.14	1.14	2.86	3.14	2.43	89.52	no

ECA TASK SCORES
MOS 63H

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers = > 216
31	Repair Mechanical Housing	7	1.29	2.57	1.14	2.29	2.43	2.29	47.94	no
32	Remove-Instal Single Disk Brak	8	1.13	2.88	1.13	2.88	3.00	2.25	70.61	no
33	Repair Single Disk Brake	7	1.14	2.29	1.14	2.29	2.43	2.14	35.51	no
34	Remove-Instal Right Outpt Hous	8	1.13	2.25	1.13	2.13	2.88	2.00	34.79	no
35	Repair Right Output Housing	8	1.13	2.88	1.13	2.75	3.13	2.25	70.36	no
36	Remove-Repair Output Carrier	8	1.50	3.00	1.25	3.13	3.25	2.13	121.40	no
37	Repair Plate, Actuating	5	1.00	2.80	1.00	2.60	2.20	2.20	35.24	no
38	Repair Retainer Plate Assy	5	1.00	2.80	1.00	2.60	2.20	2.20	35.24	no
39	Repair Rigid Shaft Coupling	4	1.00	3.00	1.00	3.00	3.00	2.75	74.25	no
40	Repair Actuator Assy	6	1.00	3.17	1.00	3.17	3.00	2.67	80.22	no
41	Replace Gear Shaft Spur	6	1.00	3.17	1.00	2.83	2.83	2.50	63.55	no
42	Repair Gear Shaft Spur	6	1.00	3.17	1.00	2.83	3.00	2.50	67.29	no
43	Remove-Instal Cool, TD, Valve	8	1.00	2.88	1.00	2.50	2.63	2.13	40.09	no
44	Replace Cool, TD, Valve Assy	8	1.00	2.88	1.00	2.50	2.63	2.13	40.09	no
45	Remove-Replace Hydraulic Accum	7	1.00	3.14	1.00	2.86	3.29	2.29	67.44	no
46	Replace Cross Shaft Assy	7	1.14	3.00	1.14	2.86	3.00	2.29	76.77	no
47	Remove-Install Controller Assy	11	3.00	1.64	2.55	1.64	1.64	2.27	76.05	no
48	Replace Controller Assy	11	2.73	1.64	2.55	1.64	1.55	2.18	62.68	no
49	Remove-Install Tow Pump Assy	7	1.14	3.00	1.14	2.71	2.71	2.43	70.11	no
50	Remove-Install Pump Makeup,Aux	7	1.14	2.86	1.14	2.71	2.57	2.29	59.53	no
51	Replace Pump Makeup,Auxiliary	7	1.14	2.86	1.14	2.71	2.57	2.29	59.53	no
52	Remov-Inst Relay Valve 2nd Rng	6	1.17	3.00	1.17	2.67	2.67	2.33	67.75	no
53	Repair Relay Valve 2nd Ring	6	1.17	3.00	1.17	2.50	2.50	2.33	59.55	no
54	Repair Main Xmission Housing	6	1.33	3.33	1.33	3.00	3.17	2.67	150.12	no
55	Repair Xmission Insert Kit	7	1.29	2.43	1.43	2.43	2.29	2.00	49.52	no
56	Repair Final Drive Assy	7	1.29	2.86	1.43	2.57	2.71	2.29	83.72	no
57	Replace Stator Assy	3	1.67	3.00	1.67	2.67	2.67	3.33	197.53	NEAR
58	Repair Fire Support System	5	1.60	1.80	2.00	2.00	2.20	2.00	50.69	no
59	Repair Fan-Vaneaxial	9	1.44	1.90	1.50	1.80	1.90	1.70	23.93	no
60	Replace Compressed Cylinder	3	2.33	1.67	2.33	2.00	1.67	2.33	70.58	no
		Mean	1.53	2.37	1.46	2.24	2.32	2.12	61.56	
		High	3.00	3.33	2.85	3.17	3.29	3.33	287.90	No. of HDs = 1
		Low	1.00	1.33	1.00	1.00	1.21	1.25	5.93	

ECA TASK SCORES
MOS 63G

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Repair MLRS Semicond DVC Assy	1	1.00	4.00	2.00	3.00	3.00	3.00	216.00	YES
2	Repair MLRS Fuel System	9	2.00	2.22	1.78	2.00	2.22	1.67	58.53	no
3	Repair Switch, Sensitive	5	1.80	1.80	1.80	1.60	1.60	2.00	29.86	no
4	Repair Cable Assy (Spec)	4	1.50	1.75	1.75	1.75	1.75	2.00	28.14	no
5	Repair Wiring Harness (1W1)	5	2.20	1.00	1.80	1.00	1.20	2.00	9.50	no
6	Replace Wiring Harness (1W1)	4	1.75	1.00	1.50	1.00	1.00	1.50	3.94	no
7	Repair Wiring Harness (1W2)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
8	Replace Wiring Harness (1W2)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
9	Repair Wiring Harness (1W5)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
10	Replace Wiring Harness (1W5)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
11	Repair Wiring Harness (1W6)	3	1.33	1.33	1.00	1.33	1.67	1.67	6.58	no
12	Replace Wiring Harness (1W6)	4	1.25	1.25	1.00	1.25	1.50	1.50	4.39	no
13	Repair Wiring Harness (1W7)	1	1.00	2.00	1.00	2.00	2.00	1.00	8.00	no
14	Replace Wiring Harness (1W7)	2	1.00	1.50	1.00	1.50	1.50	1.00	3.38	no
15	Repair Wiring Harness (1W9)	2	1.50	1.50	1.00	1.50	2.00	2.00	13.50	no
16	Replace Wiring Harness (1W9)	2	1.50	1.50	1.00	1.50	2.00	2.00	13.50	no
17	Repair Wiring Harness (1W10)	2	1.00	1.50	1.00	1.50	1.50	1.00	3.38	no
18	Replace Wiring Harness (1W10)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
19	Repair Wiring Harness (1W11)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
20	Replace Wiring Harness (1W11)	0								no
21	Repair Wiring Harness (1W13)	1	1.00	2.00	1.00	2.00	2.00	1.00	8.00	no
22	Replace Wiring Harness (1W13)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
23	Repair Wiring Harness (1W14)	2	2.00	1.00	1.00	1.00	1.00	2.00	4.00	no
24	Replace Wiring Harness (1W14)	2	2.00	1.00	1.00	1.00	1.00	2.00	4.00	no
25	Repair Wiring Harness (1W15)	2	1.50	1.00	1.00	1.00	1.00	2.00	3.00	no
26	Replace Wiring Harness (1W15)	2	1.50	1.00	1.00	1.00	1.00	2.00	3.00	no
27	Repair Wiring Harness (1W16)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
28	Replace Wiring Harness (1W16)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
29	Repair Wiring Harness (1W17)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
30	Replace Wiring Harness (1W17)	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no

ECA TASK SCORES
MOS 63G

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
31	Repair Wiring Harness (1W18)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
32	Replace Wiring Harness (1W18)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
33	Repair Wiring Harness (1W19)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
34	Replace Wiring Harness (1W19)	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	no
35	Repair Wiring Harness (1W25)	0								no
36	Replace Wiring Harness (1W25)	0								no
37	Repair Wiring Harness (1W26)	0								no
38	Replace Wiring Harness (1W26)	0								no
39	Repair Wiring Harness (1W27)	0								no
40	Replace Wiring Harness (1W27)	0								no
41	Repair Wiring Harness (1W29)	3	1.67	1.67	1.33	1.33	1.33	2.00	13.17	no
42	Replace Wiring Harness (1W29)	2	1.00	1.50	1.00	1.00	1.00	2.00	3.00	no
43	Repair Wiring Harness (1W30)	0								no
44	Replace Wiring Harness (1W30)	0								no
45	Repair Wiring Harness (1W31)	0								no
46	Replace Wiring Harness (1W31)	0								no
47	Repair Wiring Harness (1W33)	0								no
48	Replace Wiring Harness (1W33)	0								no
49	Repair Wiring Harness (1W40)	0								no
50	Replace Wiring Harness (1W40)	0								no
51	Repair Wiring Harness (3W1)	0								no
52	Replace Wiring Harness (3W1)	0								no
53	Repair Wiring Harness (3W2)	0								no
54	Replace Wiring Harness (3W2)	0								no
55	Repair Wiring Harness (3W3)	0								no
56	Replace Wiring Harness (3W3)	0								no
57	Repair Wiring Harness (3W4)	2	1.00	1.00	1.00	1.00	1.00	2.00	2.00	no
58	Replace Wiring Harness (3W4)	2	1.00	1.00	1.00	1.00	1.00	2.00	2.00	no
59	Repair Wiring Harness (3W5)	2	1.50	1.00	1.00	1.00	1.50	2.00	4.50	no
60	Replace Wiring Harness (3W5)	2	1.50	1.00	1.00	1.00	1.50	2.00	4.50	no
		Mean	1.27	1.30	1.13	1.24	1.31	1.50	11.92	
		High	2.20	4.00	2.00	3.00	3.00	3.00	216.00	No. of HDs = 1
		Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

ECA TASK SCORES
MOS 13B

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
1	Perform Op Maint .50 Ammunit	20	2.80	1.50	2.60	1.30	1.50	1.40	29.81	no
2	Load-Unload .50 Machine Gun	20	2.70	1.60	1.30	1.60	1.70	1.40	21.39	no
3	Set Headspace-Timing .50 Gun	20	3.10	1.60	2.70	1.50	1.50	1.50	45.20	no
4	Mount-Dismount .50 Gun	20	3.20	1.00	2.40	1.10	1.00	1.60	13.52	no
5	Identify Topo Symbols;Colors	19	2.40	2.10	1.70	2.10	1.90	1.70	58.12	no
6	Det Elev:Pt on Grnd Using Map	19	2.30	2.00	1.90	1.90	1.70	1.60	45.17	no
7	Converts Azimuths (Mag-Grid)	19	2.10	2.30	1.70	2.00	1.60	1.60	42.04	no
8	Loc Ukn Pt on Grnd-Map:Intsect	19	2.40	2.10	1.80	1.90	1.80	1.40	43.44	no
9	Loc Ukn Pt on Grnd-Map:Resect	19	1.90	2.30	1.80	2.30	1.80	1.50	48.85	no
10	Det Azimuth using M2 Compass	19	2.90	1.50	2.50	1.60	1.40	1.40	34.10	no
11	Det Ukn Pt on Map:Insect;M2	19	2.10	2.20	1.60	2.20	2.00	1.50	48.79	no
12	Orient Map:Declinated M2	19	2.20	2.10	1.80	2.00	1.90	1.50	47.40	no
13	Navigate Pt-to-Pt on Gnd	19	2.40	2.40	2.10	1.80	2.30	1.60	80.12	no
14	Det Azimuths:Protractor-Comput	19	2.10	2.20	1.50	2.20	2.20	1.60	53.67	no
15	Perform Crew PMCS:M109 Turret	20	3.20	1.50	3.90	1.60	2.20	1.50	98.84	no
16	Operate Vehicle in Convoy	20	3.50	1.30	3.40	1.50	1.80	1.50	62.65	no
17	Drive Vehicle:Blackout Condt's	20	2.90	2.00	2.80	1.90	2.00	1.50	92.57	no
18	Drive M109 SP Howitzer	20	3.10	1.50	3.20	1.50	2.00	1.50	66.96	no
19	Prepare Position:Howitzer	20	3.10	1.80	3.10	1.80	1.90	1.50	88.74	no
20	Record Fire Mission:Form 4513	20	3.00	2.00	2.80	1.70	1.60	1.60	73.11	no
21	Emplace-Recover Aiming Posts	20	3.20	1.10	3.00	1.10	1.30	1.40	21.14	no
22	Load Howitzer Ammunition: Veh	20	3.30	1.30	2.90	1.20	1.30	1.40	27.17	no
23	Store Ammunition for Firing	20	3.10	1.40	2.80	1.20	1.20	1.50	26.25	no
24	Prepare Separate-Load Ammunit	20	3.30	1.20	3.10	1.30	1.30	1.50	31.12	no
25	Inspect M712 Projectile	19	2.00	2.10	1.60	2.00	2.30	1.50	46.37	no
26	Repackage M712 Projectile	19	1.90	2.20	1.60	2.10	2.30	1.50	48.45	no
27	Perform Extraction:M712 Projct	19	1.90	2.20	1.70	2.10	2.20	1.60	52.53	no
28	Prepare M712 Projct for Firing	19	1.90	2.30	1.70	2.10	2.30	1.60	57.41	no
29	Chck Fire:Unsafe Condit Exists	20	3.20	1.20	3.10	1.30	1.10	1.60	27.24	no
30	Op Material Handling Kit:M548	18	2.60	1.40	2.50	1.40	1.30	1.40	23.19	no
31	Open Ballistic Door	16	2.90	1.10	2.50	1.10	1.30	1.40	15.97	no
32	Prepare Conveyor	15	2.80	1.50	2.30	1.70	1.40	1.40	32.19	no
33	Prepare X-Y Stacker	15	2.00	1.70	1.80	1.70	1.60	1.90	31.63	no
34	Operate X-Y Stacker	15	2.00	1.60	1.90	1.60	1.60	1.50	23.35	no
35	Xfer Projectiles:CAT to M109	15	2.20	1.60	2.00	1.50	1.60	1.50	25.34	no

ECA TASK SCORES
MOS 13B

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
36	Xfer Projectiles:M109 to CAT	15	2.00	1.80	1.70	1.50	1.40	1.60	20.56	no
37	Prepare Conveyor Hydraulic Sys	15	2.10	1.60	1.80	1.80	1.60	1.60	27.87	no
38	Repair Chain on Conveyor	14	2.00	2.10	1.50	1.90	2.10	1.60	40.22	no
39	Install GDU on Howitzer	20	2.60	1.60	2.90	1.80	1.50	1.40	45.60	no
40	Remove-Clean Gun Display Unit	20	2.70	1.70	2.40	1.60	1.40	1.40	34.55	no
41	Aline Aiming Posts:M100 Series	20	2.80	1.20	2.50	1.20	1.40	1.50	21.17	no
42	Reciprocal Lay Howitzer:M100	20	2.50	1.70	2.80	1.60	1.70	1.50	48.55	no
43	No Aiming Circle, Lay Howitzer:M10(	20	2.70	1.80	2.50	1.70	1.70	1.40	49.16	no
44	Lay Howitzer:Initial Fire Dir	20	2.90	1.50	3.10	1.40	1.90	1.40	50.22	no
45	Boresight Pan Telescope:DAP	20	3.10	1.80	2.90	1.50	1.70	1.40	57.77	no
46	Boresght Pan Telscpe:Test Targ	20	2.80	1.60	2.80	1.60	1.80	1.50	54.19	no
47	Set-Lay Howitzer:Deflection	20	3.00	1.50	3.10	1.50	1.60	1.40	46.87	no
48	Refer the Piece	19	2.80	1.70	3.10	1.40	1.60	1.30	42.97	no
49	Test-Trblsht Gun Display Unit	17	2.20	1.80	2.30	2.00	1.80	1.30	42.63	no
50	Prepare Howitzer for Firing	20	3.00	1.50	3.00	1.50	1.80	1.30	47.39	no
51	Determine Site-Range to Crest	20	2.90	1.20	2.90	1.40	2.00	1.40	39.56	no
52	Perform Gun's Quad Micro Test	20	2.80	1.60	2.60	1.80	1.20	1.40	35.22	no
53	Perform Gun's Quad End-End Tst	20	2.80	1.80	2.30	2.00	1.40	1.50	48.69	no
54	Prepare Range Card:Howitzer	20	2.60	1.50	2.20	1.70	1.30	1.30	24.65	no
55	Determine Howtzer Safe to Fire	20	2.60	1.70	2.50	1.60	1.60	1.40	39.60	no
56	Compute Dat:Sweep-Zone Mission	20	2.10	2.20	1.80	2.00	1.50	1.50	37.42	no
57	Set-Lay Quad:Gun's Quad	20	2.90	1.50	2.90	1.50	1.40	1.30	34.44	no
58	Measure Quad:Gun's Quad	20	2.80	1.40	2.60	1.50	1.30	1.30	25.84	no
59	Issue Fire Order:Dir Mission	20	2.40	1.80	2.20	1.60	1.60	1.30	31.63	no
60	Take Immediate Misfire Action	20	2.50	1.60	2.30	1.60	1.50	1.30	28.70	no
61	Verify PMCS:M548 Cargo Carrier	20	2.80	1.60	3.50	1.30	1.70	1.30	45.05	no
62	Mount-Maintain GDU	20	2.50	1.60	3.00	1.60	1.40	1.30	34.94	no
63	Process Fire Miss(When Ready)	20	2.60	1.50	3.20	1.50	1.50	1.30	36.50	no
64	Process Fire Miss(At Command)	19	2.60	1.50	3.10	1.80	1.50	1.30	42.44	no
65	Process Instructions:GDU	19	2.60	1.80	2.80	1.60	1.50	1.20	37.74	no
66	Boresight Dir Telescope:DAP	20	2.70	1.50	2.80	1.60	1.70	1.40	43.18	no
67	Boresght Dir Telscpe:Test Targ	20	2.50	1.60	2.50	1.60	1.40	1.30	29.12	no
68	Set/Lay Howitzer:Range Quad	20	2.70	1.30	2.80	1.40	1.60	1.30	28.62	no
69	Measure Quad:Range Quad	20	2.90	1.40	3.10	1.40	1.50	1.30	34.36	no
70	Sight Target:Dir Fire Telescpe	20	2.80	1.40	2.40	1.30	1.50	1.60	29.35	no

ECA TASK SCORES
MOS 13B

Task No.	Task Name	No. of SMEs	PP	TPD	FR	TLD	TT	DR	Task Scores	High Drivers => 216
71	Dis-Assemble Breech-Fire Mech	20	2.90	1.70	3.00	1.60	1.80	1.30	55.37	no
72	Load-Fire Prepared Round	20	3.10	1.10	3.00	1.10	1.40	1.20	18.91	no
73	Perform PMCS M109 Turret	17	2.40	1.90	2.80	1.70	1.70	1.20	44.28	no
74	Check Boresight, Telescpe:M140	20	2.90	1.50	3.20	1.30	1.50	1.30	35.29	no
75	Verify PMCS:M109 Howitzer	19	3.20	1.20	3.60	1.20	1.50	1.30	32.35	no
76	Adjust Equilibrators:M109	19	2.20	2.40	2.20	2.20	1.90	1.20	58.27	no
77	Perform Prefire Checks:M109	20	3.00	1.20	3.00	1.30	1.20	1.30	21.90	no
78	Perform Zero Pressure Check	16	3.00	1.50	3.30	1.50	1.40	1.20	37.42	no
79	Declinate Aiming Circle	18	2.20	1.70	2.60	2.10	1.70	1.20	41.66	no
80	SetUp-Recover M2 Aiming Circle	18	2.70	1.40	2.20	1.50	1.40	1.20	20.96	no
81	Establsh Azimuth(OL):Simult Ob	18	2.20	2.40	2.10	2.40	2.10	1.20	67.06	no
82	Establsh Azimuth(OL):Polar-Kb	18	2.00	2.70	1.60	2.70	2.30	1.30	69.75	no
83	Establsh Azimuth(OL):Dir Tvers	18	1.90	2.80	1.80	2.90	2.30	1.30	83.03	no
84	Determine Loc:Graphic Resect	18	1.90	2.80	1.60	2.70	2.40	1.30	71.71	no
85	Lay Battery,Aim Cir:Orient Ang	18	2.40	2.20	2.10	2.30	2.10	1.30	69.62	no
86	Lay Battery,Aim Cir:Grid Azmut	18	2.60	1.90	2.60	1.80	1.60	1.30	48.09	no
87	Lay Battery:M2 Compass	18	2.40	1.90	2.30	1.90	1.70	1.30	44.04	no
88	Lay Battery,Aim Pt Deflection	18	2.20	2.10	1.90	2.10	1.80	1.30	43.14	no
89	Lay Battery:Howitzer Back-Lay	17	2.10	2.00	1.90	2.10	1.90	1.40	44.58	no
90	Measure Orienting Angle	18	2.20	1.70	2.30	1.90	1.90	1.40	43.47	no
91	Measure Azimuth	18	2.90	1.90	2.10	1.90	1.70	1.50	56.06	no
92	Measure Piece-to-Crest Range	18	2.70	2.00	2.70	1.70	1.40	1.20	41.64	no
93	Compute XO MIN QE:Rap Fir Tabl	16	2.20	2.20	2.00	2.30	1.80	1.50	60.11	no
94	Measure Distance:Subtense	17	2.60	2.00	2.60	2.10	1.90	1.50	80.92	no
95	Prepare-Submit XO Rpt(Nuclear)	14	2.60	2.00	1.90	2.00	1.90	1.50	56.32	no
96	Supervise Prefir Ops:M454 Proj	10	1.50	1.80	2.00	1.70	2.30	1.30	27.45	no
97	Supervise Cancel Fir:M454 Proj	10	1.50	2.00	2.00	1.50	2.70	1.30	31.59	no
98	Supervise Load-Xport:M454 Proj	9	1.70	1.90	2.10	1.40	2.40	1.20	27.35	no
		Mean	2.56	1.75	2.44	1.71	1.70	1.41	43.40	
		High	3.50	2.80	3.90	2.90	2.70	1.90	98.84	No. of HDs = 0
		Low	1.50	1.00	1.30	1.10	1.00	1.20	13.52	

APPENDIX B

EXCERPTS FROM THE TASK ANALYSES OF HIGH DRIVER TASKS

Step 8 in the Early Comparability Analysis (ECA) procedure is the conduct of a task analysis of each high driver task identified based on observations of actual task performance.

In the task analysis, each independent action that has a recordable result is considered as a separate step. Setting up test equipment and similar subprocedures are considered as a single step when they are components of many tasks.

In describing the results of a task analysis, the following entries are used:

- Element is the action taken by the task performer.
- Normal Indicator is the expected result. The occurance of the normal indicator leads to the next step. In troubleshooting tasks, it is not unusual for the "normal indicator" to be a negative, i.e. nothing happens as a result of a particular test or no reading registers on a meter.
- Divergence is an alternate result that usually leads to a "Go to __" procedure.
- WARNINGs and CAUTIONs describe hazards to personnel or possible damage to equipment.
- NOTEs contain additional information on the action, equipment, or personnel required to perform the step.

The following task analysis excerpts are contained in this Appendix.

- Task Analysis of MOS 63T High Driver: "Troubleshoot the Power Distribution Box, M2 Bradley FVS/MLRS", steps 1-76 (of 129).
- Task Analysis of MOS 31V High Driver: "System Troubleshoot the VIC-1 with FM Radio", steps 216-260 (of 269). (Note: This same sequence of steps also is incorporated in another 31V high driver task, "System Troubleshoot the AN/VRC-12 series radio".)
- Task Analysis of MOS 31V High Drivers: "System Troubleshoot the VRC-64/GRC 160 Radio", steps 76-85 (of 85) and "Perform Preventative Maintenance Checks and Services (PMCS), VIC-1 Intercom", steps 1-21 (of 60).

Task Analysis of MOS 63T High Driver:

"Troubleshoot the Power Distribution Box, M2 Bradley FVS/MLRS", Steps 1-76 (of 129)

This task begins with a fault symptom of no electrical power from the Distributon Box noted on a DA Form 2404. The mechanic has the vehicle, his tool box, the proper TM, and the Simplified Test Equipment-Internal Combustion Engine (STE-ICE) diagnostic equipment. He also has one helper available to assist him. The only unusual tool he may need is an inspection mirror.

This task involves only troubleshooting, and no steps concerned with parts replacement, repair, or adjustment are included.

The task is divided into segments, shown in the task analysis by dotted lines. The first segment, steps 1 through 26, describe setting up the test equipment and checking for the two most common faults associated with the system. Steps 27-32 verify that no other faults remain in the electrical distribution system. These checks are used to verify that fault identification and any subsequent repair is complete and correct. A list of the segments from this task included in the illustration are as follows.

Segment Steps	Fault Discovered
1- 6	None; preliminary set up
7-18	Tests power supply
19-26	Wiring harness 1W1
27-32	Verifies no fault
33-37	Distribution box
38-42	Wiring harness 1W1
43-46	Wiring harness 1W15
47-51	Battery shunt
52-53	Electrical lead 1W1
54-57	Faulty turret power distribution box
58-64	Wiring harness 1W1
65-68	Master relay switch
69-73	Distribution box
74-76	Electrical lead 1W16

Step	Element	Normal Indicator	Divergence
1.	Select correct TM and section	Selects TM 9-2350 252-29-1-1, p. 3-234	
2.	Prepare vehicle	Ramp down; engine stopped; Fire Suppression Switch in MANUAL; turret shut down	
3.	Turn Master Power Switch ON	Voltmeter on panel reads No Voltage	If voltmeter shows voltage, go to Step 27
4.	Observe Master Power Indicator Light	Light is OFF	If light is ON, go to Step 112
5.	Prepare STE-ICE connecting to jack 1A1J14(DCA 3)	STE-ICE in working order	If not working, replace STE-ICE

NOTE: See TM p. 3-862 thru 3-864 for directions on conducting STE-ICE self tests.

Step	Element	Normal Indicator	Divergence
6.	Perform test no. 67, battery voltage, TM p. 3-911	17 or more volts present	If less than 17 volts, go to Step 33
7.	Remove STE-ICE from jack	STE-ICE removed	
8.	Turn Master Power Switch ON	No reaction; turret indicator lights OFF	If Turret Azimuth Indicator, Gun Elev. Indicator, or Illuminator lights ON, go to Step 103 (troubleshoot panel lights)
9.	Turn Master Power Switch OFF		
10.	Remove Power Control Access Cover		

Step	Element	Normal Indicator	Divergence
11.	Turn Master Power Switch ON		
12.	Measure voltage between Master Switch Relay and Terminal 1A2K1A2 to ground	Less than 17 volts	If 17 volts or higher, go to Step 54

WARNING: Electrical current can burn you. Equipment can get damaged. Make sure you probe correct terminal.

Step	Element	Normal Indicator	Divergence
13.	Turn Master Power Switch OFF		
14.	Measure resistance between Shunt Terminal #1 and ground	0 ohms	If resistance present, go to Step 74
15.	Turn Master Power Switch ON		
16.	Measure voltage between Master Switch Relay and ground, using multimeter	No voltage	If voltage present, go to Step 65
17.	Turn Master Power Switch OFF		
18.	Remove plug from jack 1A128		
19.	Measure resistance between jack pin Y and Relay Terminal	0 ohms	If resistance present, go to Step 69
20.	Turn Master Power Switch ON		
21.	Measure resistance between jack pin Y and pin Z	0 ohms	If resistance present, go to Step 80
22.	Turn Master Power Switch OFF		

Step	Element	Normal Indicator	Divergence
23.	Install plug 1W10P1 on jack J8		
24.	Remove plug 1W1P1 from jack J2		
25.	Measure resistance between Master Switch Relay and plug 1W1P1 pin H	Resistance exists	If no resistance, go to Step 77
26.	-Replace Wiring Harness 1W1	Verify no faults by performing Steps 27 thru 32	

NOTE: POI used for 63T AIT ends with this Step.

--------------(FROM STEP 3 OR ANY REPLACEMENT STEP)--------------

Step	Element	Normal Indicator	Divergence
27.	Read Volts Gage	Indicator is in lower half of yellow zone to green zone	If out of zone, go to "Troubleshoot Engine Starting System"
28.	Determine if Master Power Indicator Light is ON	Power Indicator Light is ON	If not ON, go to Step 83
29.	Move Engine Accessory Switch to ON	Engine Accessory Indicator Light comes ON	If not ON, go to Step 89
30.	Start engine	Engine starts in three tries or less	If engine does not start, go to "Troubleshoot Engine Starting System"
31.	Read Volts Gage while engine is running	Volts Gage is approximately mid-scale in green zone	If Volts Gage does not read in green zone, go to "Troubleshoot Engine Charging System"

Step	Element	Normal Indicator	Divergence
32.	Determine if Turret Azimuth Indicator, Gun Elevation Indicator, and Illuminator lights are ON	Lights are ON	If not ON, go to Step 123

--------------------------(FROM STEP 6)--------------------------

Step	Element	Normal Indicator	Divergence
33.	Remove STE-M1 from jack		
34.	Remove plug 1W1P1 from jack J2		
35.	Read voltage between plug 1W1P1 pin C and pin J	17 volts or higher	If less than 17 volts, go to Step 36
36.	Replace vehicle Electrical Distribution Box		
37.	Verify no faults performing by Steps 27-32		

--------------------------(FROM STEP 35)--------------------------

Step	Element	Normal Indicator	Divergence
38.	Access Battery Compartment		
39.	Measure resistance between plug 1W1P1 pin C and Battery BT3 negative terminal	0 ohms	If resistance present, go to Step 47
40.	Measure voltage between Battery, Switch Master Relay Terminal and ground	17 volts or higher	If less than 17 volts, go to Step 41
41.	Replace Wiring harness 1W1		

Step	Element	Normal Indicator	Divergence
42.	Verify no faults by performing Steps 27-32		

------------------------(FROM STEP 40)------------------------

Step	Element	Normal Indicator	Divergence
43.	Measure voltage between Battery BT4 positive terminal and ground	17 volts or higher	If less than 17 volts, go to "Service Batteries"
44.	Install 1W1P1 on jack		
45.	Replace Wiring Harness 1W15		
46.	Verify no faults by performing Steps 27-32		

------------------------(FROM STEP 39)------------------------

Step	Element	Normal Indicator	Divergence
47.	Measure resistance between lead 1W1E1 and plug 1W1P1 pin C	0 ohms	If resistance present, go to "Replace Wiring Harness 1W1"
48.	Install plug 1W1P1 on jack 1A1J2		
49.	Measure resistance between shunt end of lead 1W14 and Battery BT3 end of lead 1W14	0 ohms	If resistance present, go to Step 50
50.	Replace battery shunt		
51.	Verify no faults by performing Steps 27-32		

------------------------(FROM STEP 49)------------------------

Step	Element	Normal Indicator	Divergence
52.	Replace Electrical Lead 1W14		

Step	Element	Normal Indicator	Divergence
53.	Verify no faults by performing Steps 27-32		

-------------------------(FROM STEP 12)-------------------------

Step	Element	Normal Indicator	Divergence
54.	Measure voltage between 1A2CB1-1 and ground	17 or more volts present	If less than 17 volts, turn Master Power Switch OFF, and go to "Replace Battery Jumper Lead 1W33"
55.	Measure voltage between 1A2CB1-2 and ground	17 or more volts present	If less than 17 volts, turn Master Power Switch OFF and go to "Replace Circuit Breaker 1A2CB-1"
56.	Measure voltage between plug 1W4P1 pin B and ground	17 or more volts present	If no voltage, go to "Replace Wiring Harness 1W4"
57.	Verify no faults by performing Steps 27-32; if fault remains, write up DA Form 2404 on faulty Turret Power Distribution Box, report to supervisor, and STOP		

-------------------------(FROM STEP 126)-------------------------

Step	Element	Normal Indicator	Divergence
58.	Turn Master Power Switch OFF		
59.	Install plug 1W4P1 on jack		
60.	Turn Master Power Switch ON		

Step	Element	Normal Indicator	Divergence
61.	Measure voltage between Circuit Breaker 1A2CB1 terminal 2 and ground	17 volts or more present	If less than 17 volts, go to "Replace Circuit Breaker"
62.	Turn Master Power Switch OFF		
63	Replace Wiring Harness 1W1		
64.	Verify no faults by performing Steps 27-32		

-------------------------(FROM STEP 16)-------------------------

65.	Turn Master Power Switch OFF		
66.	Measure resistance between Master Switch Relay Terminal and STE-M1 shunt terminal 2	0 ohms	If resistance present, go to "Replace Wiring Harness 1W"
67.	Replace Battery Master Switch Relay		
68.	Verify no faults by performing Steps 27-32		

-------------------------(FROM STEP 19)-------------------------

69.	Remove plug 1W1P1 from jack		
70.	Install plug 1W10P1 on jack		
71.	Measure resistance between pin L of plug 1W10P1 and Battery Switch Relay Terminal	0 ohms	If resistance present, go to "Replace Wiring Harness 1W12"

Step	Element	Normal Indicator	Divergence
72.	Replace Vehicle Electrical Distribution Box		
73.	Verify no faults by performing Steps 27-32		

-------------------------(FROM STEP 14)-------------------------

Step	Element	Normal Indicator	Divergence
74.	Measure resistance between shunt terminal 2 and ground	Resistance present	If 0 ohms, go to "Replace Battery Shunt"
75.	Replace electrical lead 1W16		
76.	Verify no faults by performing Steps 27-32		

Task Analysis of MOS 31V High Driver:

"System Troubleshoot VIC-1 with FM Radio", Steps 216-260 (of 269)

Note: This same sequence of steps also is incorporated in another 31V high driver task, "System Troubleshoot AN/VRC-12 Series Radio".

The steps in this excerpt describe a portion of the evaluation and checkout procedure that precedes troubleshooting. They include the evaluation of components of both the VIC-1 intercom and the FM radio. The first segment, steps 216-222, is concerned with testing the handset. The second segment, steps 223-245, is concerned with evaluating the R-442 Receiver and the RT-524 Radio Transmitter using the handset. The third segment, steps 246-249, is concerned with evaluating the Radio Duplex-Intercom functions. The forth segment, steps 250-260, is concerned with Radio-Intercom checks.

Step	Element	Normal Indicator	Divergence
-----------R-442 SPEAKER MUTING, RT-524 KEYED CHECKS-------------			
216.	Connect speaker LS-454 to R-442 Audio Jack		
217.	Tune R-442 MC-TUNE-KC Controls for 75.00 MHz	Dial Lamp indicates 75.00	
218.	Turn R-442 Squelch Switch to OFF	R-442 Squelch Switch pointing to OFF; rushing noise heard at R-442 Speaker	
219.	Turn R-442 Volume Control from off one-quarter turn CW		
220.	Connect Handset to RF-524 Retransmit R/W Jack		
221.	Tune RT-524 MC-TUNE-KC Controls for 62.20 MHz	Dial Lamp indicates 62.20	

Step	Element	Normal Indicator	Divergence
222.	Depress Handset Push-to-Talk Switch momentarily several times	Depressing switch quiets R-442 rushing noise; releasing switch produces R-442 rushing noise	If depressing switch does not quiet R-442 rushing noise, go to Step T32; if releasing switch does not produce R-442 rushing noise, go to Step T32

CAUTION: Unkey RT-524 before proceeding to next step; otherwise damage to equipment may result.

---------------------RT-524/INTERCOM CHECKS---------------------

Step	Element	Normal Indicator	Divergence
223.	Turn <u>all</u> Squelch Switches to ON		
224.	Turn <u>all</u> Volume Controls to midpoint positions		
225.	Tune <u>all</u> MC-TUNE-KC Controls to unassigned, but different, frequencies	Dial Lamps indicate unassigned and different frequencies	
226.	Turn <u>all</u> Power Switches ON		

NOTE: RT-524 Power switch should be at LOW and R-442 Power Switch should be at ON.

Step	Element	Normal Indicator	Divergence
227.	Connect Handset to C-2298 Rad jack J802		
228.	Turn C-2298 Volume Control fully CW		
229.	Turn C-2298 Monitor Switch to ALL		

Step	Element	Normal Indicator	Divergence
230.	Turn AM-1780 Radio Trans Switch to "Listening Silence"		
231.	Depress Handset Push-to-Talk Switch momentarily several times	RT-524 <u>not</u> keyed	If depressing switch makes RT-524 key, replace AM-1780

CAUTION: Unkey RT-524 before proceeding to next step; otherwise damage to equipment may result.

NOTE: Do not key handset.

Step	Element	Normal Indicator	Divergence
232.	Turn AM-1780 Radio Trans Switch to CDR ONLY	RT-524 <u>not</u> keyed	If RT-524 <u>is</u> keyed, go to Step T33

NOTE: For this check, rushing noise loudness depends on C-2298 volume setting only.

Step	Element	Normal Indicator	Divergence
233.	Turn RT-524 Squelch Switch to OFF	C-2298 rushing noise heard	If C-2298 rushing noise is not heard, go to Step T34

NOTE: For this check, voice sidetone loudness depends on C-2298 volume setting only.

Step	Element	Normal Indicator	Divergence
234.	Depress Handset Push-to-Talk Switch and hold	RT-524 keyed (relays click, blower runs, rushing noise drastically reduced)	If RT-524 not keyed, go to Step T35
235.	Talk into Handset Microphone	Voice sidetone heard at Handset Earphone	If RT-524 keys but <u>no</u> voice sidetone heard, go to Step T36
236.	Release Handset Push-to-Talk Switch	RT-524 unkeyed	

Step	Element	Normal Indicator	Divergence
237.	Connect Handset to C-2298 Int jack J803 (yellow banded)	Loud rushing noise heard	
238.	Turn AM-1780 Int Accent Switch to ON		
239.	Depress Handset Push-to-Talk Switch momentarily several times	Depressing switch decreases rushing noise; releasing switch increases rushing noise	If depressing switch does not decrease rushing noise, replace AM-1780
240.	Connect Handset to C-2298 Rad jack J802	Loud rushing noise heard	
241.	Release Handset Push-to-Talk Switch	Handset is unkeyed	

NOTE: For this check, rushing noise loudness depends on both RT-524 volume and C-2298 volume settings.

Step	Element	Normal Indicator	Divergence
242.	Turn C-2298 Monitor Switch to "A"	C-2298 makes rushing noise	If C-298 does not make rushing noise, go to Step T37

NOTE: For this check, the loudness of the voice sidetone depends on both RT-524 volume and C-2298 volume settings.

Step	Element	Normal Indicator	Divergence
243.	Depress Handset Push-to-Talk Switch and hold	RT-524 keyed (relays click, blower runs, rushing noise drastically reduced)	If depressed Handset Push-to-Talk Switch does not key RT-524, replace C-2298
244.	Talk into Handset Microphone	Voice sidetone heard at Handset Earphone	If voice sidetone not heard, replace C-2298

Step	Element	Normal Indicator	Divergence
245.	Release Handset Push-to-Talk Switch	RT-524 unkeyed	

NOTE: Turn RT-524 squelch switch to ON position before proceeding to the next step.

--------------RADIO DUPLEX/INTERCOM FUNCTIONS CHECKS-------------

Step	Element	Normal Indicator	Divergence
246.	Turn C-2298 Monitor Switch to ALL		

NOTE: For this check, rushing noise loudness depends on C-2298 volume setting.

Step	Element	Normal Indicator	Divergence
247.	Turn R-442 Squelch Switch to an OFF position	C-2298 makes loud rushing noise	If C-2298 does not make rushing noise, go to Step T39

NOTE: For the next two checks, the loudness of the rushing noise depends on both R-442 and C-2298 volume settings.

Step	Element	Normal Indicator	Divergence
248.	Turn C-2298 Monitor Switch to "B"	C-2298 makes rushing noise	If C-2298 does not make rushing noise, go to Step T39
249.	Depress Handset Push-to-Talk Switch momentarily several times	RT-524 keys (relays click, blower runs) and rushing noise heard at C-2298 R-442	If depressed Handset Push-to-Talk Switch does not key RT-524 or cause rushing at C-2298 R-442, replace C-2298

------------------C-2297 RADIO/INTERCOM CHECKS-----------------

Step	Element	Normal Indicator	Divergence
250.	Turn <u>all</u> Squelch Switches to ON position		

Step	Element	Normal Indicator	Divergence
251.	Turn <u>all</u> Volume Controls to midpoint position		
252.	Connect Handset to C-2297 Rad jack J902		
253.	Turn C-2297 Monitor Switch to ALL		
254.	Turn C-2297 Volume Switch fully CW		
255.	Turn C-2297 External Control Switch to OFF		

NOTE: For this check, the loudness of the voice sidetone depends on the C-2297 volume setting only.

Step	Element	Normal Indicator	Divergence
256.	Depress Handset Push-to-Talk Switch and hold	RT-524 keyed (relays click, blower runs) and voice sidetone heard	If depressing Handset does not key RT-524, go to Step T35
257.	Talk into Handset Microphone	Voice sidetone heard at Handset Earphone	If RT-524 keys but <u>no</u> voice sidetone heard, replace AM-1780
258.	Release Handset Push-to-Talk Switch	RT-524 unkeyed	
259.	Turn C-2297 Monitor Switch to "A"		
260.	Depress Handset Push-to-Talk Switch momentarily several times	RT-524 keys (relays click, blower runs) and unkeys several times	If depressing Handset Push-to-Talk Switch does not key RT-524, replace C-2297

Task Analysis of MOS 31V High Driver:

"System Troubleshoot the VRC-64/GRC 160 Radio", Steps 76-85 (of 85)

The steps in this excerpt include the last step in the checkout and all of the troubleshooting steps in this task. A system-based troubleshooting procedure is used that requires an understanding of schematics and the logic of troubleshooting to decide what checks are to be performed.

Step	Element	Normal Indicator	Divergence
76.	One at a time, turn AM-2060 Ant Freq Control Switch to each of nine (9) frequencies listed; for each, tune RT accordingly and repeat Steps 72 through 75 above (record results on worksheet)	At each frequency setting, indicators should be as described in Steps 72 through 75 above	

------------------------TROUBLESHOOTING------------------------

Step	Element	Normal Indicator	Divergence
77.	Identify adverse symptom	EPC step not performed	
78.	Select one of six possible communication circuits as the bad circuit	Bad communication circuit selected e.g., Receiver Signal Path, Keying Circuit, or DC Input Power Circuit	

NOTE: For the above step, knowledge of defects causing adverse symptoms is required.

Step	Element	Normal Indicator	Divergence
79.	Analyze diagram(s) of circuit for suspected bad items		

Step	Element	Normal Indicator	Divergence
80.	Determines type of test to be performed on each suspected bad item	Voltage and resistance tests selected (e.g., circuit disturbance or signal trace)	
81.	Determines test points for voltage or resistance tests, and order of the tests	Cable plugs, jacks, etc. are selected for testing	
82.	Perform voltage and resistance tests in sequence		
83.	Classify reading (at test point) as normal or abnormal to identify the bad item		
84.	Take corrective action	Bad item replaced or repaired	
85.	Reevaluate communication system	Communication system working properly	

Task Analysis oF MOS 31V High Driver:

"Perform Preventative Maintenance Checks and Services (PMCS), VIC-1 Intercom", Steps 1-21 (of 60)

The segments covered in this excerpt include initial inspection, preliminary set-up, and performing basic operational checks.

PMCS of the VIC-1 intercom system includes visual and operational inspections, connection tests, and equipment performance checks. The steps for checking equipment performance are included in the procedures for other tasks that include equipment evaluation. This sample includes the inspection and operational checks of the VIC-1.

Step	Element	Normal Indicator	Divergence
		INSPECTION	
1.	Inspect Outside Control Box Signal Lamp	Lamp in place and not broken	Replace if missing or broken
2.	Inspect Outside Control Box Handset and Cord	Undamaged	Replace if damaged
3.	Test MX-7777 Circuit Breaker	Operates smoothly	Replace if operation is faulty
	CAUTION: Turn radio-intercom system OFF.		
4.	Test MX-7777 Battle Override Switch	Operates smoothly	Replace if operation is faulty
		PRESET CONTROLS RT UNIT	
5.	Inspect MX-7777 Ground Strap	Secure and undamaged	Tighten if loose; replace if frayed or damaged

Step	Element	Normal Indicator	Divergence
6.	Inspect MX-7777 cable connections	Cable plug and jack locking rings are tight	If loose, tighten locking rings with a spanner wrench; if loose, tighten loose gland nut using an adjustable wrench
7.	Test AM-1780 Circuit Breaker	Operates smoothly	Replace if operation is faulty
8.	Perform AM-1780 Equipment Modifications if required (see DA Pam 310-1 for a listing of MWOs)		

---------PERFORM OPERATIONAL CHECKS FOR THE INTERCOM SET---------

WARNING: To safeguard against electrical shock and possible damage to equipment, remove or tape all personal exposed metal objects such as watches, rings, or medallions.

Step	Element	Normal Indicator	Divergence
9.	Set vehicle Master Switches to OFF	Hull and Turret Switches OFF	
10.	Set MX-7777 Circuit Breaker to OFF		
11.	Set MX-7777 Battle Override Switch to OFF		
12.	Set AM-1780 Radio Main Power and Power Circuit Breaker Switches to OFF		

Step	Element	Normal Indicator	Divergence

CAUTION: Do not start vehicle engine with any communication equipment turned ON. Make certain that all communications components that have POWER switches are turned OFF. Starting a vehicle with communication equipment ON can cause serious damage to its components.

Step	Element	Normal Indicator	Divergence
13.	Examine all components and cables for proper installation	All components and cables properly installed (refer to appropriate TM)	If incorrect, reinstall components or cables
14.	Start vehicle		
15.	Set vehicle Master Power Switches to ON		
16.	Set AM-1780 Installation Switch to Int Only		
17.	Set Radio Trans Switch to "Listening Silence"		
18.	Set Int Accent Switch to OFF		
19.	Open Power Lamp Lens Cover by turning lens CCW to stop; then 1/8 turn CW		

CAUTION: The POWER lamp socket may become loose and rotate in the AM-1780/VRC housing causing an adverse short. Do not operate the equipment when this receptacle is loose.

Step	Element	Normal Indicator	Divergence
20.	Set the C-2297/VRC (if included at the driver's position) SIG-EXT-OFF Switch to OFF		

Step	Element	Normal Indicator	Divergence
21.	Open the C-2297 Lamp Lens Cover (if included at the driver's position)		

CAUTION: The POWER lamp socket may become loose and rotate in the C-2297/VRC housing causing an adverse short. Do not operate the equipment when this receptacle is loose.

APPENDIX C

ANALYSES OF HIGH DRIVER TASKS

NOTE: For purposes of this study, an effort was made to target as many deficiencies as possible, and then to identify at least one solution for each deficiency. For this reason, some of the deficiencies cited may seem insignificant and some of the solutions proposed may seem not entirely practical.

Part I: Analysis of High Driver for MOS 63T

Introduction

One task surveyed in MOS 63T was identified as a high driver. This task, "Troubleshoot Power Distribution System of Bradley-MLRS Vehicle", received a total ECA Score of 293.3.

An on-site task analysis was performed on this task at Fort Knox, KY. This is where AIT for MOS 63T is offered even though the proponent school for this MOS is USAOC&S, Aberdeen Proving Ground, MD. The task analysis consisted of direct observations of task performance by an MOS 63T trainee who recently completed that segment of AIT. The observations were supplemented by interviews with school personnel.

At the beginning of the demonstration, the instructor inserted a fault the trainee was to locate. The trainee then proceeded to identify the fault following the troubleshooting procedure in the TM. The trainee did not appear to experience any difficulty performing any of the required steps. Because this is a troubleshooting task, not all steps in the procedure were observed. However, a review of the remaining segments of the task and comments from the school personnel indicated that none of the other steps were different from, or more difficult than, the steps observed. Based on this portion of the task analysis, no one step or group of steps could be identified that would account for the task being rated a high driver.

KSA Analysis

A list of generic steps representing all of the steps in the task was developed to determine the KSAs required to learn and perform the task. The following 16 generic steps account for all of the steps required to perform this task.

Action	Tools and Procedures
1. Select and use the correct troubleshooting tree	Technical Manual
2. Hook up the TMDE	Connect at quick disconnects
3. Self-test the TMDE	Follow TM procedures, press keys, read displays
4. Measure voltage	Use multimeter probes, read correct scale
5. Measure resistance	Use multimeter probes, read correct scale
6. Inspect on-off indicators, panel lights	Visual
7. Operate electrical switches	Hand movement
8. Identify test points on equipment	Visual
9. Remove and install cable connectors	Quick disconnects
10. Identify test points in cable connectors	Visual
11. Remove and replace access covers	Socket wrenches
12. Manually traverse turret	Hand movements
13. Remove and install floor plate	Socket wrenches
14. Notify supervisor as directed by TM troubleshooting tree	Refer identified problem to DS-GS maintenance for repair
15. Follow safety precautions	Observe all TM warnings and cautions
16. Complete DA Form 2404	Write up fault and action taken

Based on these generic steps, the following KSAs were identified as necessary to learn and perform the task. According to instructor personnel, all students completing AIT for MOS 63T have these KSAs. All of these KSAs were observed in the performance of the 63T10 student who participated in the task analysis except for "use an inspection mirror". This skill was not required during the demonstration because the equipment had been removed from a vehicle and placed on a bench for easy access during training.

Knowledge

Basic electricity as taught in AIT

Skills

Use STE-M1 (TMDE)
Use a multimeter
Use hand tools
Connect and disconnect cables
Identify test points
Locate and inspect indicators
Locate and operate switches
Manually traverse turret
Remove and replace cables and parts
Use an inspection mirror
Follow path in TM troubleshooting tree

Abilities

Average reading ability
Average dexterity and motor abilities

All of the required KSAs, according to school personnel, are present among MOS 63T trainees, and they do not seem to have unusual difficulty mastering this task during training. It was noted, however, that aptitude qualifications for entry to MOS 63T are mechanical rather than electrical, and that this task was one of only a handful of tasks taught in AIT that depend on an understanding of electrical rather than mechanical or hydraulic principles. The task analysis indicates that task performance is fully supported by the TM, on the other hand, and that aside from a basic comprehension of the electrical principles taught in AIT, no significant amount of electrical aptitude is needed.

Deficiency Analysis

No specific steps or groups of steps in the task could be identified as the reason for this task being a high driver. Because no KSA deficiencies other than the possible need for some electrical aptitude appear to limit task learning or performance, it was necessary to examine other possible causes and solutions as ways of making this task less intensive in its use of MPT resources.

In the Deficiency Analysis, the task was examined along seven dimensions that potentially could cause, or contribute to, task learning and performance difficulty. Possible deficiencies were evaluated, in part, using the pattern of subscores that comprise the task's overall ECA score.

ECA Subscores. The ECA subscores and their relative contribution to the total ECA score obtained for this task were:

	Subscore	Value	Average of All MOS 63 Tasks
A.	Percent Performing	3.3	2.64
B.	Task Performance Difficulty	2.4	1.65
C.	Frequency Rate	2.8	1.85
D.	Task Learning Difficulty	2.3	1.52
E.	Time-to-Train	2.3	1.48
F.	Decay Rate	2.5	1.66
TOTAL ECA SCORE		293.3	44.31

Deficiencies and Solutions. The task was examined with respect to each of seven dimensions: manpower, personnel, training, equipment design, task procedures, supporting tools-manuals-job aids, and performance conditions. Both possible deficiencies and solutions to overcome them were examined for each dimension.

1. Manpower. This task is not manpower intensive. It requires only one mechanic plus an untrained helper for some steps. According to the MLRS Table of Organization and Equipment (TOE), three MOS 63T10 mechanics are allocated to each battery maintenance section to perform chassis maintenance at the organizational level. Adequate supervision for these soldiers is available within the section. Increasing authorized manpower at a unit or activity would not affect task performance. However, if the number of mechanics was increased, each might not perform the task as frequently. Thus, "frequency rate" would go down, but "percent performing" might increase.

   In a more general sense, the present ECA study suggests that electrical and electronic tasks, both operator and maintenance, very frequently received high ECA scores whether they achieve high driver status or not. Electrical concepts in general appear to be the source of the unusual difficulty experienced when these tasks are performed by soldiers in MOSs that traditionally perform mechanical tasks, including MOS 63T. It is possible that current recruits into the Army have less of a basic understanding of electricity and electronics than earlier recruits. Alternatively, the proportion of all recruits with some electrical and electronic capability may not have changed but, instead, those who do have this capability are being directed into electrical and electronic MOSs leaving few for assignment to traditionally mechanical MOSs such as 63T.

One manpower solution would be to reassign this entire task to the DS-GS level. As it is, a sizable proportion of the troubleshooting branches already end in a referral of the problem to DS-GS maintenance because the repair required is beyond the capabilities of an MOS 63T mechanic. However, an ECA survey recently conducted by USAOC&S on a parallel DS-GS task for this same equipment identified that task as a high driver for MOSs 63G and 63H as well.

2. Personnel. Personnel in this MOS are selected for mechanical, not electrical, aptitude. No individual steps of this task, however, are beyond the basic abilities required by MOS 63T. An increase in electrical aptitude, on the other hand, might decrease "time-to-train" and "decay rate" for this task. But, any shift in aptitude requirements toward electrical or troubleshooting abilities might sacrifice the mechanical aptitude required for the preponderance of the tasks assigned to this MOS. Also, as just noted, the apparent scarcity of Army recruits who have electronic aptitudes would make it difficult to get sufficient numbers of qualified candidates.

   Alternatively, electrical maintenance tasks could be separated from mechanical maintenance tasks at the organizational level, to be performed by personnel in different MOSs. Although this would require the creation of a new MOS, the increased use of electrical and electronic components for weapons mounted on tracked vehicles may support the addition of another MOS, one specializing in electrical power and electronic control systems and components.

3. Training. With many more mechanical tasks to learn, electrical training for this MOS is necessarily "short circuited" in AIT. Not many steps in this task are explicitly taught and, because troubleshooting is time consuming, the task is seldom repeated or varied. Formal task training covers only 10 of the 23 task segments in the TM. Of the 10, eight are generic troubleshooting steps and only two require the student to locate a specific failure. However, instructors report that students do not appear to experience unusual difficulty during instruction on this task, and all do complete the Practical Exercises (PEs). Nevertheless, this task received a very high ECA rating on "task learning difficulty".

   Another way of looking at this task suggests potential training deficiencies. Altogether, there are 127 possible steps to perform during this task, even though most failures will be identified after far fewer steps. Thus, because this is a sequential troubleshooting procedure, steps required late in the procedures almost never will be practiced.

"Decay rate" may be high as a result, regardless of the high "frequency rate".

Also, while the training for this task does not include repair or replacement activities to correct a failure, these steps may have been considered part of the task by the SMEs who rated it. Replacing a wiring harness may, in fact, be a difficult and time consuming job.

A training device may be helpful to teach the logic of troubleshooting and to give more extensive practice in this type of task, where alternate branches of a troubleshooting tree are followed without consuming excessive time. A training device of this kind could be used to call up a step (by number or letter), display the alternatives, and then display the outcome based on the student's choice.

4. <u>Equipment Design</u>. This task was rated considerably higher than most mechanical tasks in "frequency rate". This indicates a design change might be considered to improve hardware reliability.

   Enhancing the labeling of test points and providing a hinged control panel to eliminate the necessity of using an inspection mirror for some steps might reduce training time or the possibility of error.

   Although repair and replace steps were not included in the task analysis, the difficulty in replacing a faulty wiring harness may have been a source of this task being designated a high driver. Designing harness enclosures to improve access and making the cables easier to replace would be a solution if this is a major source of the problem. Most other end-branch items either are surface-mounted assemblies with quick disconnect cabling or simple internal parts such as switches and lamps. None of these would be difficult to replace.

5. <u>Task Procedures</u>. This task is designed using serial, symptom-based troubleshooting procedures. That is, the soldier begins at a single starting point and then proceeds through the steps in order until the failure is identified. This is a considerably simpler troubleshooting approach than the system-based approach more often used at the DS and GS levels to identify failures in electrical and electronic equipment. It should be noted that the TM covering this task currently is being rewritten to increase the number of symptoms used as starting points in the troubleshooting tree. Thus, instead of potentially having to check out each subsystem in its entirety to locate a fault, the soldier can proceed directly to the subroutine designated for a particular symptom of the kind likely to be reported by operator personnel. This change is likely to reduce the time required to perform the task because many of the steps in the

present 127 step procedure can be skipped over. On the other hand, some of these sequences may never be practiced, leading to an increase in "decay rate". Also, having to match the problem reported by the operator with a corresponding symptom specified as a starting point in the TM may be more difficult than it sounds.

6. Supporting Tools-Manuals-Job Aids.

   a. Tools and Test Equipment. With the exception of the hand mirror, no unusual tools are required for this task. Performance of the task depends, however, both on the proper use of the STE-M1 test equipment and the capabilities of that equipment. As applied to this task, the STE-M1 provides very little diagnostic information beyond checking the continuity of circuits. An increase in the specificity of diagnosis performed using the STE-M1 could reduce the requirements of this task. Other TMDE have been developed that employ programs to thoroughly check out systems and identify specific defects automatically.

   b. Manuals. The troubleshooting TM is not difficult to follow although the "tree" with its many branches is quite lengthy. The reading ability required is well within bounds of this MOS. The task is, however, manual-dependent. Soldiers with a low reading ability could have difficulty. The tree is now definitive and certain. However, the rewritten TM may make the outcome less certain by forcing the soldier to select the subroutine needed to diagnose a problem.

      The new manual also will include schematics for individual vehicle subsystems. These identify harness, lead, and pin callouts to aid the repairman. However, soldiers who have little basic understanding of electrical concepts may be unable to use schematics. Learning to use them may be difficult. The proposed revision may reduce the length of the task and thereby simplify performance. However, the procedures may place an additional burden on the 63T repairman and on the training the repairman receives.

   c. Job Aids. Job aids that could simplify this task include dummy connector halves that can be inserted into a live connector to expose and identify test points, and a preprogrammed display that would lead the repairman step-by-step through the procedure so use of the TM was not required.

7. Performance Conditions. When observed for the task analysis, this task was performed on a work bench in a shop environment. No problems attributable to performance environment were reported to us although, in the field,

performing this task in the driver's seat could make cable and connector labels more difficult to identify.

Part II: Analysis of High Drivers for MOS 31V

Introduction

Eight tasks surveyed in MOS 31V were identified as high drivers. Seven of these tasks received ECA scores above 216. One other task, not included in the survey of SMEs, was added to the high driver list by DOTD, USASIGCEN when the ECA survey results were reviewed. Task Analyses and Deficiency Analyses were performed on all eight of these tasks but, because information on two of these tasks is "For Official Use Only", the details of the analysis on these two tasks, those involving the KY-57, have been omitted from this report.

The six tasks reported here involve very similar equipment and procedures that overlap extensively with one another. For this reason, the analyses for all six tasks have been combined.

The eight MOS 31V high drivers are:

1.	Evaluate Operation of the VRC-12 Series Radio	ECA Score:	275.68
2.	System Troubleshoot the VRC-12 Series Radio	ECA Score:	532.92
3.	System Troubleshoot the VRC-64 Series Radio	ECA Score:	501.19
4.	Perform Unit PMCS on VIC-1	ECA Score:	413.28
5.	Evaluate Operation of VIC-1	ECA Score:	253.48
6.	System Troubleshoot VIC-1 with FM Radio	Not in ECA Survey	
7.	Install KY-57 Installation Kit	ECA Score:	225.05
8.	System Troubleshoot KY-57 with FM Radio	ECA Score:	808.65

On-site task analyses were performed on these six tasks at USAFAS, Fort Sill. Because of the extensive overlap among these tasks, each principal segment was demonstrated only once. In various combinations, however, these segments represent all of the steps in the procedures for the first six tasks. Most of the segments were performed by a recent AIT graduate who was awaiting assignment. However, some of the set-up and inspection segments were demonstrated by an instructor when the student was not available. The instructor inserted faults for the student to identify in the troubleshooting segments.

The student did not appear to experience any particular difficulty when performing the procedures. According to school personnel, those steps performed by the instructor also do not cause the students any particular difficulty. Students graduating from AIT generally are proficient in all of these tasks. Based on the observation of task performance during the task analyses and a review of the procedures, no one step or group of steps could be identified that were particularly difficult and would account for any of these tasks being rated high drivers.

KSA Analysis

A list of generic steps representing all of the steps in the six tasks being reported was developed to determine the KSAs required to learn and perform these tasks. The following 12 generic steps account for all of the steps appearing in the six tasks.

Action	Tools and Procedures
1. Set switches, knobs and dials	Follow TM procedures
2. Connect and disconnect cables	Quick disconnects
3. Read indicators and lamps	Recognizes abnormal indicators
4. Set up test equipment	PRM-34 Test Set
5. Measure voltage and resistance	Use multimeter with probes, read correct scale values
6. Talk into handset, listen	Recognizes abnormal sounds
7. Complete DA Form 2404	Write up defects
8. Perform distance check	Direct driver
9. Follow safety procedures	Observe TM warnings and cautions
10. Remove and replace control boxes, speakers, etc.	Screwdriver, other hand tools
11. Choose and sequence tests	Uses color-coded schematics
12. Locate equipment test points	TM illustrations

Based on these generic steps, the following KSAs were identified as necessary to learn and perform the six tasks. According to instructor personnel, all students completing AIT for MOS 31V have these KSAs. All of these KSAs were observed in the performance of the recent MOS 31V graduate who participated in the task analyses except those involving vehicle operation or installation.

Knowledge

Basic electronics as taught in AIT

Skills

Recognize symptoms of defects
Read schematic diagrams
Troubleshoot logically
Use multimeter and test set
Use hand tools
Disconnect and connect cables

Abilities

Average reading ability
Average dexterity and motor abilities
Analytic ability to perform electronic troubleshooting

Most of the required KSAs appear to be present among MOS 31V trainees, and all students seem to be able to achieve proficiency during training. However, school personnel indicated that while all entrants to the MOS have qualifying scores in electronic aptitude, the students are not as capable learners as they could be. The instructors also felt that the learning ability of students had deteriorated over the past several years. Based on observation of performance during the task analyses, proficiency in these tasks appears to depend heavily on the soldier's ability to "Read schematic diagrams" and "Troubleshoot logically", and on the soldier's "Analytic ability to perform electronic troubleshooting". Despite their qualifying scores, then, MOS 31V entrants may be deficient in these KSAs relative to their importance in achieving proficiency in the tasks.

A review of the content of the TMs revealed major deficiencies and errors in the checklists and symptom-based troubleshooting procedures presented in them. During AIT, the student's have to learn to disregard the TMs and, instead, depend on schematics handed out during training and on their own analytic abilities to accomplish these tasks. Also, the TMs do not satisfactorily identify typical abnormal symptoms. Although these generally are covered during training, the student would require extensive experience to become familiar with what differentiates normal from abnormal checkout results.

Because of the weaknesses in the TMs, the MOS 31V soldier is called upon for analytic abilities an entrant may not have. Current qualifications for entering this MOS seem to be predicated on the availability of clear, step-by-step directions for all procedures. The TMs do not adequately support performance, however, and require the MOS 31V soldiers to devise their own approaches to each troubleshooting assignment. The abilities necessary may be beyond those established for this MOS.

Deficiency Analysis

Although no specific steps or group of steps within the six tasks could be identified as the reason for these tasks being high drivers, a possible KSA deficiency does exist in that MOS 31V repairers are required to use abilities they may not have to compensate for errors and weaknesses in the TMs covering these six tasks. The implications of this possible deficiency were examined along with other possible causes to identify opportunities to make these tasks less intensive in their use of MPT resources.

During the analysis, the six tasks were examined, as a group, along seven dimensions that potentially could cause, or contribute to, task learning and performance difficulty. Possible deficiencies were identified, in part, using the pattern of subscores that comprise the overall ECA scores for each of these tasks.

ECA Subscore	Eval. 12-ser	Sys TS 12-ser	Sys TS VRC-64	PMCS VIC-1	Eval. VIC-1	Sys TS V1C-1 +FM
A. Percent Performing	3.42	3.08	2.91	3.30	3.18	Not in ECA Survey
B. Task Performance Difficulty	1.83	2.33	2.27	2.50	2.00	
C. Frequency Rate	.75	3.33	3.09	3.30	3.27	
D. Task Learning Difficulty	2.17	2.50	2.45	2.44	2.27	
E. Time-to-Train	2.50	3.33	3.55	2.70	2.45	
F. Decay Rate	2.17	2.67	2.82	2.30	2.18	
TOTAL ECA SCORE	275.68	532.92	501.19	413.28	253.48	

ECA Subscore	Sys TS KY-57	Install KY-57 KT	Remaining 29 Tasks	Range 29 Tasks
A. Percent Performing	3.45	3.09	2.77	(1.60-3.36)
B. Task Performance Difficulty	3.00	2.45	1.82	(1.33-2.40)
C. Frequency Rate	3.18	2.64	2.74	(1.50-3.25)
D. Task Learning Difficulty	3.09	2.36	1.89	(1.27-2.18)
E. Time-to-Train	2.91	2.18	1.71	(1.27-2.25)
F. Decay Rate	2.73	2.18	2.00	(1.58-2.27)
TOTAL ECA SCORE	808.65	225.05	89.28	(22.95-147.75)

1. Manpower. None of the tasks are individually manpower intensive but, in some units, the number of radios relative to the number of MOS 31Vs assigned could cause a heavy workload. With better procedures, available maintenance kits, and simple directions, responsibility for more PMCS and rudimentary checkout and troubleshooting procedures might be assumed by the vehicle crew.

   According to the MLRS TOE, only one MOS 31V, Radio Repairer, is allocated to each battery to perform radio maintenance at the organizational level. There are 44 radios per battery plus numerous intercom systems and other items in this area of responsibility. The very high "frequency rates" reported for each of the high driver tasks suggests that, for some units, an increase in manpower in this MOS might be beneficial.

   It should be noted, however, that the generally high subscores for "percent performing" and "frequency rate" may be distortions resulting from how an ECA score is determined. MOS 31V is responsible for only a few items of equipment and for a narrow range of functions. Both subscores would be reduced if the scope of responsibilities for the MOS were broader and included a greater range of equipment even if all tasks presently assigned to this MOS remained the same.

2. Personnel. No specific deficiencies attributable to physical capabilities could be identified. The qualifiers for this MOS are passing scores on Electronics and on Surveillance-Communications. Discussions with course instructors gave the impression that the top qualifiers in these aptitudes were being lost to more highly technical MOSs, and that some of their MOS 31V students are only marginally qualified. Not many students in the MOS have profound reading difficulties.

Their most distinctive deficiency is that the troubleshooting procedures they now perform depend on analytic abilities that may be beyond the capacity of many MOS 31V entrants.

Soldiers entering this MOS do not appear to have analytic aptitudes comparable to those in more demanding electronic MOSs. It appears as if the qualifications for this MOS presume the step-by-step procedures for equipment evaluation and troubleshooting usually provided by specific checklists and diagnostic flow charts. Because of the poor quality of these materials in TMs covering the high driver tasks identified for this MOS, however, MOS 31V soldiers are taught to use schematics to help them detect and isolate faults. This system-based approach depends on higher aptitudes and more skill than the symptom-based approach more frequently associated with organizational level maintenance MOSs.

3. Training. Training for this MOS consists of ten weeks of electronic theory and radio troubleshooting. The course is divided into 2 weeks of theory and 8 weeks of practical exercises. Even though very little theory is taught, what is presented may be more than would be necessary if the soldier could depend on the step-by-step procedures in the TMs, and not have to rely on schematics. The training devoted to practical exercises also may be longer than necessary if the simpler troubleshooting procedures could be used. More explicit troubleshooting procedures would therefore significantly reduce training time. "Time-to-train" was a subscore that was rated particularly high for these six tasks, especially the more complex troubleshooting tasks. "Task learning difficulty" was not relatively as high. The instructors appear to be successful in teaching at least the basic elements of these tasks through a combination of school-developed learning aids and a fairly lengthy training program. "Decay rate" also is high, however, suggesting students are unable to perform as well in a unit as they do in a more structured, and more helpful, school environment.

4. Equipment Design. The project team did not observe any tasks in which characteristics of the equipment made its operation, evaluation, troubleshooting, or repair physically difficult. The equipment maintained in all of these tasks is rugged, and the probability of failure seems reduced as much as possible for radio devices. Connectors are simple and sturdy. The project team was advised that some vehicle installations of the VIC-1 have more complicated cabling than was observed, but this was not considered a design problem by any SMEs interviewed.

An equipment modification that could simplify the entire troubleshooting procedure would be the addition of power indicator lamps on each component. The present VIC-1 configuration has a power indicator lamp on the main junction box only. Adding such a lamp, as every state-of-the-art "boom box" civilian radio has, to every component would substantially reduce troubleshooting time, training time, and task performance difficulty.

The soldier in this MOS is a component replacer. Knowing which components are receiving power and which are not should help the MOS 31V isolate defective equipment. The cost of adding this technology to the radios and intercom components may be less than supplying more manpower trained to troubleshoot the present equipment.

The project staff was informed that most of the equipment now serviced by MOS 31V will be replaced by SINCGARS equipment in the near future. When that occurs, special attention should be given to the development of checkout and troubleshooting procedures that are both explicit and within the abilities of MOS 31V personnel.

5. Task Procedures. The procedures presented in the TMs for the evaluation and most of the troubleshooting segments are symptom-based using equipment performance checks to isolate faulty components. This procedure is usual for troubleshooting tasks at the organizational maintenance level for electrical and electronic equipment. However, weaknesses and deficiencies in these procedures make it necessary for students to use system-based troubleshooting techniques that depend on an understanding schematic diagrams. Because of the analytic ability required, this may be difficult for some MOS 31V students. Also, the TM procedures provide no guidance on how to differentiate normal from abnormal checkout results based on the sounds heard.

   Some of the particular defects in task procedures that were identified by SMEs at the time the task analyses were conducted are:

   - Evaluation segments are difficult because the students fail to recognize symptoms that indicate defects. Many failure determinations require the ability to make subtle discriminations between normal and abnormal checkout results. The TMs describe only normal results and the student generally must learn the distinguishing characteristics of abnormal results through experience. Many are discernable only because a failure produces a slightly different sound over the speaker when a test is performed.

   - Inspection segments are very time consuming because they require some disassembly and assembly.

   - Symptom troubleshooting segments are difficult because of how the steps in the diagnostic flow charts are written. Many cannot be understood even by instructors (e.g., "Both points not at 22 to 30 VDC = YES/NO?). Also, many of the diagnostic flow charts leave out vital information, such as identification of the test points to be used in performing some checks. In addition, these diagnostic procedures contain a large number of errors. Approximately one step in 20 refers the user to the wrong reentry ("Go To") point, contains errors in how to perform a test, or has incomplete directions.

- System-based troubleshooting segments taught at the school as a way of overcoming the deficient symptom-based procedures depend entirely on the student's ability to read schematics and understand the logic of troubleshooting. This is considerably more difficult than following a diagnostic flow chart or troubleshooting tree. Furthermore, there is no assurance that the job aids developed at the school to support system-based troubleshooting will be available to the MOS 31V soldier once assigned to a unit.

6. Supporting Tools, Manuals, and Job Aids.

   a. Tools and Test Equipment. No special tools are used. The soldiers are thoroughly trained in use of the multimeter and other test equipment needed during the performance of these tasks.

   b. Manuals. The procedures in the TM for evaluation and troubleshooting are poorly written and incomplete. Consequently, the school has designed its own job aids based on schematic diagrams. For any of the equipment not superseded by the SINCGARS replacement radio, a thorough revision of the TM procedures seems necessary.

   c. Job Aids. As just noted, the school has developed its own job aids from schematic diagrams. Graduates of the AIT course must retain the school-distributed job aids to be prepared to perform these tasks in the field.

7. Performance Conditions. When observed for the task analyses, the tasks were performed in a classroom environment. No problems attributable to the performance environment were reported.

Part III: Analysis of High Drivers for MOS 63H

Introduction

Two tasks from MOS 63H were identified as high drivers. One task, "Repair Transmission HMPT-500", received an ECA score of 287.90 in the SME survey and was confirmed as a high driver by USAOC&S, the proponent school. The other task, "Repair Bradley Fighting Vehicle Diesel Engine", received an ECA score of only 155.82 which is below the recommended cut-off score of 216 when all six ECA dimensions are considered. However, the school determined that this task should be designated a high driver based on other evidence.

Both of these tasks are quite comprehensive and include repairing all failures to the HMPT-500 transmission and BFVS engine that can be performed at the intermediate (DS-GS) maintenance level. For the purposes of this analysis, the school suggested limiting the scope of these two tasks to specific subtasks identified by school personnel as those responsible for most of the problems associated with these tasks, and those that were placing the heaviest demands on MPT resources.

The subtasks selected for emphasis within the HMPT-500 transmission task were "Replace Disconnect Clutch", "Replace Controller Assembly" and "Adjust Controller and Neutral Steer". A fourth subtask, "Replace Disconnect Clutch Assembly", was added by the school instructor staff because the clutch assembly must be removed from the vehicle to perform the other tasks, then replaced, and, finally, a checkout must be completed. Interestingly, three of these transmission subtasks also were represented individually as tasks in the ECA survey, but did not themselves yield high driver scores. The first and second were included in the ECA survey for MOS 63H and the third was surveyed as an MOS 63T task. The results of the ECA surveys of these tasks are:

Task	PP	TP	FR	TL	TT	DR	Total
Replace Disconnect Clutch	1.55	2.36	1.27	2.18	1.91	2.00	38.73
Remove-Install Controller Assembly	3.00	1.64	2.55	1.64	1.64	2.27	76.05
Adjust Controller and Neutral Steer	3.10	2.40	2.40	2.10	1.60	1.80	90.0

Three subtasks from the BFVS engine task were chosen by the school as the most difficult to learn and perform. These were "Replace Cylinder Head", "Adjust Fuel Injectors" and "Adjust Valves". Again, the MOS 63H ECA survey included two of these as separately rated tasks. Both received relatively low ECA scores. The results of the ECA survey of these tasks are:

Task	PP	TP	FR	TL	TT	DR	Total
Replace Cylinder Head	1.92	1.92	1.50	1.85	2.31	2.08	49.09
Adjust Fuel Injectors	2.07	1.71	2.00	1.86	1.64	1.71	37.15

The selected subtasks were demonstrated by an instructor at USAOC&S for the task analyses. School personnel also were interviewed regarding these two tasks.

Based on the observations of task performance, the project staff concluded that a student or recent graduate might experience considerable difficulty when performing these tasks, and require considerable time, because of the need to locate the procedures in the TMs, refer back and forth between the job and the TM at almost every step, and make the required close tolerance adjustments. However, it did not appear that any steps were inherently difficult.

During the interviews that followed the task observations, the instructors offered a number of opinions as to why these tasks were unusually difficult.

- BFVS Engine Task. Only 10 hours are allotted to the BFVS engine task during AIT, and only 9 hours are scheduled when the task is taught in BNCOC. As a result, practice time is very limited. The task is long and tedious. Many of the components are quite heavy, and most bolts are highly torqued. Physical discomfort is likely, particularly when the task is performed in the field. The task is not required frequently so most MOS 63H soldiers have little experience with it. Two special tools are used. One, the Rocker Lever Actuator, does not work well and breaks easily but a 3/4" socket wrench with a long extension can be used as a satisfactory substitute. The other, the Dial Indicator used to set valve clearances, also is more fragile than the instruments most engine mechanics are likely to use. There is one prominent error on page 3-283 of the TM.

- HMPT-500 Transmission Task. Transmission repair tasks are difficult to learn. Few students successfully perform the clutch repairs during classroom practice. The controller and steering adjustments are complex and must be performed to closer than usual tolerances. New MOS 63H graduates rarely are assigned as other than helpers when any of these subtasks are required. On the other hand, HMPT-500 transmission repairs are needed quite frequently, so there is considerable opportunity for on-the-job experience. The TM is deficient in the way the procedures for the disconnect clutch are described, and it currently is undergoing revisions to make it more precise.

Although the subtasks in both tasks are considered difficult, no one step or group of steps in any of the subtask procedures could be identified from the task analyses that would account for either of the tasks being designated as a high driver.

KSA Analysis

The subtask procedures from both the engine and transmission repair tasks all share a number of generic steps that are typical of heavy equipment maintenance and that must be accomplished to close tolerances. The following nine generic steps represent virtually all of the steps needed when learning or performing any of these subtasks.

	Action	Tools and Procedures
1.	Inspect parts and seals	Follow TM procedures
2.	Tighten bolts to standards	Torque wrench
3.	Reads micrometers and gages	Recognizes abnormal wear or damage
4.	Set up test equipment	STE/ICE
5.	Remove heavy components	Use lifting device, direct assistant
6.	Use special tools skillfully	Dial Indicator, Rocker Lever Activator
7.	Complete DA Form 2404	Write up defects
8.	Make mechanical adjustments within tolerance	Accuracy and patience
9.	Follow safety procedures	Observe TM warnings and cautions

Based on these generic steps, the following KSAs were identified as necessary to learn and perform the steps. According to instructor personnel, all soldiers completing AIT for MOS 63H have these KSAs.

Knowledge

Basic mechanics as taught in AIT

Skills

Recognize defects in parts
Use STE-ICE (TMDE)
Read micrometers and gages
Remove and replace heavy components
Direct assistant
Use common hand tools
Use a torque wrench
Use a Rocker Lever Actuator (tool)
Make fine adjustments of mechanical parts to close tolerances

Abilities

Average reading ability
Average dexterity and motor abilities

Based on the requisite KSAs needed to perform the high driver subtasks, MOS 63H personnel should not have any difficulty with any individual step. The small amount of training provided may be a problem, however. If it were practical to provide more task practice, task performance difficulties might be reduced. These tasks have two characteristics that make them stand out from most other MOS 63H tasks. First, each is lengthy and therefore the steps are hard to remember. The soldier must rely extensively on the TM. Second, each requires precision and delicate adjustments. A "trained" eye and ear that mechanics may need to perform these adjustments proficiently likely will result only from considerable experience.

Deficiency Analysis

Although the two MOS 63H tasks identified as high drivers involve quite different procedures, they overlap closely in the generic steps performed and in the KSAs required. Both tasks therefore were considered together in an effort to determine what factors may be contributing to task learning and performance difficulty. The ECA subscores for these tasks are:

ECA Subscore	Repair Trans-mission	Repair Engine	Remaining 58 Tasks
A. Percent Performing	2.38	2.36	1.44 (1.00-3.00)
B. Task Performance Difficulty	2.46	2.21	2.37 (1.50-3.33)

C.	Frequency Rate	2.46	2.29	1.41 (1.00-2.85)
D.	Task Learning Difficulty	2.46	2.29	2.28 (1.00-3.17)
E.	Time-to-Train	2.77	2.86	2.23 (1.21-3.29)
F.	Decay Rate	2.92	2.00	2.11 (1.25-3.33)
TOTAL ECA SCORE		287.90	155.82	54.32 (7.21-197.53)

The high scores on "Time-to-Train" for these two tasks are attributable to the performance time required for each task, the need to employ special tools, and the need to perform many mechanical operations that may be new to a recent entrant to this MOS. As skills are acquired, task performance time reportedly decreases dramatically but, for both tasks, there seems to be little opportunity to practice either in school or soon after joining a unit. The high decay rate on the transmission repair task appears due to the tendency to assign this task to mechanics who have developed a specialization in transmission repairs rather than to recent MOS 63H graduates.

Deficiencies and Solutions

Both tasks were examined as to possible deficiencies in manpower, personnel, training, equipment design, task procedures, supporting tools-manuals-job aids, and performance conditions. The likely deficiencies that were noted, together with possible solutions for overcoming them, are summarized in the following paragraphs.

1. Manpower. Neither of these tasks are manpower intensive. Each requires only one repairer and some assistance from a helper. According to USAOC&S, 5 to 7 MOS 63H Track Vehicle Repairers and about the same number of MOS 63W Wheel Vehicle Repairers would be assigned as contact team members to an MLRS battalion having 40 launchers to service. An estimated 10 to 16 of the vehicles would require transmission work in a one-year period, and 2 or 3 would require major engine work. Under these circumstances, manpower allocations seem adequate. However, it is projected that more transmission disconnect clutch work will be required if the chassis is used for heavier turret assemblies (such as for AFAS).

   While the availability of manpower seems to be sufficient, the scope of tasks assigned to this one MOS may be excessive. Each mechanic is expected to develop proficiency on repairing major components, such as "engine" or "transmission" that are functionally similar but configured very differently from one weapon system to the next. If the variety of systems grows, this can become an increasing problem. One solution would be to divide the MOS. The most promising way to do this would be to create specialties by component, such as creating a "transmission specialist". This would promote the transfer of skill across vehicles but, unfortunately, may not be as workable in the Army environment as specialization by type of vehicle, as the MLRS.

2. Personnel. Entrants to MOS 63H are reportedly above average in qualifying aptitudes relative to other 63-series MOSs. No observable learning deficiencies are evident, and reading difficulties are rare. Nevertheless, soldiers at the entry point of the MOS are not usually intensive readers. Yet, these tasks both require constant use of a TM. Also, these tasks demand a degree of precision higher than the average for tasks assigned to this MOS.

   Fundamentally, the students appear adequately qualified to learn these tasks and perform them up to standard if they have sufficient opportunity to practice them regularly.

3. Training. 63H is a broad MOS. Only a few days are spent learning the Bradley during the eight-week AIT course. This time is focused on the most difficult tasks, including these two high drivers. Time constraints within the course do not allow enough practice to develop or sustain proficiency, however. There is a Bradley designation for this MOS but only at skill level 30. MOS 63Gs and 63Ws who are promoted to 63H30 have no formal channel for absorbing the "H" skills until they are selected for the BNCOC course. USAOC&S has developed a Master Diagnostician course for warrant officers who would then use their skills to offer intensified unit training. This is a fairly new undertaking and its effects have not yet been fully realized.

4. Equipment Design. Some steps in the engine repair task are physically demanding, but no ready solution is apparent.

   The transmission adjustments are critical and some parts are fairly delicate relative to most Army equipment. Reliability has been a problem with this transmission and the SMEs expect more disconnect clutch problems if the Bradley chassis is used for heavier loads without modification of the transmission. The project team was told that both DoD and the manufacturer are aware of this problem.

5. Task Procedures. Both tasks are closely supervised in the field because, as students, the MOS 63H repairers do not develop proficiency at these tasks.

   TM directions for the tasks, by and large, are clearly written and well illustrated. Additional job aids might be considered for both tasks to ease judgmental considerations during inspection and adjustment procedures.

6. Supporting Tools-Manuals-Job Aids.

a. Tools and Test Equipment. Special tools are used in performing these tasks. Use of micrometer and dial indicator gage is taught to all students in the MOS 63H AIT course, but practice with them is limited to a few tasks. The breakage rate of the dial indicator gage at the school suggests the availability of an operable one in the field might be questionable. The Rocker Lever Actuator is a special tool used for engine tasks that does not work well and breaks easily, but an ordinary socket wrench with an extension is a good replacement for it. While special cradles hold the power pack during practice at the school, the customary field rest is a group of 4" x 4"s. An easily transportable cradle might be developed for use when the power pack has to be removed.

b. Manuals. There are some four -20 manuals and four -34 manuals describing Bradley repairs at the DS-GS level. Beginning mechanics are known to have difficulty identifying the correct reference to use. The -34 manuals for engine and transmission repair are clearly written and well illustrated. The -20 troubleshooting manual is quite difficult for an inexperienced soldier (this problem also was noted concerning the same TM for the MOS 63T high driver). Some errors in the -34 manuals were identified by the SMEs. The project team was told that revisions to correct these errors are in process. In performing these tasks, the assistant often reads the TM procedure to the mechanic. This no doubt makes the work more efficient, but increases the manpower required.

c. Job Aids. Both of these tasks depend on carefully following the TM procedures. The subtask steps are difficult to remember. More job aids, especially for unit use, should be considered.

7. Performance Conditions. When observed for the task analyses, the tasks were performed in a school shop environment. No problems attributable to performance environment were reported, except for precautions needed to keep the components free of dirt in the field.

APPENDIX D

COMPOSITION OF AN AFAS MOBILE CONTACT MAINTENANCE TEAM

Summary

During the course of a series of Early Comparability Analysis (ECA) studies for the Advanced Field Artillery System (AFAS), a need emerged for information that would contribute to a field maintenance concept for AFAS. This substudy was initiated to gather information on likely field maintenance requirements and to use that information to prepare a recommendation as to which MOSs should be represented in an AFAS Mobile Maintenance Contact Team (MMCT). Although it was not possible to compile information on all maintenance tasks that appropriately would be performed by an MMCT, the results suggest the range of skills likely to be required within the team and the combination of MOSs that best match these skill needs.

Data for this substudy were obtained from surveys of subject matter experts (SMEs) that were conducted concurrently with surveys administered to obtain ECA data. Only selected AFAS subsystems could be examined during the substudy, however, either because the necessary Maintenance Allocation Chart (MAC) data was not readily available or because access to SMEs who also were experienced maintenance supervisors was not always possible.

For each subsystem that could be examined, the project staff planned to:

a. Assemble available Technical Manual (TM) maintenance allocation information including a list of tasks, the maintenance level at which each task is performed, and the estimated performance time for each task;

b. Exclude tasks from the list normally performed by the crew itself, usually as a segment of Preventive Maintenance Checks and Services (PMCS), as well as tasks normally performed at the depot level;

c. Exclude tasks from the list that would not likely be performed under the 96-hour battle scenario proposed for AFAS, including all tasks requiring 8 hours or more to complete, any tasks not bearing on combat capability, any tasks dependent on the availability of unusual equipment such as two hoists, and any repair tasks that would require more than twice the time of equivalent replacement tasks;

d. Present the remaining tasks to maintenance supervisor SMEs so they could report on a survey form the frequency

of the task, the MOS currently responsible for performing the task, any special equipment required to perform the task, and any clear disagreements with the task performance time as stated in the TM;

e. Determine which tasks received an average frequency rating of 2.5 (between "semiannually" and "monthly") or higher; and

f. Estimate, on the basis of how frequently each task was performed and the MAC time for that task, a "need index" for each MOS responsible for organizational or DS-GS maintenance for that task.

The intended analysis did not work out as well as had been planned. Very few of the 772 tasks examined in this substudy were judged by maintenance supervisors as ones likely to be required at all frequently. Instead of being able to focus on a finite series of high probability repairs, an MMCT for AFAS may have to be prepared to perform a wide range of repairs, including ones that occur with a fairly low frequency. This means both that the team members will have to have considerable proficiency in identifying and overcoming any of numerous problems, and also that the MMCT vehicle will have to be furnished with an extensive inventory of spare parts if it is to restore the capability of disabled AFAS sections during a 96-hour battle scenario.

Introduction

A new self-propelled howitzer, the Advanced Field Artillery System (AFAS) is being developed to replace the M109A2/A3 (M109) self-propelled howitzer currently in inventory. In addition to significantly improved capabilities and a substantially reduced crew size, AFAS is planned as a highly mobile platform that will operate independently of a battery position under the dispersed battlefield concept. These independent operations have major implications for how urgently needed corrective maintenance will be performed to sustain AFAS combat readiness over as long as 96 hours under battle conditions.

Two considerations suggest that most corrective maintenance during combat will have to be performed by a Mobile Maintenance Contact Team (MMCT) similar to the team now used to provide maintenance for the Multiple Launch Rocket System (MLRS) or the mechanical and electronic teams that now provide maintenance support for the M109. First, AFAS sections will be widely dispersed on the battlefield instead of being grouped at a battery position. There will be no particular location where maintenance personnel, spare parts, and essential equipment would be accessible to sections in need of repairs. And, second, it is not likely that the substantially smaller AFAS crews would have the capability to make most repairs themselves even if they had a modest supply of on-board spare parts.

Limiting this study's analysis of maintenance functions to combat conditions is not meant to exclude the need for a comprehensive approach to preventive and corrective maintenance for AFAS that will insure ongoing combat readiness. However, maintenance needs that could be met during a 96-hour battle scenario are likely to be limited for several reasons:

- emphasis will be on repairs that quickly restore an AFAS to operational capability;
- vehicle recovery operations will be restricted if not impossible;
- lengthy repair tasks, those of 8 hours or more, would not be undertaken;
- repair tasks dependent on servicing equipment that cannot easily be transported to the breakdown site would not be performed; and
- spare parts will be limited, because of space and weight, to those frequently needed and those that can be carried in the maintenance vehicle.

The series of comprehensive Early Capability Analysis (ECA) studies that served as an umbrella for this substudy included 11 MOSs that now perform organizational or DS-GS maintenance on systems or components similar to those AFAS is likely to have. These MOSs and the systems or components they are responsible for are identified in Table D-1.

Clearly, not all of these MOSs should, or would have to be, represented on an MMCT for AFAS. The problem, then, is to determine which MOSs are most needed based on the frequency they would be called upon to perform field repairs.

Purpose

The purpose of this substudy was to examine the corrective maintenance tasks likely to be required to restore an AFAS section following a breakdown under combat conditions in order to identify the appropriate composition of an MMCT for AFAS. The substudy focused on three major subsystems: the AFAS chassis, the AFAS cannon and turret, and the AFAS radio communications and electronics equipment. The proposed Positioning Determining System (PDS) for AFAS was not covered. It is an electronic device that, if malfunctioning, would be removed and replaced rather than repaired, a relatively simple procedure. Depending on how it is designed, the PDS may have to be "zeroed" after installation. This could be difficult, but typically would be the responsibility of the crew rather than the MMCT.

Table D-1

Maintenance MOSs Relevant to AFAS

MOS	Title	Function
31V	Unit Level Communications Maintainer	Org. Maint., Radios
45D	Self-Propelled FA Turret Mechanic	Org. Maint., Cannon
63E	M1 Tank Systems Mechanic	Org. Maint., NBC
63T	BFVS Mechanic	Org. Maint., Chassis
27M	MLRS Repairer	DS-GS Maint., PDS
29E	Communications-Electronics Radio Repairer	DS-GS Maint., Radios
29S	Field Communications Security Equipment Repairer	DS-GS Maint., KY-57
39L	Field Artillery Digital Systems Repairer	DS-GS Maint., AFCS
45L	Artillery Repairer	DS-GS Maint., Cannon
63G	Fuel and Electrical Systems Repairer	DS-GS Maint., Chassis
63H	Track Vehicle Repairer	DS-GS Maint., Chassis

Methodology

A list of corrective maintenance tasks was developed for each major subsystem:

- AFAS Chassis. The source of tasks for this subsystem was the MAC chart for the Bradley-MLRS chassis from TM 9-1450-646-20-5.

- AFAS Turret and Cannon. The source of tasks for this subsystem was the MAC chart for the M109A3 turret and cannon from TM 9-2350-303-20-2. Tasks relating to the travellock and spade for the M109 were taken from TM 9-2350-303-20-1.

- AFAS Radio Communications and Electronics. Because a number of different items of equipment are involved, and because relatively few corrective maintenance tasks are performed on electronics in the field, the list of tasks developed for the ECA was used as the source of tasks for this subsystem.

Each list of tasks was then reviewed to eliminate those that, for one reason or another, were determined to be inappropriate for a MMCT. The criteria applied to exclude tasks resulted in the elimination of:

- inspection and routine PMCS tasks that would have low priority under a 96-hour battle scenario;

- all corrective maintenance tasks that are allocated to the operating crew;

- repair or replacement tasks that require 8 hours or more to perform;

- repair tasks that require twice as much time or more than the equivalent remove and replace task;

- repair tasks that are not critical to combat capability, such as repair of a seat; and

- repair or replacement tasks that depended on special or unusual equipment, such as two hoists.

The resulting lists did not encompass all corrective maintenance tasks that might be required for AFAS and could be performed in the field. The MAC tables do not include all possible or necessary repair tasks, and some components that might be included in AFAS were not represented within the major subsystems that were examined. The number of tasks included on the final list for each major subsystem is shown in Table D-2.

Table D-2

Tasks Rated for Each Major Subsystem

Major Subsystem	No. of Tasks
AFAS Chassis	461
AFAS Turret & Cannon (plus travellock and spade)	292
AFAS Radio Communications & Electronics Equipment	19
TOTAL	722

A survey form was developed incorporating these lists. The form identified the component or assembly that might require maintenance and the applicable maintenance functions, such as "repair", "adjust", or "replace", that might have to be performed on that component or assembly. Space on the form was provided for respondents to indicate how frequently the repair might be required for each AFAS section:

1. seldom (annually)
2. occasionally (semiannually)
3. often (monthly)
4. frequently (daily-weekly).

Space also was provided for the respondent to indicate the MOS of the person who usually performs that repair, and to record any special equipment needed to accomplish that task.

The survey was administered in conjunction with ECA survey forms when the group of SMEs who were assembled to participate in an ECA survey included a number of maintenance supervisors. Only those SMEs with maintenance supervision experience participated in the MMCT survey. A total of 9 maintenance supervisors from MOSs 63D and 63E provided information for the AFAS turret and cannon (M109) survey. Nine MOS 63T maintenance supervisors participated in the AFAS chassis (Bradley-MLRS) survey, and 7 MOS 29E maintenance supervisors responded to the AFAS radio communications and electronics survey.

Results

The frequency scores assigned by the maintenance supervisors to each task were averaged. A mean score of 2.5 or greater was selected as the cut-off score; tasks receiving a score of 2.5 (between "semiannually" and "monthly") or higher was considered to occur frequently enough to be an essential requirement for a MMCT serving AFAS. To put this value into perspective, a task scoring 2.5 would likely be required approximately 3.5 times per year per section, or 28.0 times per year per battery of eight sections. Even considering one 96-hour period under combat conditions as equivalent to 12 days of normal operations, the task would be required only once to maintain all eight sections for the 96-hour period.

The results are shown in Table D-3. Five tasks received a score of 2.5 or above within the AFAS chassis tasks, five also scored this high in frequency within the AFAS turret and cannon tasks, and four scored 2.5 or higher in the AFAS radio communications and electronics tasks. In the table, an "O" under Maintenance Level refers to organizational level, "DS" refers to direct support, and "GS" refers to general support.

Access to special test equipment was noted as a requirement for three of the four radio and electronics tasks, and for two of the turret and cannon electrical tasks. No other special equipment requirements were noted.

Recommendations

This substudy did not suggest that corrective maintenance tasks that can be performed in the field are concentrated in only a few specific areas. Although 14 tasks were identified as high frequency tasks, these represent only a small proportion of all of the corrective maintenance tasks that are likely to be required.

Three tentative conclusions are apparent from these findings:

1. The causes of loss of capability by an AFAS section during combat, and excluding damage from enemy action, are quite diverse. Even high frequency tasks are likely to correspond to only a small proportion of equipment breakdowns.

2. What corrective maintenance can be performed under the dispersed battlefield concept will have to be performed by the AFAS crew or by an MMCT. Crew-performed corrective maintenance will be limited not only by their training, but also by the variety of spare parts, tools, and test equipment that can be carried aboard AFAS.

Table D-3

Surveyed Tasks with a Frequency Rating of 2.5 or Above

Task	Average Freq	Maint Level	Time Reqd	Current MOS
AFAS Chassis:				
Service Crankcase Breather	2.7	O	1.2h	63T
Remove and Install Transmission XDR HMPT-500*	2.6	O,DS	2.3h	63T-63H
Remove-Install Controller Assy	3.0	DS	1.8h	63H
Service Pressure Fluid Filter	2.7	O	0.3h	63T
Service Storage Batteries	4.0	O	3.4h	63T
AFAS Turret and Cannon:				
Test and Troubleshoot Main Accumulator Assy	2.7	O,DS	.4h	45D
Service Power Pack Assy	3.0	O	.5h	45D
Test and Troubleshoot Electrical Leads & Harness Assy	2.6	O	.5h	45D
Test and Troubleshoot Contact Segment Ring	2.5	O	.2h	45D
Service Traversing Mechanism	2.8	O	1.0h	63D
AFAS Radio Communications and Electronics:				
Troubleshoot and Repair RT-524*	3.7	DS,GS	2.3h	29E
Troubleshoot and Repair RT-841*	3.7	DS,GS	3.3h	29E
Replace CC 2298	3.0	O	1.0h	31V
Evaluate and Repair CC 2298	2.8	DS,GS	1.2h	29E

* These three tasks also were identified as "high drivers" in the ECA surveys.

3. The range of spare parts required also will limit the repair capability of an MMCT. In most instances, corrective maintenance will have to be restricted to remove and replace functions to keep maintenance time to a minimum. It may not be worthwhile to include bulky or heavy assemblies among the spare parts carried by the MMCT vehicle.

If a Mobile Maintenance Contact Team concept is adopted for AFAS, it will be necessary to include personnel familiar with each of the three major subsystems on the team. Whether these personnel represent DS-GS or organizational level maintenance will depend on the types of spare parts provided to the team and the amount of troubleshooting that may be required to diagnose a breakdown. An organizational level team could be composed of one MOS 63T, one MOS 45D, and one MOS 31V, plus an MOS 13B driver-assistant. If extensive troubleshooting or other than remove and replace tasks are to be performed, as is more likely, a DS-GS level team composed of one MOS 63H, one MOS 45D or 63D, one MOS 29E, and one MOS 13B driver would be appropriate. Extensive cross-training would be needed to insure that any one specialist could be assisted during task performance by the other team members.

Working Paper MSG 90-05

METHODOLOGICAL CONSIDERATIONS IN APPLYING EARLY COMPARABILITY ANALYSIS (ECA)

March 1989

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METHODOLOGICAL CONSIDERATIONS IN APPLYING EARLY COMPARABILITY ANALYSIS (ECA)

SUMMARY

This report examines the methodology of Early Comparability Analysis (ECA) based on its application during the early stages of concept development for a new weapon system. The ECA technique was devised as a MANPRINT tool by the Soldier Support Center-National Capital Region (SSC-NCR) to further uses of a "lessons learned" approach for reducing the demands of new weapon systems on manpower, personnel and training resources. The ECA methodology consists of a step-by-step procedure for identifying antecedent systems that have similar hardware components, for determining operator and maintenance tasks currently performed on those components that are particularly resource intensive, and for analyzing these "high driver" tasks to diagnose deficiencies and propose solutions for overcoming them.

The emphasis in this report is primarily on the methodology of an ECA and the experience gained from applying it to a new field artillery weapon, the Advanced Field Artillery System.

AFAS is a complex, crew-served weapon system that will depend on a broad range of operator and maintenance tasks to achieve its full design potential. Much of the advanced equipment planned for AFAS, particularly its electronic devices, are relatively new to the field artillery. It is important to determine as early as possible during the planning of the system whether it imposes any demands on human performance that will burden anticipated manpower, personnel and training (MPT) resources. The ECA methodology was devised to identify MPT resource intensive tasks now performed on comparable weapon systems so they can be overcome in planning the new system.

In addition to developing information that would contribute to the development of AFAS, this study provided an opportunity to document the implementation of SSC-NCR's step-by-step procedure. This experience yielded several suggestions for enhancing the technique and for strengthening the utility of ECA findings. This analysis of the ECA methodology also identified several technical issues that became apparent during the study, but could not be examined in depth within the scope of the effort. These include the results of several incidental substudies that addressed the interjudge reliability of subject matter expert (SME) survey results, the intercorrelations among the subscales used in arriving at a total ECA task score, and the method suggested by SSC-NCR for calculating total ECA task scores. These substudies and their findings are described in an Appendix to this report.

Other outcomes from the study are presented in two companion reports. Application of Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS) summarizes the results obtained when ECA procedures were used to investigate more than 400 operator and maintenance tasks now being performed on equipment designated as predecessors to the hardware planned for the AFAS. It describes the results when SMEs in 14 military occupational specialties (MOSs) were surveyed to identify resource intensive tasks, the findings of detailed task analyses that examined the more than a dozen high drivers that were identified, and the conclusions on ways of overcoming, or at least diminishing, the impact of these likely high drivers.

The second report, Alternative Procedural Guide for Early Comparability Analysis (ECA) presents a revised step-by-step guide for conducting an ECA based on the experience obtained from this study. The main procedural changes recommended expand the scope of steps that follow the task analyses of high drivers to examine a broader range of alternatives for overcoming the impacts of resource intensive tasks. The revised guide also clarifies the instructions for a number of steps and offers suggestions for conducting an ECA when the source documentation on relevant tasks is sparse or atypical.

Overall, the ECA approach itself appears to provide very useful insights into manpower, personnel and training issues that should be considered during the design, development and deployment of a new weapon system. When performed sufficiently early in the concept exploration phase of the materiel acquisition process, as was done for AFAS, an ECA both documents current problems and uncovers possible solutions. Suggested refinements in the technique may further increase the utility of the ECA approach. These include ways of adapting ECA to the more generic definition of "task" now emerging for many maintenance MOSs and improvements in its internal consistency with respect to what high drivers represent.

METHODOLOGICAL CONSIDERATIONS IN APPLYING EARLY COMPARABILITY ANALYSIS (ECA)

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METHODOLOGICAL CONSIDERATIONS IN APPLYING EARLY COMPARABILITY ANALYSIS (ECA)

INTRODUCTION

New weapon systems are initiated in response to an evident threat to our national security resulting from improvements in a potential enemy's weapon technology, numerical strength, or combat doctrine. In order to successfully counter the threat, a new weapon must be capable of being operated and maintained to do what it is supposed to do, and able to accomplish its mission within the limits of the manpower, personnel, and training (MPT) resources that will be available to support it. It is important to avoid mistakes that can result in a costly drain on these resources or, even worse, in the production of a system that does not achieve its design capability when fielded. Preventing these problems requires a concentrated effort to assemble and then integrate MPT information into the materiel design and acquisition process. A number of techniques collectively referred to as MANPRINT, for manpower-personnel integration analyses, have been devised to produce this information.

One new MANPRINT technique is Early Comparability Analysis (ECA). Developed by the Soldier Support Center-National Capital Region (SSC-NCR), ECA is designed to build on experience with antecedent systems that have similar components to those planned for the proposed system. Tasks performed to operate or maintain these components can be examined to identify any that place significant demands on MPT resources. Once identified, these "high driver" tasks then can be studied in detail to determine the likely source of the difficulty and to propose possible remedies. This "lessons learned" approach is intended to prevent similar problems from arising again when the new weapon system is fielded.

When a Justification for Major System New Start (JMSNS) was initiated for the Advanced Field Artillery System (AFAS), the combat development team responsible for the AFAS at the U.S. Army Field Artillery School (USAFAS), Fort Sill, began a comprehensive MANPRINT effort in support of the program with the cooperation of the Army Research Institute for the Behavioral and Social Sciences (ARI). Because the procedures for conducting an ECA had not yet been tested in a large-scale application, and had not yet been tried at a very early stage of the materiel acquisition process, this study was planned both to compile ECA results that would be of interest and value to combat developers and to examine the use of the ECA methodology itself.

This report describes the application of the step-by-step procedure for conducting an ECA recommended by SSC-NCR in Early Comparability Analysis: Procedural Guide. That methodology was adhered to in general, but some changes in it were made to adapt the procedure to a complex weapon system, to reflect the kinds of information about tasks that are commonly available, and to expand the analysis of identified deficiencies so a wider range of possible causes and solutions could be explored. The report also summarizes, in an Appendix, the results of several statistical analyses carried out to examine the SSC-NCR methodology. These findings identify aspects of the methodology that should be considered when future ECA studies are planned.

In addition to this report on the ECA methodology, two other reports documenting the study have been prepared. One, Application of Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS), contains the results of the study's examination of more than 400 operator and maintainer tasks being performed by soldiers in 14 military occupational specialities (MOSs) on equipment items similar to those planned for AFAS. The other, Alternative Procedural Guide for Early Comparability Analysis (ECA), presents a revised step-by-step procedure for conducting an ECA based on this study's experiences.

Background

Because of the threat posed by the increasing technological capabilities of potential enemies, a requirement emerged for a self-propelled howitzer (SPH) considerably more advanced than the M109A2/A3 currently in the Army's inventory. In response to this requirement, a program of immediate improvements to the M109, the Howitzer Improvement Program (HIP), was began in 1984. The authorization for HIP also directed the start of work on a next generation howitzer, the Advanced Field Artillery System (AFAS). This new weapon would be considerably more advanced in technology and capability than the M109, and would be designed to support the doctrine of the dispersed battlefield concept. An Operational and Organizational (O&O) Plan for AFAS was approved in mid-1985 and a Justification for Major System New Start (JMSNS) was initiated.

The following equipment capabilities and characteristics are among those envisioned for AFAS, relative to the M109:

- considerably increased maximum range of fire from the present 18 km;
- considerably increased sustained rate of fire from the present 2 rounds per minute;
- addition of a position determining system (PDS), eliminating the need for survey data prior to occupying a firing position;

- new capability for onboard automated fire control data processing and targeting;
- new capability for onboard automated loading; and
- new capability for automated ammunition transloading during resupply.

These capabilities are intended to support new tactical roles for the AFAS developed around a highly mobile platform able to carry out sustained indirect fire missions under deep battlefield conditions for periods of up to 96 hours. Unlike present M109 sections, each AFAS section will be able to operate independently of other sections in the platoon and at a distance from the battery command location. Digital radio transmissions containing targeting data, together with the onboard position determining system (PDS) and automatic fire control instrumentation, will allow the AFAS to complete an assigned fire mission and then rapidly change position to avoid return fire. Automated loading devices will permit a substantial reduction in crew size. Resupply from a Future Armored Resupply Vehicle (FARV) also would be equipment-assisted to eliminate what, for the M109, is a time-consuming and labor-intensive activity.

Scope of the ECA

Because this study was initiated very early in the weapon system development process, many aspects of the AFAS concept were still undecided or had not yet been considered in detail. For example, several advanced cannon technologies have been under consideration including the use of liquid propellents and electromagnetic propulsion. In addition, numerous decisions were pending regarding equipment, operations, maintenance and resupply. Some examples of these unsettled issues were:

- whether AFAS would be airborne capable, perhaps through the use of detachable armor;
- the size and composition of an AFAS section's crew, except that it would be smaller than the 9 or 10 soldiers currently authorized for an M109 section including its resupply vehicle;
- what chassis AFAS would have, even if one of the planned Armored Family of Vehicles (AFV) chassis now being developed will be used;
- how maintenance would be accomplished under combat conditions, and what the scope of this maintenance would be;
- the extent to which AFAS would be equipped with redundant

systems or spare parts, and the amount of maintenance responsibility that would fall on the crew;

- what kind of equipment would be provided for transloading ammunition from a resupply vehicle to AFAS;
- how resupply would be accomplished under combat conditions, and whether each resupply vehicle would be dedicated, as now, to a single AFAS section;
- whether a single resupply vehicle would transport both ammunition and fuel; and
- the specific roles of platoon, battery and battalion headquarters in command, communications, maintenance and resupply functions.

Beginning the ECA study before these issues were resolved provided a significant opportunity to help shape the planning for AFAS so that potential problems identified by the study could be avoided. But, at the same time, the lack of specificity made it much more difficult to determine what equipment was appropriate as antecedents to AFAS and what functions should be included within the scope of the ECA study. The advantages and disadvantages of initiating an ECA before many of the new system's design and operating concepts are firmly established will have to be weighed carefully when any future ECA study is planned.

As will be described later in this report, some changes and additions affecting the scope of the ECA were made as the study progressed. Most importantly, the study was expanded after it began to include applicable intermediate (DS-GS) maintenance functions in addition to organizational maintenance functions. However, several guidelines established by the AFAS combat development team remained constant throughout the study. Excluded from the study were tasks required for:

- all resupply activities,
- operation of the resupply vehicle,
- airborne operations,
- air assault missions,
- vehicle recovery operations,
- battery support activities that would not be performed by the AFAS crew,
- crew-level corrective maintenance, and,
- all activities pertaining to special weapons.

Study Objectives

The requirement for an ECA study to identify tasks now performed on antecedent systems that are MPT resource intensive was established by the AFAS combat development team as a component of the AFAS System MANPRINT Management Plan. The conduct of the study was expected to follow the procedures outlined in SSC-NCR's procedural guide for an ECA to the extent possible.

Also, this study was seen as an opportunity to see if the procedures developed by SSC-NCR could be employed effectively by a contractor and to gain experience that might guide future applications of the technique. The study, therefore, had four primary objectives:

1. Identify any operator or maintenance tasks now performed on antecedent systems that would be applicable to AFAS and that are "high drivers" because of the demands they place on MPT resources.

2. Analyze the high driver tasks to determine why they are resource intensive and propose solutions that would diminish the resources required with respect to manning, learning, or performing these tasks.

3. Identify, on the basis of experience gained from the study, where refinements might make the ECA technique more efficient, more useful, or more productive.

4. Determine whether a contractor would experience any unexpected difficulties in carrying out an ECA, and whether a contractor would be able to produce a quality ECA study.

METHODOLOGY

This ECA study was carried out generally following the procedures established by SSC-NCR. The only major changes made were to expand the analyses called for in the last few steps of the procedure to encompass a broader range of possible causes for a task being identified as a high driver, and the consequent range of potential solutions that might be considered. Throughout the study, however, opportunities arose to suggest where minor refinements in the methodology would make the procedure clearer or more comprehensive with respect to problems that were encountered. Also, the data gathered permitted some statistical analyses that suggest where further development of the ECA methodology would be advantageous.

In the remainder of this section, the steps performed in carrying out the study are described, the experience obtained when conducting each step is documented, and possible refinements in the procedure for that step are suggested. Where appropriate, the special problems that emerged because the study was performed by a contractor instead of directly by Army personnel are discussed. Examples of the results obtained are used to illustrate the outcome of various steps. A more complete description of all of the study findings are presented in a companion report, Application of the Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS). Similarly, revised step-by-step procedures recommended for conducting future ECAs on the basis of experience obtained during this study are presented in another product of this study, Alternate Procedural Guide for Early Comparability Analysis (ECA).

The description of each step includes an overview of its purpose, a summary of the SSC-NCR procedure, highlights of what happened during the step illustrated by examples of the results obtained, and a discussion of the methodology together with recommendations regarding the procedure.

Step 1. Study Initiation

Decide whether an ECA is appropriate, which predecessor and reference systems should be considered, and who largely will be responsible for performing the ECA.

Procedure

An ECA presumes most new weapons are evolutionary, having similar components and performing the same functions as the predecessor system the new weapon will replace. The conceptual system also may incorporate additional components that can be studied by identifying reference systems which already include those components. An ECA is appropriate when there is one or more suitable predecessor systems in the Army inventory and there is no vast technological gap between existing predecessor systems or their components and those envisioned for the new system under development.

Predecessor systems and components from reference systems are selected for the study by determining whether the tasks performed on those systems are similar to ones that will be required to operate and maintain the new system.

Personnel resources are needed to carry out an ECA. In addition to identifying how these personnel requirements will be met, the proponent school for the study should take responsibility for coordinating the effort with other affected service schools, preferably through the MANPRINT Joint Working Group (MJWG).

Highlights

The decision to conduct an ECA was made by the Directorate of Combat Developments (DCD) and the Training and Doctrine Command (TRADOC) System Manager for Cannon (TSM-Cannon) responsible for AFAS at the U.S. Army Field Artillery School (USAFAS), Ft. Sill, OK. The team sought assistance from the Army Research Institute for the Behavioral and Social Sciences (ARI) which, in turn, arranged the participation of a contractor to work on this study as well as on some companion MANPRINT studies focusing on AFAS.

AFAS combat developers, ARI representatives, and contractor staff participated in a two-day meeting to define the scope of the ECA study, to select appropriate predecessor and reference systems, and to identify relevant MOSs as described under Step 2. Questions raised during the meeting pointed to several issues that had to be considered. Among these were:

a. There was uncertainty within the TSM-Cannon and DCD offices about the scope of the study, and what operator and maintainer functions it should include. The primary interest of TSM-Cannon and DCD personnel was in gathering data that would help them recognize potential problems likely to detract from the combat capability of AFAS. Generally, they chose to exclude command, support and resupply functions as well as maintenance functions at echelons above the organizational level. Their rationale for this decision was that these functions would change little, if at all, when AFAS was fielded.

b. The TSM-Cannon combat developers often were uncertain about equipment incorporated in already fielded system also may incorporate additional components that can be studied by identifying reference systems which already include those components. An ECA is appropriate when there is one or more suitable predecessor systems in the Army inventory and there is no vast technological gap between existing predecessor systems or their components and those envisioned for the new system under development.

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The decision to conduct an ECA was made by the Directorate of Combat Developments (DCD) and the Training and Doctrine Command (TRADOC) System Manager for Cannon (TSM-Cannon) responsible for AFAS at the U.S. Army Field Artillery School (USAFAS), Ft. Sill, OK. The team sought assistance from the Army Research Institute for the Behavioral and Social Sciences (ARI) which, in turn, arranged the participation of a contractor to work on this study as well as on some companion MANPRINT studies focusing on AFAS.

AFAS combat developers, ARI representatives, and contractor staff participated in a two-day meeting to define the scope of the ECA study, to select appropriate predecessor and reference systems, and to identify relevant MOSs as described under Step 2. Questions raised during the meeting pointed to several issues that had to be considered. Among these were:

a. There was uncertainty within the TSM-Cannon and DCD offices about the scope of the study, and what operator and maintainer functions it should include. The primary interest of TSM-Cannon and DCD personnel was in gathering data that would help them recognize potential problems likely to detract from the combat capability of AFAS. Generally, they chose to exclude command, support and resupply functions as well as maintenance functions at echelons above the organizational level. Their rationale for this decision was that these functions would change little, if at all, when AFAS was fielded.

b. The TSM-Cannon combat developers often were uncertain about equipment incorporated in already fielded antecedent systems except for the M109 self-propelled howitzer. A number of equipment questions were resolved by various subject matter experts (SMEs) who were invited to participate in the discussions. However, several iterations of the list of predecessor and reference systems were required, and the need to add still other systems was not recognized until after the study was well underway.

c. No maintenance concept had yet been developed for AFAS, and there was only limited agreement on who would be responsible for what. The dilemma centered on AFAS operating independently of a battery position and therefore at a distance from maintenance support. How maintenance would be provided, and what the scope of this maintenance would include, had not been determined. Although it was expected that the AFAS crew would have increased maintenance responsibilities, these had not been defined. Overall, the primary interest in maintenance tasks centered on "quick-fix" functions appropriate to a 96-hour battle scenario.

d. Although the M109A2/A3 had been presumed to be the logical choice as the predecessor system for AFAS, primarily because AFAS would replace the M109, it quickly became apparent that the Multiple Launch Rocket System (MLRS) actually might be a better match. MLRS has a number of components similar to those planned for AFAS, but not required on the M109. However, the MLRS is not a cannon weapon and does not serve the same combat mission as the M109 and the AFAS.

e. The potential value of conducting an ECA was more evident to the combat developers, who were familiar with MANPRINT concerns, than to the participating SMEs, who were not. Several SMEs questioned the need to "look backward" and raised doubts as to whether a study of tasks performed on equipment that was due to be phased out was worthwhile. They suggested that emphasis should be given instead to human factors studies that focused on design alternatives for the new equipment.

Discussion

This initial step was neither particularly difficult nor time consuming. Nevertheless, several impediments were evident that easily could have had a detrimental effect on the study.

One was the decision to begin the ECA very early in the system design process. Many particulars regarding AFAS and how it would be equipped had not yet been established, and many of its design and doctrine concepts were continuing to change. Documentation on the system was sparse and some of what was available could not be released, particularly to a contractor. While this lack of a definitive configuration made it difficult to determine which predecessor and reference systems and components were the most parallel to those that would be adopted for AFAS, it did open the opportunity to inform equipment decisions early enough to influence the outcome. We recommend initiating an ECA as early in the concept exploration phase as possible, even if there is considerable uncertainty about system design and doctrine.

Another difficulty was adapting the procedure to a complex system. AFAS is a very complex weapon system that incorporates a considerable range of newer technologies. Establishing suitable predecessor and reference systems was eased substantially by dividing the system into its major components, such as engine-transmission and automatic fire control instrumentation, before deciding which antecedent systems should be examined. We recommend this approach when initiating an ECA for any complex weapon system.

Still another problem was establishing a common knowledge base for all participants. Although the ECA project team included M109-experienced former artillery officers, considerable time was spent learning about AFAS. Similarly, a number of participating SMEs from USAFAS were not familiar with the purpose and procedures of an ECA. While having an ECA performed by proponent school DCD personnel would avoid the need for this learning time, the participation of "outsiders" with a fresh perspective seemed valuable. We recommend the use of other than the new weapon's combat development team to conduct an ECA study. Uniformed Army, civilian military, or contractor personnel could undertake the work so long as they had some familiarity with task analysis techniques and with current manpower, personnel and training policies and practices.

Step 2. Identify Relevant MOS(s)

Identify the MOSs responsible for operating and maintaining the designated predecessor and reference system components.

Procedure

The MOSs of soldiers who operate and maintain the systems and components that were selected for study in Step 1 are identified. If it is not clear which MOSs are to be included, the service schools most knowledgeable about the existing system should be contacted. Information about relevant MOSs also can be obtained from a Qualitative and Quantitative Personnel Requirements Information (QQPRI) report if one is available.

Highlights

The MOSs to be included in the ECA study tentatively were identified at the initial two-day meeting with the AFAS combat developers. The results of this step had to be revised later, however, because of a subsequent decision to add intermediate Direct Support (DS) and General Support (GS) maintenance functions to the study and because some of the MOSs had been incorrectly identified. These problems are attributable, in part, to beginning the study before a maintenance concept for AFAS has been developed and, in part, to incomplete knowledge among the personnel at the meeting as to which MOSs are responsible for various maintenance functions on non-cannon systems.

Seven relevant operator and maintenance MOSs were identified for inclusion in the ECA during this step. When the decision to limit the study to organizational-level maintenance was reexamined several months later, four DS and GS maintenance MOSs were added. Subsequently, as the task lists for these MOSs were being developed, three further MOSs were identified that also perform relevant maintenance tasks. This brought the total number of MOSs included in the ECA to 14.

Discussion

Although this step did not seem very difficult at the time, subsequent events suggested some added attention would have prevented problems that emerged later. Based on this experience, three refinements in this step are recommended.

First, formal points of contact (POCs) should be identified at other proponent schools as early as possible. It was difficult to locate appropriate contacts at several proponent schools and, even when a POC was identified, one or more formal "tasking" requests had to be arranged before needed information, documents, and visit authorizations could be obtained. This led to substantial delays throughout the ECA study even though cooperation from the schools generally was excellent on an informal level. Partly, these problems could be attributed to having the study performed by a contractor with no "official" standing. We recommend that, for ECAs not performed directly by the new weapon's combat development team, establishing formal authorization for access to information and assistance be given a high priority at the very beginning of the study.

Second, it is important to have knowledgeable SMEs participate in identifying MOSs for the study, particularly for maintenance tasks. Combat developers for AFAS were thoroughly familiar with operator MOSs for antecedent systems, and with most of the maintenance MOSs likely to be assigned to an SPH unit. However, ECAs directed at complex new systems such as AFAS might involve a dozen or more maintenance MOSs at the DS and GS levels.

We recommend that maintenance supervisors who are experienced with all identified antecedent systems participate in designating MOSs during this step. They also could help determine what maintenance functions will be required to support the new system. These SMEs often will be available from other departments at the proponent school such as the Directorate of Training Development (DOTD) or the Weapons Department. In addition, it may be appropriate to delay the identification of relevant MOSs until meetings can be held with representatives of other proponent schools more directly involved with those antecedent systems.

And, third, the need for iterations in the lists of equipment, MOSs, and tasks to be examined during an ECA should be expected, at least for a complex weapon system. Omissions or mistakes in identifying relevant MOSs are not the only factors involved. Increasing specificity in the design of the new system as its configuration evolves also may result in the need to include additional MOSs concerned with components that are defined only after the study is underway. We recommend that enough flexibility be build into a planned ECA to accommodate expanding the study to additional MOSs if the need arises.

Step 3. Prepare Task Lists

Obtain task inventories for each MOS, if available, and prepare a task list containing all tasks performed on the predecessor and reference components(s) by that MOS.

Procedure

An existing, complete list of tasks performed by an MOS usually can be obtained from DOTD at the proponent school. If one is available, the tasks performed by the MOS on the predecessor and reference system components can be extracted to develop a task list for use in conducting an ECA. If no comprehensive task inventory is available for the MOS, the tasks that should be included on the ECA task list can be generated from the Soldier's Manual, Logistic Support Analysis Records, Technical Manuals, and other sources. It is important to insure the ECA task list for each MOS is complete.

Highlights

The development of task lists covering components parallel to those that would be employed for AFAS turned out to be much more difficult than had been anticipated. Task lists covering most of the 14 MOSs included in the study were available from the DOTD at the proponent schools. These lists turned out to be incomplete or inappropriate for use in an ECA, however, for many of both the operator and maintainer MOSs. Three major problems associated with using existing lists of soldier tasks emerged. These problems had a significant impact on the time and level of effort required.

One problem is that many MOSs are very broad and the soldier tasks covered by them are concerned with the operation or maintenance of a sizable number of weapon systems. Rather than exhaustively enumerating every task for every weapon system separately, the proponent school may instead adopt a "matrix" approach. Relatively similar tasks performed on several systems may be allocated among these systems to reduce replication. As a result, some tasks that have to be performed on the identified antecedent system may be designated as ones performed on some other system. The assistance of an SME familiar with the full range of tasks in the MOS may be required to sort through the comprehensive task list for the MOS and identify all tasks applicable to the antecedent system.

Another difficulty is that recently several proponent schools have adopted a "generic" approach for specifying tasks that fall within the responsibility of a particular MOS. Two schools that are proponents for MOSs included in this ECA study, USAOC&S, the Ordnance Center and School at Aberdeen Proving Ground and USASIGCEN, the Signal Center at Ft. Gordon, now use generic task lists. Although the trend toward generic tasks probably results in clearer descriptions of functional responsibilities and simplifies the way training is organized, they result in task designations that are far too broad to be appropriate for purposes of an ECA. For example, "Repair Transmission on a Tracked Vehicle" may encompass a dozen or more of the specific tasks that formerly were listed. If generic tasks are used as the basis for an ECA, a "washout" may result, with easier constituent tasks balancing out the more difficult constituent tasks that should be identified as high drivers.

Two substitute approaches were tried in this ECA for MOSs where generic task lists have been adopted by the proponent school. The first was to create a task list from the Maintenance Allocation Charts (MACs) provided in the applicable Technical Manuals (TMs). These tables often are incomplete, however, and they often designate tasks in a way that is inconsistent with the way work assignments are made. As a result, tasks derived from a MAC may not be familiar to the SMEs who are asked to rate the tasks. The second substitute approach was to expand the generic task lists by breaking each entry into several, more specific entries both by dividing up the task and by relating it to the particular equipment items relevant to the ECA. This appears to improve opportunities to identify high drivers but nevertheless lacks the detail represented by the type of task designations previously used.

The third problem was that, in several instances, the task list for an MOS was undergoing revision at the time of this study, and the proponent school felt neither the old, outdated version nor the new, unapproved version was appropriate for an ECA. One MOS, for example, was being split into two separate MOSs and the division of tasks between them was still in progress.

SSC-NCR recommends the use of Logistic Support Analysis Records (LSARs) and TMs in place of soldier task lists for maintenance MOSs. The use of these sources, as already noted, is difficult because of disparities in the specificity and meaningfulness of tasks derived from these different sources. Soldier tasks describe soldier performance while LSARs and TMs relate to equipment details. An ECA, although it is structured around equipment systems and components, nevertheless depends on ratings of the learning and performance difficulties associated with tasks required to operate and maintain the hardware, and not with the hardware itself. As will be described with respect to Step 10, the reliability and operability of the hardware should be considered when trying to identify deficiencies that will account for high driver tasks. However, other deficiencies such as inadequate training or poorly organized manuals, may be equally relevant as sources of performance problems.

Discussion

Despite the difficulties encountered, task lists were developed for all 14 MOSs to be examined by the study. The length of the lists ranged from as few as two tasks for one MOS to as many as almost one hundred for another. Each list was submitted to the proponent school for review. Most of the lists, including those that were created from MACs or Programs of Instruction (POIs) and lesson plans, were returned with at least a few minor corrections, deletions or additions.

The procedure for an ECA depends on reasonable accurate, up-to-date, and detailed task lists that describe functions in a way that will be understood consistently by SMEs. But these cannot always be generated without more effort than is likely to be made available for an ECA study. The trend toward adopting generic task lists may be a particular problem for future ECA studies, and the pace of revision in other task lists may make the creation of an ECA data base increasingly difficult.

Substantial delays were encountered during this step in getting the proponent school to verify the task list prior to conducting the survey of SMEs. In part, these delays reflected the school's concern over generic versus specific lists, rather than the actual content of the lists. In some instances, the turnaround time for verifying a draft task list was as long as several months.

No easy solution to the problems encountered in generating usable, performance-based task lists is apparent. The type of task list presumed for an ECA was available for the operator MOSs included in this study, but not for a majority of the maintenance MOSs. And, in almost every instance, the task lists had to be adapted to relate them to the systems or components that were specified in Step 1. Based on this experience, the following two refinements in the ECA procedure are recommended.

First, we recommend securing the participation of SMEs in the preparation of the task lists. Experts from one MOS, 13B (Cannon Crewmember), were available to help generate the task list for that MOS. As a result, this list was produced quickly and seems to be both comprehensive and precise. We recommend working directly with SMEs during the development of all task lists for an ECA, and particularly for those maintenance MOSs that have converted to the use of generic task lists or those where task lists have to be derived from LSARs or TMs.

And, second, we recommend obtaining verification of the list from the proponent school. The schools involved with this ECA did make several corrections in the task lists we had developed. Some were in response to errors caused by a lack of detailed knowledge about the equipment or the relationships among tasks. Others, however, resulted from the reassignment of the task to a different maintenance echelon, or even to another MOS. We recommend sending the draft list to the proponent school for that MOS for verification unless representatives from the school actively participated in developing the list.

Step 4. Collect Task Data

Survey SMEs for their ratings and compile available data for every task on each task list concerning:

- Percent Performing
- Task Learning Difficulty
- Task Performance Difficulty
- Frequency Rate
- Decay Rate
- Time-to-Train.

Procedure

Although the opinions of SMEs usually will be the primary source of data for an ECA, considerable amounts of other data on task dimensions may be available. These include information developed by the Army Occupational Survey Program, the Army Operational Test and Evaluation Agency, the Army Research Institute, the Army Human Engineering Laboratory, and various studies, analyses and publications prepared by the proponent schools. An effort should be made to compile this information as a supplement to or, in some instances, a replacement for data collected using an SME survey instrument.

The SME survey instrument consists of a six-column rating form. Each task appearing on the task list for that MOS is rated on a scale of 1 to 4 along each of the six dimensions, or criteria, used to differentiate problem tasks from non-problem tasks. Descriptions of the dimension and the anchors for each scale value are provided to the SMEs to improve the consistency of their ratings. The six scales are:

a. Percent Performing: What proportion of the relevant MOS and skill level performs this task?

   1 = 1-25%
   2 = 26-50%
   3 = 51-75%
   4 = 76-100%

b. Task Learning Difficulty: How difficult is it for the average soldier, in the appropriate MOS and of the appropriate skill level, to learn this task?

   1 = Not difficult
   2 = Somewhat difficult
   3 = Moderately difficult
   4 = Very difficult

c. Task Performance Difficulty: How difficult is it, for the average soldier, of the proper skill level and in the proper MOS, to perform this task? Consider both cognitive and physical difficulty.

   1 = Not difficult
   2 = Somewhat difficult
   3 = Moderately difficult
   4 = Very difficult

d. Frequency Rate: On the average, how often is this task performed by the average soldier of the proper skill level and in the proper MOS?

   1 = Seldom (Annually)
   2 = Occasionally (Semi-annually or quarterly)
   3 = Often (Monthly)
   4 = Frequently (Daily or weekly)

e. Decay Rate: Given this task, how much proficiency is lost by the average soldier from the end of his formal training until he first performs the task in the field? (Assume that the task is performed within a reasonable period of time after training and is performed by an average soldier of the proper skill level and in the proper MOS.)

1 = Low
2 = Moderately low
3 = Moderately high
4 = High

f. Time-to-Train: How much time is required to train the average soldier, of the proper skill level and in the proper MOS, to perform this task to standard?

1 = Less than 3 hours
2 = 3 hours or more but less than 6 hours
3 = 6 hours or more but less than 9 hours
4 = 9 hours or more

Highlights

The SSC-NCR procedure for this step gives considerable emphasis to other sources of data that may be available on the dimensions used to establish whether any particular task is a high driver. Each time a task list was sent to a proponent school for review, the school was asked to identify any additional information it was aware of that dealt with these tasks. None of the five proponent schools cooperating in the study were able to identify any pertinent data already compiled. Either such information does not generally exist or the schools are not aware of it.

This issue aside, the major difficulty encountered in accomplishing this step was in locating a reasonable number of SMEs to participate in the survey for several of the MOSs. There were two reasons for this. First, a number of the maintenance MOSs are very thin and only small numbers of SMEs are likely to be present in any one location, even including the proponent school. For MOS 45D (Field Artillery Turret Mechanic), for example, only three SMEs were available on one trip to Aberdeen Proving Ground, only three others on a second trip two months later, and only two more at Fort Sill. Although the numbers of personnel in these low density MOSs are higher at operating unit locations, not that many will qualify as SMEs based on their skill level and experience, and the cost of visiting sizable numbers of field sites was beyond the scope of this study.

The second reason, which may be unique to but a few MOSs, results from combining MOSs at the higher skill levels. Both MOS 63G (Fuel and Electrical System Repairer) and MOS 63W (Wheel Vehicle Repairer) merge into MOS 63H (Track Vehicle Repairer) at skill level 3. For purposes of an ECA, a 63G20 cannot be presumed to be an SME. But, most 63H30s and 63H40s who supervise 63Gs are not themselves very knowledgeable about 63G tasks. Only one task could be rated by more than five of the 14 MOS 63H SMEs participating in the 63G survey. Over one-third of the 60 MOS 63G tasks could not be rated by any of the 63H SMEs.

The actual administration of the ECA survey instruments went smoothly. The SMEs generally had no problems with the directions, although some required a further explanation of what was meant by "Decay Rate". Usually, the entire session, including directions, lasted under one hour. The survey for one MOS, 29S, was administered by mail because the proponent school, USASIGCEN, advised us that there were too few SMEs holding this MOS who would be available at any one location to make a visit worthwhile.

Finally, one issue that did not arise during the conduct of this step but which may have influenced the results from it is the skill level of the soldier performing the task. Most tasks are allocated among skill level not by the inherent difficulty of the task but, rather, according to the assignment of the soldier performing the task. A task designated for skill level 4 might be easy to learn for someone with considerable related experience, but difficult to learn for someone with fewer years of service. Similarly, that same task may be performed frequently by a soldier at skill level 4, but rarely if ever by most other soldiers in that MOS. How the designated skill level for a task is taken into account by an SME rating that task might well influence the survey results.

Discussion

As will be described in considering Step 7 of the ECA procedure, "Identifying High Drivers", it appears that the dimensions along which tasks are rated during the survey may be in need of refinement or modification. Aside from suggestions regarding this issue, several other recommendations that may improve this step are appropriate.

One recommendation concerns the need to assemble groups of SMEs for administering the survey instruments. As already noted, soldiers holding some MOSs are widely scattered, usually among operating units. Compiling ratings from the minimum of at least 10 SMEs for each MOS as recommended by SSC-NCR turned out to be both difficult and expensive. Obtaining ratings by mail neither is very efficient nor does it assure consistency in how the raters respond to the survey instrument. Our recommendation is to collect the ECA ratings in person whenever possible, but to increase the payoff from the investment required by surveying most, if not all, of the tasks performed by that MOS. The increment in costs would be small relative to resurveying the same MOS on behalf of some other weapon system at some future time.

Another concerns the availability of additional data. No additional data could be identified by any of the five proponent schools that would contribute to the development of ECA scores. Independently, a Computerized Occupational Data Analysis Program (CODAP) report was obtained for MOS 13B. However, this information could not be used for the ECA because the CODAP tasks almost exclusively focused on garrison rather than battlefield tasks and thus did not match those in the Soldier's Manual. Further, they were scaled on task criticality rather than task difficulty. We recommend that the SME survey be emphasized as the primary source of ECA data with other sources, such as Sample Data Collection (SDC) studies, used if they are available.

One other recommendation concerns the number of SMEs participating in the survey. The SSC-NCR procedure suggests 10 SMEs as the minimum number required. As described above, this number may be very difficult to obtain. In order to examine this issue, a correlation coefficient was calculated comparing the ECA task scores from half of the 20 SMEs participating in the MOS 13B survey with those from the other half. As reported in the Appendix, the obtained value was $r = .48$. This is only a crude measure of reliability for several reasons, particularly because of the way an ECA score is calculated. Although this outcome is not remarkably high as a value for interjudge reliability, it probably is sufficient to establish which tasks are high drivers. This is because high driver tasks fall at the extreme end of the ECA score distribution where the preciseness of the score is not critical. We recommend some future ECA study be planned to allow a more extensive examination of ECA score reliabilities and the minimum number of participating SMEs required.

Step 5. Assign Values to Data

Assign values to data other than SME survey results on a scale of 1 to 4, and combine the results with the survey data.

Procedure

Data from sources other than SME surveys are transposed to correspond to the 1 to 4 scale applied to the survey data. This may require scaling raw data, converting the data so they match the scale values used for the surveys, or adjusting the scale used to a four-point scale. Data for each of the six dimensions are transposed separately. This information is then merged with the corresponding survey data by calculating the average SME rating for that dimension of each task and weighting each source of information, including the survey results, equally. The outcome will be a single composite score, ranging from 1 to 4, representing each dimension of each task.

Highlights

Assigning values to supplemental data was not required because no supplemental data were obtained. The ECA survey results were entered into a computer spreadsheet program to calculate an average value for each dimension of each task. Care had to be taken during these calculations to correct for the unequal numbers of SMEs rating each task.

Discussion

Based on the experience of this study, encompassing 14 MOSs from five proponent schools, there is a general lack of usable supplemental data, suggesting this step may not be required very often. In order to simplify the procedure, we recommend restructuring Steps 4, 5, 6 and 7. Step 4 should consist of preparing and administering the survey instrument. Step 5 should consist of assembling and assigning scale values to any available supplemental data. Step 6 should consist of calculating ECA scores, including merging the results from Step 5, as well as identifying the high drivers. What is now Step 7 could then be omitted.

Step 6. Calculate ECA Scores

Compute an ECA score for each task by multiplying together the composite scores for each of the dimensions of the task.

Procedure

The composite scores in the form of scale values between 1 and 4 for each dimension of each task are multiplied together to obtain a total ECA score for each task. In other words, the ECA task score is equal to:

(Percent Performing) x (Task Learning Difficulty) x
(Task Performance Difficulty) x (Frequency Rate) x
(Decay Rate) x (Time-to-Train)

Information on Percent Performing will not be available if the predecessor or reference system has not been fielded for a sufficiently long time to permit reliable estimates. When this occurs, the total ECA score will be based on only five dimensions.

Highlights

The computer spreadsheet program used to calculate the average score on each dimension for each task also was used to calculate an ECA score for each task. No difficulties appeared in this step.

Discussion

We were not able, within the scope of this study, to determine the efficacy of using the product of the average dimension scores to calculate an overall ECA task score as opposed to some other method, such as using the sums. The mathematical consequences of using products instead of sums are to greatly magnify the effects of higher scale values so the apparent differences between scores at the upper end are more pronounced, and to make certain that tasks with particularly low ratings on some dimensions never will be identified as high drivers.

Three examples can help clarify this point:

	Dimension Averages						Product	Sum
A.	2	2	2	3	3	3	216	15
B.	2	2	2	2	3	3	144	14
C.	1	1	1	4	4	4	64	15

Example A illustrates the array of dimension scores needed to determine that a task is a high driver because the product of the averages is 216 or higher. Example B shows the impact of just a slightly lower average in one dimension; the product is considerable smaller while the sum is only slightly smaller. Example C shows how any task with several low scores will be far from a high driver even when the array also contains several high average subscores.

As reported in the Appendix, we did calculate the correlation between using products and using sums on the ECA task scores for MOS 13B. The result, a very high r = .92, suggests that either method yields very similar outcomes, even for the restricted range of scores for this MOS which produced no ECA task scores above 100.

We recommend conducting a more extensive study of how ECA task scores are calculated and then combined. Two issues should be considered in designing that study, both of which will be discussed in more detail in the description of Step 7. First, tasks that are identified as high drivers or nearly high drivers based on their ECA scores do not coincide precisely with which tasks the proponent schools believe are high drivers using other evidence. Although perfect agreement need not be expected, the

ECA procedure for determining which tasks are high drivers should function as a shorthand way of getting to the same conclusion. Second, the product method of calculating an overall task score is more dependent on an assumption of independent weighting among dimension scores than the sum method. To the extent the subscores are intercorrelated, the product method may exaggerate these relationships.

Step 7. Identify "High Drivers"

Evaluate each calculated ECA score to identify any that are "high drivers", those with scores of 216 or more (if subscores on 6 dimensions were used) or 90 or more (if subscores on only 5 dimensions were used).

Procedure

The ECA scores calculated in Step 6 are inspected to identify those that are 216 or greater using six dimensions, or 90 or greater using five dimensions. These are problem tasks, those with high enough composite averages within each dimension to suggest the task is a "high driver" in its use of manpower, personnel and training resources. These tentative high driver tasks are then reviewed by SMEs to verify that they are resource intensive. At the same time, tasks with ECA scores approaching the high driver cut-off value should be reviewed to determine if any are perceived as particularly resource intensive.

Highlights

As described in Application of the Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS), a total of 11 high drivers were identified from among the more than 400 tasks surveyed. Eight of these were from a single MOS, 31V (Unit Level Communications Maintainer), and the remainder were tasks from two MOSs performing maintenance on the Bradley/MLRS chassis. No high drivers were identified for any of the three operator MOSs studied, although these represented about one-third of all of the tasks surveyed.

After the identification of high drivers was complete, a tabulation of all surveyed tasks for that MOS together with each task's total ECA score was sent to the proponent school for review. The school was asked to confirm the identification of tasks scoring 216 or more, the SSC-NCR recommended cut-off, as high drivers and to consider, particularly, any tasks that received a score within 20 percent of the cut-off, or between 173 and 215, to see whether any additional tasks should be designated high drivers.

As a result of these reviews, one task, an MOS 63G task rated by only one 63H SME that received an ECA score of 216.00, was deleted by USAOC&S. An MOS 63H task that received a score of only 155.82 was identified by the school as a high driver. One MOS 31V task scoring 216.00 was deleted by USASIGCEN as fundamentally a supervisory task, but another 31V task that was not surveyed because it was not a Soldier's Manual task and had not been added by the school when it reviewed the task list, was identified as a high driver. The review process often took considerably longer than expected. One reason reported to us was reluctance on the part of some school staff to acknowledge that their MOSs had any high driver tasks.

More than half of the high drivers identified by this study were electrical or electronic troubleshooting tasks. Although this outcome is not necessarily surprising, it appears that these tasks may reflect a difficulty that is widespread within the Army. The problem is one that may become increasingly severe as new weapon systems employing more extensive and more sophisticated automation are fielded. One of these tasks, performed by MOS 63T, also was identified as a high driver during an earlier survey of selected generic MOS 63H tasks conducted by USAOC&S.

Discussion

The identification of a high driver depends on the average ratings produced by SMEs on up to six dimensions. Whether these dimensions are the most appropriate ones is therefore an important question. One minor issue is the breadth of an MOS. Obviously, when soldiers are responsible for a large number of tasks, the percent performing that task and the frequency with which any one soldier performs the task is reduced. Generally, scores on these dimensions were low for broad MOSs, such as 13B, but high for MOSs that are responsible for only a small range of tasks, such as 31V. As noted under Step 6, even one or two low subscores may preclude a task score of 216 or more when the product method is used. Another minor issue is that neither task performance time nor task performance effort is addressed although we suspect that these variables may account for a significant share of what makes some tasks resource intensive.

By far the most important issue is what these dimensions measure. As part of our statistical analysis of some of this study's ECA data, a set of intercorrelations was computed on the subscores obtained for two MOSs, 13B and 63H. The results, reported in detail in the Appendix, were rather surprising. While some dimensions have extremely high correlations with others, the correlation between some of the dimensions is both sizable and negative. These findings are summarized in Table 1.

Table 1

Intercorrelations of ECA Subscores

Note: The top score in each data cell is from MOS 13B (20 SMEs, 98 tasks) and the bottom score is from MOS 63H (14 SMEs, 60 tasks).

	TPD	FR	TLD	TT	DR	ECA
PP	-.71	.79	-.64	-.61	-.06	-.05
	-.64	.95	-.59	-.49	-.15	.22
TPD		-.66	.90	.70	.08	.61
		-.59	.96	.86	.75	.44
FR			-.62	-.42	-.32	.02
			-.53	-.44	-.09	.29
TLD				.60	.06	.61
				.87	.76	.49
TT					.06	.61
					.72	.54
DR						.15
						.75

PP = Percent Performing
TPD = Task Perf. Difficulty
FR = Frequency Rate
TLD = Task Learn. Difficulty
TT = Time-to-Train
DR = Decay Rate
ECA = Total ECA Score for the Task

The intercorrelations obtained suggest the dimensions rated for an ECA are divided into three distinct factors or families. The first is Percent Performing and Frequency Rate. The correlations between these two are highly positive, but they are highly negative with most other dimensions. The second is Task Performance Difficulty, Task Learning Difficulty, and Time-to-Train. Again, the intercorrelation among these dimensions is highly positive, but highly negative between any dimensions in this family and the dimensions in the first family. The results for Decay Rate are inconsistent. The intercorrelations were generally low between Decay Rate and the other dimensions for MOS 13B, but higher for MOS 63H. No one dimension appears to account for an overwhelming proportion of the total ECA score for a task, particularly considering that the subscore is part of the ECA score and thus some autocorrelation is inherent.

Based on these preliminary results, we recommend implementing a systematic study of the dimensions included in an ECA task score, how they correspond to expert judgments of which tasks are resource intensive, and how the subscores are combined to achieve a total ECA score. The use of multiple measures as recommended by SSC-NCR, even if they overlap, seems desirable both for their diagnostic value in determining why a task is a high driver and for their potential contribution to the objectivity of SME ratings. However, subscores that overlap to the extent they did in this analysis add little to the composite score. Also, substantial negative correlations, as we obtained, are likely to produce a considerable distortion in the outcomes of an ECA. If such a study is undertaken, it also should examine the anchors used for the scale values, whether ratings are adequately distributed over the scale, the desirability of adding scales for performance time and effort, and the potential gain of looking at deviations from the MOS mean rather than an absolute cut-off as the criterion for a high driver.

Step 8. Conduct Task Analyses

> Perform a task analysis on each high driver that specifies its individual procedural steps, the tools and test equipment required, the conditions under which the task is performed, and the standard(s) that must be met.

Procedure

A task analysis is required for each high driver. An already completed task analysis often will be available from DOTD at the proponent school. If one is not available, the task analysis must be developed. In most cases, sufficient information will be available from Field and Technical Manuals or other publications to prepare a task analysis sufficient for the purposes of an ECA.

Highlights

Detailed, onsite task analysis were performed on every high driver task identified in this study. Although SSC-NCR suggests already existing task analyses or task analyses developed solely from TMs and other documentation may be used, direct observations of task performance were made instead to make certain all aspects of the task that might cause it to be resource intensive were thoroughly understood. Overall, one to two days of preparation time was required for the average high driver task to assemble relevant documentation and prepare a preliminary list of procedural steps. The observation of a task rarely required more than a half day.

Of the 11 high drivers examined, not one included any steps or groups of steps that were inherently difficult. However, the relationships between task performance and other factors such as the quality of supporting TMs, the aptitudes required for entry to that MOS, and the content of the training provided turned out to be very productive sources for determining why particular tasks were high drivers.

Discussion

Our experience from this study suggests an onsite task analysis that includes direct observations of task performance should be considered an integral step in the ECA process. The only already existing task analyses that could be provided to us by the proponent schools consisted of Form 550s, Task Analysis Worksheets, and these were available for only one MOS. Form 550s usually are very brief and general and, we suspect, may be a reflection of the high driver problem rather than a source of useful clues to its solution. Onsite visits, on the other hand, not only yielded a detailed step-by-step inventory of the procedure, but also afforded worthwhile opportunities to examine the equipment first hand, discuss student qualifications and learning difficulties with instructors, inspect job aids and special tools or equipment used in performing the task, and learn about any planned changes in manuals or hardware from school personnel.

We recommend performing an onsite task analysis of all high driver tasks as a highly desirable step in the ECA procedure, even if the observations are made in a school environment. While the task analysis itself may not contribute any definitive information on why the task is a high driver, it does facilitate the identification of manpower, personnel, and training (MPT) or other deficiencies that may make the task resource intensive. The task analysis visit should include an assessment of relevant MPT considerations by experienced school personnel and an examination of task related equipment, tools and job aids, and supporting manuals. The task analysis should be sufficiently detailed to permit pinpointing specific steps in performing the task that may be beyond a student's aptitude or training, inconsistent with the procedures specified in the TM, or particularly demanding in the time, physical attributes, or degree of skill required.

Step 9. Conduct Learning Analysis

Identify the knowledge, skills and abilities (KSAs) needed to accomplish each high driver task, and determine the manpower, personnel, and training (MPT) requirements for performing each step of the high driver task.

Procedure

The task analysis information generated in Step 8 is thoroughly reviewed to identify the knowledge, skills and abilities (KSAs) a soldier must have to perform each high driver task to specified standards under expected conditions. These KSAs are then examined to determine the MPT requirements for each step of the high driver task, such as the number of personnel, the mental and physical attributes, and the scope of training required. An already completed learning analysis may be available from the proponent school DOTD.

Highlights

The project's approach to this step differed somewhat from the one laid out by SSC-NCR, primarily because of the complexities of examining troubleshooting tasks. Also, we elected to change the title of this step to "Conduct Performance Analysis" to make it more encompassing. The substitute procedure adopted by the project consisted of the following steps:

a. Obtain a completed learning analysis from the proponent school DOTD, if available, and integrate the findings with those of the ECA study.

b. Assemble information on the relevant knowledge, skills and abilities (KSAs) specified or surmised as qualifications for entrance into the MOS and on the content of Advanced Individual Training (AIT) common subjects that are taught to soldiers in this MOS as verified by instructors at the teaching school.

c. Identify the individual task steps, if any, that are responsible for the task being a high driver. Identify the KSAs required for successful performance of each of these steps and compare them with the KSAs presumed present based on the soldier's MOS. Note any discrepancies for attention in Step 10 of the ECA, "Identify Deficiencies".

d. Identify the common steps comprising task performance. For this purpose, a "common" step is one that is performed similarly across various equipments operated or maintained by that MOS, such as "change radio frequency" or "reconnect hose clamp". Generally, a soldier proficient at a step with several models of field radios or several models of vehicles can be expected to have little or no difficulty performing it on a new radio or vehicle. This analysis should be performed for the task as a whole whether or not an individual step has been identified as responsible for the task being a high driver.

e. Identify the KSAs required for successful performance of each of these common steps, and thus for the task as a whole, and compare them with the KSAs presumed present based on the soldier's MOS. Note any discrepancies for attention in Step 10 of the ECA, "Identify Deficiencies".

The first two substeps, as already noted, were accomplished as part of the onsite task analysis visits. The third substep produced no relevant information in that none of the task analyses revealed any individual steps or groups of steps that appeared to cause unusual difficulty. Extracting common steps from the task analyses for the fourth substep was a useful approach for identifying the KSAs required to perform the task in the fifth substep. Checking back with the school instructors who were present during the task analysis allowed confirmation of the KSAs we identified.

Discussion

Deriving common steps from the task analyses simplified the identification of pertinent KSAs. This approach also permitted comparing high driver tasks within an MOS, and would allow similar comparisons among MOSs responsible for similar tasks if the lists of common steps were retained for a high driver data base. Common steps also help pinpoint deficiencies that are not necessarily evident from the task analysis itself by aggregating steps in a way that facilitates establishing KSA requirements for the task as a whole. We recommend retitling this step in the ECA "Conduct Performance Analysis" to better reflect its use to examine manpower and personnel, as well as training, issues.

Step 10. Identify Deficiencies

Compare the KSAs required to perform each high driver task with the KSAs required by the MOS to identify any manpower, personnel or training deficiencies.

Procedure

Examine data such as unit manpower authorizations, personnel qualifications for the MOS, and the training given with respect to the results of the learning analysis in Step 9 to identify any manpower, personnel or training deficiencies such as too few authorized personnel, personnel in the MOS who do not have the qualifications required to perform this task, or the omission of some key knowledge or skill from the training program.

Highlights

We decided to broaden this step in order to examine several additional sources of deficiency beyond manpower, personnel and training. These additional areas were: equipment design, task procedures, tools-manuals-job aids, and performance conditions. The reasons for expanding the analysis beyond MPT considerations included our recognition that there often was considerable interaction among these factors and that, at least for some of the high drivers identified in this study, the most direct, least expensive solution did not involve manpower, personnel or training. Similarly, the "lessons learned" logic suggested that deficiencies in existing hardware or procedures could be avoided in future systems if recognized in time to affect design or doctrine decisions.

A couple of examples may help illustrate the value of considering many aspects of the problem task concurrently. For MOS 63T, the electrical troubleshooting task identified as the one high driver for this MOS appears to depend on aptitudes other than the mechanical aptitude used as the basis for qualifying personnel for this MOS. We therefore targeted a personnel issue as the likely source of the problem, one that could be solved by changing the aptitude requirements or by reassigning the task to a better qualified MOS. We also noted that a planned changed in the troubleshooting procedures authorized for this task would place a still heavier burden on the repairer's analytic abilities, and recommended this change not be implemented. For MOS 31V, the analysis revealed that, because of defects and deficiencies in applicable TMs, the repairer was being called upon for a level of aptitude well beyond that required to qualify for the MOS. While the deficiency could be overcome by more selective entry to the MOS, or by considerably increasing the amount of training, revising the TMs would likely reduce not only the aptitude requirement but the length of the present training program as well.

Discussion

We are convinced that it is important to consider at least seven factors concurrently when diagnosing deficiencies that result in a high driver: manpower, personnel, training, equipment design, task procedures, tools-manuals-job aids, and performance conditions. Our experience in this study also suggests that the analysis should avoid focusing on a single, or most prominent, deficiency. Instead, all possible sources of the problem should be examined so that a variety of alternative or complementary solutions can be suggested. For instance, it was learned that a new series of radios, SINCGARS, will be fielded in the near future to replace the current 12-series equipment. The study's observations of the difficulties MOS 31V repairers experience because of poor TMs suggests the need to take particular care with the SINCGARS TMs if repair tasks on this equipment also will be the responsibility of 31Vs.

During this step, possible deficiencies were verified against the pattern of ECA subscores for the task. Possible deficiencies that were inconsistent with the pattern of subscores were excluded. If, as proposed earlier, the dimensions rated to establish a task as a high driver are revised, the utility of assessing the validity of deficiencies using the subscore results may contribute even further to this step. The subscores themselves also may suggest other possible sources of observed deficiencies.

Based on this experience, we recommend expanding the identification of possible deficiencies to encompass equipment design, task procedures, tools-manuals-job aids, and performance conditions as well as manpower, personnel and training as contributing causes. We also recommend trying to identify as many sources of deficiency as possible during this step, and then using the pattern of ECA subscores that established the task as a high driver to verify these deficiencies and to identify others.

Step 11. Suggest Solutions

Identify all possible manpower, personnel and training solutions that will overcome the deficiency and eliminate the high driver status of the task.

Procedure

During this step, changes in manpower, personnel and training that will resolve the identified deficiencies are considered. These include, for example, increasing the authorized manpower in an MOS, modifying the qualifications of accessions into an MOS, or improving the current training program with the introduction of new training devices. Each suggested change must be evaluated with respect to its Army-wide implications. Reasonable manpower, personnel or training solutions can be implemented by the proponent school. If there is no reasonable MPT solution, some materiel change may be proposed as a solution.

Highlights

An effort was made in this step to propose as many solutions, and to cover as broad a range of options, as possible. There were two primary reasons for suggesting multiple solutions. First, we could not always be aware of constraints, such as manpower availability, or developments, such as plans to field new test equipment, that might have a substantial bearing on which remedies would be feasible. And, second, we could have no way of knowledgeably estimating either the costs or consequences of adopting any one solution or combination of several of them.

Another deviation from the SSC-NCR procedure was to include equipment design solutions, when appropriate, among the proposed remedies. Partly, these solutions were encouraged by the timing of this study because neither the AFAS design nor its doctrine was firmly established. Had we identified a major equipment-related problem, it presumably would be possible to eliminate it from AFAS. Another reason was to call attention to problems that might detract from the operability or maintainability of other future weapon systems, even those not yet under development. Built-in, or programmable, test equipment (BITE) may be a necessary job aid for any troubleshooting task, for instance, given the apparent shortfall of recruits who have sufficient analytic ability to learn and then correctly perform diagnostic functions.

We did not attempt to prepare Target Audience Descriptions, as recommended by SSC-NCR, for three reasons. First, only a small or modest proportion of all of the tasks falling within the responsibilities of an existing MOS were included in the study. These particular tasks may or may not be representative of the remaining tasks assigned to that MOS. Second, we elected to expand the analysis of deficiencies and solutions to include more than manpower, personnel and training. For almost all the high drivers identified in this study, non-MPT issues seemed the most salient. And, third, it appeared too early in the system development cycle for AFAS to presume which MOSs would be assigned responsibility for what functions, or even what functions would be required for the new system.

Discussion

It appeared easier to accomplish this step concurrently with Step 10, "Identify Deficiencies", in that solutions to the various problems uncovered could only be presented in a general way, and not in the form of detailed plans. We recommend merging these two steps so descriptions of the deficiencies do not have to be repeated when solutions are presented. We also recommend identifying as many potential solutions as possible, even if not all are likely to be implemented. They may serve a useful purpose later when other changes relating to the same area are being considered. Finally, we recommend expanding the search for possible solutions to include equipment design, task procedures, tools-manuals-job aids, and performance conditions. Changes in these areas may be easier to bring about than in manpower, personnel or training, or yield a considerably less expensive or more elegant solution to a problem that causes a task to be a high driver.

Step 12. Prepare a Report

Prepare a report to document and disseminate ECA study findings. The report should support system development requirements and also serve secondary needs when manpower, personnel and training issues are considered.

Procedure

This step is intended to document the ECA study. At a minimum, the report should include the following information:

a. summary;
b. study scope;
c. sources of task criteria data;
d. complete task lists, by MOS, with ECA scores and subscores for each task;
e. "high drivers" identified, by MOS;
f. MPT constraints identified;
g. MPT data examined;
h. target audience descriptions; and
i. identified solutions to deficiencies.

Highlights

This study's findings are described in Application of Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS). Preparing the report was not particularly difficult. However, the report was difficult to organize because of the number of MOSs involved. The results of each step had to include the results for each MOS. Also, as already noted, the analyses went beyond the manpower, personnel and training issues emphasized in the SSC-NCR outline to include equipment design, task procedures, tools-manuals-job aids, and performance conditions, and the preparation of Target Audience Descriptions was eliminated.

Discussion

When, as in this study, several MOSs are being examined concurrently because the ECA is being performed on a complex weapon system, the report of results can be confusing if it attempts to follow the sequence of steps in the ECA procedure. We recommend that aside from an introduction that describes the new system, presents the scope of the study, specifies the predecessor and reference systems and components selected, and identifies the MOSs surveyed, all of the findings should be grouped by MOS. Each section should present the task list for the MOS and how it was derived, indicate the subscores and total

ECA score for each task, and present the outcome of the analysis of any high driver or group of high drivers, the performance analysis, the deficiency analysis, and the suggested solutions for that task or group of tasks. Then, a final conclusion section can summarize the results and recommendations across MOSs.

CONCLUSIONS

This extensive ECA study was undertaken primarily to provide information of use to AFAS combat developers by identifying and analyzing tasks that have been MPT resource intensive in similar, already fielded systems. The study examined more than 400 tasks performed by personnel in 14 MOSs, and identified 11 of these tasks as high drivers. A more detailed investigation of these 11 high drivers yielded a variety of possible causes for each, and a number of potential solutions that could be achieved by changes in manpower, personnel, training, equipment design, task procedures, tools-manuals-job aids, or performance conditions.

A secondary purpose of this study was to conduct a large-scale tryout of the ECA approach to determine whether or not the procedure could be carried out successfully by a contractor, whether or not the procedure was appropriately applied to a complex crew-served weapon system, and whether or not the procedure could be undertaken at a very early stage of the material acquisition cycle.

In the earlier sections of this report, we have summarized our experiences in applying ECA in support of the design for a major weapon system and presented our recommendations regarding possible refinements to specific steps in the ECA procedure based on this experience. In the remainder of this section we discuss various, more general issues that we believe should be considered when future ECA studies are planned.

Suitability Considerations

The decision to establish an ECA as a requirement for AFAS was made very early in the system development process for a very complex weapon. These factors resulted in a number of problems, particularly during the early steps in the ECA procedure. One of these was the uncertainty surrounding the desired scope of the study, particularly the extent to which echelons of maintenance other than the unit or organizational level should be included. The primary emphasis of the USAFAS combat development team appeared to center on AFAS combat operations within a presumed 96-hour battle scenario. The extent to which any DS-GS maintenance would be feasible under these conditions is problematic. However, our own assessment of how combat maintenance might be provided, as reported in Application of Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS), suggests that a mobile maintenance contact team possibly staffed by intermediate-level maintenance personnel is a promising possibility. Nevertheless, at the time, the combat developers suggested limiting the study to operator and unit maintenance personnel, and to exclude both supply and higher echelon maintenance MOSs. This decision was reexamined well after the study was underway, and a number of intermediate maintenance MOSs were then added to the study.

The consequences of adding a sizable number of MOSs nearly midway through the study affected the efficient use of study resources and our ability to complete all of the work within the planned timeframe. We recommend that the scope of an ECA study should be thoroughly thought through beforehand, both with respect to the range of antecedent equipment components to be covered and the extent to which maintenance and support functions will be considered. Even then, our experience from this study suggests that equipment items or MOSs may have to be added, and that this eventuality should be planned for. As examples, no maintenance tasks on the position determining system originally were included but were added later. MOS 39L was split into MOSs 39L and 39Y while the study was in process and the division of tasks between these MOSs was not certain. Some tasks identified as the responsibility of MOS 29E turned out to be the responsibility of MOS 29S.

The technological complexity of a crew-served weapon system such as AFAS also produced some difficulties. Because this study began very early in the system life-cycle, many of the details of the new howitzer were not yet fixed. Generally, the combat developers selected equipment components as the most appropriate antecedents primarily because they were the most advanced items now in the Army's inventory. AFAS was likely to have a different chassis than MLRS, substantially different communications equipment than any in use, and certainly a much different cannon. The pace of advances in technology may be so rapid as to make references to systems already in inventory unusable. When this study was first planned, we suggested that it may be desirable to explore very different weapon systems as antecedents, such as the navigational and fire control instrumentation aboard a helicopter or the projectile loading equipment used on Navy ships. While the resulting match in hardware may have been greater, however, the utility of the information generated would have been less because that equipment would be operated and maintained by personnel with totally different qualifications and service experiences. In retrospect, it is important to recognize that very convincing rationales would be required to create any new MOSs for a new weapon. Therefore, an ECA study should be designed to stick as closely as possible to systems with similar missions even if their hardware components are not as similar as might be found elsewhere.

Beginning an ECA very early during the system design process, on the other hand, appears to make the results more useful in that fundamental equipment design, operator staffing, and maintenance concept decisions can be influenced. We are convinced that the advantages of starting early more than outweigh the disadvantages, and that the lack of certainty in equipment design should not be a reason to decide that an ECA is inappropriate. It may be useful to view an ECA as an iterative effort continuing over the full length of the system design process rather than as an investigation that will be scheduled at some optimum point in the weapon development cycle. MOSs and tasks can be examined when appropriate to support decisions about how the new system will be equipped and staffed. This will help insure the predecessor and reference components selected for the study are as close as possible to those being proposed for the new system, and help keep the findings in step with ever changing manpower, personnel and training conditions.

Staffing Considerations

This ECA study was performed largely by contractor rather than by Army personnel as assumed by SSC-NCR. Although the use of a contractor did not seem to generate any entirely new problems, it did appear to magnify ones likely to be present no matter who performs the study.

Access to experiential information was one concern recognized in advance. The Field Artillery branch is not unique in its long tradition of policies, practices and preferences that are not particularly explicit. Tapping this reservoir to clarify system planning documents and other sources of information is essential for an ECA or any other study concerned with MTP issues. For this reason, two former artillery officers who both had considerable M109 experience were included on the project staff. They contributed substantially to giving the remainder of the staff needed perspective. The staff also included an individual with considerable experience in ordnance maintenance training and one with an extensive background in military electronics, areas that were emphasized in examining maintenance functions.

Adequate access to both tactical and technical knowledge seemed to be very helpful in the conduct of this ECA and we recommend including persons who have these kinds of backgrounds on an ECA project staff, whether the study is performed by an Army component or by an outside contractor. Even staff with these qualifications may not be sufficient, however. As we pointed out earlier when describing the difficulties encountered in specifying antecedent hardware and identifying pertinent MOSs, arranging the participation of SMEs from proponent schools is essential, particularly in the early stages of an ECA.

Another problem also partly related to having the work performed by a contractor was the sometimes lengthy process of establishing tasking authorization when source documents, school reviews, or onsite demonstrations were required. Even after the needed authorization had been arranged, delays of up to six months occurred in obtaining the requested information or feedback. Efforts by USAFAS combat developers and ARI personnel to speed response times were not uniformly successful. We are convinced that MANPRINT efforts will continue to experience these interorganizational delays, no matter who performs the work, unless a more effective approach to securing the formal cooperation needed from proponent schools and other units is devised. Even with this help, we are convinced that sufficiently large and comprehensive ECA studies should be planned to minimize any downtime that results from an unexpected delay. ECAs on several systems could be planned, contracted and funded concurrently, lessening the likelihood that delays on one system will affect the overall schedule of the project. By massing the work to be accomplished, the work can be averaged out and project resources can be used more efficiently.

Procedural Considerations

A number of recommendations were presented throughout this report on desirable refinements in the ECA procedure. Many have been incorporated into the revised description of the steps presented in Alternate Procedural Guide for Early Comparability Analysis (ECA). Beyond these, the problem that deserves the most immediate attention and further investigation is the array of task dimensions that are rated, and the way these values are then combined to produce a total ECA score. The preliminary statistical results summarized earlier and presented in more detail in the Appendix point to some possibly significant methodological issues. These include:

- whether the ECA survey addresses the appropriate task dimensions,
- whether the results correspond to subjective judgments as to which tasks are high drivers,
- whether the scale anchors that are used distribute ratings satisfactorily,
- whether the pattern of subscore intercorrelations obtained in this study support the continued use of these six scales,
- whether the use of products rather than sums to calculate a composite score is beneficial, and
- how many SME raters are required to produce reliable survey results.

Another procedural consideration that we had intended to explore was the level of effort and amount of elapsed time required for each step in the ECA procedure. The SSC-NCR guidelines contain such estimates and we had planned to verify these during this study. The substantial delays that were encountered due both to the additions to the study's scope and to the difficulties encountered in making administrative arrangements with respect to several MOSs made our findings too variable to be useful. However, this issue should be considered as part of a future ECA study. Incidentally, our own experience suggests that the number of tasks surveyed and the number of high drivers identified and analyzed are less significant determinants of the resources needed than the number of proponent schools involved, the availability of TMs and other documents, and the opportunity to administer the ECA survey to a sufficient number of SMEs in a single location.

Finally, we observed numerous instances of unfavorable attitudes toward the ECA approach throughout the study. Generally, these were expressed by line operator and maintenance personnel, as opposed to instructor or combat development personnel. The core of their comments was to question how an examination of past mistakes could improve planning for a new system when these past problems and their consequences already are well known. These negative views did not appear to have any real impact on this study. However, we recommend the development of a briefing, and perhaps a succinct brochure, that describes the ECA approach and relates its typical results to decisions that will have to be made by materiel, combat, and training developers. In particular, the distinct contribution made by an ECA study, in contrast to Hardware versus Manpower (HARDMAN) or Human Factors studies, should be emphasized. A briefing or a brochure should be provided to all SMEs contributing to the study both to stress the importance of their collaboration and to popularize knowledge about ECA and other MANPRINT techniques.

Summary

Overall, this experience in conducting a comprehensive ECA study confirms the value of the ECA approach as an important component of MANPRINT efforts. The study identified a number of high driver tasks that could consume excessive manpower, personnel, and training resources when the AFAS is fielded, and potentially constrain the new weapon's combat effectiveness. The study also yielded suggestions for overcoming these problem tasks, often using relatively simple solutions.

While various refinements in the technique are desirable, an ECA even in its present form can yield information very useful to new system planners. The approach encourages a detailed look at what interferes with the efficient use of human resources in already fielded equipment. In addition to suggesting how these "lessons learned" can be used to reduce the MPT resources required to introduce some new system, an ECA study has two additional benefits. One is that it systematically examines and diagnoses existing problems in a way that often suggests solutions to those problems that might not otherwise have been identified. The other is that the collective findings from a series of ECA studies, when merged into a data base, are likely to document pervasive problems that are not system specific and will have to be considered Army-wide. Both of these additional benefits emerged from this study, and both should be viewed as additional reasons to conduct an ECA.

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LIST OF ACRONYMS

AFAS	Advanced Field Artillery System
AFV	Armored Family of Vehicles
AIT	Advanced Individual Training
ARI	Army Research Institute for the Behavioral and Social Sciences
BITE	Built-In Test Equipment
CODAP	Computerized Occupational Data Analysis Program
DCD	Directorate of Combat Developments
DOTD	Directorate of Training Development
DS	Direct Support (Maintenance)
ECA	Early Comparability Analysis
FARV	Future Armored Resupply Vehicle
GS	General Support (Maintenance)
HARDMAN	Hardware versus Manpower
HIP	Howitzer Improvement Program
JMSNS	Justification for Major New System Start
KSA	Knowledge, Skill, Ability
MAC	Maintenance Allocation Chart
MANPRINT	Manpower, Personnel Integration
MJWG	MANPRINT Joint Working Group
MLRS	Multiple Launch Rocket System
MOS	Military Occupational Specialty
MPT	Manpower, Personnel, Training
O&O	Operational and Organizational (Plan)
PDS	Position Determining System
POI	Program of Instruction

LIST OF ACRONYMS (Continued)

QQPRI	Qualitative and Quantitative Personnel Requirements Information
SDC	Sample Data Collection
SME	Subject Matter Expert
SSC-NCR	Soldier Support Center-National Capital Region
TM	Technical Manual
TRADOC	Training and Doctrine Command
TSM-Cannon	TRADOC System Manager for Cannon
USAFAS	U.S. Army Field Artillery School
USAOC&S	U.S. Army Ordnance Center and School
USASIGCEN	U.S. Army Signal Center

APPENDIX

STATISTICAL ANALYSES OF SELECTED ECA ISSUES

Introduction

During the course of a series of Early Comparability Analysis (ECA) studies covering tasks performed by 14 MOSs on predecessor and reference systems for the Advanced Field Artillery System (AFAS), some incidental opportunities emerged to examine issues related to the ECA methodology using simple statistical tests. The ECA methodology was developed by the Soldier Support Center-National Capital Region (SSC-NCR) to identify tasks being performed on equipment already in inventory that are particularly intensive in their use of manpower, personnel or training (MPT) resources. These "high driver" tasks are ones that should be considered carefully during the design of new weapon systems so that the deficiencies that led to them will not be repeated.

Although no project resources were set aside for the purpose of gathering data or performing analyses beyond what was needed in support of the planning for AFAS, it turned out that three methodological issues of interest could be examined incidentally using the findings generated for the main study. The scope of these additional analyses were limited, however, in that even tentative statistical tests could be justified only for those MOSs with sufficient numbers of SMEs participating and sufficient numbers of tasks being rated. The three issues examined were:

- Interjudge Reliability, the consistency of ECA scores from two randomly formed groups of SME raters;
- Subscore Intercorrelations, the pattern of overlap in what is measured by the six subscales used in arriving at a total ECA task score; and,
- Total Score Computation, the effects of calculating composite ECA scores as the product of the subscores rather than as their sum.

Caution should be used in considering the findings from these three analyses. Because the data base for them was opportunistic, it was not possible to insure that the values used in the computations would be representative of most ECA studies. On the other hand, the findings raise some questions about the ECA methodology and call attention to some issues that should be addressed in more detail as the ECA technique is used more frequently.

Interjudge Reliability

An important consideration when conducting an ECA survey of SMEs is how many participants are required to achieve reliable, or stable, task ratings. If SMEs tend to differ among themselves in how tasks are rated, more SMEs are required than if SMEs tend to be consistent in their ratings. One technique for estimating the reliability of ratings across judges is to calculate an interjudge reliability, the correlation between the sets of scores produced by two separate groups of raters.

In this study, one MOS (13B) had a sufficient number of SMEs participating (20), and a sufficient number of tasks to be rated (98) to calculate an interjudge reliability. The SMEs were randomly divided into two groups of 10 each, average ECA subscores were determined for each dimension on each task separately for each group, ECA task scores then were calculated for each group of 10 SMEs, and a correlation coefficient was calculated on the similarity of the ECA task scores determined for each group.

The obtained correlation coefficient was $r = .48$. Although such "raw" coefficients can be adjusted upward to estimate what the interjudge reliability would be for all 20 SMEs as a group, this was not possible for the ECA scores because of the effects of calculating them as the product of the subscores. The value of $r = .48$ probably is a reasonable approximation of the reliability of ratings for a single group of 10 SMEs, however, and appears satisfactory for identifying tasks that have high enough ECA scores to fall at the extreme of the distribution.

It should be noted that, unlike the SMEs who served as task raters for many of the maintenance tasks, this particular group consisted only of USAFAS instructors at Fort Sill. They probably are more homogeneous in both their experience and views than the same number of SMEs who might work on several different weapon systems and who might be contacted at several different locations.

Subscore Intercorrelations

Whenever several subscores are combined to produce a single composite score, their pattern of intercorrelations can be computed to show how the subscores relate to each other and how each subscore contributes to the composite score. The rationale for using multiple subscores it to assemble components of an underlying conceptual score both to better reflect what is meant by the conceptual score and to improve its reliability by decreasing the influence of chance or random errors that may affect the outcome when only a single or small number of measures are employed to determine the conceptual score.

In theory, multiple subscores that are to be combined should all relate to each other to some extent, so they can be presumed to all reflect the same underlying conceptual score. On the other hand, the relationship should not be perfect, or else many of the measures would be superfluous. Whenever subscores substantially disagree with each other, the resulting composite score will have a lower reliability than it otherwise would have, and be less able to differentiate among cases. Ideally, then, multiple subscores should have moderately positive intercorrelations with each other and with the resulting composite score.

Two sets of intercorrelations were calculated from the findings of this ECA study. One was obtained using MOS 13B data (20 SMEs, 98 tasks), and one using MOS 63H data (14 SMEs, 60 tasks). The results are shown in Table A-1.

Table A-1

Intercorrelations of ECA Subscores

Note: The top score in each data cell is from MOS 13B (20 SMEs, 98 tasks) and the bottom score is from MOS 63H (14 SMEs, 60 tasks).

	TPD	FR	TLD	TT	DR	ECA
PP	-.71 -.64	.79 .95	-.64 -.59	-.61 -.49	-.06 -.15	-.05 .22
TPD		-.66 -.59	.90 .96	.70 .86	.08 .75	.61 .44
FR			-.62 -.53	-.42 -.44	-.32 -.09	.02 .29
TLD				.60 .87	.06 .76	.61 .49
TT					.06 .72	.61 .54
DR						.15 .75

PP = Percent Performing TLD = Task Learn. Difficulty
TPD = Task Perf. Difficulty TT = Time-to-Train
FR = Frequency Rate DR = Decay Rate
ECA = Total ECA Score for the Task

The results indicate consistently high positive intercorrelations within certain groups of subscores. One group is represented by Percent Performing and Frequency Rate; another group is represented by Task Performance Difficulty, Task

Learning Difficulty, and Time-to-Train; and a third is represented by Decay Rate. The most striking results are the consistently high negative intercorrelations between any of the subscores in the first group and any of the subscores in the second group. These results indicate there are at least two distinct "families" represented and that, in combination, the two tend to cancel each other out. The results for Decay Rate show more modest intercorrelations with the other two dimensions, and are inconsistent between the two MOSs. In all but one instance, the correlations between a subscore and the total ECA score was positive, but this should be expected because the total ECA score contains that subscore and some autocorrelation is therefore at work.

The pattern of intercorrelations suggests the need for some refinements in the dimensions that are rated to establish an ECA score for a task. As it is, some scales such as Task Performance Difficulty and Task Learning Difficulty are so similar as to make one or the other unnecessary. At the same time, the presence of sizable negative intercorrelations, as between Percent Performing and Task Performance Difficulty, raises questions as to what an ECA score represents. It is possible, for example, that the most difficult tasks are assigned only to the most competent personnel, or that tasks performed only infrequently also are perceived as the most difficult. A more extensive examination of these issues should be undertaken before the more widespread application of the ECA methodology is advocated.

Total Score Computation

In the SSC-NCR procedure, a total ECA score for a task is determined by calculating the product of the subscores. The mathematical effect of using products instead of sums is to give much greater weight to higher subscale values, and proportionately lower weight to lower subscale values. Thus, even a small reduction in one high average subscore will cause a considerable reduction in the composite task score while a similarly sized increase in one low average subscore for the same task will produce only a modest increase in the task score. This methodology may or may not be desirable depending on what the composite ECA score for a task is presumed to represent.

We calculated the correlation between composite ECA task scores computed using the product method and composite scores computed using the sum method for MOS 13B results (20 SMEs, 98 tasks). The correlation between the two outcomes was r = .92, suggesting the two methods yield very similar outcomes, and that either method could be used interchangeably. It should be noted, in addition, that the ECA scores for the MOS 13B tasks were relatively homogeneous and no high drivers appeared among them. A somewhat lower correlation coefficient would be expected because of a divergence from linearity at the upper end if the range of ECA scores had been greater.

The use of products rather than sums has the effect of magnifying the differences among composite ECA task scores at the upper end. This makes the application of a "cut value" easier in that few composite task scores will be near the criterion, even when the subscores are calculated to one or more places after the decimal point. On the other hand, the procedures will tend to increase the proportion of high drivers in MOSs responsible for only a small number of tasks because those tasks almost necessarily will have high Percent Performing and Frequency Rate subscores.

Working Paper

WP MSG 90-06

Alternative Procedure Guide for Early
Comparability Analysis (ECA)

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Working Paper

ALTERNATIVE PROCEDURAL GUIDE FOR EARLY COMPARABILITY ANALYSIS (ECA)

June 1989

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ALTERNATIVE PROCEDURAL GUIDE FOR EARLY COMPARABILITY ANALYSIS (ECA)

SUMMARY

The Early Comparability Analysis (ECA) technique was devised as a MANPRINT tool by the Soldier Support Center-National Capital Region (SSC-NCR) to further uses of a "lessons learned" approach for reducing the demands of new weapon systems on manpower, personnel, and training (MPT) resources. The SSC-NCR methodology, as described in Early Comparability Analysis: Procedural Guide, is a step-by-step procedure for identifying antecedent systems that have similar hardware components, for determining operator and maintenance tasks currently performed on those components that are particularly resource intensive, and for analyzing these "high driver" tasks to diagnose deficiencies and propose solutions for overcoming them.

During the course of applying the ECA methodology to support planning for a complex, crew-served weapon system, the Advanced Field Artillery System (AFAS), several refinements in the procedure were identified that might make the technique easier to use and more comprehensive in its analysis of current deficiencies and ways of preventing them in new systems. This report presents an alternative step-by-step procedure for conducting an ECA based on the experience obtained during the AFAS study. Essentially, this alternative procedure incorporates the same overall methodology that was developed by SSC-NCR. However, it expands the scope of the steps concerned with examining the causes of resource intensive tasks and what remedial actions might be taken. It also clarifies the instructions for a number of steps and offers suggestions for conducting an ECA when the source documentation on relevant tasks is sparse or atypical.

Other outcomes from the AFAS study are presented in two companion reports. Methodological Considerations in Applying Early Comparability Analysis (ECA) examines the experience of carrying out the study with respect to beginning an ECA very early in the concept development cycle for a new weapon system and to having an ECA performed by a contractor. That report also identifies several technical issues that emerged from a series of incidental substudies addressing the interjudge reliability of subject matter experts (SMEs) surveyed for task ratings, the intercorrelations among the subscales used to determine which tasks are high drivers, and the consequences of multiplying subscores to arrive at a total ECA task score.

The other report, Application of Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS), summarizes the results obtained when ECA procedures were used to investigate more than 400 operator and maintenance tasks now being performed on equipment designated as predecessors to the hardware planned for AFAS. It describes the findings from surveys of SMEs in 14 military occupational specialities (MOSs) conducted to identify resource intensive tasks, the outcomes of detailed task analyses that examined the more than a dozen high drivers that were identified, and the conclusions on ways of overcoming, or at least diminishing, the impact of these high drivers on future weapon systems.

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INTRODUCTION

Considerable efforts have been undertaken recently to enhance the policies and procedures of the Army's Manpower and Personnel Integration (MANPRINT) Program. The results have produced a number of useful techniques and tools for implementing MANPRINT practices throughout the material acquisition process. One of these techniques is Early Comparability Analysis (ECA), a methodology for examining tasks that are now performed on existing weapon systems and that also may be required in order to operate and maintain a new weapon system that is under development.

The ECA approach was devised by the Soldier Support Center-National Capital Region (SSC-NCR) to support the use of a "lessons learned" approach during the design of new weapon systems. Its aim is to create new systems that will be less resource intensive in their manpower, personnel, and training requirements. The methodology employs step-by-step procedures to identify antecedent systems having similar components to those proposed for a new system, to establish which operator and maintainer tasks currently performed on those components are particularly resource intensive, and then to analyze these "high driver" tasks to diagnose deficiencies and propose solutions for overcoming them.

During one of a series of MANPRINT studies recently undertaken to support the design of a new field artillery weapon system, the Advanced Field Artillery System (AFAS), the ECA approach was applied to more than 400 operator and maintainer tasks spread over 14 military occupational specialities (MOSs). This experience verified the capability of the ECA methodology to uncover significant MANPRINT issues, to diagnose the reasons why particular tasks are resource intensive, and to guide the formulation of suggestions for overcoming these problems for a new system under development. This comprehensive application of the ECA approach also allowed a detailed review and analysis of the specific procedures described by SSC-NCR in order to determine whether any refinements would make the procedures more workable and more productive.

Not all of the issues concerning the SSC-NCR methodology for conducting an ECA could be resolved within the scope of the study. Among these were the dimensions of a task to be considered when identifying a "high driver", the way scale values are combined to establish an ECA score, and the effects of irrelevant factors such as the breadth of an MOS on the likelihood of identifying a high driver. Although these concerns deserve systematic attention and, if resolved, would strengthen the ECA methodology considerably, the fundamental approach nevertheless appears to be a valuable component of the MANPRINT program. Based on the results obtained in the study, the ECA approach is recommended as one that should be utilized more widely not only to improve the design of new weapon systems, but to document and deal with ongoing man-machine difficulties as well.

This application of the ECA methodology also facilitated the identification of a number of refinements in the step-by-step procedure laid out by SSC-NCR that may make the process easier to use and more suited to the constraints characteristic of most personnel studies in the Army environment. This alternative version of the ECA procedure builds on the practical experience of carrying out an ECA for a complex, crew-served weapon system. It combines or reorganizes several steps from the SSC-NCR procedure, expands the scope of steps relating to identifying and overcoming deficiencies, and augments the instructions for accomplishing various steps to reflect difficulties encountered during the study.

Basically, an ECA looks at tasks performed on weapon systems already in inventory which have components similar to those proposed for a new system in order to identify tasks that are particularly difficult to learn or perform. The tasks considered are limited to those now required to operate and maintain the antecedent equipment. Lists of relevant tasks are presented to subject matter experts (SMEs) in the various MOSs responsible for the existing hardware. The SMEs rate these tasks on several dimensions that address how difficult the task is to train or accomplish. A composite score is then developed from these ratings to determine which tasks are "high drivers", or intensive in their use of manpower, personnel, or training resources.

Once such "high driver" tasks are identified, they are analyzed in detail to determine the source of the problem and how the problem can be avoided for the new system. As described in this revised procedure, the hunt for likely causes of deficiencies and promising solutions for them considers seven areas: manpower, personnel, training, equipment design, task procedures, tools-manuals-job aids, and performance conditions. These causes and their remedies are derived from actual observations of task performance, from interviews with school instructors and other SMEs, and from the pattern of subscores from the survey that established the task as a "high driver".

Scope

This guide is intended to provide MANPRINT personnel with the procedures and information needed to conduct an ECA. In it, special attention is given to problems that may arise when an ECA is initiated early in the materiel acquisition cycle, before the design of the new system has been fully determined and even before doctrine for the new system is fully established. Beginning an ECA at this point requires a number of sometimes arbitrary assumptions to be made but, at the same time, may contribute more than otherwise would be possible to decisions on how the new system will be configured, staffed, and utilized.

The 10 steps in this alternative Early Comparability Analysis procedure are:

Step 1. Study Initiation

Step 2. Identify Relevant MOSs

Step 3. Prepare Task Lists

Step 4. Collect Task Data

Step 5. Calculate ECA Scores and Identify "High Drivers"

Step 6. Conduct Task Analyses

Step 7. Conduct Performance Analyses

Step 8. Identify Deficiencies

Step 9. Recommend Solutions

Step 10. Prepare an ECA Study Report

Generally, the guide follows the same overall sequence of events established by SSC-NCR in its Early Comparability Analysis (ECA): Procedural Guide. Revisions and clarifications were made where they seemed appropriate based on experience accumulated in applying ECA procedures to AFAS. The reasons behind these changes are discussed in a companion report, Methodological Considerations in Applying Early Comparability Analysis (ECA). Similarly, the results from that effort are described in Application of Early Comparability Analysis (ECA) to the Advanced Field Artillery System (AFAS).

This report considers only the steps for carrying out an ECA. The SSC-NCR Procedural Guide should be consulted when an ECA study is being planned for additional information on the methodology as well as for some examples of source materials and data analyses.

Overview of the ECA Study of AFAS

The conceptual system examined by the ECA study was the Advanced Field Artillery System (AFAS), a technologically sophisticated self-propelled howitzer (SPH) intended as successor to the presently fielded M109A2/A3 (M109) and soon to be fielded Howitzer Improvement Program (HIP) howitzers. The principal differences between the M109 and the AFAS, some of which are being introduced incrementally through HIP, are that AFAS will have:

- new cannon technology that provides a considerably increased maximum range of fire from the present 18km;

- automated loading and fusing capabilities that permit a considerably increased rate of fire from the present 2 rounds per minute;

- onboard positioning determining system (PDS), computerized fire control system, and both voice and digital radio communications that allow the AFAS howitzer to operate independently of a battery position; and

- automated ammunition transloading equipment to facilitate rapid resupply from a Future Armored Resupply Vehicle (FARV) with far fewer personnel.

Because this ECA was begun while concept development for AFAS was barely underway, many of its operational and equipment features had not yet been determined, and therefore the choice of antecedent systems to be examined was somewhat arbitrary. Furthermore, the study intentionally emphasized tasks that would be required during the 96-hour continuous battle scenario envisioned for AFAS under the dispersed battlefield concept. Thus, maintenance tasks at other than the unit and direct support-general support (DS-GS) levels were largely ignored. Also, tasks involving special weapons, resupply operations, and battery command activities were excluded.

Although this study was directed primarily at supporting materiel acquisition planning for AFAS, many of its findings are equally applicable to the HIP and to its manpower, personnel, and training requirements. HIP is incorporating many of the operational features of AFAS, particularly the ability to operate in a highly mobile mode away from an established battery position.

THE ALTERNATIVE ECA PROCEDURE

In this section, each step in the alternative ECA methodology is described in terms of the step's purpose, procedure, anticipated results, sample findings from the AFAS study, and estimated resource requirements:

- Purpose defines the step, its objective, and how the information developed in the step fits into the overall analysis.
- Procedure describes the specific substeps and activities to be performed in accomplishing the step.
- Anticipated Results indicates the desired information or conclusions to be derived from this step.
- AFAS Illustration provides a concrete example from the ECA study performed in support of the Advanced Field Artillery System (AFAS).
- Resources Required lists the source documents, estimated personnel requirements in person-hours, and projected elapsed time needed to accomplish the step.

Step 1. Study Initiation

Decide whether an ECA is appropriate, which predecessor and reference systems should be used, and who largely will be responsible for performing the ECA.

Purpose

This planning step usually will be accomplished by the combat development team responsible for a new weapon system. However, an ECA study also might be initiated by a proponent school independently of new weapon system development to identify and evaluate tasks that are particularly intensive in their use of manpower, personnel, or training resources.

An ECA generally will be appropriate when a conceptual system will have missions, doctrine, and functions similar to those for some predecessor system and when it will employ hardware components similar to those used for already fielded systems. An ECA generally will not be appropriate when there is a considerable technological gap between the proposed system and relevant antecedent systems, or when the planned operational or maintenance concepts for the new system are considerably different than those for comparable existing systems.

An important consideration in selecting antecedent systems for operator tasks is the similarity in the mission of that weapon and the mission of the projected system. The value of the ECA results for operators may be limited when there is a significant discrepancy in the missions of two otherwise similar systems.

Perhaps the most significant issue to be considered in deciding the appropriateness of an ECA is how early in the system development cycle the study can be begun. On the one hand, the earlier the results are available, the more they can contribute to operational and materiel decisions, including what equipment will be specified, who will man the system, and how training will be conducted. On the other hand, an ECA begun before the configuration of the new system is fully established might end up examining tasks performed on components totally different from those finally adopted for the new system. Usually, the description of the proposed weapon contained in the Operational and Organizational (O&O) Plan will be sufficient as the basis for making predecessor and reference system decisions.

The more complex the new system, the larger the number of reference systems that likely will be identified. For many complex systems, it may be necessary to divide them into subsystems in order to establish a set of best matches with already available equipment. This also permits focusing in on those subsystems where information on existing tasks would be most helpful. It is important when selecting predecessor and reference systems to involve SMEs familiar with those systems as early as possible. This will help insure that hardware matches are the most logical ones and that components using obsolete technologies are not considered.

An ECA is likely to be most objective and productive if it is performed by personnel not on the staff of any participating proponent school. Unfortunately, there is a tendency among some school personnel to view the identification of any "high driver" as a deficiency in the school's ability to overcome problems, and to consider only those solutions to high driver problems that coincide with school priorities. However, it is essential to have ECAs performed by staff familiar with the technology base and implicit policies that characterize individual Army branches and schools. Prior experience with similar operator and maintainer functions greatly reduces learning time and simplifies communications. Beyond this and some familiarity with data analysis, task analysis, and the derivation of knowledge, skill, and ability (KSA) requirements, ECA studies can be staffed by uniformed Army, civilian Army, or contractor personnel.

Procedure

Performing an ECA virtually is necessary if a new weapon system is to avoid incorporating, and depending on, tasks that make heavy demands on manpower, personnel, and training resources. Combat developers should initiate an ECA if the new system is sufficiently similar to existing systems to identify tasks generally comparable to those that may be required for the new system. The decision to proceed with an ECA is accomplished in three incremental substeps:

a. Establish that an ECA is feasible for the conceptualized new system. An ECA can be performed only on existing tasks, so it is appropriate only when essentially similar tasks will be required for the new system. To the extent that the new system will employ radically new technologies or significantly different operating or maintenance concepts, the appropriateness of an ECA will be diminished. At the same time, there must be sufficient latitude remaining in the design of the new system to permit changes in planned hardware or manning that will take advantage of findings from the ECA.

b. Establish that a predecessor system and, if needed, additional reference systems which encompass the range of tasks to be performed in operating and maintaining the new system are in the inventory. The number of antecedent systems included in the ECA generally will reflect the complexity of the conceptual system. When possible, a predecessor system with similar missions and functions should be selected first, and then additional reference systems should be identified. Complex conceptual systems should be divided into principal subsystems or components to facilitate matching them with subsystems and components on existing systems. It is important to consider the selection of predecessor and reference systems carefully in this step to avoid having to add other systems later in the study because some significant component was overlooked or mismatched.

c. Establish that sufficient resources will be available to conduct the ECA. The resource requirements for an ECA usually will reflect the complexity of the new system. Generally, the more complex the new weapon, the larger the number of antecedent systems and Military Occupational Specialities (MOSs) there will be to examine.

Anticipated Results

A decision to proceed with an ECA should be made in conjunction with a careful analysis of what predecessor and reference systems will be examined. The operator tasks that will be surveyed by and large will be those now performed on a predecessor system. These tasks tend to be defined by what the equipment does rather than by its internal mechanisms. Maintenance tasks, on the other hand, should be ones that are performed on similar hardware. The antecedent systems chosen should be ones that are deployed in sufficient numbers and for a sufficient period of time to expect that there will be a reasonable number of subject matter experts (SMEs) available who are familiar with these tasks.

AFAS Illustration

The need for an ECA was recognized by the combat development team, the TRADOC System Manager for Cannon (TSM-Cannon) group, Directorate of Combat Developments (DCD), at the U.S. Army Field Artillery School (USAFAS), Fort Sill, OK, that was responsible for AFAS, and was initiated by these combat developers. The Army Research Institute for the Behavioral and Social Sciences (ARI) was asked to provide technical assistance both for the ECA and for several related MANPRINT efforts also undertaken in support of the AFAS program. ARI, in turn, arranged for much of the work to be performed by a contractor.

Although the AFAS combat developers proposed the M109 SPH as the predecessor system, two additional reference systems also were selected because they had components that closely matched those planned for AFAS. Certain generic equipment planned for AFAS but not included in the AFAS development program, such as the .50-cal. machine gun, was excluded from the ECA. The antecedent systems chosen for the study, and the AFAS subsystems or components they represent, were:

existing system	for the AFAS
▪ M109A2/A3 Self-Propelled Howitzer	▪ driver controls ▪ turret ▪ cannon and gun mount ▪ ammunition handling
▪ Multiple Launch Rocket System (MLRS)	▪ track and suspension ▪ engine and transmission ▪ automatic fire control (AFC) and position determining system (PDS) ▪ digital and voice radio
▪ M1 Tank	▪ NBC collective system

Resources Required

a. Materials: The following materials generally will be needed to begin an ECA. They should be assembled during this step to help select predecessor and reference systems:

- Operational and Organizational (O&O) Plan for the new system,
- Use Study (Logistic Support Analysis, Task 201 document) for the new system, and
- Technical Manuals (TMs) for all possible antecedent systems.

b. Personnel: The amount of personnel time required to identify antecedent systems and plan the study will depend on the complexity of the conceptual system and whether it must be divided into subsystems. The following figures are estimates of the time required for a relatively complex new system represented by 5 subsystems.

Position	Time Required	Activities
Combat Developers	16.0 pers hrs (2 x 8 hrs each)	4 hrs preparation 4 hrs meeting
Analysts	8.0 pers hrs	4 hrs preparation 4 hrs meeting
Administrative	2.0 pers hrs	2 hrs admin-coord
TOTAL	26.0 pers hrs	

c. Elapsed Time: The length of this step depends on the complexity of the conceptual system and its similarity to already fielded systems. A reasonable estimate of the elapsed time required for this step is 1 week. Usually, this step will be performed together with Step 2 during the same time period.

Step 2. Identify Relevant MOSs

Identify the MOSs responsible for operating and maintaining the predecessor and reference system components selected for the study.

Purpose

The MOSs of personnel performing operator and maintainer tasks on the components matching those planned for the new system are identified to determine what tasks will be examined. Several MOSs may be involved in these functions, depending on how the equipment presently is used and what levels of maintenance are to be considered. Generally, the combat developers of the new system are in the best position to decide which MOS should be specified for operator tasks performed by more than one MOS, such as "Drive a tracked vehicle". The combat developers also should decide what echelons of maintenance are to be considered so the corresponding MOSs will be included. Usually, maintenance tasks through the direct support (DS) and general support (GS) levels will be examined for an ECA.

Considerable amounts of time may be required to identify the relevant MOSs, particularly when the combat developers for the conceptual system are not thoroughly familiar with each of the antecedent systems. Contacts with SMEs at the appropriate proponent schools often will help clarify which MOSs have responsibility for operating or maintaining the designated equipment. Another possible difficulty is that an MOS may undergo restructuring shortly before or during the ECA. Tasks that were performed by one MOS may now be shared with, or transferred to, another MOS. In these instances, it may be better to select the MOS that historically has had the most experience with the equipment rather than the MOS now responsible for its operation or maintenance.

Procedure

Identify the MOSs responsible for operating and maintaining each component selected for inclusion in the ECA during Step 1. Usually, this can be done in conjunction with the process of selecting components. As each MOS is identified, the following additional information should be obtained:

- the proponent school for that MOS, and the names of SMEs or MANPRINT liaison personnel at the school who can serve as a points-of-contact (POCs); and

- the skill level of the soldiers in that MOS who generally are assigned operator or maintainer tasks on that component.

Anticipated Results

For most new weapon systems, particularly for complex, crew-served systems that will utilize a number of newer technologies, a sizable number of pertinent MOSs may have to be identified. In many instances, several different MOSs may participate in performing necessary maintenance functions. Generally, AR 611-201 (Enlisted Career Management Fields and Military Occupational Specialties) will serve adequately as an initial starting point for identifying MOSs, although confirmation by knowledgeable proponent school personnel should be considered essential.

One concern that may arise during this step is whether any of the identified MOSs are particularly "thin", those held by relatively few personnel, particularly if they are stationed at widely dispersed locations. Assembling a group of SMEs to rate the relevant tasks from these MOSs may prove difficult. Similarly, some MOSs are very broad and serve a number of different systems; individuals in that MOS may be familiar only with tasks performed on systems specific to units to which they previously have been assigned.

AFAS Illustration

Altogether, 14 MOSs were identified as ones having operator responsibilities or performing maintenance tasks at the unit or DS-GS level for components chosen as AFAS antecedents. These were:

Operator

- 13B Cannon Crewmember
- 13M MLRS Crewmember
- 19K M1 Armor Crewman

Unit Maintenance

- 31V Unit Level Communications Maintainer
- 45D Self-Propelled FA Turret Mechanic
- 63E M1 Tank Systems Mechanic
- 63T BFVS Mechanic

DS-GS Maintenance

- 27M MLRS Repairer
- 29E Communications-Electronics Radio Repairer
- 29S Field Communications Security Equipment Repairer
- 39L Field Artillery Digital Systems Repairer
- 45L Artillery Repairer
- 63G Fuel and Electrical Systems Repairer
- 63H Track Vehicle Repairer

Resources Required

a. Materials: The MOSs responsible for operating or maintaining a particular component are best identified through contacts with SMEs at the appropriate proponent schools. More general guidance can be found in:

- AR 611-201: <u>Enlisted Career Management Fields and Military Occupational Specialties</u>

b. Personnel: The amount of personnel time required to identify the relevant MOSs will depend on the complexity of the conceptual system, the echelons of maintenance to be examined, and the number of proponent schools involved. The following are estimates of the time required for a relatively complex new system served by 10 MOSs divided among 3 proponent schools.

Position	Time Required	Activities
Combat Developers	6.0 pers hrs (2 x 3 hrs each)	1 hr preparation 2 hrs meeting
Analysts	6.0 pers hrs	1 hr preparation 2 hrs meeting 2 hrs telephone 1 hr report
Administrative	2.0 pers hrs	2 hrs admin-coord
TOTAL	14.0 pers hrs	

c. Elapsed Time: Usually, this step will be accomplished concurrently with Step 1. The elapsed time for both steps together is approximately 1 week.

Step 3. Prepare Task Lists

Prepare a list of tasks performed by each MOS on components of the predecessor and reference systems identified for inclusion in the ECA.

Purpose

The lists of tasks to be examined are developed in this step. Almost always, the tasks chosen will represent only a small fraction of all the tasks assigned to each MOS. Very broad MOSs often have responsibility for operator or maintainer functions on a wide variety of equipment and systems. Only those tasks directly relevant to the predecessor and reference systems and components should be listed, however, unless the study has been initiated to identify manpower, personnel, and training problems associated with an MOS or career field, as opposed to problems that should be avoided for a new conceptual system as is done with an ECA study. These broader studies, while using much the same methodology as an ECA, are not usually carried out as part of a MANPRINT effort.

Although fairly comprehensive task inventories are available for many MOSs, these may not be entirely satisfactory for the purposes of an ECA for two reasons. First, both operator and maintainer tasks sometimes are described as if they are specific to only one of the systems that are the responsibility of that MOS, even though the same task also is performed on other systems. Often, a review of the complete task inventory with the assistance of an SME is needed to make certain all relevant tasks are identified. Second, a number of proponent schools recently have switched from equipment-specific task inventories to much simpler generic task inventories. These generic tasks, such as "Repair the transmission" or "Troubleshoot the electrical system", are far too encompassing to be suitable for an ECA task list because any one may contain both very easy and very difficult task segments and only some of these segments will be performed to complete any given task assignment. Thus, rating the difficulty of the task will be nearly impossible and SME surveys will produce unreliable results.

One alternative to using generic tasks from an existing task inventory, at least for maintenance MOSs, is to use the tasks identified in the Maintenance Allocation Chart (MAC) in the TMs for the equipment item. Problems may be encountered using this approach, however, in that not all relevant tasks always appear in the MAC, many tasks listed in a MAC are not as comprehensive as those usually used when making assignments, and the MAC does not specify which MOS is responsible for the task. A second alternative is to relate generic tasks to specific equipment items and also to divide the tasks into more manageable segments. Still a third alternative is to rely on Logistic Support Analysis Records (LSARs) as a source of task lists. LSARs may not be readily accessible, however, particularly for older systems unlikely to have had Integrated Logistics Support studies conducted on them.

<u>Procedure</u>

When available, existing task inventories for each MOS to be included in the ECA should be obtained from the proponent school. These inventories are then reviewed to identify all tasks performed by that MOS on the predecessor and reference systems or components specified in Step 1. In the absence of an existing task inventory, other sources of task information, such as relevant MACs or LSARs, can be used. Where proponent schools have adopted generic tasks in place of equipment-specific tasks, the generic tasks can be divided into task segments. A review of each ECA task list by SMEs at the appropriate proponent school is essential. The SMEs should be encouraged to focus on the completeness as well as on the accuracy of the draft task list.

Anticipated Results

This step should yield an SME-approved task list for each MOS which encompasses all tasks that MOS performs on the predecessor and reference systems and components. The number of tasks on each list will vary considerably depending on the functions for which that MOS is responsible and the specificity of the task descriptions. When available, the skill level at which the task is performed should be specified.

AFAS Illustration

Both equipment-specific and generic-based task lists were used as sources for the ECA study carried out in support of the AFAS, depending on the proponent school. The number of resulting tasks for any particular MOS ranged from 2 for MOS 63E, the M1 Tank Systems Mechanic responsible for maintenance on the NBC collective system, to 98 for MOS 13B, the Cannon Crewmember responsible for operating the predecessor M109 SPH. Altogether, more than 400 tasks were identified for the 14 MOSs. Some examples of equipment-specific tasks derived from task inventories are:

- Perform organizational maintenance on the Launcher Loader Module (LLM) electronics box (13M)
- Determine the elevation of a point on the ground using a map (13B)
- Adjust gear shift and clutch linkage (63T)

Some examples of tasks developed from the generic task inventories adopted by some proponent schools are:

- Repair wiring harness 1W26 (63G)
- Evaluate R-442 configuration (29E)
- Replace gear shaft spur (63H)

Resources Required

a. Materials: Some source of task inventory information for each MOS to be included in the ECA is required in order to generate the task lists. Possible sources include:

  - current task inventories available from proponent schools,
  - Soldier's Manuals (SMs) or Skill Qualification Tests (SQTs)for the MOS,

- Maintenance Allocation Charts (MACs) contained in Technical Manuals (TMs) for the systems and components of predecessor and reference systems, and

- Logistic Support Analysis Records (LSARs).

b. Personnel: The amount of personnel time required to prepare the task lists to be generated in this step depends on the accessibility of task inventory information, the number of MOSs involved, and the number of proponent schools that must be contacted. The actual number of tasks per MOS is not a very significant variable. The following figures are estimates of time required per MOS and per proponent school. The "TOTAL" time given assumes 10 MOSs divided among 3 proponent schools.

- For each MOS:

Position	Time Required	Activities
Proponent School SMEs	8.0 pers hrs	2 hrs inventory 4 hrs discussion 2 hrs list review
Analysts	12.0 pers hrs	6 hrs list prep 4 hrs discussion 2 hrs revisions
Administrative	4.0 pers hrs	2 hrs draft list 2 hrs final list

- For each Proponent School:

Position	Time Required	Activities
Proponent School SMEs	4.0 pers hrs	4 hrs liaison
Analysts	4.0 pers hrs	4 hrs liaison

- TOTAL Personnel, assuming 10 MOSs and 3 Proponent Schools:

264.0 pers hrs

c. Elapsed Time: The length of this step depends on the accessibility of information, the number of MOSs and proponent schools involved, and on the time required by the school to review, comment on, and refine the draft task lists. A reasonable estimate of the elapsed time for this step is between 8 and 12 weeks.

Step 4. Collect Task Data

Survey SMEs for their ratings, and compile any additional data available, on the tasks listed for each MOS along six dimensions:

- Percent Performing
- Task Learning Difficulty
- Task Performance Difficulty
- Frequency Rate
- Decay Rate
- Time-to-Train

Purpose

SME ratings of the tasks, along with other information that may be available, are the primary sources of data for establishing which tasks are "high drivers" because they place high demands on manpower, personnel, or training resources. Because these SME ratings often will be the only information available, it is very important to obtain the help of SMEs who are particularly knowledgeable about the range of tasks included on the ECA task list for their MOS. One example of the kind of problem that may be encountered in obtaining knowledgeable ratings stems from the progression path in certain career fields. MOS 63G, Fuel and Electrical Systems Repairer, exists only through skill level 2. At skill level 3, an MOS 63G becomes an MOS 63H, Track Vehicle Repairer. Very few MOS 63H SMEs, however, are thoroughly familiar with the fuel and electrical system repair tasks that generally are the responsibility of an MOS 63G. Most will not be able to assign ratings to these tasks. Because MOS 63G ends at skill level 2, on the other hand, few if any holders of this MOS quality as an SME. In these instances, it may be necessary to limit the survey to instructors assigned to the absorbed MOS.

Procedure

Task data consists of two kinds of information that can be used to provide quantitative scores for each task along six dimensions. One type of information is represented by the results of past studies, surveys, and analyses of records that relate to one or more of the six dimensions. The proponent school is the most likely source of these studies. The other type of information is the results of a survey of SMEs who are familiar with those tasks.

The SME survey instrument consists of a six-column rating form. Each task appearing on the task list for that MOS is rated on a scale of 1 to 4 along each of the six dimensions. Descriptions of the dimensions and the anchors for each of the numerical scale values are provided to the SMEs to improve the consistency of their ratings. SSC-NCR's descriptions of the dimensions and the scale values used for each are:

a. Percent Performing: What proportion of the relevant MOS and skill level performs this task?

   1 = 1-25%
   2 = 26-50%
   3 = 51-75%
   4 = 76-100%

b. Task Learning Difficulty: How difficult is it for the average soldier, in the appropriate MOS and of the appropriate skill level, to learn this task?

   1 = Not difficult
   2 = Somewhat difficult
   3 = Moderately difficult
   4 = Very difficult

c. Task Performance Difficulty: How difficult is it for the average soldier, of the proper skill level and in the proper MOS, to perform this task? Consider both cognitive and physical difficulty.

   1 = Not difficult
   2 = Somewhat difficult
   3 = Moderately difficult
   4 = Very difficult

d. Frequency Rate: On the average, how often is this task performed by the average soldier of the proper skill level and in the proper MOS?

   1 = Seldom (Annually)
   2 = Occasionally (Semi-annually or quarterly)
   3 = Often (Monthly)
   4 = Frequently (Daily or weekly)

e. Decay Rate: Given this task, how much proficiency is lost by the average soldier from the end of his formal training until he first performs the task in the field? (Assume that the task is performed within a reasonable period of time after training and is performed by an average soldier of the proper skill level and in the proper MOS.)

   1 = Low
   2 = Moderately low
   3 = Moderately high
   4 = High

f. <u>Time-to-Train</u>: How much time is required to train the average soldier, of the proper skill level and in the proper MOS, to perform this task to standard?

1 = Less than 3 hours
2 = 3 hours or more but less than 6 hours
3 = 6 hours or more but less than 9 hours
4 = 9 hours or more

A minimum of 10 SMEs should rate each task. When possible, these SMEs should be assembled as a group to facilitate data collection. If this many SMEs are not available at one location, the survey can be administered in smaller groups or, if necessary, by mail. A copy of the blank survey instrument is provided in the Appendix of this report.

It also is desirable to collect some biographical information on the SMEs prior to administering the survey. This may help clarify the causes of any substantial discrepancies among raters. It may be, for instance, that SMEs with 15 or more years of experience will have different views of tasks than SMEs with fewer than 10 years of experience. The biographical information might include the SME's grade, primary and secondary MOSs, years in service, instructor or supervisory positions held, and current position. It also may be helpful to have the SMEs identify which of the predecessor and reference systems identified in Step 1 they have operated or maintained. A sample biographical information questionnaire is included in the Appendix.

If additional information about some or all of the tasks is available from previous studies, that information will be combined with the survey results when total ECA scores are calculated in Step 5.

<u>Anticipated Results</u>

Most SMEs should have no difficulty rating tasks from their own MOS provided they have had experience with the system or component on which the task is performed. It is possible, however, that some arbitrariness may emerge if the SMEs are asked to rate too many tasks, perhaps 100 or more, at one session. Some omissions also can be expected, either because an SME is not familiar with that particular task or because he has not had the experience as a supervisor or instructor that would allow him to assign values along some of the dimensions for one or more of the tasks.

Usable data from past studies and other sources often will not be available. Even when quantitative information can be found, it often will have been compiled for some totally different purpose and be inappropriate for the ECA. Occasionally, however, the results from some prior ECA study covering overlapping tasks may be available and should be compiled.

AFAS Illustration

No usable data from past studies of the MOSs examined could be identified by any of the proponent schools, so information on the tasks was obtained solely from surveys of SMEs. The number of SMEs available to rate each task list ranged from as few as 7 to as many as 20. Although the number of SMEs participating was fewer than 10 for several of the MOSs included in the ECA, an inspection of the results indicated a reasonable consistency among raters and, therefore, there was no pressing need to locate additional SMEs.

Resources Required

a. Materials: No additional materials are needed for this step beyond copies of the survey instrument and a simple form to collect biographical information on the participating SMEs.

b. Personnel: The amount of personnel time required for the administration of the surveys depends on the number of MOSs involved, the number of SMEs participating in rating tasks for each MOS, and the number of locations that have to be visited. The actual number of tasks per MOS is not a very significant variable. The following figures are estimates of the time required for each MOS with 10 SMEs per MOS in two separate locations. The "TOTAL" time given assumes 10 MOSs.

- For each MOS, assuming 2 sites:

Position	Time Required	Activities
Participating SMEs	20.0 pers hrs (10 x 2 hrs each)	2 hrs survey
Analysts (3 hrs per site)	6.0 pers hrs	2 hrs survey
Administrative	4.0 pers hrs	2 hrs forms 2 hrs admin-coord

- TOTAL Personnel, assuming 10 MOSs and a total of 20 sites:

300.0 pers hrs

c. Elapsed Time: The length of this step depends primarily on the ease of arranging visits to groups of SMEs, which can take a month or longer. A reasonable estimate of the elapsed time for the step is between 4 and 12 weeks.

Step 5. Calculate ECA Scores and Identify "High Drivers"

Calculate an ECA score for each task by multiplying the average of the SME ratings, combined with other available task information, across the six dimensions in order to identify tasks with a score of 216 or more as "high drivers".

Purpose

This step identifies which tasks among those surveyed should be considered "high drivers" because of the demands they place on manpower, personnel, or training resources. Although the process for determining which tasks are high drivers is somewhat arbitrary, there is general agreement that tasks with high composite scores are problem tasks deserving further examination. Caution should be used when interpreting the ECA score for individual tasks if any of three influences may have contributed to making the score higher or lower than it otherwise would be.

- First, the breadth of the MOS is likely to have a substantial impact on two of the dimensions, Percent Performing and Frequency Rate. If the total number of tasks performed by soldiers in that MOS is small, the percentage of soldiers performing any one task and how frequently it is performed will be artificially high.

- Second, the dimensions themselves overlap in some instances and are in conflict in others. Future refinements in the dimensions can be expected to increase their independence and perhaps improve the diagnostic value of an ECA for prescribing remedies for problem tasks. Nevertheless, the current six dimensions provide a reasonable basis for calculating ECA scores.

- Third, computing the composite ECA task score by calculating products of the subscores rather than some other way, such as calculating sums, may result in the differences between various task scores appearing larger than they really are. The procedure makes problem tasks stand out, but also calls less attention to marginally problem tasks than they may deserve.

Procedure

A mean, or average, rating is calculated for each dimension of each task by adding the ratings provided by the SMEs and then dividing the total by the number of ratings. If any additional data about a dimension have been obtained, this information is converted to a scale with a range of 1 to 4 and then averaged with the mean SME rating with each source weighted equally. Care should be taken with respect to the dimensions of any tasks that were rated by only a few SMEs or that were rated very inconsistently by the SMEs.

The average ratings, or combined averages of ratings and other data, are then multiplied together to provide a composite ECA score for each task. For example:

Dimension	Average Rating
Percent Performing	2.3
Task Learning Difficulty	3.1
Task Performance Difficulty	2.7
Frequency rate	2.8
Decay Rate	2.2
Time-to-Train	3.0

$$(2.3) \times (3.1) \times (2.7) \times (2.8) \times (2.2) \times (3.0) = 355.76$$

This result, 355.76, is the composite ECA score for the task.

Any task with a composite score of 216 or greater is considered a "high driver" task if information on that task is available for all six dimensions. If information on only five dimensions is available, as when the predecessor system was fielded too recently to permit SMEs to judge Percent Performing, the task is a high driver if it has an ECA score of 90 or more. A composite score at this level suggests the task is a problem task in its use of manpower, personnel, or training resources. A list of these tasks, along with any other tasks that are reasonably close to being identified as high drivers (perhaps within 20 percent of 216, or a composite score of 173, when all six subscales are used) is then furnished to the proponent school for its review. The school is asked to confirm the high driver status of each task with a high composite score.

Anticipated Results

Considerable variability among MOSs can be expected in the number of high drivers that will be identified. Overall, operator tasks appear less likely to include high drivers than maintenance tasks. When the lists of apparent high drivers are reviewed by the appropriate proponent schools, a few changes are to be expected. Some tasks may be deleted because the problem already has been recognized and some remedy already is in progress, or because the school is not convinced a task is significant enough to raise concerns. At the same time, the school may add tasks with lower composite scores to the high driver list because they are regarded as problem tasks, often because they are unusually demanding along some one dimension such as Task Learning Difficulty.

AFAS Illustration

Of the more than 400 tasks examined in the ECA for AFAS, over 3 percent yielded ECA task scores of 216 or more, and another 1 percent yielded scores between 173 and 215. No high driver tasks were identified for over half of the MOS, while a single MOS accounted for 8 high drivers among the 37 tasks surveyed in that MOS.

The schools made only a few changes in the lists of high drivers. Two tasks were eliminated from the lists, and two were added from among the tasks receiving ECA task scores below 216.

Resources Required

a. Materials: No additional materials are needed for this step except for documentation on prior studies of tasks in that MOS. Data from these prior studies are used if they relate to one or more of the dimensions considered by an ECA to establish whether a task is a high driver.

b. Personnel: The amount of personnel time required for calculating ECA task scores and for determining high drivers depends primarily on the number of MOSs involved, the number of SMEs surveyed, and whether the calculations are performed by hand or using a computer. The following figures are estimates of the time required for each MOS, with 10 SMEs rating approximately 50 tasks, and when the calculations are performed on a computer. The "TOTAL" time given assumes calculating ECA scores on 50 tasks for each of 10 MOSs.

- For each MOS of 50 tasks:

Position	Time Required	Activities
Proponent School SMEs	2.0 pers hrs	2 hrs review high drivers
Analysts	3.0 pers hrs	2 hrs data entry 1 hr determine high drivers
Administrative	1.0 pers hrs	1 hr admin-coord

- TOTAL Personnel, assuming 10 MOSs:

60.0 pers hrs

c. Elapsed Time: The length of this step depends primarily on the length of time required by each proponent school to review the tentative list of high driver tasks. A reasonable estimate of the elapsed time for this step is between 4 and 6 weeks for 10 MOSs.

Step 6. Conduct Task Analyses

Perform a task analysis on each "high driver" to specify its individual procedural steps, the tools and test equipment required, the conditions under which the task is performed, and the standard(s) that must be met.

Purpose

In order to propose remedies for alleviating the demands on resources associated with high driver tasks that may be required for a planned new weapon system, the sources of these demands must be determined. A task analysis of each high driver task, based on observations of actual task performance and interviews with knowledgeable instructors and other SMEs, provides the information needed to diagnose the problem and suggest solutions. The task analysis for an ECA does not have to be exacting, but it should be performed to at least the level of detail represented by a procedure step in a typical Technical Manual (TM) or Soldier's Manual (SM).

Procedure

Various formats are used to generate a task analysis. One example is shown in the Appendix. Typically, the entries for each step in the procedure include, in addition to the task, subtask and step number:

- <u>action</u>--what is done, and the control or display involved;
- <u>indication</u>--what is supposed to happen, if anything; and
- <u>correction</u>--what to do if the normal indication does not occur.

In addition, a task analysis should contain the following information accompanying the step or steps where relevant:

- CAUTIONs and WARNINGs regarding safety precautions to protect personnel or equipment.
- NOTEs that describe anything unusual about the step determined from observations of step performance, from an analysis of the TM or SM, or from comments from SMEs.

The easiest way to perform a task analysis for an ECA is to first develop a draft list of procedural steps using available information from TMs, SMs, or Programs of Instruction (POIs). In some instances, every step already will be specified clearly in one of these publications. In other instances, the steps may have to be derived from broad descriptions of the procedures, from a troubleshooting chart, or directly from observations of the step being performed.

Once a draft of the task analysis is prepared, its content should be confirmed by observing how the task is performed by an experienced soldier in a unit or by a student or recent graduate at a school. To insure the task is performed correctly, it should be done under the supervision of an SME. The observations are necessary to confirm the accuracy of the draft procedure, to detect steps that are difficult or time consuming to perform, and to obtain inputs from the SME on steps that frequently are performed incorrectly. Observing performance of the task also provides an opportunity to examine the equipment, to become familiar with any job aids, tools, or test equipment used to perform the task, and to establish what conditions of performance may make the task difficult. All observations should be recorded either as corrections to the draft task analysis or as additional notes.

Anticipated Results

The task analysis performed on each high driver will consist of perhaps as few as 30 steps or as many as 300 or more. It is not desirable to attempt to compress the procedure into fewer steps than are needed to fully describe the procedure. As a rule of thumb, no step should be more complicated than the instruction a student would be able to perform correctly after it is read aloud to him.

AFAS Illustration

Task analyses were drafted for each task identified as a high driver and then confirmed by observing a student or an instructor perform the task. The format used, and the types of information obtained, can be illustrated by some very brief segments of a few of the resulting task analyses:

- TASK: Repair Transmission HMPT 500 (MOS 63H)

Step	Action	Indication	Correction
49.	Set fuel injector limit by turning adjustment screw CCW until dial shows 0.187 inch	Indicator dial shows adjustment of 0.187± 0.001 inch	
50.	Torque locknut to 30-35 ft-lb	Indicator dial shows 30 to 35 ft-lb	

NOTE: Rocker lever actuator is part of fuel injector adjustment kit.

Step	Action	Indication	Correction
51.	Check setting of fuel injector: ▪ Position rocker lever actuator on rocker arm ▪ Pull rocker lever actuator down to depress link ▪ Slowly release rocker lever actuator ▪ Note reading on indicator dial	Indicator dial shows adjustment of 0.186 to 0.188	If adjustment is out of range, repeat steps 49, 50, 51
52.	Remove injector adjusting tools		

- TASK: System Troubleshoot VIC-1 with FM Radio (MOS 31V)

Step	Action	Indication	Correction
250.	Turn all squelch switches to ON		
251.	Turn all volume controls to midpoint position		
252.	Connect handset to C-2297 rad jack J902		
253.	Turn C-2297 monitor switch to ALL		

Resources Required

a. Materials: Preparation of the draft task analysis depends on descriptions of the equipment and procedures that usually can be found in:

- Technical Manuals (TMs)
- Soldiers Manuals (SMs)
- Programs of Instruction (POIs) and Lesson Plans

b. Personnel: The amount of personnel time required to prepare the draft task analysis, observe task performance, and then document the final task analysis depends primarily on the availability of thorough documentation on the task and the scope of the task in terms of the number of steps. The following figures are estimates of the time required for a high driver task of approximately 100 steps. The "TOTAL" time given assumes 4 task analyses will be required.

- For each high driver:

Position	Time Required	Activities
Proponent School SMEs	5.0 pers hrs	1 hr documentation 4 hrs demonstration
Student Demonstrator	4.0 pers hrs	4 hrs demonstration
Analysts	22.0 pers hrs	2 hrs documentation 12 hrs draft analysis 4 hrs demonstration 4 hrs revisions
Administrative	4.0 hrs.	3 hrs draft analysis 1 hr revisions

- TOTAL Personnel, assuming 4 high drivers:

140.0 pers hrs

c. Elapsed Time: The length of this step depends primarily on the number of high drivers, the availability of documentation for preparing the draft task analyses, and the ease of scheduling a demonstration of task performance. A reasonable estimate of the elapsed time for this step is between 4 and 8 weeks for 4 high drivers.

Step 7. Conduct Performance Analysis

Identify the knowledge, skills, and abilities (KSAs) needed to learn and accomplish any problem steps included in each high driver task, and to accomplish the task as a whole.

Purpose

This step continues the analysis of each high driver task to identify the knowledge, skills, and abilities (KSAs) required to learn and perform both the task as a whole and any problem steps that appear in the procedure. Its purpose is to establish the requisites that, if not met, will preclude the task from being performed successfully. During this step, the results of the task analysis are examined to identify any specific problem steps in the procedure, to create a list of generic steps needed to perform the task, and to specify the KSAs required to accomplish both any problem steps and the task as a whole. It should not be assumed that the KSAs required are consistent with the requisites for entry to an MOS or assured by the training provided.

Identifying the KSAs required for a task, and communicating these using adequately descriptive terms, may require assistance from a personnel specialist. Generally, knowledges refer to the facts and principles that support task performance, such as knowing there are 6400 mils in a circle or knowing the difference between a series and a parallel circuit. Skills are the generic units of performance that are combined within a task, such as operating a gearshift on a vehicle or welding a seam. Abilities are the mental and physical qualifications that allow an individual to learn a task and then perform it up to standard, such as being able to understand a schematic drawing or having the strength to lift a projectile.

Procedure

This step in the ECA procedure consists of three substeps:

a. Identify any problem steps. Examine the results of the task analysis to determine whether any individual steps comprising the task are particularly difficult to learn or perform. Problem steps are ones that appear to be unusually difficult to perform or often are performed incorrectly. These are likely to be steps that are different from other steps in the procedure because they depend to an unusual degree on the performer's precision, strength, dexterity, judgment, or knowledge.

b. Determine the task's generic steps. A "generic" step is one that characteristically is part of the procedure for many tasks performed by that MOS, such as "adjust radio frequency" or "reconnect hose clamp". Generic steps are not specific to any particular equipment component or system, but together they should account for nearly all of the steps in the procedure for the task that was analyzed. Steps that cannot be subsumed under generic steps also should be identified. Generally, one or more generic steps will be required for each different verb used in the element statement of the task analysis, such as "adjust", "inspect", "remove", "calculate" or "supervise".

c. Specify the task's KSA requirements. Most of the skills required to perform the task can be derived directly from the list of generic steps. For example, the skill represented by the generic step "measure voltage" is "use a voltmeter (multimeter)". Knowledge requirements are those facts and principles that are assumed necessary to perform the steps in the task, such as knowledge of nomenclature, of weights and measures, of the products of multiplication, or of the elements of electricity. Aptitude requirements are the less teachable determinants of performance, such as "reading level", "dexterity" or "judgment". Not all KSA requirements have to be specified. For an ECA, those that are characteristic of most soldiers entering the Army, such as "auditory acuity", can be omitted.

Anticipated Results

It may not be possible to identify specific problem steps for many high driver tasks and, if there are any, they are not likely to account fully for the task being a high driver. A problem step is most likely to emerge when the step cannot be described easily in words, involves special tools such as a torque wrench, or requires some relatively unusual skill, knowledge, or ability.

Determining the generic steps that characterize a task is not difficult if the task analysis was carefully prepared. Most tasks should not involve more than 10 to 20 generic steps regardless of the number of steps in the procedure. Identifying the KSAs corresponding to the generic steps also is not difficult, although identifying the particular KSAs needed to attain proficiency on any problem step may be more challenging.

Most often, any reasonable description of the personnel qualifications that contribute to successful task performance will be satisfactory for the purpose of an ECA.

AFAS Illustration

A performance analysis was conducted on the MOS 63T task, "Troubleshoot Power Distribution System of Bradley-MLRS Vehicle" that had been identified as a high driver. The following generic steps accounted for all of the specific steps covered by the task analysis of this task:

- Select the correct troubleshooting tree in the TM
- Hook up and self-test the test equipment
- Measure voltage (or resistance)
- Inspect indicators
- Operate switches
- Identify cable connector test points
- Identify internal test points
- Remove-replace cable connectors
- Remove-replace access plates
- Manually traverse turret
- Notify supervisor when directed by troubleshooting tree
- Follow safety precautions
- Complete DA Form 2404

The following knowledge, skills, and abilities were identified as necessary to perform these generic steps. The last skill, "Use an inspection mirror" is an unusual requirement for performing the one step in the procedure that was identified as a problem step during the task analysis. This is a skill needed for performing the generic step "Identify internal test points".

Knowledge

- Basic electricity as taught in AIT

Skills

- Follow path in TM troubleshooting tree
- Use a STE-M1
- Use a multimeter
- Use hand tools

- Connect and disconnect cables
- Identify test points
- Locate and inspect indicators
- Locate and operate switches
- Manually traverse turret
- Remove and replace cables and parts
- Use an inspection mirror

Abilities

- Average reading ability
- Average dexterity and motor abilities

Resources Required

a. Materials: No additional materials are required for this step beyond the completed task analysis.

b. Personnel: The amount of personnel time required to conduct a performance analysis depends on the number of high drivers being examined and the complexity of the tasks. The following figures are estimates for a single high driver task of approximately 100 steps. The "TOTAL" time given assumes a performance analysis for 4 high driver tasks.

- For each high driver:

Position	Time Required	Activities
Analysts	4.0 hrs	4 hrs analysis

- TOTAL Personnel, assuming 4 tasks:

16.0 pers hrs

c. Elapsed Time: The length of this step depends primarily on the number of tasks examined. A reasonable estimate of the elapsed time for this step is 1 week for up to 4 tasks.

Step 8. Identify Deficiencies

Identify sources of deficiencies contributing to the task being a high driver in terms of:

- manpower
- personnel
- training
- equipment design
- task procedures
- supporting tools, manuals, and job aids
- performance conditions

Purpose

In this step, the likely causes of a task being designated a high driver are identified. More than one contributing cause may be found as, for example, when a procedure is too complex considering the KSAs of soldiers in that MOS. Possible causes should be sought in seven areas:

- Manpower. Are sufficient numbers of personnel available in fielded units to perform the task when required? Does performance of the task consume more time than is available? Is more than one qualified person required to perform the task? Are an adequate number of personnel capable of performing this task being retained in appropriate assignments?

- Personnel. Do personnel entering the MOS have the KSAs required to learn and perform the task to standard? Are personnel who have the required KSAs being retained in the MOS? Are the KSAs required for this task substantially different from those required by most other tasks assigned to this MOS?

- Training. Is the task included in the institutional training program for the MOS? Have all soldiers likely to be assigned the task received training on it? Does institutional training result in the attainment of adequate proficiency? Is sufficient on-the-job training and practice provided to sustain proficiency?

- Equipment Design. Are there any features of the equipment that preclude proficient and efficient task performance, such as weight, access, labeling, or unusual configurations? Does the equipment design tend to increase the likelihood of errors during task performance? Are there characteristics of the equipment that threaten personnel safety or result in the likelihood of damage?

- Task Procedures. Are the procedures simple, straightforward and fully described? Does the procedure have to be memorized? Is the soldier responsible for the task required to perform several steps concurrently or have to think about preceding or subsequent steps while performing the task? Is the task procedure linear or does it include branches? Does it have to be adapted for each situation?

- Supporting Tools, Manuals, and Job Aids. Are the necessary tools and test equipment available and does the soldier know how to use them? Are the manuals clear, well-illustrated, at the right reading level, and free of errors? Would new, additional, or improved job aids help reduce mistakes or the time needed for performance or training?

- Performance Conditions. Is the task often performed under hazardous or adverse conditions? Are there special requirements to perform the task very quickly? Do soldiers have to be in unusual positions to perform the task? Is the task particularly fatiguing?

Information needed to ascertain the causes of the task being a high driver can be derived from the task analysis, from the performance analysis, from the observations of task performance, from interviews with SMEs participating in the task demonstration, and from the pattern of subscores resulting from the ECA survey. In addition, applicable manuals, job aids and the proponent school's POI covering the task should be examined.

Procedure

All available information about the task and the soldiers who perform it should be examined in this step. When identifying deficiencies, the focus of attention should be on what makes this particular task unusual among the range of tasks generally performed by that MOS. All plausible sources of the deficiency should be listed, even if they may be influencing performance of the task by only some soldiers or under only some circumstances. Also, each deficiency may be attributable to several interrelated causes. For example, the text in the TM covering the task may be at a demanding reading level. This deficiency should be noted under "Supporting Tools, Manuals, and Job Aids" and then also under "Personnel" if the average reading skill in the MOS is not particularly high.

Once a list of suspected causes has been prepared, the entries should be assessed against the subscores from the six dimensions that originally established the task as a high driver. Although deficiencies in training may have been a possible cause, for example, this conclusion would not be confirmed if the "Learning Difficulty" and "Time-to-Train" subscores were relatively low. At the same time, a particularly high subscore may suggest some other possible cause for a deficiency. For instance, a high "Decay Rate" subscore may suggest the need for a job aid to support task performance.

Anticipated Results

Generally, it will be possible to identify at least one deficiency in each of the seven areas that could account for the task being a high driver. As many causes as possible should be identified in order to consider trade-offs when solutions to the problem are proposed. Furthermore, more pervasive patterns may emerge when several high driver tasks for the same MOS are examined. For instance, it may become apparent that many problem tasks for an MOS require mathematical calculations, suggesting renewed attention might be given to the aptitudes considered to qualify soldiers for that MOS.

AFAS Illustration

One high driver task, "Troubleshoot Power Distribution System of Bradley-MLRS Vehicle" was identified for MOS 63T. Subscores for this task relative to the average subscores for all 26 of the MOS 63T tasks surveyed are:

Subscore	High Driver Task	All 26 Tasks
Percent Performing	3.3	2.6
Task Performance Difficulty	2.4	1.7
Frequency Rate	2.8	1.9
Task Learning Difficulty	2.3	1.5
Time-to-Train	2.5	1.7
Decay Rate	2.5	1.7
ECA SCORE	293.28	44.31

The deficiency analysis for this task produced a variety of conclusions regarding possible causes for this task being identified as a high driver. Some representative examples of the conclusions regarding this task are:

- Manpower. The task is not highly manpower intensive. It is a task performed by most MOS 63T soldiers.

- Personnel. MOS 63T personnel are selected on the basis of mechanical aptitude, not the electrical aptitude required for this task. The task is one of the few electrical tasks assigned to MOS 63T.

- Training. Only some branches of this troubleshooting task are presented or practiced during advanced individual training (AIT), perhaps because any amount of troubleshooting practice is very time-consuming.

- Equipment Design. Better labeling of test points would help, as would a hinged control panel to eliminate the need for using an inspection mirror.

- Task Procedures. The procedure follows the symptom-based troubleshooting approach used for most organizational level troubleshooting rather than the more complex system-based approach. However, revisions of the Technical Manual now underway will incorporate more symptoms as starting points, which may make learning this task more difficult even if task performance time is reduced.

- Supporting Tools, Manuals, and Job Aids. The STE-M1 test device used for the task provides very little diagnostic information compared with other test equipment. The present manual appears adequate. No job aids are provided.

- Performance Conditions. No special problems attributable to performance conditions were observed or reported.

Resources Required

a. Materials: In addition to the task analysis, the array of ECA subscores for the task, the observations of task performance, and the results of interviews with SMEs, relevant information can be obtained from:

  - TMs and SMs describing the task.

  - POIs, handouts, and other materials used to teach the task at the proponent school.

b. Personnel: The amount of personnel time required to conduct a deficiency analysis depends on the number of high drivers being examined. The following figures are estimates of the time required for one high driver task. The "TOTAL" time given assumes a deficiency analysis for 4 high driver tasks.

  - For each high driver:

Position	Time Required	Activities
Proponent School SMEs	2.0 hrs	2 hrs conferring
Analysts	8.0 hrs	2 hrs conferring 6 hrs analysis

  - TOTAL Personnel, assuming 4 tasks:

40.0 pers hrs

c. Elapsed Time: The length of this step depends on the number of tasks examined. Also, this and the following step, Recommend Solutions, usually will overlap. A reasonable estimate of the elapsed time for this step is 1 to 2 weeks.

Step 9. Recommend Solutions

Identify all possible solutions with respect to manpower, personnel, training, equipment design, task procedures, supporting tools-manuals-job aids, and performance conditions that will alleviate the high driver status of the task.

Purpose

The purpose of this step is to offer suggestions to the combat and materiel developers on ways to overcome the demands on resources imposed by the high driver tasks. A variety of solutions should be proposed whenever possible, both to provide a range of alternatives and to promote the adoption of combinations of solutions. It should not be assumed that materiel or any other solutions are the most difficult or most costly to implement. Better labeling of test points, for example, might be accomplished very simply with well-placed decals and yet result in substantial savings in the time to perform the task as well as in training time.

Because an ECA focuses on a "lessons learned" approach, it does not attempt to address the overall design, capabilities, or functions of a new system. Instead, an ECA examines tasks now performed on similar systems and components to identify those that are likely to have manpower, personnel, or training implications. In many instances, these examinations of existing problems also suggest ways of improving the use of scarce resources for the already fielded predecessor and reference systems.

Procedure

Each deficit identified in the preceding step is reviewed to see if ways of overcoming it can be found. For example, an apparent shortfall in some necessary aptitude among personnel in a particular MOS could be overcome by increasing training on the task to reduce the impact of the low aptitude, by restructuring the task to make it easier to learn and perform by soldiers with lower aptitudes, or by reassigning the task to another MOS. More impactful solutions, such as changing the aptitude requirements for entry to an MOS or creating a new MOS, generally should be avoided as impractical.

Care should be taken when preparing a recommendation in order to document the deficiency it is intended to address. The new system may not require that the task be performed in the same way as is performed on the already existing system, which also could eliminate the problem. Including built-in test equipment (BITE) in the design of relevant components of the new system, for example, could substantially reduce the need for troubleshooting skills at the operator or unit maintenance level.

Anticipated Results

Generally, it will be possible to suggest one or more solutions for each identified deficit. Understandably, innovative "quick-fix" solutions will have more appeal than those that would require considerable effort to implement. All possible solutions should be presented, however, to provide alternatives for combat and materiel developers to consider. Pervasive problems that have no ready solution also should be highlighted. For instance, the broad consequences resulting from introducing electronic equipment into career fields where such equipment has not been in common use is emerging as an Army-wide problem. Even though no solution is readily apparent, calling the problem to the attention of combat and materiel developers at least will allow them to anticipate the manpower, personnel, and training implications that will result from adding complex electronic components to new weapon systems.

AFAS Illustration

Eight tasks were identified as high drivers from among the 37 tasks examined in MOS 31V. All but one of these tasks involved troubleshooting radios or other electronics equipment in the field.

The outstanding deficiency affecting all eight of these high driver tasks was the poor quality of the TM procedures available to support both learning and performance. As presented in the TMs, these procedures contain numerous errors and inconsistencies, and require the user to depend heavily on difficult-to-understand schematic diagrams. Qualifications for entry to MOS 31V are modest. While these soldiers should be able to develop proficiency at organizational level checkouts and troubleshooting communications equipment using "symptom" techniques based on an explicit, step-by-step guide, they cannot be expected to fully master "system" techniques that are based on the use of schematics as they now are required to do.

Significant improvements in the procedures should substantially improve the quality of MOS 31V performance, reduce performance time, and shorten training time. Although the communication equipment currently maintained by MOS 31V is due to be phased out as more modern SINCGARS equipment enters the inventory, an inexpensive investment in clearer, more accurate, and more easily used troubleshooting guides would yield a worthwhile return. Also, the "lessons learned" with respect to these high driver tasks should be considered in the design of procedures and TMs for organizational maintenance on SINCGARS.

Resources Required

a. Materials: No additional materials or references are required for this step.

b. Personnel: The amount of personnel time required to propose solutions depends on the number of high drivers being examined and whether the tasks are related. The following figures are estimates of the time required for one high driver task. the "TOTAL" time given assumes solutions are being proposed for 4 unrelated high driver tasks.

- For each high driver:

Position	Time Required	Activities
Analysts	6.0 hrs	6 hrs analysis

- TOTAL Personnel, assuming 4 tasks:

24.0 pers hrs

c. Elapsed Time: The length of this step depends on the number of tasks being examined and whether the tasks are related. Usually, work on this step will overlap with the preceding step, Identify Deficiencies. A reasonable estimate of the elapsed time for this step is 1 to 2 weeks.

Step 10. Prepare an ECA Study Report

Document each of the steps in the ECA to communicate what was done and what results were obtained for each step.

Purpose

The findings from the ECA should be communicated both to the combat and materiel developers responsible for the new weapon system and to the proponent schools for the MOSs examined. Because not all likely users of the report will be familiar with an ECA, it is important to at least summarize the process. Data on all tasks surveyed, whether they turned out to be high drivers or not, should be included. This information will contribute to the growing ECA data base that will be increasingly valuable as other new weapon systems are planned. Also, the data base will facilitate the kinds of studies that cut across weapon systems and bring to light pervasive problems that may have implications for Army-wide manpower, personnel, and training efforts.

<u>Procedure</u>

The following sections are recommended for an ECA report:

- <u>Introduction</u> describing the purpose of the study, the ECA methodology, the conceptual weapon system being addressed, and assumptions made affecting the scope of the study.

- <u>Survey Findings</u> listing all tasks surveyed, by MOS, with ECA subscore results, the ECA total task score, and the number of SMEs surveyed.

- <u>High Driver Analysis</u> containing the findings of the task analysis, the deficiency analysis, and the recommended solutions for each high driver identified.

- <u>Discussion</u> considering any overall conclusions reached regarding the ECA study's findings or Army-wide implications of the results for manpower, personnel, and training.

<u>Anticipated Results</u>

The ECA study report should be addressed primarily to combat and materiel developers responsible for the new weapon system. It should identify tasks required for the new system that, based on experience with the tasks required to operate and maintain predecessor and reference systems, are likely to place heavy demands on the manpower, personnel, or training resources that will be needed. It also should document the results of the analyses performed on these high driver tasks to highlight both the deficiencies uncovered and the solutions proposed for alleviating these deficiencies.

<u>Resources Required</u>

a. Materials: No additional materials or references are required for this step. However, if any prior ECA studies have been conducted that cover the same, or similar tasks, the results of these studies should be reflected in the report.

b. Personnel: The amount of personnel time required to prepare the report depends on the number of MOSs examined and the number of high drivers identified. The following figures are estimates of the time required for a study of 10 MOS resulting in the identification of 4 high drivers.

Position	Time Required	Activities
Analysts	40.0 hrs	40 hrs report
Administrative	20.0 hrs	20 hrs report

TOTAL Personnel, assuming 10 MOSs and 4 high drivers:

60.0 pers hrs

c. Elapsed Time: The length of this step also depends on the number of tasks surveyed and the number of high drivers uncovered. A reasonable estimate of the elapsed time for this step is 2 to 3 weeks.

RESOURCE REQUIREMENTS FOR AN ECA

Considerable time and resources may be required to conduct a comprehensive ECA, particularly if the planned system is complex and if several different antecedent systems are identified as predecessor or reference systems. To aid in planning an ECA, estimates of resource requirements and elapsed time to perform the steps in the study are summarized on the following page for two hypothetical new weapons. The first is for a relatively simple new weapon, such as an improved antitank mine. Only one operator MOS and one maintenance MOS might be involved, no more than a few dozen tasks would have to be considered, and possibly one high driver would emerge. The second is for a somewhat more complex, crew-served weapon, such as a new armored vehicle or field communications system. Perhaps ten MOSs would perform relevant tasks, several hundred tasks would have to be examined, and possibly four high drivers would be identified for further analysis. A hypothetical system of this second type was used to estimate the resources and elapsed time required for the steps described in this guide.

Table 1

Resource Requirements for an ECA Study

Requirements for a Relatively Simple New Weapon (2 MOSs, 30 tasks, 1 high driver):

Step	Combat Developers	SMEs	Analysts	Administ.	Elapsed Time
1. Study Initiation	4.0 hrs		4.0 hrs	1.0 hrs	0.2 wks
2. Identify MOSs	2.0 hrs		2.0 hrs	1.0 hrs	0.2 wks
3. Prepare Task Lists		24.0 hrs	32.0 hrs	8.0 hrs	4.0 wks
4. Collect Data		40.0 hrs	12.0 hrs	8.0 hrs	4.0 wks
5. Calculate ECA Scores		4.0 hrs	6.0 hrs	2.0 hrs	2.0 wks
6. Conduct Task Analyses		5.0 hrs	22.0 hrs	4.0 hrs	2.0 wks
7. Conduct Perf. Analyses			4.0 hrs		0.4 wks
8. Identify Deficiencies		2.0 hrs	8.0 hrs		1.0 wks
9. Recommend Solutions			6.0 hrs		0.4 wks
10. Prepare a Report			20.0 hrs	10.0 hrs	1.0 wks
TOTALS	6.0 hrs	75.0 hrs	116.0 hrs	34.0 hrs	15.2 wks

Requirements for a Relatively Complex New Weapon (10 MOSs, 200 tasks, 4 high drivers):

Step	Combat Developers	SMEs	Analysts	Administ.	Elapsed Time
1. Study Initiation	16.0 hrs		8.0 hrs	2.0 hrs	0.5 wks
2. Identify MOSs	6.0 hrs		6.0 hrs	2.0 hrs	0.5 wks
3. Prepare Task Lists		92.0 hrs	132.0 hrs	40.0 hrs	10.0 wks
4. Collect Data		200.0 hrs	60.0 hrs	40.0 hrs	8.0 wks
5. Calculate ECA Scores		20.0 hrs	30.0 hrs	10.0 hrs	5.0 wks
6. Conduct Task Analyses		20.0 hrs	88.0 hrs	16.0 hrs	8.0 wks
7. Conduct Perf. Analyses			16.0 hrs		1.0 wks
8. Identify Deficiencies		8.0 hrs	32.0 hrs		2.0 wks
9. Recommend Solutions			24.0 hrs		1.0 wks
10. Prepare a Report			40.0 hrs	20.0 hrs	3.0 wks
TOTALS	22.0 hrs	340.0 hrs	436.0 hrs	130.0 hrs	39.0 wks

REFERENCES

Department of the Army (1986, July). <u>Early comparability analysis (ECA): Procedural guide</u>. Alexandria, VA: U.S. Army Soldier Support Center-National Capital Region.

Klaus, D.J., Niernberger, K.J. & Maisano, R.E. (in preparation). <u>Methodological considerations in applying early comparability analysis (ECA)</u>. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Klaus, D.J., Niernberger, K.J. & Maisano, R.E. (in preparation). <u>Application of early comparability analysis (ECA) to the advanced field artillery system (AFAS)</u>. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

APPENDIX

This appendix contains:

- Blank ECA Survey Instrument, a blank copy of the instrument used to conduct the survey of SMEs for their ratings of tasks,

- Blank Task Analysis Form, a blank copy of the SME biographical information form, and

- Blank SME Biographical Form, a blank copy of the form used to list the steps performed when a task analysis is accomplished.

ECA

QUESTIONNAIRE

MOS:
COMPONENT:

	A. PERCENT PERFORMING 1 = 1% - 25% 2 = 26% - 50% 3 = 51% - 75% 4 = 76% - 100%	B. TASK PERFORMANCE DIFFICULTY 1 = Not Difficult 2 = Somewhat Difficult 3 = Moderately Difficult 4 = Very Difficult	C. FREQUENCY RATE 1 = Seldom (annually) 2 = Occasionally (semi-annually) 3 = Often (monthly) 4 = Frequently (weekly/daily)	D. TASK LEARNING DIFFICULTY 1 = Not Difficult 2 = Somewhat Difficult 3 = Moderately Difficult 4 = Very Difficult	E. TIME TO TRAIN 1 = Less than 3 hours 2 = 3 up to 6 hours 3 = 6 up to 9 hours 4 = 9 hours or more	F. DECAY RATE 1 = Low 2 = Moderately Low 3 = Moderately High 4 = High

SME BACKGROUND INFORMATION

NAME ______________________________ RANK-GRADE ____________

LOCATION ____

YEARS IN SERVICE ____________ PRIMARY MOS ____________

SECONDARY MOS(S) _____________ _____________ _____________

CURRENT ASSIGNMENT ____

YEARS OF ARMY SUPERVISORY EXPERIENCE _____________

YEARS OF ARMY INSTRUCTOR EXPERIENCE ______________

Please check the vehicles or weapons systems covered by your expertise:

______	M109 Series Howitzer	______	M113 Series (includes TOW, FISTV)
______	M110 Series Howitzer	______	M548 Carago Carrier
______	M2 Bradley FV	______	M1 Series Tank
______	MLRS	______	M60 Series Tank
______	Wheeled Vehicles	______	Towed Artillery

TASK ANALYSIS

Step	Action	Indication	Correction

Working Paper MSG 88-02

LHX MANPRINT INTEGRATION

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LHX MANPRINT INTEGRATION

CONTENTS

INTRODUCTION

Overview

This project was initiated early in the LHX (Light Helicopter Experimental) MANPRINT (Manpower and Personnel Integration) assessment process. The purpose of this effort was to develop a method that integrates the results of the various processes and methodologies addressing MANPRINT program areas. The result of the integration was intended to be a MANPRINT assessment package compiled on a timetable that permits interaction with the technical hardware design. The Milestone I and II Army Systems Acquisition Review Council (ASARC) decision briefing was chosen as the first point at which a complete MANPRINT summary would be formulated.

Approach

When this project was conceived, there was no methodology for the management of MANPRINT information nor was there consensus among the Army as to exactly what information and in what form was pertinent to MANPRINT. Therefore, the goals of this effort were to:

1) determine what information was pertinent,

2) develop a method to manage the information, and

3) consolidate the information into a MANPRINT assessment package in preparation for ASARC.

Three major characteristics of the information required for an affirmative decision from the ASARC served to unify the direction of the effort. Those characteristics are the ability to: (1) demonstrate that the LHX is operable; (2) demonstrate that the LHX is supportable; and (3) express the operability and supportability by quantifying the requirements of each MANPRINT domain and the degree to which fulfillment of the requirement can be assured.

It was determined that the information when consolidated should be positively oriented because if it becomes clear that the LHX is either not operable or not supportable, corrective action must be taken prior to ASARC. It is contrary to the decision review process to request approval to proceed if the evidence indicates that continuing is imprudent. The concept that is presented at Milestone I/II must appear to be feasible within the established risk parameters. If it is not feasible, a Milestone I/II decision review should not be scheduled. Therefore, the inability to provide evidence that a domain is operable or supportable becomes the criteria for designating a possible issue that should be resolved prior to Milestone I/II.

The third characteristic, quantification, is based on the conclusion that the most convincing evidence of attainment of a resource capability is the comparison of a numerically defined requirement with the projected outcome of a plan or approach.

For the purposes of this analysis, operability is defined as the capability of all personnel affected by the system to successfully perform all of their system related tasks to a standard sufficient to enable the accomplishment of the mission and thereby effectively neutralize the threat without exposing any personnel to unacceptable risks. Therefore, operability is dependent on health hazard, safety and human factor MANPRINT domains as they pertain to the tactical, garrison or training environment.

Supportability in this context is defined as the ability to recruit, train and sustain those individuals in the force necessary to attain and maintain operability. Supportability, therefore, is dependent upon the remaining MANPRINT domains; manpower (numbers of individuals of specific descriptions), personnel (descriptors and management policy and procedures relating to individuals throughout their tenure in the Army), and training. Again, this is an all encompassing criteria in that it pertains to the entire spectrum of events and activities relative to the subject weapon, not just the tactical employment of the weapon system.

Operability and supportability are operationalized by two questions. First, can this soldier operate this machine with this training? And second, can the soldier and the training be made available? The problem then is to define the soldier, the machine (to include interface characteristics) and the training required and also to assess the Army's ability to recruit, train and manage the career of the soldier. The apparent simplicity of the question belies the complexity of the problem. An appropriate comparison might be chinese boxes nested one inside the other. Every element has many sub-elements within it and the answer to every question seems to pose another question. For example, if the answer to enabling the soldier to accomplish a series of missions is to automate tasks, the addition of the automated hardware poses its own series of MANPRINT questions. In the case of aviation and aviation support, the presence of computer operations and support personnel is limited. The inherent complexities of fielding a new weapon make it necessary to establish a systematic approach to assess system operability and supportability.

The third characteristic, quantification of the domain, establishes the research goal. Ideally, each domain should be expressed in numerical terms that describe the requirement and the total systems response to the requirement. Table 1 provides examples of the terms in which the final status of each domain might be expressed.

Table 1

Quantification of MANPRINT Domains

Manpower	Required strengths Manpower authorization criteria Basis of issue
Personnel	Recruiting rates Re-enlistment rates Attrition rates Promotion rates Trainees, transients, holdees and students (TTHS) time Education level
Training	Number of courses Course lengths Instructor ratios Equipment ratios
Human Factors	Aptitudes Height Weight Medical profile Vision acuity Reaction time
Health Hazards	Dose rates Mortality rates Morbidity rates
Safety	Accident rates Exposure rates and times Lost time rates

The methodology used was an iterative process resulting in a topical outline that evolved from a review of acquisition documents. The six MANPRINT domains provided the basis for the development of the outline. Documents were reviewed to extract pertinent information addressing the questions of system operability and supportability for each domain. As the acquisition documents were reviewed and through conversations with members of the acquisition community, the research team was able to expand and define the outline to include subdivisions for each of the six domains. For example, the domain Human Factors was subdivided to address system operability and supportability for the areas of Human Characteristics, Anthropometric Data, System Interface Requirements, and Human Performance. A complete outline structure is presented in Appendix A.

Once the outline had been developed, an exhaustive research effort was undertaken to quantify each of the domains as completely as possible. That effort included a more detailed literature search which included a review of the documents listed in Appendix B as well as participation in numerous meetings and briefings held by the various members of the acquisition community.

The effort resulted in a MANPRINT assessment package presented in outline form. Unfortunately, the results of the Advanced Rotorcraft Technology Integration (ARTI) effort, the Cost and Operational Effectiveness Analysis (COEA) and the Cost and Training Effectiveness Analysis (CTEA) were not available to the research team making conclusive results impossible. It is the determination of the research team that complete information is necessary to develop a complete assessment and presentation of the LHX MANPRINT condition.

Report Organization

The results of the research effort are presented in the MANPRINT Affordability Section of this report in the form of the outline described above. The Conclusions Section presents the research team's conclusions based upon the information available. In addition to the assessment package presented in the MANPRINT Affordability Section, the information obtained was applied to the critical questions specified in the System MANPRINT Management Plan and a outline for presentation of information for the pre-ASARC MANPRINT review. The responses to the questions are presented in Appendix C and the pre-ASARC MANPRINT review briefing outline is included in Appendix D.

MANPRINT AFFORDABILITY

Human Factors

Human factors includes a discussion of the description of the soldier in terms of his innate ability to perform tasks from a cognitive and physical perspective.

Human Characteristics

This topic encompasses sufficiency of soldiers' aptitudes in terms of the forces acting that cause aptitude requirements to change.

Operators. It has not been demonstrated conclusively that the aptitudes specified for aviators will be suitable to enable operation of the LHX.

The LHX Tentative Qualitative and Quantitative Personnel Requirements Information (TQQPRI) and the Target Audience Description (TAD) assume that the aviator, as currently described in the appropriate personnel regulations, will be able to operate the LHX. The LHX Required Operational Capability (ROC) implies the same by requiring that the LHX must not increase skill numbers or levels. However, conclusions about the sufficiency of those aptitudes, mental category, or physical characteristics cannot be drawn at present. To the contrary, the LHX Trade Off Analysis (TOA) states that the pilot may require capabilities superior to those of current pilots. There are several concepts that would tend to drive aptitude requirements up insofar as they change the types and mix of skills and increase the workload particularly in the cognitive area. Specific concepts that change operator skill requirements include the following:

a) The all-weather concept changes the skills required to navigate by introducing the digital database mapping system. The concept may cause the workload to increase substantially depending upon the accuracy and resolution of the marking system and the effectiveness of the automated terrain following and terrain avoidance system.

b) Multi-mission affects aptitude by requiring operational proficiency in a larger number of tasks or set of tasks simultaneously.

c) Single pilot has the obvious workload increase attendant to elimination of the co-pilot. Single pilot changes the nature of tasks so as to increase the emphasis on the operation and management of the automated systems designed to absorb many of the co-pilot functions.

Maintainers. In light of the application of advanced technology and the sketchy definition and implementation of two-level maintenance, the sufficiency of the aptitudes required of maintainers specified is questionable.

Similar to the operators, the TQQPRI, the TAD, and, by implication, the ROC specify that the current maintenance soldier must be able to support the LHX. However, the application of technology particularly in the areas of electronics and automation, coupled with increased density of mission equipment and military occupational speciality (MOS) consolidations, make the requirement difficult to attain. Two-level maintenance and the accompanying removal of all piece part repair tasks to depot level have been put forward as the solution to skill creep. However, for that to be successful in a combat theater, either the aircraft must be so reliable as not to require any in theater maintenance in support of the supply system or civilian support must be available in the combat theater. Although not impossible, both of those are highly unlikely. Furthermore, as an alternative solution to civilian support in a combat theater, it has been proposed that the aviation classification repair activity depots (AVCRADs) be activated to provide piece part repair support in theater. The rationale seems to be that the AVCRADs are staffed with civilians and, therefore, don't impact the Army personnel system. However, once activated the AVCRADs must rely on the Army personnel system for replacements which will in turn require that some of the personnel in the replacement stream will need aptitudes sufficient to perform piece part repair on LHX systems.

The following concepts have been included in the LHX program and will tend to hold down the aptitudes required by mainframes at the user level:

a) BIT/BITE(built-in test/built-in test equipment)-- provided it performs up to the established goal,

b) Two-level maintenance,

c) Line replacement unit (LRU) maintenance, and

d) On condition maintenance.

As yet, the military role in the accomplishment of depot maintenance has not been determined. However, should military personnel be required, the following concepts would tend to increase the aptitudes required:

a) BIT/BITE - To understand the operation and perform the troubleshooting that BIT/BITE does not cover.

b) LRU Maintenance - To perform piece part repair on technologically advanced components and to operate sophisticated automated test equipment.

c) All-weather - To perform maintenance on advanced digital equipment.

d) Cockpit automation and integration - To diagnose (beyond BIT/BITE capability) troubles and perform maintenance.

Although not otherwise mentioned, the Human Factors Engineering Analysis (HFEA) recommends analysis of the aptitudes required for maintenance of composites. The CTEA is expected to address this issue in detail and the HFEA recommends resolution prior to full-scale development (FSD).

Anthropometric Data

This section includes discussion of size, strength, and gender in terms of the apparent requirement to perform the necessary functions and the forces acting upon the requirement.

Operators. Current aircraft are criticized for having cockpit and aircraft control configurations that do not fit the pilot well, causing the pilot to slouch and thereby reducing visibility and creating the hazard of spinal damage. However, the anthropometric requirements have been clearly specified in the draft request for proposal (RFP) and there is no reason to believe that the LHX configuration will not be an improvement. Among the expected improvements are more seat adjustments and use of a side-arm-controller.

Maintainers. To date, there does not appear to be any anthropometric issues or concerns with respect to maintainers.

System Interface Requirements

System interface requirements are those design characteristics necessary to enable certain performance, as well as those that are required of one subsystem to preclude it from hindering the performance of another subsystem.

Operators. There remain serious questions as to the development of aircraft systems that the pilot can use effectively to accomplish more complex missions. It does not seem to be a question of each systems ability to perform its individual function, but much more whether the systems can be arranged and operated concurrently. For example, can the pilot engage a series of off-axis targets while flying nap of the earth (NOE) at night in adverse weather and still monitor the caution and warning system and the radar warning system sufficiently to take appropriate emergency or evasive action if the situation dictates? The research indicates that technology is adequate to accomplish each of those tasks separately. It remains to be seen if the switches, knobs, buttons, and displays can be positioned and integrated in such a way that the pilot can physically operate all of the system controls as well as see and react to all information displays. This issue is also an integral part of the workload question which will be discussed later.

The HFEA has raised specific questions related to the pilot and system interface for the following areas:

Helmet Mounted Displays,
Digital Data Base Map System,
Crew Station Lighting,
Night Vision Pilotage System, and
Communication and Voice Recognition.

Helmet Mounted Display (HMD) is desirable for single pilot operations and low risk (Army Science Board (ASB) Final Report, p. 8). The TOA, however, asserts that a limited amount of information can be placed on the HMD display (TOA, p. R-28) and based on their assessment of current technology, full capability of HMD will most likely not be available for initial fielding of the LHX (TOA, p. R-27). The TOA's major area of concern with the HMD deals with the limitations of field of view (FOV) and field of regard.

According to the HFEA (reference number 1-1/17/86), the Night Vision Electro-Optic Center will conduct flight tests to evaluate the effects of FOV and resolution. Hughes Aircraft Company has conducted simulation evaluations of HMD FOV trade-offs. The results are to be available shortly. Additionally, each ARTI contractor is using existing technology to demonstrate integrated cockpit concepts which include HMD.

Both the TOA (p. R-26 and R-67) and the ASB Final Report comment on the necessity for real-time, accurate digital mapping systems. The ASB characterizes the technological risk of attaining the digital mapping system as low, but the TOA calls for placing a high priority on improvement in this area. The HFEA (14-1/18/76) states that the accuracy and resolution of the digital data base seems to be less than what is required for NOE adverse weather navigation. In light of those concerns, the specifications in the RFP for level 1 and 2 digital feature analysis data and for coverage of 300 km are not sufficient to close the issue. Furthermore, the explanation put forth that improved navigation will allow the pilot to concentrate his attention on the outside environment is moot when visibility is obscured by weather or battlefield obscurants.

The TOA does not address a night vision pilotage system (NVPS) as an issue. However, the HFEA (37-1/17/86a) characterizes a NVPS with the requisite night vision sensor and wide FOV with suitable sensitivity and resolution as a high risk. The LHX Program Manager (PM) responds that the RFP establishes stringent requirements that exceed the capabilities of existing helicopter systems. The NVEOL (Night Vision and Electro-Optics

Laboratory) is conducting a technology development program that will develop the necessary components. NVEOL is also conducting flight tests to determine the optimum NVPS and HMD FOV for the LHX. The ARTI program is addressing this issue too and indicates that the FOV can be slightly reduced. The PM plans to initiate a program for further risk reduction as a follow up to ARTI. The program is intended to start in late 1986 and will include brassboard and breadboard demonstrations of critical mission equipment packages (MEPs). Until these efforts are completed and indicate otherwise, the NVPS appears to be a high risk.

The HFEA (12-1/17/86) determined that improvement in speech intelligibility is necessary. Also, the TOA and the ASB both identified improved voice recognition as essential for the developing system and both expressed serious doubt that the technology could be adequately improved for the LHX. Therefore, in spite of the firm specifications cited in the RFP, improved voice recognition remains an issue until the required capability is demonstrated. The Army Simulation Evaluation Team (SET) will evaluate the audio distribution and voice interactive control display systems on each of the ARTI contractor's simulators.

The HFEA (19-1/17/86) expresses concern that the state of maturity of voice recognition technology will not allow the degree of recognition accuracy required, particularly under the stress, noise, and workload levels imposed by combat. The LHX PM response indicates that the RFP requires a voice recognizer and speech synthesizer capable of speaker dependent connected word voice recognition with a 95% accuracy. The PM also points out that some ARTI contractors have employed limited voice recognition and have discovered that touch controls are a faster and better workload reducer. On the other hand, HFEA (32-1/17/86) expresses concern that there may be too many switches and buttons planned for installation on the side-arm-controller. In both cases the PM's recommendation is to monitor the ARTI evaluations.

The HFEA (13-1/17/86) raises concern that the utility copilot will not have adequate night vision capability. The LHX PM responds that the RFP specifies night vision goggles with incorporated flight symbology thus obviating the need to refer to cockpit instrumentation.

HFEA (29-1/17/86a) expresses concern for crew station lighting as well as lighting for maintenance and forward arming and refueling points in that, if the lighting is not properly integrated into the system there is potential for a critical adverse impact on the ability to accomplish night missions. The LHX PM responds that the lighting requirements are adequately covered in the RFP to include provisions for mockup and simulation demonstrations.

<u>Maintainers</u>. The research did not indicate any significant difficulties dealing with the physical interface of maintenance

personnel and the conceptual LHX with the exception of some general concerns expressed by the HFEA.

The HFEA has recommended placing a high priority on NBC and cold weather clothing development to reduce any negative impact. This would appear to be more of a problem of existing clothing design than an aircraft design problem but should be considered none the less.

The HFEA recommends ensuring the ease of accessibility for trouble shooting component replacement and repair under all expected operational conditions. From a review of current system documentation, there is no indication that attaining that accessibility will be difficult.

The HFEA (23-1/17/86) also expresses concern over the impact of metrification particularly if the LHX employs a mix of English standard and metric. The LHX PM responds that metrification is a Department of Defense program to ultimately convert the Army to the metric system. Although there are some impacts of applying the metric system to the LHX, the decision has been made that the LHX must be metric. Therefore, metrification becomes an element or consideration in other analyses, but does not stand alone.

Human Performance

This section deals primarily with the workloading of the individual. That is the combined effect of aptitudes, training, the character of the system interfaces, and the frequency order and combinations in which tasks present themselves. In the case of the LHX, it pertains more to the cognitive workload than the physical workload.

Operators. Given current information, the ability of a single pilot to accomplish all missions under all flight conditions is doubtful. The primary concern in the area of human performance is the reduction of workload required to accomplish single pilot operations. Several concepts have been proposed for the LHX which have an impact on operator workload. These concepts are single pilot operations, an integrated and automated cockpit, LHX performance of multiple missions, development of an air-to-air capability, continuous operations, and all-weather operability. These concepts introduce additional pilot workload attributable to the management of more equipment and information, and the reduction of the crew size. Should workload become excessive, the pilot will either perform less effectively or, in extreme cases, be unable to perform. Either result decreases the LHX system's effectiveness and reduces survivability. To counter this effect, and comply with the ROC requirement that the number of skills and skill levels for air crew will not exceed those required for current light fleet operations, functions related to flight control, threat assessment, information and data display, target acquisition and others are being automated and improved.

The development and validation of these technologies is critical to keeping pilot workload within practical limits.

Pilot workload has been an area of continuous study and concern. The ASB concluded that a crucial output of the ARTI program would be the aircrew workload profiles. The ASB also noted that certain technologies which facilitated single pilot operation were medium or high risk (voice command, automated NOE, automated terrain following, and automated obstacle avoidance). The TOA performed a human factors man-machine interface assessment and cited several technologies, to include those above, as presenting substantial obstacles in achieving a workload acceptable for single pilot operations. For example, the TOA cites the Voice Recognition System (VRS) as critical to achieving the single pilot goal and having high potential to reduce workload; but, it also reports that in simulations, voice actuated weapons systems failed to fire and that the probability of a VRS maturing during LHX initial development was low (TOA, p. R-26 and R-67). Similar findings were reported for an automatic target acquisition system (TOA, p. R-56). The HFEA (15-1/17/86a) raises the concern that the pilot will not be able to control the aircraft and engage off-axis targets. The LHX PM responds that the ability to perform such an operation has been adequately demonstrated by the back seat pilot of the AH-64.

The TOA also raised questions about the capability of low risk automated and improved technologies to reduce workload. One finding (TOA, p. R-67) stated that "Even with full automation, the single crew member will experience overloads during critical mission segments such as target engagement and reconnaissance". Results of workload simulations reported in the TOA support this conclusion, and assume that the LHX pilot will be at least as capable as today's Army pilots. The recommendation of the TOA included review and update based on ARTI and crew simulation results and consideration of a two-crew member initial LHX design if the critical technologies did not become sufficiently mature within program goals and schedules (TOA, p. R-68). The HFEA (25-1/17/86a), also conducted without ARTI results, has echoed TOA workload concerns.

The conclusions that can be drawn at this time about operator human performance are primarily related to workload. The outstanding question is whether or not ARTI will demonstrate a manageable pilot workload. Specifically, has adequate capability been demonstrated in the following areas?

a) Terrain following and avoidance flight control system
b) Voice recognition system
c) Automatic target acquisition system
d) Pilot operation under MEP degraded modes
e) Data entry into automated systems (HFEA 26-1/17/86)
f) Automation of flight controls (HFEA 27-1/17/86)

As pertains to the concern about the single pilot's ability to react to mission changes and degraded equipment (HFEA 22-1/17/86) the LHX PM responds that the RFP contains appropriate requirements and that the ARTI evaluations by the SET and the crew station verification program should be monitored.

With respect to automatic target acquisition, the HFEA (24-1/17/86a) states that automatic target acquisition is critical to operational effectiveness. The LHX PM responds that the RFP design and qualification requirements are adequate and that the issue is being evaluated by the SET during ARTI, the Army Aeroflight Dynamics Directorate as part of the LHX crew station research and development study, and other Army laboratories investigation of advanced prototype hardware which will increase the automatic target recognition technology base.

Regarding the automation of flight controls, the LHX PM responded that the RFP requires multimode flight path guidance to include hover hold, navigational modes and weapons aiming modes; as well as extensive contractor analyses, simulation, hot mockup evaluations, flight surveys, and demonstrations of those controls. Most automatic control features have been or will be demonstrated through either existing Army helicopters (AH-64A and OH-58D), the ADOCS (advanced digital optical flight control system) flight demonstrator or ARTI. National Aeronautics and Space Agency, Ames Research Center, has recently completed single pilot simulation evaluations of the ADOCS concept.

Current NBC and cold weather equipment could hamper performance. In spite of the expected hybrid environmental control system, some missions will require the crew to operate in an environmental and NBC protective posture. The LHX RFP requires a hybrid collective NBC protection system as well as placing extensive emphasis upon design, development, and testing of both variants to verify minimum adverse impact of NBC conditions (HFEA 7-1/17/86a).

Maintainers. The performance requirements for maintenance personnel hinge on the success of the LRU concept as supported by BIT/BITE and the provisions for piece part repair under the two-level maintenance concept. Success has not been assured in either of those areas.

The crux of human performance question was expressed by the Assistant Commandant of the U.S. Army Aviation Logistics School (USAALS) in a briefing to the members of the Department of the Army, Office of the Deputy Chief of Staff of Logistics in 1985, as the skill creep associated with the introduction of new technology and the two-level maintenance concept.

The requirement has been established by the ROC and the TAD that skill levels and training levels must not be increased. The ROC goes on to say that maximum use will be made of on-board trouble shooting equipment and BITE to provide real-time condition, fault location, and trend recording to the LRU level (ROC, p. 5). The intent is that those latter characteristics will simplify maintenance tasks sufficiently. The question remains, who will repair the BIT/BITE and LRU? During peace time the two-level maintenance concept places that workload at depot maintenance activities with the civilians performing the repairs. According to the Director for Combat Development of the Aviation School, (meeting of Lindquist and Cole, Directorate of Combat Developments (DCD), USAALS, Mayer and Hatch, DCD, U.S. Army Aviation Center, and Reading, LHX Program Manager Office, October 1985) that capability must be available in a combat theater within 30 days of the commencement of hostilities. The mechanism for inserting civilians in a combat theater or for training the necessary military personnel has not been addressed.

In addition to the above, the HFEA (40-1/17/86) expresses concern that the design will not adequately consider maintainer human factors issues which include:

a) Accessibility for troubleshooting and component replacement under all operational and environmental conditions and wearing the full range of clothing and protective equipment.

b) BIT/BITE simple enough for the maintainer to operate and understand.

c) Repairability and maintainability of composites.

The LHX PM responds that the RFP requires the contractor to conduct a MANPRINT analysis to include maintainers and that the reliability, availability, maintainability and integrated logistic support requirements directly address ease of maintenance.

A electronic aids to maintenance draft final report, (Horizons Technology, Incorporated, January 1987) indicates that the technology has been achieved to produce BIT/BITE that current maintenance personnel can understand. However, achieving the required reliability in the BIT/BITE has historically been extremely difficult and in many cases has not been achieved.

Other Support Personnel. The research indicated two areas of concern as to the performance of other support personnel. First, the HFEA (44-1/17/86a) has questioned whether personnel requirements for weapons loading at the forward arming and refueling point will increase. The LHX PM responds that the RFP requires the SCAT (scout/attack) aircraft to be capable of being rearmed in not more than 15 minutes by not more than three people using no special ground handling equipment. Furthermore, the RFP requires that the refueling capabilities be demonstrated during the qualification program. There is no indication that those specifications will be difficult to achieve.

The second area of concern expressed by the HFEA (16-1/17/86a) is that the manpower needs to support computer-based mission planning and maintenance activities have not been fully defined. Included in those needs are the human performance characteristics. The LHX PM response does not directly address the issue in that it resolves the problem by citing the RFP requirements for the computer systems and merely the requirement to stay within manpower constraints. It should be noted than when this report was compiled, the computer resource management plan was not available.

Health Hazards

This section presents and discusses the hazards to the individuals physical and mental well being other than intentional harm inflicted by hostile forces and accidental harm.

Operators

The central concern in the area of biomedical factors for aviators are stress and fatigue particularly as they are aggravated by single pilot operations. As with other areas sensitive to single pilot, maintaining stress and fatigue within acceptable limits is difficult. Currently, no aircraft stress, fatigue, or anxiety standards exist which are applicable to the LHX. The LHX PM recommends that Human Engineering Laboratory conduct research to develop standards.

The TOA indicates that simulated single pilot operations associated with air-to-ground and air-to-air engagements are found to cause considerable stress and that stress in combat situations is expected to be even higher (TOA, p. R-28). The HFEA asserts that the ARTI evaluations should validate the helmet design, and investigate the effects of noise, vibration, and temperature on fatigue and stress in a simulated operational environment. In addition, the HFEA has recommended an empirical study of the work rest cycle. However, the expectation is that the ARTI program will only evaluate stress and fatigue to a limited degree (HFEA 2-1/17/86, 3-1/17/86a, and 9-1/17/86a).

With respect to physical contributors to stress, weight of the helmet, vibration, and noise in addition to a single operator performing all tasks have all been related to pilot fatigue and loss of effectiveness (TOA). The ROC has required LHX to meet the latest aeronautical design standards with acoustic noise limits, vibration levels and comfort zone temperatures (ROC, p. 3). The helmet weight will be specified in the RFP not to exceed 3.95 pounds (HFEA 3-1/17/86a). The RFP also specifies noise control. The LHX vibrations will be reduced to 50% of those present in the UH-60 (HFEA 4-1/17/86). Environmental controls are specified for both the SCAT and utility aircraft. The crew will also have micro-climatic vest cooling. There is also a requirement for a crew environment survey to be conducted during flight tests of both variants (HFEA 6-1/17/86a).

Maintainers

Maintainers as well as operators will be expected to support and sustain continuous operations as required by the ROC (p. B-1). The HFEA (39-1/17/86a) expresses concern that continuous operations will create undue fatigue and stress ultimately impairing mission capability. It recommends monitoring of current LHX efforts (HARDMAN (hardware vs. manpower), logistic support analysis, two-level maintenance (2LM) study, life cycle contractor-delivered training) to see if a problem exists. The LHX PM responds that the contractor shall task load operators, maintainers and support personnel under realistic, stressful conditions. Additionally, operational testing will evaluate the maintainers capability to sustain operations under realistic, continuous mission conditions.

Safety

Safety embraces accidental hazards and their causes particularly the influence of the LHX design or method of employment on the probability of accidents.

Operators

There have been four areas of concern expressed relative to the safety of the LHX from an operator perspective. They are fatigue induced accidents, flight helmet weight, exposure to non-ionizing radiation, and crashworthiness. The requirements in the ROC for improved safety characteristics seem to have provided adequate assurance that the other major safety considerations will be satisfied. Those requirements include provisions for hazard avoidance, tail rotor protection, anti-torque control, crashworthiness, and twin engines, that will meet MIL-STD-1290B (Revised) as well as the requirement that the LHX cockpit and total system architecture of the aircraft will be fully compatible with aviation life support equipment so as not to hamper mission performance and crew ingress and egress.

Another major concern appears to be the accident rate. The TOA states that the majority of aircraft mishaps have pilot error as a contributing factor, many involving mistakes where the pilot fails to notice an emergency situation or fails to follow the procedural methods in time (TOA, p. R-32). It goes on to say that increased levels of fatigue (as discussed under Health Hazards) were found to result in an increase in the number of errors. Given the reduced number of crew members and the requirement for longer missions, we can expect a significant increase in fatigue related mishaps (TOA, p. R-37). On the other hand, the two-seat LHX is approximately 25 percent more survivable against all threats modeled (TOA, p. R-36).

Similarly, the HFEA (20-1/17/86a and 21-1/17/86) expresses concern that the single pilot may not be able to perform all emergency procedures in light of the envisioned twin engine design and that adequate consideration is not being given to the relative survivability of the one- versus two-pilot configuration. The LHX PM state that appropriate steps have been taken to ensure that emergency procedures are incorporated into LHX designs and that the procedures will be demonstrated during FSD. Additionally, the PM points out that AH-64 emergency procedures may be accomplished by either crew member singly. As pertains to crew size, the PM asserts that this issue is being addressed by the COEA and that the results will be available to support the crew complement decision during ASARC.

As pertains to flight helmet weight, the TOA states that the weight and size of the helmet with binocular HMDs and head position sensors may cause injury to the head, neck and shoulder areas (TOA, p. R-13). Subsequently, the RFP limited helmet weight to 3.95 pounds. The research did not reveal conclusively that this weight restriction resolved the weight problem.

The HFEA (8-1/17/86a) raises the question of non-ionizing radiation by recommending design to MIL-STD-1425, AR 40-46 and AR 40-583 to minimize non-ionizing radiation exposure. In response, the LHX PM pointed out that the RFP requires eye safe lasers when used in the training mode and that, although the contractor has design freedom to select and optimize the aircraft survivability equipment, appropriate health and safety standards will be set for any potential sources of non-ionizing radiation. Further the Army Environmental Hygiene Agency will evaluate the entire LHX for harmful sources of non-ionizing radiation and establish appropriate protection procedures.

Maintainers

The only safety issue raised for maintenance personnel is exposure to non-ionizing radiation. In this case the recommendation is to train soldiers in safe operation and maintenance of the emitting devices in conjunction with the establishment of appropriate administrative controls (HFEA 8- 1/17/86a).

Personnel

This section discusses the personnel management system and its interaction with and its support of the LHX. It includes discussion of status and availability of administrative data and the ability of the system to react to and accommodate the needs of an LHX equipped force by ensuring an adequate flow of the correct types of people with the correct training.

The personnel domain includes the management of all categories of personnel affected by the LHX. However, because of the limited information available, except for the brief comments that follow, the discussion is limited to personnel management of operators and maintainers.

With regard to supply personnel, the LHX is required to be supportable by the standard (multitiered) supply system (ROC, p. E-60). The indications are that the personnel burden relating to supply, other combat service support and training support personnel will be no worse and probably somewhat reduced from the current burden. Although the concepts taken individually may tend to add to the supply burden, the projected size of the authorized stockage list (ASL) and prescribed load list will be substantially reduced (as reported by LHX PM to 2LM Working Group, February 1986). Since ASLs are based on demands and order ship times, it follows that the net effect on the supply pipeline will be a reduction. Furthermore, no special handling, marking, storage or maintenance in storage tasks or procedures have been identified.

In the absence of information to the contrary it would appear that the requirement for other combat support services will decrease in direct proportion to the manpower reductions in other areas and to the reductions in support equipment in the field. Reductions in support equipment will be a side effect of the two-level maintenance concept. In accordance with the two-level concept, all automatic test equipment and most other special tools will be located at depot.

The only personnel related change discovered during the research was a brief discussion in Annex F of the ROC of awarding an additional skill identifier (ASI) for operators of training devices. Otherwise, it would appear that the personnel management requirement will decrease in direct proportion to the reductions in the overall training burden.

Aptitudes Required

Following is a discussion of the specificity, consistency, and media used for the identification of aptitudes of operator and maintainer personnel.

Operators. The ROC requires that the number of skills and skill levels shall not increase. However, the TQQPRI does not describe the pilot's characteristics. In that same vein, the HFEA (19-1/17/86) expresses concern that the current aviator and expected future recruits may not be able to operate the advanced systems expected in the LHX (see discussion on page 10 concerning human performance). The LHX PM responds that the contractors have been provided a target audience description and the publication, "I am the American Soldier", which provides a demographic portrayal of the current force and accessions beyond the year 2000. The PM further asserts that the LHX is being designed considering the current and projected aviator intelligence and skill level, and that the development program, including the ARTI program, has been structured to design the aircraft for the soldier of the future.

Regardless of the sufficiency of currently specified aptitudes, there does not appear to be a readily available effective method to determine either the required aptitudes or the degree to which individuals in the resource population might possess them. In any case, the documents pertaining to the LHX acquisition do not identify nor discuss changing the specific aptitude requirements. Additionally, the requirement to accommodate the aviator, as currently described, is not clearly stated in all of the various LHX acquisition documents, most notably the TQQPRI and MOS decision memorandum.

<u>Maintainers</u>. The TQQPRI is very specific as to the aptitudes required for maintenance personnel. The aptitudes are as specified in AR 611-201 for CMF (career management field) 67 and CMF 28. The question remains as to the sufficiency of the specified aptitudes (See the discussion on page 5 concerning human characteristics).

<u>Experience Required</u>

As with aptitudes this section deals with the specificity, consistency and media pertaining to the identification of the experience requirements for entry into each of the skills related to the LHX. The special requirements peculiar to the transition or ramp up phase are equally as important as the long term requirements.

<u>Operators</u>. The research effort was unable to locate any discussion of experience requirements for LHX aviators. Specification of experience is necessary because the five types of training indicated in the new equipment training (NET) plan consisting of: 1) developmental and operational test training, 2) initial and key personnel training (IKPT), 3) new equipment training, 4) transition training, and 5) initial qualification training, all demand significantly different experience. For example, IKPT requires aviator qualification and assignment to a specific job, NET requires qualification as an aviator and assignment to the unit being trained on new equipment, transition training only requires aviator qualification, and initial qualification training does not require any specific experience.

<u>Maintainers</u>. Historically, there have been three types of training providing initial maintenance MOS qualification for new aircraft. These are NET, transition, and individual qualification training. By necessity, each has had different individual experience requirements. To date those differences have not been identified which has the effect of reducing the

target population to zero for certain courses. For example the TQQPRI specifies the technical inspectors will be as described in AR 611-201. A LHX repairman, 67(), is required to have 18 months experience. Obviously, for the first 18 months of the LHX program, there will be no one with 18 months experience. Reason demands that in the initial phases of the program the experience requirement relates to experience as a technical inspector who can be trained on the LHX, not on a LHX mechanic who can be trained as a technical inspector. Similarly, the TQQPRI specifies that individuals to be trained as LHX mechanics must have experience in CMF 67. That has the effect of precluding any initial entry qualification training. Although initial entry qualification training need not begin immediately with the delivery of the production aircraft, it has been historically necessary to start that training in the first year of the program in order to sustain the force.

In light of the above and the various permutations possible when dealing with the entire CMF, it is necessary to establish separate and distinct experience requirements for each avenue of entry into each MOS related to the LHX. Additionally, in the event the decision is made to assign military personnel to depots, the experience question should be carefully considered since piece part repair experience is being eliminated from user maintenance.

Recruiting

This section contains a discussion of the ability to recruit and retain adequate numbers of personnel with the aptitudes and experience identified above.

Operators. Presuming successful design of an aircraft with adequate integrated and automated systems to enable a pilot of the same characteristics as those operating the current fleet to accomplish the required missions, the total number to be recruited will decrease. Therefore, recruiting less people from the same pool should not present a problem attributable to LHX.

Maintainers. The research did not discover any particular discussion of the ability to sustain the required LHX manpower levels. The assumption appears to be that recruitment and re-enlistment at current rates can be sustained. Therefore, since the preponderance of the concepts are tending toward reductions in manpower and initial analysis (HARDMAN and the Army Research Institute (ARI) organizational modeling effort) show reductions, it appears as if current recruiting rates will suffice. However, if it should become necessary to assign military personnel to depots, there will be significant changes required in the career management of depot personnel. Those changes will be driven primarily by the more complex piece part repair skills and the lack of opportunity to acquire or sustain depot repair skills at the user level. The recruitment and re-enlistment of personnel under those conditions must be studied.

Training

The training addressed below differs from the training domain in that it is only concerned with the personnel management ramifications of putting sufficient personnel through the training pipeline and insuring that training requirements can be fit appropriately in the various career patterns.

Operators. Again, assuming successful design of a single pilot aircraft and assuming accomplishment of the requirement not to exceed current training times; there will be fewer people attending training for the same or less time. Therefore, once the steady state is achieved, training from a personnel perspective will not present a problem. However, single pilot still appears difficult at best. The complexities inherent in single pilot operation make attainment of the training goal equally difficult.

Maintainers. Similar to the discussion of pilot training, if the LRU and two-level maintenance concepts are successful in conjunction with effective MOS consolidation, there will be fewer personnel to manage through the training pipeline. Therefore, training from a personnel perspective should not pose a problem. However, the ability to accomplish those goals has not been conclusively demonstrated.

The two areas that appear to present the greatest risk are electronics maintenance and depot maintenance. In the first case, the density and complexity of electronic equipment is being greatly expanded. Without judicious management, that will tend to extend the training for those personnel. An increase in the duration of individual training coupled with the retention problems inherent in the electronics field is likely to cause a personnel management problem. Depot maintenance training poses a problem from a utilization perspective. That is, the number of depot assignments will be limited tending to cause skill degradation between assignments which in turn may require refresher training, all of which complicate personnel management.

Personnel Assignment

Included in this section is a discussion of the status actions pertaining strictly to the personnel management system such as identification and viability of MOS, ASI, and SQI (special qualification identifier).

Operators. In general, the planned reduction in total operators will reduce the burden on the management of personnel. However, the tentative MOS decision does not envision additional skill identifiers, which is in direct contradiction of the ROC. ASIs and SQIs will be critical during the phase-in or transition phase. The potential for the loss of visibility of school trained skills exists for warrant officers in the additional skill areas.

Maintainers. The reduction in numbers of personnel and consolidation of MOS would appear to enable the system to manage the assignment of personnel at least as well as the current light fleet. However, the MOS decisions have not been made nor has the viability of each MOS been assured. Again the military role in depot maintenance impacts heavily.

Training

The training domain includes the actions conditions, and resources necessary to perform all training including individual qualification, sustainment, and career development training as well as collective training.

Training Effort and Cost

This section discusses the aggregation of the training burden in terms of resources and total students to be trained.

There are several major factors which will tend to contain or limit the training costs for LHX. They are:

1. The operations and support cost savings goal as described in the acquisition plan.

2. The requirement to reduce maintenance personnel.

3. The requirement that training times will not exceed current times.

4. The embedded training concept which will reduce the support requirement, tend to reduce training times, and tend to reduce costs by increasing the degree of simulation.

5. Life cycle contractor-delivered training has as its main thrust the avoidance of cost.

6. The intended MOS consolidations will reduce the number of courses which will at least reduce overhead.

7. The LRU concept simplifies tasks which simplifies training.

8. Commonality of hardware allows for consolidation of instruction.

9. Single pilot will reduce the total number of students to be trained.

Conversely, there are some factors which will tend to increase training costs. They are:

1. The multi-mission concept will require the operator to be trained to proficiency in all scout and attack tasks which will tend to increase training times.

2. Integration and automation of the cockpit will tend to add tasks due to the additional equipment on board and the additional emergency and manual backup tasks.

3. Air-to-air missile engagement will require additional tasks.

4. Two-level maintenance will tend to increase the training burden if military personnel are assigned to perform depot maintenance.

Assuming a reasonable level of success in each of the areas cited above, it appears that the combined effect will be a reduction in the aggregate training effort and cost. The CTEA, COEA, and ARI's life cycle contractor-delivered training analysis will provide a better indication of level of effort and cost data.

Training Times

The following discussion concerns the duration of a single course of instruction and the time that a single individual might have to spend attending a series of courses.

Although the aggregate training burden may decrease it is very likely that individual course lengths may increase in spite of the requirement in the ROC that training times will not exceed those for the systems replaced (ROC, Annex F).

The ARTI program may provide some insight into the number of skills and tasks which must be trained for LHX operators. At present however, it appears as if the contemplated action to hold down the length of pilot training is the expanded use of devices, simulators and embedded training. On the other hand, several additional capabilities described below have been proposed for the LHX which will tend to increase course length.

a) Air-to-air combat will require additional course time to present material pertinent to the emerging air-to-air doctrine, tactics, operations and safety.

b) An integrated and automated cockpit will require additional training for those systems that are flight critical or mission essential because the pilot will require skills pertinent to the manual back up or emergency procedures as well as the normal or automated procedures.

c) The integration of additional weapon systems through the pre-planned product improvement will cause course lengths to be extended to the extent that they are additions and not replacements.

Achievement of the ROC requirement for the LHX not to exceed the training time of the systems it replaced is attainable for maintenance personnel. However, the previously mentioned caveats pertaining to BIT/BITE, two-level maintenance, and the LRU concept also apply to this requirement. Additionally, MOS consolidations dealing with the electronics, armament, and avionics repair MOS could cause courses of unacceptable length. Some of the courses for those specialties are currently approaching the limit in terms of length. On the other hand the efficiencies attendant to the state of the training media and devices to include embedded training will tend to shorten all courses. Further, electronic and automated systems lend themselves to simulation.

The HFEA (33-1/17/86) expresses concern that there may be an unacceptable training burden during the phase in period for two-level maintenance. The LHX PM response to the issue is that it is being analyzed by an ARI analysis and by the 2LM study. However, it appears as if the second phase of the 2LM study will not begin until well into 1987 and possibly not until 1988.

It is significant to note that of the approximately 95 courses dealing with LHX maintenance specialties, the individual and collective training plan (ICTP) only estimates lengths for 26 courses. For this discussion IKPT, NET, transition, and initial qualification are each considered a separate course for each affected MOS.

Program Development Appropriate to Aptitudes

Very specific language has been included in the ROC, the ICTP and the FSD RFP requiring the use of the Systems Approach to Training (SAT) and targeting of the programs to the individuals identified in the TQQPRI. SAT by definition ties aptitudes of trainees to training development. Until the sufficiency of the aptitudes identified is clearly demonstrated, it will be impossible to assure the appropriateness of the training programs.

New Equipment Training

NET pertains to the individual qualification training of an entire unit as that unit receives its aircraft. The NET plan has been published. The plan stipulates that all NET training will be done at TRADOC schools. Historically, the reserve component units have not been able to attend the resident schools. The ICTP discusses the investigation of the use of the U.S. Army

Reserve schools for NET for the reserve units. The research failed to locate such a study. An ARI research report on methodologies for training planning does propose an approach for netting the reserve components that combines extra drill periods with an initial active duty for training phase.

Qualification Training During the Sustainment Phase

Planning for qualification training is extremely sketchy at this time and, therefore, will not insure adequate training. The ICTP does not make provision for transition training beyond NET for maintenance courses. Furthermore, the experience required by the TQQPRI for a LHX repairman, 67(), precludes initial entry training and the experience required by the TQQPRI for a LHX technical inspector, 66(), precludes transition training. Provisions have not been made for reserve component configured courses in the ICTP.

Officer, Warrant Officer and NCO Career Development Training

Schedules have been included in the ICTP for amendment of existing career development training. However, specialty areas which would seem to have a training impact but which have not been addressed in the ICTP are aviation life support, aviation ground support equipment, safety, and movements control training.

Unit Training

Unit training includes individual sustainment and collective task training required to achieve full mission capability of each unit and their associated parent unit. However, there are no provisions in the ICTP and Annex F to the ROC for on-the-job training, nor is there any mention of pilot refresher training.

The assumption is that pilot refresher training will be covered by the aircrew training manual and will be a unit responsibility until the LHX becomes an initial entry training aircraft at which time it will also be included in the refresher course. Additional refresher training is provided for in the NET plan. The NET plan provides for NET teams to provide refresher for skills degraded while awaiting the issue of equipment.

The HFEA (30-1/17/86) indicated that the full scope structure, and level of unit responsibility have not yet been defined. Although studies have been initiated, they have not been completed to date. The LHX PM responds that the contractor is required to address the full scope of training and that contractors have been provided the individual and collective tasks to assist their design effort. The PM states that the source selection evaluation board (SSEB) will evaluate the contractors proposals. The implication is that the SSEB will insure adequacy. However, given the current status of the ICTP (26 Aug 86), and other critical training documents, that may be unlikely.

Devices in Tactical Units

The HFEA (38-1/17/86a) questions if the LHX design will take advantage of computer assisted embedded training. The LHX PM responds that the contractor is required to propose options for embedded training. Furthermore, the contractors have been encouraged to take advantage of computer assisted training. Also, Annex F to the ROC locates low cost devices and embedded devices at the unit and assigns maintenance responsibility to the unit commensurate with similar inherent capability of the unit.

More complex devices will be located based on cost and training effectiveness considerations (ROC, Annex F). The implication is that they will be located at schools, installation and training sites and supported by TDA (table of distribution and allowance) organizations.

The HFEA (17-1/17/86a) considers the two-seat trainer necessary to reduce training hazards created by an unfamiliar pilot operating an unfamiliar system. The LHX PM response describes the mix of simulators and aircraft anticipated for LHX training. However, it does not address the requirement in the units, particularly in a theater of operation. Annex F to the ROC states that only the relatively simple devices will go to the units and lists the two-seat trainer as being available to the units.

The HFEA (36-1/17/86a) hypothesizes that early designation of the LHX as the primary initial entry rotary wing trainer aircraft early in the program may save money in the long run. The LHX PM responds that the intent is to replace the TH-55 and the UH-1 with LHX utility airframes.

Manpower

There are many ongoing efforts pertaining to manpower. The most notable being HARDMAN and ARI's LHX organizational modeling effort, which are not yet complete. The HFEA (31-1/17/86) expresses concern for the adequacy of manpower particularly in light of non-aviation combat duties and operational losses in combat. The LHX PM responds that the MARC considers differential productivity rates for each type of unit specified and that the effectiveness of the LHX test unit will be evaluated during operational testing.

CONCLUSIONS

The conclusion of the research team is that the methodology is efficient and has the potential to lead materiel planners and acquisition decision makers to accurate conclusions. However, to insure accuracy and the ability to defend conclusions it is imperative to include the results of all pertinent efforts and plans. For various reasons, certain critical documents were not available to the research team. Among them were the ARTI program results, the HARDMAN final report, the COEA, the CTEA, and the results of the 2LM study. In the absence of the information included in those reports, it is fruitless to attempt to draw any conclusions as to the MANPRINT operability or supportability of the LHX. Instead, it is recommended that the information from the MANPRINT Affordability Section of this report be integrated with the study results and that the combination serve as the foundation for the MANPRINT presentation to ASARC. Towards that end Appendix D presents the MANPRINT Affordability Section data reorganized in the pre-ASARC MANPRINT review briefing format.

During the course of the research, it was necessary to refer to and comment on the issues and critical questions included in the LHX System MANPRINT Management Plan (SMMP). The consensus resulting from that interaction was that by comparison the SMMP approach is cumbersome and provides an erroneous sense of closure. The tendency is to believe that once each of the questions has been answered, the MANPRINT assessment is complete. The reality is that the MANPRINT assessment is not complete until 1) the hardware design specifications accommodate the human factors, health hazards and system safety requirements and 2) detailed programs have been developed to manage and train sufficient personnel to sustain the weapon system throughout its life cycle.

APPENDIX A

OUTLINE STRUCTURE

The following outline structure is used to present the results in the MANPRINT Affordability Section of this report.

I. HUMAN FACTORS

Human Characteristics
- Operators
- Maintainers

Anthropometric Data
- Operators
- Maintainers

System Interface Requirements
- Operators
- Maintainers

Human Performance
- Operators
- Maintainers
- Other Support Personnel

II. HEALTH HAZARDS

Operators

Maintainers

III. SAFETY

Operators

Maintainers

IV. PERSONNEL

Aptitudes Required
- Operators
- Maintainers

Experience Required
- Operators
- Maintainers

Recruiting
- Operators
- Maintainers

Training
- Operators
- Maintainers

Personnel Assignment
- Operators
- Maintainers

V. TRAINING

Training Effort and Cost

Training Times

Program Development Appropriate to Aptitudes

New Equipment Training

Qualification Training During the Sustainment Phase

Officer, Warrant Officer and NCO Development Training

Unit Training

Devices in Tactical Units

VI. MANPOWER

APPENDIX B

LIST OF DOCUMENTS REVIEWED

The following contains a list of the LHX documents reviewed during this research effort.

Application of Hardman to the LHX, In-Progress Review	Apr 1986
Army Science Board Final Report of the Ad Hoc Subgroup on the Army's LHX Program	Dec 1984
ARTI Program Management Plan	Nov 1984
A Computer Analysis to Predict Crew Workload During LHX Scout-Attack Missions, Vol I, II	Oct 1984
DCSPER Guidance Letter: LHX Milestone I/II Decision Review by ASARC	Nov 1985
Draft LHX Full-Scale Development Request for Proposal	Nov 1986
Human Factors Engineering Analysis (HFEA)	Jun 1986
Draft Report: MANPRINT in LHX: Organizational Modeling Project	Jan 1987
Individual and Collective Training Plan (ICIP)	Dec 1985
Integrated Logistics Support Plan (ILSP)	Nov 1985
Letter of Agreement (LOA)	Mar 1985
LHX Mission Profiles	May 1983
LHX Required Operational Capabilities (ROC)	Nov 1985
LHX System MANPRINT Management Plan (SMMP)	Jun 1986
MANPRINT Primer	Jan 1986
New Equipment Training Plan (NETP)	Sep 1985
Operational and Organizational Plan (O&O Plan)	Apr 1985
Program Manager/Material Systems Assessment	May 1986
Reliability, Availability and Maintainability (RAM) Rationale Report	Nov 1985

System Attributes Document	Feb 1984
Target Audience Description (TAD)	Aug 1985
Tentative Basis of Issue Plan (TBOIP)	Aug 1986
Test and Evaluation Master Plan (TEMP)	Nov 1985
Trade-Off Analysis (TOA)	May 1985
Tentative Qualitative and Quantitative Personnel Requirements Information (TQQPRI)	Dec 1985
Draft Report: Analysis of Life Cycle Contractor-Delivered Training for Military Aircrew and Aircraft Maintainers	Jan 1987

APPENDIX C

Findings to LHX MANPRINT Questions

This appendix presents the results of a review of the LHX studies and analyses available at the time this report was written. MANPRINT related evaluations, as presented earlier in the MANPRINT Affordability Section, and the MANPRINT questions contained in the LHX System MANPRINT Management Plan (SMMP) were used to develop the information presented. Each question includes a LHX SMMP question number, a statement of the question, a brief discussion of the relevant findings to date, any response by the LHX PM addressing the question, the Required Operational Capability (ROC) citation, and any outstanding or recommended follow-on actions. The remainder of this appendix is organized around the seven MANPRINT critical issues and associated questions as presented in the LHX SMMP (June 1986). These critical issues are as follows:

1) Is single pilot operability feasible?

2) Are manpower requirements greater than predecessor systems?

3) Are personnel aptitude and skill level requirements supportable?

4) Are the training requirements greater than predecessor systems?

5) Can LHX performance, reliability, and maintainability goals be achieved by the target audience?

6) Will the organizational structure effectively support sustained operations?

7) Can operations be sustained in a hostile environment (NBC, Laser) without undue biomedical, health hazard or safety compromise?

MANPRINT CRITICAL ISSUE NUMBER ONE

IS SINGLE PILOT OPERABILITY FEASIBLE?

The great majority of questions related to single pilot operability center around the development or integration of specific technologies. These technologies include helmet mounted displays, speech communication, night vision, digital mapping, voice recognition, and cockpit automation. Many have been specifically cited as required for or supportive of single pilot operations. At this time, it is uncertain as to how many of these technologies will be developed to a sufficient level of maturity to enable their inclusion in the final LHX design. Also yet to be determined is an assurance that all developed technologies can be integrated, particularly in a manner which will not produce excessive operator workload or require operator skill and intelligence levels that are so high as to significantly restrict the population of candidate operators.

CRITICAL QUESTION NUMBER: 1.1

STATEMENT OF CRITICAL QUESTION: Is the wide field of view (FOV) display technology mature to support LHX FSD?

RATIONALE: Helmet Mounted Display (HMD) is desirable for single pilot operations and low risk (Army Science Board (ASB) Final Report, p. 8). The TOA, however, asserts that a limited amount of information can be placed on the HMD display (TOA, p. R-28) and based on their assessment of current technology, full capability of HMD will most likely not be available for initial fielding of the LHX (TOA, p. R-27). The TOA's major area of concern with the HMD deals with the limitations of field of view (FOV) and field of regard. The HFEA, number 1-1/17/86, expresses concern over the trade-off between HMD FOV and resolution. LHX operational effectiveness is dependent on the best presentation of visual information and an inadequate HMD would degrade pilot performance and prevent or hinder mission accomplishment.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: A minimum instantaneous 90^{o} horizontal by 60^{o} vertical FOV to display information is required with an instantaneous FOV of 120^{o} horizontal by 60^{o} vertical desired (ROC, p. A-6).

RESOURCES REQUIRED FOR ANSWER: According to the HFEA, number 1-1/17/86), the Night Vision Electro-Optic Center will conduct flight tests to evaluate the effects of FOV and resolution. Hughes Aircraft Company has conducted simulation evaluations of HMD FOV trade-offs and results should be available shortly. Additionally, proposed ARTI contractor risk reduction programs will address the concern.

CRITICAL QUESTION NUMBER: 1.2

STATEMENT OF CRITICAL QUESTION: Is the integrated helmet development supportive of 1.8 kilogram (3.95 pound) criteria?

RATIONALE: 1) The addition of HMDs; sighting systems; NBC, laser and flashblindness protective devices tends to increase helmet weight and decreases dead tracking ability, increases neck fatigue, and increases head-neck loading during a crash impact. (HFEA, number 2-1/17/86). 2) The weight and size of the helmet with binocular HMDs and head position sensors may cause injury to the head, neck and shoulder areas (TOA p. R-VIII-13). The LHX PM states that the second draft of the RFP specifies a helmet weight not to exceed 1.8 kilograms (3.95 pounds).

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: No ROC requirement.

RESOURCES REQUIRED FOR ANSWER: Required capability has not yet been demonstrated. No planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 1.3

STATEMENT OF CRITICAL QUESTION: Are the speech communication and audio cues of sufficient clarity and intelligibility to permit effective communication?

RATIONALE: The TOA and Army Science Board (ASB) both expressed doubt that the technology could be adequately improved for the LHX, suggesting that the technology currently is high-risk. The LHX PM states that the RFP establishes stringent requirements for speech intelligibility through the audio distribution system and by the voice interactive control display system.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Must have a long range, reliable communications at nap of the earth (NOE) altitudes (ROC, p. B-2-55) and a communications system which is joint service interoperable, integrated, automated, TEMPEST approved with communications and electronic operating instructions (ROC, p. A-6). Provide uninterrupted operation of all on-board communications in a secure mode and provide airborne retransmission of voice and data communications in a secure mode (ROC, p. B-2).

RESOURCES REQUIRED FOR ANSWER: Required capability has not yet been demonstrated. The Army Simulation Evaluation Team (SET) will evaluate the audio distribution and voice interactive control display systems on each of the ARTI contractors simulators.

CRITICAL QUESTION NUMBER: 1.4

STATEMENT OF CRITICAL QUESTION: Is single pilot operability supported effectively by night vision goggle (NVG) operation?

RATIONALE: The basis for this question is not clear. 1) The TOA does not cite this as an issue. 2) The HFEA, number 13-1/17/86, expresses concern over reduced capability and increased hazards when flying at night, especially at NOE altitudes. 3) The LHX PM states that the RFP requires the utility LHX to use an ANVIS-type NVG and complete provisions for the night vision pilotage system (NVPS).

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Ability to conduct day and night, adverse weather and NOE operations (ROC, p. B-1 and B-2-55). Improved capability for continuous operations through single pilot, multiple shift operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. See critical question number 1.18.

CRITICAL QUESTION NUMBER: 1.5

STATEMENT OF CRITICAL QUESTION: Is the digital data base map supportive of single pilot operations?

RATIONALE: 1) The TOA and ASB cite the necessity for real-time, accurate digital mapping systems. 2) The ASB assigns risk as low, but TOA calls for placing a high priority on improvement in this area. 3) The HFEA, number 14-1/18/86a, states that the technology is expected to reduce pilot work load, but the accuracy and resolution of the digital data base seems to be less than that required for NOE and adverse weather navigation. 4) The RFP requires a full-color digital map with real-time update of map position and orientation; selectable multiple scale coverages including the optimum, display of detail for NOE flight, and other selectable display formats; and level 1 and 2 digital feature analysis data and cover a 300 km square area.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Ability to conduct day and night, adverse weather and NOE operations (ROC, p. B-1 and B-2-55).

RESOURCES REQUIRED FOR ANSWER: This question should remain open since the requisite technology has not been demonstrated. The LHX PM states that the Army SET will thoroughly explore this issue during the ARTI contractor simulation demonstration.

CRITICAL QUESTION NUMBER: 1.6

STATEMENT OF CRITICAL QUESTION: Can the pilot effectively fly and navigate the aircraft while simultaneously acquiring and servicing targets, especially for off-axis weapon employment?

RATIONALE: 1) The TOA cites the probability of development of a automatic target acquisition system as low. 2) The HFEA, number 15-1/17/86a, raises the concern that the pilot will not be able to control the aircraft and engage off-axis targets. 3) LHX PM states that the ability to perform such an operation has been adequately demonstrated by the back seat pilot of the Apache (AH-64A).

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Must be able to designate targets for precision-guided munitions (ROC, p. B-2-55). RFP requires the gun shall be capable of engaging targets 0-90 degrees off the aircraft centerline.

RESOURCES REQUIRED FOR ANSWER: This question should remain open because it is a major contributor to pilot workload. Even though the concept has been demonstrated in isolation, it remains to be seen if it can be adequately performed in the context of an LHX mission, particularly in light of the difficulties envisioned with voice recognition, target acquisition terrain avoidance radar, and digital mapping. The ARTI effort is expected to address this issue.

CRITICAL QUESTION NUMBER: 1.7

STATEMENT OF CRITICAL QUESTION: Is the voice recognition system of sufficient maturity to permit their use in the LHX?

RATIONALE: 1) The TOA cites the voice recognition system (VRS) as critical to achieving the single pilot goal, but concludes that the probability of a VRS maturing during LHX initial development as low. 2) The HFEA, number 18-1/17/86a, states that voice recognition technology does not appear to have reached the state of maturity required to allow this [reduction in pilot workload] to be accomplished under the noise, stress, and work load levels imposed by combat. 3) The LHX PM states that the LHX shall have a voice recognizer and speech synthesizer capable of speaker dependent, connected word voice recognition. It shall have at least a 95-percent average recognition accuracy.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Improved capability for continuous operations through single pilot operations (ROC, p. 3). Will have an integrated and automated cockpit (ROC, p. B-1).

RESOURCES REQUIRED FOR ANSWER: Stating the requirement does not assure the capability will be achieved. ARTI results should be evaluated, and voice recognition capability again should be evaluated during development testing (DT). Voice recognition capabilities will be demonstrated to the Army SET on the individual ARTI contractor simulators.

CRITICAL QUESTION NUMBER: 1.8

STATEMENT OF CRITICAL QUESTION: Is the aviator to operate as the system integrator or the commander?

RATIONALE: 1) The TOA states that the pilot may have to have capabilities superior to those of the current pilot and may in fact compound the pilot availability problem. 2) The HFEA, number 19-1/17/86, expresses uncertainty as to whether an aviator with the intelligence and skill levels of current aviators and expected recruits could be expected to effectively operate the advanced systems in the LHX. 3) The LHX PM states that the LHX contractor is required to structure his proposed integrated training system to minimize the training burden and to optimize training effectiveness to reduce training time. 4) The LHX PM also states that ARTI has been structured to design the LHX for the soldier of the future and will provide continuous comprehensive evaluation to ensure the soldier is capable of using the system.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Requirement for number of skills and skill levels for aircrew shall not exceed those required for current light fleet operations (ROC, p. 6 and B-4).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. The provision of special information to the contractors not withstanding, the documents officially charged to describe the soldier have not been completed. Specifically, the TQQPRI does not describe the aviator and the MOS Decision Memorandum does not enumerate any new or changed MOS, SQI or ASI.

CRITICAL QUESTION NUMBER: 1.9

STATEMENT OF THE CRITICAL QUESTION: Is the single pilot able to effectively handle all emergency procedures and associated actions?

RATIONALE: 1) The HFEA, number 20-1/17/86a, cites the inability of one crew member to control the aircraft while executing emergency procedures in current aircraft. 2) The LHX PM states that the LHX contractor must develop emergency procedures and demonstrate them on mock-ups, simulator, and during DT and OT flight testing for a single crew member.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Single pilot operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: Procedures demonstrated during FSD should be evaluated. Any deficiencies noted should be corrected prior to production.

CRITICAL QUESTION NUMBER: 1.10

STATEMENT OF CRITICAL QUESTION: Can a single pilot complete the mission, given single point failures?

RATIONALE: 1) The HFEA, number 22-1/17/86, questions the pilot's ability to complete the mission if part of the mission equipment capability is lost by damage of failure. 2) The LHX PM states that the contractor, as part of the detailed cockpit analyses, shall determine the effects of degraded modes and flexibility of the integrated cockpit to react to mission changes. The contractor is also required to demonstrate degraded modes and ability to react to mission changes during flight qualification. The RFP contains appropriate flexibility and degraded modes requirements for analysis, simulation, and flight qualification.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Improved capability for continuous operations through single pilot operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: This question should remain open given the complexity and uncertainty associated with LHX integrated and automated systems. 1) Army SET will evaluate during contractor ARTI simulation demonstration. 2) Crew station verification program will investigate.

CRITICAL QUESTION NUMBER: 1.11

STATEMENT OF CRITICAL QUESTION: Can a single pilot react to changes in the mission?

RATIONALE: The HFEA, number 22-1/17/86, expresses concern that mission accomplishment will be impacted by the flexibility provided the aviator during combat, particularly if part of the mission equipment is lost.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Single pilot operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: See critical question number 1.10. This question should remain open.

CRITICAL QUESTION NUMBER: 1.12

STATEMENT OF CRITICAL QUESTION: Can the automatic target acquisition system (TAS) operate quickly accurately enough to allow the single pilot to accomplish the mission and have acceptable survivability?

RATIONALE: 1) The HFEA, number 24-1/14/86a, states that automation of the target acquisition process is critical to operational effectiveness and is needed to support single crew member operations. 2) The LHX PM states that the RFP contains specific target acquisition design criteria, including search sector and error rate, and requirements for target acquisition analyses, simulation, and flight qualification throughout development which fully address the issue.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: LHX SCAT TAS will be capable of manual and automatic searching, detecting, tracking, cuing and designating and automatically presenting recognized and prioritized targets (ROC, p. 4).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Statement of the requirement does not assure operational capability. 1) Army SET will evaluate on ARTI contractor simulations. 2) Army Aeroflight Dynamics Directorate will address as part of LHX crew station R&D program. 3) Army laboratories will increase technology base for automatic target recognition through investigation of advanced prototype hardware.

CRITICAL QUESTION NUMBER: 1.13

STATEMENT OF CRITICAL QUESTION: Can system automation reduce the pilot workload to a point that will all the single pilot to accomplish the mission with an acceptable level of survivability?

RATIONALE: 1) Study findings in the TOA state that even with full automation, the single crew member will experience overloads during critical mission segments. 2) The HFEA, number 25-1/17/86a, echoes TOA concerns, stating that if automation is not fully developed and integrated, the likelihood of mission accomplishment and survivability will be greatly reduced. 3) The LHX PM states that the RFP contains many automation requirements including: automatic flight control modes; automatic navigation; automatic fire control; automatic communication features; automatic configuration; automatic target acquisition; and automatic ASE activation.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Will have an integrated and automated cockpit (ROC, p. B-1).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Acceptable workload levels have not been demonstrated. 1) Army SET will evaluate during ARTI contractor simulation demonstrations. 2) Army Aeroflight Dynamics Directorate will evaluate human factors aspects of ARTI automation options in crew station R&D program. 3) RFP includes requirements for analyses, simulations, hot mock-up demonstrations, mission equipment surveys, and flight qualification demonstrations.

CRITICAL QUESTION NUMBER: 1.14

STATEMENT OF CRITICAL QUESTION: Will single point failures of the system automation increase pilot workload so as to prevent mission accomplishment or reduce survivability?

RATIONALE: See critical question numbers 1.10 and 1.13.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Unknown. See critical question numbers 1.10 and 1.13.

RESOURCES REQUIRED FOR ANSWER: See critical question numbers 1.10 and 1.13.

CRITICAL QUESTION NUMBER: 1.15

STATEMENT OF CRITICAL QUESTION: What data entry procedures present the least workload to the pilot and the least diversion of his attention from the battlefield?

RATIONALE: 1) The TOA does not raise this as an issue. 2) The HFEA, number 26-1/17/86, states that the effectiveness of proposed data entry systems to maintain acceptable pilot workload levels has not yet been determined. 3) The LHX PM states that the RFP requires single-pilot data entry through numerous modes including the bulk data loading system, the multifunction displays, the flight control grip, the voice interactive control system, and other conventional cockpit controls.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Bulk data transfer device easily accessible within the cockpit for all bulk data transfer required by LHX subsystems (ROC, p. A-6).

RESOURCES REQUIRED FOR ANSWER: Continue to monitor and verify capability at DT. 1) ARTI trade-off studies. 2) The Army SET will evaluate data entry systems installed in ARTI simulations. 3) The Aeroflight Dynamics Directorate will investigate data entry concepts during the crew station R&D program.

CRITICAL QUESTION NUMBER: 1.16

STATEMENT OF CRITICAL QUESTION: Can flight control automation reduce workload enough for the single pilot to accomplish the mission?

RATIONALE: 1) The ASB and TOA noted that the technologies of automated NOE, automated terrain following, and automated obstacle avoidance were necessary to facilitate single pilot operations and were medium or high risk. 2) The HFEA, number 27-1/17/86, states that the extent to which technology can accomplish such functions (automation of flight control) has yet to be validated. 3) The LHX PM states that the RFP requires multimode flight path guidance to include hover hold, navigational modes and weapon aiming modes; contractor requirements also include: analyses, simulation, hot mock-up evaluations, flight surveys, and demonstrations pertaining to automatic flight controls.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Will have an integrated and automated cockpit (ROC, p. B-1).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. The automation of the flight controls is generally accepted to be essential to the LHX and according to the TOA (p. R-67), "Even with full automation the single crew member will experience overloads during critical mission segments such as target acquisition and reconnaissance. Therefore, it is not appropriate to close the issue until the requisite level of automation has been demonstrated to be feasible. 1) Some automatic flight control features have been demonstrated through Apache, Army helicopter improvement program, ADOCS flight demonstrator or ARTI flight experiments. 2) Some automatic flight control features will be demonstrated through one or more of the vehicles above. 3) Army SET will evaluate during ARTI simulator demonstrations. 4) National Aeronautics and Space Agency, Ames Research Center, recently completed simulation evaluations of ADOCS concept including automatic features.

CRITICAL QUESTION NUMBER: 1.17

STATEMENT OF CRITICAL QUESTION: Does the mounting of secondary switches and buttons on the side-arm-controller degrade the pilot's performance?

RATIONALE: 1) Not cited by the TOA. 2) The HFEA, number 32-1/17/86, concern summarized above; concern primarily related to impact on pilot workload.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: In lieu of the potential impact on pilot workload, this question should remain open. 1) Army SET will evaluate side-arm-controller concept in ARTI simulation demonstrations. 2) ADOCS technology base supports side-arm-controller concepts and numerous other DOD and commercial aircraft are currently successfully utilizing this concept.

CRITICAL QUESTION NUMBER: 1.18

STATEMENT OF CRITICAL QUESTION: Can the night vision pilotage system allow a single pilot to fly NOE at night and in adverse weather to accomplish the mission with an acceptable level of safety?

RATIONALE: 1) The HFEA, number 37-1/17/86a, characterizes a night vision pilotage system with the requisite night vision sensor and wide field of view with suitable sensitivity and resolution as high risk. 2) The LHX PM responds that the RFP establishes stringent requirements that exceed the capabilities of existing helicopter systems. 3) Additionally, the PM plans to initiate a program for further risk reduction as a follow up to ARTI. The program is intended to start in late FY 86 and will include brassboard, breadboard demonstrations of critical MEP.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Ability to conduct day and night, adverse weather and NOE operations (ROC, p. B-1 and B-2-55). Improved capability for continuous operations through single pilot, multiple shift operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: Given the complexity of the system and the number of efforts yet to be completed, this question should remain open. 1) The Night Vision Electro-Optical Laboratory (NVEOL) is conducting a technology development program that will develop the sensor components. 2) NVEOL is conducting flight tests to determine the optimum NVPS and HMD FOV for the LHX. 3) The ARTI effort is expected to address this issue and indicate that the field of view can be slightly reduced.

MANPRINT CRITICAL ISSUE NUMBER TWO

ARE MANPOWER REQUIREMENTS GREATER THAN PREDECESSOR SYSTEMS?

There are many ongoing efforts pertaining to manpower. The most notable being HARDMAN and ARI's organizational modeling effort, which are not yet complete. The HFEA, number 31-1/17/86, expresses concern for the adequacy of manpower particularly in light of non-aviation combat duties and operational losses in combat. The LHX PM responds that the MARC considers differential productivity rates for each type of unit specified and that the effectiveness of the LHX test unit will be evaluated during operational testing.

CRITICAL QUESTION NUMBER: 2.1

STATEMENT OF CRITICAL QUESTION: Are there enough people in the LHX units to support, maintain and operate the system?

RATIONALE: 1) Given the mission requirements, the advanced technical characteristics of the aircraft and the potential reliance on other organizations for support, what will the LHX manpower requirements be, and will these be supportable by the LHX unit (HFEA, numbers 31-1/17/86 and 42-1/17/86). 2) Efforts directed to determine the manpower requirements for LHX (i.e. HARDMAN, ARI's LHX organizational modeling, TQQPRI, COEA, and two-level maintenance study) are not complete, and consequently the adequacy of LHX unit manpower cannot be answered. 3) While the LHX is expected to reduce the overall manpower required for the Army, the impact at the depot and that of the overall Army has not yet been fully addressed (HFEA, number 43-1/17/86). 4) Maintenance man-hour per flight hour requirements will be developed using Manpower Requirements Criteria (MARC) methodology. Effectiveness of the LHX test unit will be evaluated during operational testing. The LHX PM states that the results of the LHX organizational modeling effort will be provided to the LHX TSM, and that HARDMAN II will quantify depot level maintenance personnel requirements.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Manpower requirements for the LHX will be no more extensive than those required for the current system (ROC, p. 6). No RFP requirement.

RESOURCES REQUIRED FOR ANSWER: 1) Efforts yet to be completed and which will address manpower requirements include those listed above in the rationale. 2) The LHX PM states that the results of the organizational modeling effort will be provided to LHX TSM for consideration in developing LHX TOE.

CRITICAL QUESTION NUMBER: 2.2

STATEMENT OF CRITICAL QUESTION: How many maintenance man-hours will be required to keep the LHX functioning 6 hours per day during continuous combat operations, and will there be enough maintainers in the units to support that requirement?

RATIONALE: See critical question number 2.1

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Manpower requirements for the LHX will be no more extensive than those required for the current system (ROC, p. 6). RFP specifies that direct maintenance man-hours per flight hour not exceed 2.6 for SCAT and 2.4 for utility variants.

RESOURCES REQUIRED FOR ANSWER: The LHX PM recommends consolidation of this question with critical question number 2.1.

CRITICAL QUESTION NUMBER: 2.3

STATEMENT OF CRITICAL QUESTION: What are the manpower requirements for the LHX at the depot level?

RATIONALE: 1) The HFEA, number 43-1/17/86, expresses concern that the impact of LHX manpower and personnel requirements have not been fully addressed for depot and that of the overall Army. 2) The LHX PM states that the RFP requires LHX contractors to develop programs to train active and reserve component operator, maintainers, and support personnel as well as depot level personnel.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Manpower requirements for the LHX will be no more extensive than those required for the current system (ROC, p. 6). Reduce the force structure. Requirement for maintenance personnel and number of skills and skill levels for maintenance personnel shall not exceed those required for current light fleet operations (ROC, p. 6 and B-4).

RESOURCES REQUIRED FOR ANSWER: Given the increased sophistication of the LHX system and the shift of component repair to depot, this question should remain open. The LHX PM states that HARDMAN II will quantify depot level maintenance personnel requirements.

CRITICAL QUESTION NUMBER: 2.4

STATEMENT OF CRITICAL QUESTION: What are the manpower and personnel requirements for the mission planning and maintenance workstations?

RATIONALE: 1) The HFEA, number 16-1/17/86a, indicates that the full capabilities, requirements, and manpower needs for computer-based capabilities for mission planning and maintenance activities have not yet been defined. Included in those needs are the human performance characteristics (ROC, p. 6). 2) RFP requires the contractor to define mission planning and maintenance diagnostic capability within manpower constraints (maintenance ratio). Contractor is required to provide an approach to design of a system for collecting all data required for loading into the LHX before flight, including a description of data and the interface system. The LHX PM states that the on-board portion of the diagnostic and prognostic system will diagnose 95 percent of all electronic failures.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Requirement for maintenance personnel and number of skills and skill levels for aircrew and maintenance personnel shall not exceed those required for current light fleet operations (ROC, p. 6). Reduce the complexity and variety of maintenance skills required (ROC, p. 6).

RESOURCES REQUIRED FOR ANSWER: The LHX PM response does not address the issue in that it assumes away the problem by citing the RFP requirements for the computer systems and the requirement to stay within manpower constraints. Furthermore, specifying identification of 100% of the electronic faults is clearly impossible. This question should remain open because merely requiring it does not make it so and, because the issue of computer support personnel has not been addressed at all. It is significant to note that the computer resource management plan has not been completed. No planned or current research efforts identified.

MANPRINT CRITICAL ISSUE NUMBER THREE

ARE PERSONNEL APTITUDE AND SKILL LEVEL REQUIREMENTS SUPPORTABLE?

The ROC requires that the number of skills and skill levels will not increase. Several concepts have been proposed that would tend to drive operator aptitude requirements up. These include: all-weather operations, multi-mission capability and single pilot operations. Concepts proposed for maintenance; specifically use of BIT, BITE and line replaceable units, will tend to reduce maintenance aptitude requirements. It is significant to note, however, there does not appear to be a reliable method to predict either the required aptitudes or measure the degree to which individuals in the resource population possess them.

CRITICAL QUESTION NUMBER: 3.1

STATEMENT OF CRITICAL QUESTION: What are the aircraft personnel requirements?

RATIONALE: 1) The HFEA, number 11-1/17/86, raises concern that the manpower and personnel requirements for the LHX utility second crew member have not been determined. 2) The TOA (p. 35) states, "The pilot may have to have capabilities superior to those of the current pilot. If it requires such high-caliber people to use it, have we not, in fact, compounded the pilot availability problem? A two-man crew would reduce entrance and training requirements." 3) Only tentative conclusions about required aviator aptitudes, etc. can be drawn at present; specific aptitudes can not be defined. 4) The ROC establishes no requirement to limit aviator aptitudes, mental category, or physical characteristics. 5) The LHX PM states that the RFP requirement states the LHX utility shall be single-pilot operable and have two flight crew stations.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Requirement for number of skills and skill levels for aircrew shall not exceed those required for the current fleet (ROC, p. 6 and B-4). Manpower requirements for the LHX will be no more extensive than those required for the current system (ROC, p. 6).

RESOURCES REQUIRED FOR ANSWER: Continue to monitor on-going analysis and resolve prior to production. 1) ARTI results, particularly simulation results, may address the areas (if any) where current aviator personnel demonstrate shortcomings, 2) CTEA, 3) TQQPRI, 4) two-level maintenance study, and 5) target audience description are all expected to provide information relevant to this question.

CRITICAL QUESTION NUMBER: 3.2

STATEMENT OF CRITICAL QUESTION: What are the manpower and personnel requirements for the mission planning and maintenance workstations?

** This is a repeat of critical question number 2.4. **

CRITICAL QUESTION NUMBER: 3.3

STATEMENT OF CRITICAL QUESTION: Can an aviator with the intelligence and skill levels of current aviators and expected future recruits effectively operate the advanced systems?

RATIONALE: The HFEA, number 19-1/17/86, questions whether future recruits will have skill and intelligence levels required to operate the LHX. If not it could result in increased training cost, increased manpower requirements or reduced effectiveness on the battlefield. The LHX PM states that the LHX is being designed considering the intelligence and skill levels of current aviators and expected future recruits. Target audience descriptions and the publication "I am the American Soldier" have been developed to provide a demographic portrayal of the current and projected force.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: As a minimum, the number of skills and skill levels for aircrew personnel shall not exceed those required for current light fleet operations (ROC, p. 6).

RESOURCES REQUIRED FOR ANSWER: Continue to monitor ongoing efforts and resolve prior to production. 1) CTEA, 2) BOIP, 3) TQQPRI, and 4) target audience description are all expected to provide information on this question.

CRITICAL QUESTION NUMBER: 3.4

STATEMENT OF CRITICAL QUESTION: What additional skills are required of the LHX aviator?

RATIONALE: See critical question number 3.3.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: See critical question number 3.3.

RESOURCES REQUIRED FOR ANSWER: See critical question number 3.3.

CRITICAL QUESTION NUMBER: 3.5

STATEMENT OF CRITICAL QUESTION: Will the LHX maintenance MOS structure have fewer or slower promotion opportunities that currently exist in non-LHX maintenance MOSs?

RATIONALE: The HFEA, number 28-1/17/86, expresses concern that the LHX MOS career progression opportunities are adequate to maximize job satisfaction and thereby maximize retention rates within the appropriate career fields for both active Army and reserve component personnel.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: See discussion in critical question number 3.6.

RESOURCES REQUIRED FOR ANSWER: Continue to monitor ongoing efforts and resolve prior to production. 1) The two-level maintenance study, 2) TQQPRI, and 3) TRADOC manpower assessment are all expected to provide information on this question.

CRITICAL QUESTION NUMBER: 3.6

STATEMENT OF CRITICAL QUESTION: Will we be able to recruit enough soldiers of sufficient quality to maintain and operate the LHX?

RATIONALE: The HFEA, number 35-1/17/86, states that if the Army is unable to recruit sufficient number of people with appropriate aptitudes the LHX operational capability will decrease. The HFEA also questions whether future recruits will have skill and intelligence levels required to operate the LHX. The LHX PM states that the LHX is being designed considering the intelligence and skill levels of current aviators and expected future recruits. Target audience descriptions and the publication "I am the American Soldier" have been developed to provide a demographic portrayal of the current and projected force.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The LHX is to be designed to reduce the force structure requirement for maintenance personnel. As a minimum, the number of skills and skill levels for aircrew and maintenance personnel shall not exceed those required for current light fleet operations. Reduce the complexity and variety of maintenance skills required (ROC, p. 6).

RESOURCES REQUIRED FOR ANSWER: Continue to monitor ongoing efforts and resolve prior to production. 1) LSA, 2) CTEA, 3) BOIP, 4) TQQPRI, 5) two-level maintenance study, and 6) target audience description are all expected to provide information on this question.

MANPRINT CRITICAL ISSUE NUMBER FOUR

ARE THE TRAINING REQUIREMENTS GREATER THAN PREDECESSOR SYSTEMS?

The questions related to LHX training reflect the diversity of the concepts proposed and the complexity overall training system requirements. For example, single pilot and embedded training concepts have introduced uncertainty regarding appropriate use of aircraft as training devices and location of specific types of training and training schedules. In addition, there is no overwhelming trend which can be predicted for training and most of the training documentation and training analyses are currently incomplete. In general, the CTEA, two-level maintenance study, life cycle contractor-delivered training effort, unit and displaced equipment training effort and others must be completed before further resolution of the training system can be made.

CRITICAL QUESTION NUMBER: 4.1

STATEMENT OF CRITICAL QUESTION: Is there an effective means to provide SCAT pilot training without the use of two-seat SCAT training aircraft?

RATIONALE: 1) The HFEA, number 17-1/17/86a, considers the two-seat trainer necessary to reduce training hazards created by an unfamiliar pilot operating an unfamiliar system. 2) The LHX PM states that use of the integrated training system (ITS) approach will allow the contractor to optimize the mix of general purpose aircraft and mission specific training aircraft and hardware to accomplish SCAT pilot training.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The ROC (p. F-2) states that the two-seat trainer will be available to units for standardization and evaluation rides. It also describes the two-seat trainer as essential to insure a reasonable level of proficiency prior to solo practice of mission activities and for maintenance test pilot training.

RESOURCES REQUIRED FOR ANSWER: This question should remain open. As mentioned above, the two-seat trainer is considered essential to insure a reasonable level of proficiency prior to solo practice of mission activities and for maintenance test pilot training. This would pertain particularly to testing armament systems. The CTEA and use of the ITS approach by the contractor are expected to address cost-effective approaches to LHX pilot training to include specification of required training devices.

CRITICAL QUESTION NUMBER: 4.2

STATEMENT OF CRITICAL QUESTION: Will the use of metric tools and measurements adversely affect maintenance training?

RATIONALE: 1) The HFEA, number 23-1/17/86, raises concern that metricism may be costly and could delay the repair process. The HFEA also recommends a performance analysis of the effects of employing metrics. 2) The LHX PM response is that metrics have been directed and a performance analysis would not change the decision to make LHX metric. 3) Also, the LHX PM indicates that existing english designs would have metric interfaces, which will reduce the total impact of conversion of metrics.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: LHX RFP Section 4.2.2. Conversion to metricism has been directed by DOD (AR 700-1, SI Standard ASTM (E380), IEEE Standard 268).

RESOURCES REQUIRED FOR ANSWER: Resources spent on addressing this issue would not be cost-effective. No planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 4.3

STATEMENT OF CRITICAL QUESTION: What training for operators and maintainers should take place at the unit?

RATIONALE: 1) The HFEA, number 30-1/17/86, cites the need to fully define and structure unit responsibility for training. 2) The LHX PM responds that the contractor is required to address the full scope of training and that contractors have been provided the individual and collective tasks to assist their design effort. 3) The LHX PM states that the contractor is required to address the full scope of training, including operator, maintenance support personnel, and depot level maintenance for both the active Army and reserve component.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: A training system to support mission, continuation, skill level advancement and sustainment training for qualified LHX personnel worldwide is required (ROC, p. F-1). In addition to proposing a traditional training concept, contractors shall propose their concept for a turn-key approach to LHX training (ROC, p. F-2).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. The entire LHX training program is extremely complex in that it includes new procurement strategy, new training delivery technology, many more sophisticated devices, as well as the requirement to train doctrine and technology that in some cases have not yet been fully developed. The PM also states that the source selection evaluation board (SSEB) will evaluate the contractors proposals. The implication is that the SSEB will insure adequacy. However, given the current (26 Aug 86) status of the ICTP, the doctrine, and the technologies associated with the system,this is unlikely. Continue to monitor the ICTP and the life cycle contractor-delivered training analysis for further resolution of training requirements and responsibilities.

CRITICAL QUESTION NUMBER: 4.4

STATEMENT OF CRITICAL QUESTION: What is the effect on institutional training of having to conduct two-level maintenance training and three-level maintenance training simultaneously during the LHX phase-in period?

RATIONALE: 1) The HFEA, number 33-1/17/86, states that although two-level maintenance is expected to reduce the overall training burden when a steady state condition is reached, it may result in an increased burden during the phase-in or transition period. 2) The HFEA cites the ICTP, CTEA and the two-level maintenance study as necessary to resolve the question. The LHX PM responds that the issue is being analyzed by an ARI analysis and by the two-level maintenance study.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The LHX will operate within the current force structure and will have two levels defined as user and depot level maintenance (ROC, p. B-7). Composite system training is required at the institution to teach maintenance trouble-shooting, and repair interaction of aircraft systems and MEP (ROC, p. F-3). LHX training times will not exceed those of systems that it will replace (ROC, p. F-4).

RESOURCES REQUIRED FOR ANSWER: This question should remain open given the complexity of the training system, and the number of efforts yet to be completed. Also, should depot maintenance be performed by military personnel, transition training burden on the institution will tend to increase. Analyses identified as relevant include: 1) ICTP, 2) CTEA, 3) the ARI unit and displaced equipment training analysis, and 4) two-level maintenance study.

CRITICAL QUESTION NUMBER: 4.5

STATEMENT OF CRITICAL QUESTION: What is the effect on unit training?

RATIONALE: As discussed in critical question number 4.3, definition and structure of unit training has not been fully defined. Overall maintenance training burden will tend to decrease. The ICTP and Annex F to the ROC do not require any OJT. Also, the NET plan specifies NET teams to provide refresher for skills degraded while awaiting issue of equipment.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The contractor will develop all training for the entire LHX training system in accordance with applicable TRADOC regulations (ROC, p. F-4).

RESOURCES REQUIRED FOR ANSWER: This question should remain open until further resolution of the training system allows evaluation. Relevant efforts include: 1) ICTP, 2) CTEA, 3) unit and displaced equipment training analysis, and 4) two-level maintenance study.

CRITICAL QUESTION NUMBER: 4.6

STATEMENT OF CRITICAL QUESTION: Will the training plan produce enough people with the right training to support the LHX system as it is fielded?

RATIONALE: 1) The HFEA, number 34-1/17/86, questions whether the training plan will be adequate to support LHX fielding at its projected rate. The concern, however, appears to be directed at assuring that recruitment rates, the training plan, and the fielding rate all match so that adequate numbers of trained personnel are supplied. Critical question number 3.6 discusses the recruitment issue, and the HFEA cites the BOIP, ICTP and other related efforts as having bearing on this issue. 2) The LHX PM states that a study with ARTI has been initiated, however, this would be expected to only address operators. The ARI analysis cited by the LHX PM in critical question 4.4 (unit and displaced equipment training analysis) may also address this question.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The LHX training system will satisfy all training required by the final qualitative and quantitative personnel requirements information (ROC, p. B-5).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Relevant efforts not yet complete include: 1) ICTP, 2) BOIP, and 3) unit and displaced equipment training analysis.

CRITICAL QUESTION NUMBER: 4.7

STATEMENT OF CRITICAL QUESTION: Should the LHX be used in Initial Entry Rotor Wing (IERW) training?

RATIONALE: 1) The HFEA, number 36-1/17/86a, cites designation of LHX aircraft for IERW training as a method for potentially reducing long-term training costs. 2) The LHX PM plans to provide LHX utility airframes for early phases of IERW, with advanced phases of training being conducted in mission specific aircraft (i.e., two-seat utility, single-seat SCAT, etc).

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: 1) The CTEA is expected to address the cost-effectiveness of all proposed training alternatives to include use of LHX for IERW training. 2) The life cycle contractor-delivered training analysis may also provide information to address this question.

CRITICAL QUESTION NUMBER: 4.8

STATEMENT OF CRITICAL QUESTION: Can embedded training be utilized in the LHX? Will embedded training (ET) reduce instructor requirements and improve training accessibility?

RATIONALE: 1) The HFEA, number 38-1/17/86a, cites the potential benefits of ET and questions whether or not ET will be utilized for LHX, and if so, whether or not it can reduce instructor requirements, training time, and increase accessibility of training. 2) The LHX PM responds that the contractor is required to identify and propose options for ET and his selection rationale. 3) Annex F (p. F-2) to the LOA anticipates embedded training by locating low cost embedded devices at the unit with more complex devices to be located based on cost and training effectiveness considerations. 4) The RFP requires a built-in MILES capability and specifies other desired applications of ET.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Embedded training will allow aircraft systems use as training media and will provide realistic force-on-force training using currently fielded system (ROC, p. 5).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Preliminary indications suggest embedded training can be utilized in LHX to reduce instruction requirements, however, this capability has not been demonstrated. The CTEA is expected to provide cost and training effectiveness data on embedded training.

CRITICAL QUESTION NUMBER: 4.9

STATEMENT OF CRITICAL QUESTION: Can the available maintainer personnel be trained to maintain the LHX?

RATIONALE: 1) The HFEA, number 45-1-17-86, cites increased training requirements, decreased system availability, increased time to repair and other negative effects expected if available maintainer personnel do not possess the minimum acceptable personnel characteristics. 2) The ROC has specified that maintainer skills and skill levels will not increase over current levels. A discussion of recruitment and aptitude requirements is presented at critical question number 3.6. 3) The LHX PM response states that the contractor is required to structure training to optimize effectiveness and the LHX PM has provided the contractor with target audience descriptions and other projected demographic information.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: LHX training system will satisfy all training required by the final qualitative and quantitative personnel requirements information (ROC, p. B-5). Reduce the complexity and variety of maintenance skills required (ROC, p. 6).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. The CTEA is expected to provide information on training effectiveness given projected available personnel.

MANPRINT CRITICAL ISSUE NUMBER FIVE

CAN LHX PERFORMANCE, RELIABILITY, AND MAINTAINABILITY GOALS BE ACHIEVED BY THE TARGET AUDIENCE?

The postulate of this issue is that maintainers' performance will influence the reliability, and maintainability of the LHX. Specific questions raised address three primary areas: the LHX environment, system design, and the characteristics of the maintenance and support population. Several questions have been raised regarding the adequacy of lighting for the cockpit, crew workstations, maintenance and FARP operations areas. Given the additional requirements for eyewear, displays, and day and night operations, lighting performance will require continuing evaluation particularly under operational conditions. Other LHX design features facilitating maintenance will also require further evaluation and should be included during DT.

CRITICAL QUESTION NUMBER: 5.1

STATEMENT OF CRITICAL QUESTION: Will the use of metric tools and measurements adversely affect maintenance?

RATIONALE: 1) The HFEA, number 23-1/17/86, raises concern that metricism may be costly and could delay the repair process. The HFEA also recommends a performance analysis of the effects of employing metrics. 2) The LHX PM response is that metrics have been directed and a performance analysis would not change the decision to make LHX metric. 3) Also, the LHX PM indicates that existing english designs would have metric interfaces, which will reduce the total impact of conversion of metrics.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: LHX RFP Section 4.2.2. Conversion to metricism has been directed by DOD (AR 700-1, SI Standard ASTM (E380), IEEE Standard 268).

RESOURCES REQUIRED FOR ANSWER: Resources spent on addressing this issue would not be cost-effective. No planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 5.2

STATEMENT OF CRITICAL QUESTION: Can the differing lighting requirements of the various cockpit systems (night vision devices, panel and helmet displays, laser and flashblindness protectors) be resolved and an integrated lighting system developed that does not interfere with the operation of any of those systems?

RATIONALE: 1) The HFEA, number 29-1/17/86a, expresses concern for crew station lighting as well as lighting for maintenance and forward arming and refueling points in that, if the lighting is not properly integrated into the system, there is potential for critical adverse impact on the ability to accomplish night missions. 2) The LHX PM response is that lighting requirements are adequately covered in the RFP to include provisions for mockup and simulation demonstrations.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Continuous day and night operations are required (ROC, p. B-2).

RESOURCES REQUIRED FOR ANSWER: This question should remain open since the integration of crew station design is sufficiently complex that the establishment of a requirement may not be adequate to assure necessary performance. 1) Currently proposed contractor mockups and simulation demonstrations should be documented and evaluated for lighting-related performance deficits. 2) ARTI results may provide information on necessary crew station design characteristics.

CRITICAL QUESTION NUMBER: 5.3

STATEMENT OF CRITICAL QUESTION: What lighting is required to facilitate maintenance?

RATIONALE: The HFEA raises the same basic concerns for maintenance lighting as expressed in critical question number 5.2.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Continuous day and night operations are required (ROC, p. B-2).

RESOURCES REQUIRED FOR ANSWER: Since the LHX PM response is the same, and the design issues are also basically the same, the conclusion follows that again requiring the lighting to be adequate does not necessarily assure that it will be so. Same as critical question number 5.2.

CRITICAL QUESTION NUMBER: 5.4

STATEMENT OF CRITICAL QUESTION: What lighting is required to facilitate FARP activities?

RATIONALE: See critical question numbers 5.2 and 5.3.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Continuous day and night operations are required (ROC, p. B-2).

RESOURCES REQUIRED FOR ANSWER: See critical question numbers 5.2 and 5.3.

CRITICAL QUESTION NUMBER: 5.5

STATEMENT OF CRITICAL QUESTION: Does the LHX design allow for maintenance while wearing protective garments under all climatic conditions?

RATIONALE: 1) The HFEA, number 40-1/17/86, expresses concern that the LHX design will not adequately consider maintainer human factors issues related to ease of accessibility under all operational conditions, maintainer induced failure, etc. 2) The LHX PM response is that the RFP requires a MANPRINT analysis to include maintainers and the RAM and ILS requirement directly addresses ease of maintenance. No known studies have been conducted to predict the effects of various operational conditions on LHX repairability.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: All-weather operations are required (ROC, p. B-2).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Establishing a requirement for an analysis does not assure ease of maintenance will be a result. 1) No planned research efforts currently identified. 2) Results of MANPRINT program (contractor) may provide indications of problem areas, if any.

CRITICAL QUESTION NUMBER: 5.6

STATEMENT OF CRITICAL QUESTION: Does the LHX design preclude maintainer induced failure?

RATIONALE: See critical question number 5.5.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: See critical question number 5.5.

CRITICAL QUESTION NUMBER: 5.7

STATEMENT OF CRITICAL QUESTION: Does the LHX design provide BIT, BITE, and ATE which the maintainer can use and understand?

RATIONALE: See critical question numbers 5.5, 3.1, and 3.6.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Maximum use will be made of on-board trouble shooting equipment and Built-in Test Equipment (BITE) to provide real-time condition, fault location, and trend recording to the line replaceable module level (ROC, p. 5).

RESOURCES REQUIRED FOR ANSWER: Continue to monitor relevant efforts and identify and resolve deficiencies cited during DT. An ARI electronic aids to maintenance analysis is expected to provide "lessons learned" regarding ease of use of BIT, BITE, and ATE. Also see critical question number 5.5.

CRITICAL QUESTION NUMBER: 5.8

STATEMENT OF THE CRITICAL QUESTION: Has the repairability and maintainability of composite materials been considered?.

RATIONALE: See critical question number 5.5. No RFP requirement.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: Evaluate, identify and correct cited deficiencies if any during DT. No planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 5.9

STATEMENT OF CRITICAL QUESTION: Have any pre-planned product improvements (P^3I) been examined for MANPRINT implications?

RATIONALE: 1) The HFEA, number 41-1/17/86a, recommends integration of P^3I to prevent an increase in pilot workload and ensure continued safe and effective mission performance. 2) The LHX PM response is concurrence, and inclusion of P^3I items in the revised RFP.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: System will include preplanned product improvements to incorporate new promising technologies, changes in threat and environmental considerations (ROC, p. 5). The ROC identifies four P^3I items: a multimode, high resolution target acquisition and ground mapping radar; ATGM capability, TOW 2 capability, and IFF.

RESOURCES REQUIRED FOR ANSWER: Given that P^3I items include the addition of components which may drive operator workload and maintenance man-hours, this question should remain open. No research efforts have been identified to address MANPRINT impacts of specific P^3I.

CRITICAL QUESTION NUMBER: 5.10

STATEMENT OF CRITICAL QUESTION: Will the design of the LHX allow it to be serviced at the FARP by only two soldiers without ground handling equipment in 15 minutes?

RATIONALE: 1) The HFEA, number 44-1/17/86a, questions whether personnel requirements for weapons loading will expand given the lack of ground handling equipment. 2) The LHX PM response is to cite the requirement for rearming at the FARP by not more than three personnel using no special ground equipment. This does not assure that personnel requirements will not expand, nor does it consider current manning levels which do not take into consideration 24 hour a day continuous operations.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: Evaluate at DT. Operational capability has not been demonstrated. ARI's LHX organizational modeling effort are expected to provide data which may be used to evaluate the capability and requirements at the FARP.

CRITICAL QUESTION NUMBER: 5.11

STATEMENT OF CRITICAL QUESTION: What is the MOS and civilian designation description and number to include special requirements (i.e., security clearance) required to directly operate and maintain the LHX?

RATIONALE: 1) The MANPRINT Joint Working Group (MJWG) is the source of this question. The Tentative Operator and Maintenance Proposed Decision for LHX SCAT and utility (8 June 1985) proposes several new enlisted MOS and does not specify security requirements. 2) The LHX PM states that the contractor will be responsible for the total training system requirements, the implication being that specific requirements will be developed by the contractor.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: This question should remain open. The MOS Decision Memorandum does not enumerate any new or changed MOS, SQI, or ASI. 1) The NET plan and 2) ICTP are expected to provide additional specific details on MOS designation, ASI, and specific security requirements.

CRITICAL QUESTION NUMBER: 5.12

STATEMENT OF CRITICAL QUESTION: What is the MOS and civilian designation description and number to include special requirements (i.e. security clearance) required to support the LHX?

RATIONALE: See critical question number 5.11.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: See critical question number 5.11.

CRITICAL QUESTION NUMBER: 5.13

STATEMENT OF CRITICAL QUESTION: What is the MOS and civilian designation description and number to include special requirements (i.e., security clearance) required to indirectly support the LHX? (i.e., vehicle drivers, generator mechanics, etc.)

RATIONALE: See critical question number 5.11.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: See critical question number 5.11.

CRITICAL QUESTION NUMBER: 5.14

STATEMENT OF CRITICAL QUESTION: What is the MOS and civilian designation description and number to include special requirements (i.e., security clearance) required to provide administrative support to the LHX? (i.e., company first sergeant, company clerk, etc.)

RATIONALE: See critical question number 5.11.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: See critical question number 5.11.

CRITICAL QUESTION NUMBER: 5.15

STATEMENT OF CRITICAL QUESTION: What is the anthropometric description of the population of individuals involved in operating, maintaining, and supporting the LHX? (i.e., range of physical dimensions for men and women)

RATIONALE: The MJWG is the source of this question. The TOA cites a poor fit between the pilot and the current cockpit and aircraft control configuration, recommending further seat adjustments and a side-arm-controller as possible solutions. The RFP specifies that the LHX System shall accommodate the middle 90 percent of the soldier population (male and female). The RFP also specifies anthropometric dimensions for the crew station expressed in terms of percentages of the Army aviator population. The RFP also specifies the use of mockups and models to validate functional data.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: 1) The results of the mockups and models should provide specific information regarding problem areas in achieving a optimum operator and maintainer fit with the system. 2) ARTI results may provide an evaluation of operator anthropometric requirements.

CRITICAL QUESTION NUMBER: 5.16

STATEMENT OF CRITICAL QUESTION: What is the physical description of the population of individuals involved in operation, maintaining, and supporting the LHX (i.e., Male and female PUHLES, MEPSCAT range, color vision, strength and stamina)?

RATIONALE: The MJWG is the source of this question. If the MOS for operation, maintenance and support of the LHX reflect the physical descriptions of current MOS, then AR 611-201 provides such data. However, should LHX MOS be changed, or if new MOS are developed, this data will require development.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: The 1) TQQPRI, 2) NET plan, and 3) Final MOS Decision Paper are expected to provide additional specific information.

CRITICAL QUESTION NUMBER: 5.17

STATEMENT OF CRITICAL QUESTION: What is the aptitude description of the population of individuals involved in operation, maintaining, and supporting the LHX (i.e., mean test score for each specialty, education level, reading grade level, and psychomotor ability)?

RATIONALE: The MJWG is the source of this question. The discussion presented in critical question number 5.16 is also relevant to aptitude description.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: None.

RESOURCES REQUIRED FOR ANSWER: See critical question number 5.16.

CRITICAL QUESTION NUMBER: 5.18

STATEMENT OF CRITICAL QUESTION: What is the biographical profile of the predicted population of the 1990s that will operate, maintain, and support the LHX (i.e., number of high school graduates, percent of population with english as a second language, special abilities)?

RATIONALE: The MJWG is the source of this question.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: The publication "I am the American Soldier" provides current projections of the predicted population through the 1990s.

CRITICAL QUESTION NUMBER: 5.19

STATEMENT OF CRITICAL QUESTION: What are the skills and knowledge to be trained to the MOS and civilians operating, maintaining, and supporting the LHX (i.e., a list by MOS of those tasks that will be trained in the institutions versus the on-the-job unit training)?

RATIONALE: The MJWG is the source of this question. Specific tasks to be trained have not yet been defined.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Skill levels for aircrew, support, and maintenance personnel shall not exceed those required for current light fleet aircraft systems (ROC, p. B-4).

RESOURCES REQUIRED FOR ANSWER: Given the number of training efforts yet to be completed and the lack of specific detail in current program documentation, this question should remain open. The 1) NET plan, 2) ICTP, 3) CTEA, and 4) unit and displaced equipment training analysis, and results of LSA tasks are expected to provide additional information on specific tasks to be trained and the location of training.

CRITICAL QUESTION NUMBER: 5.20

STATEMENT OF CRITICAL QUESTION: From review of the MOS tasks and known previous task performance, are there any critical tasks that the contractor should attempt to eliminate or reduce in difficulty when designing the LHX?

RATIONALE: The MJWG is the source of this question. The TOA and HFEA both cite the introduction of new technologies and the increase in automation as having a critical impact of operator tasks, particularly in terms of workload. Several of these technologies, including the integration aspects are considered high risk.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Eliminate costly and manpower intensive tasks to support a two-level maintenance concept (ROC, p. 4).

RESOURCES REQUIRED FOR ANSWER: 1) ARTI and 2) HARDMAN are expected to develop critical tasks which are problematic or high workload drivers respectively.

MANPRINT CRITICAL ISSUE NUMBER SIX

WILL THE ORGANIZATIONAL STRUCTURE EFFECTIVELY SUPPORT SUSTAINED OPERATIONS?

Three questions were raised in association with this issue. Questions 6.1 and 6.2 will be a directly impacted by LHX design in that specific RFP requirements have been developed, and these requirements focus primarily on the man-machine interface. Question 6.3 suggests that the LHX organization should be designed for continued performance given the realities of additional duties and combat losses. This latter question, to be answered, requires further definition and quantification of the LHX organization responsibilities and functions. The effects of combat losses typically are anticipated through combat modeling.

CRITICAL QUESTION NUMBER: 6.1

STATEMENT OF CRITICAL QUESTION: Is the interaction of fatigue, stress and anxiety overdemanding in the single placed cockpit to the extent that mission accomplishment is risked?

RATIONALE: 1) Currently no aircraft fatigue, stress, or anxiety standards exist which are applicable to the LHX. 2) The TOA (p. 28) and the HFEA, number 3-1/17/86a, question the extent to which these factors will have a debilitating effect on the operator. Degraded modes of operation and increased duration of missions may compound the effects of stress, fatigue, and anxiety. Simulated single pilot operations associated with air-to-ground and air-to-air engagements were found to cause considerable stress. Stress in combat situations is expected to be even higher (TOA, p. 28). 3) The LHX PM recommends research to determine fatigue, stress and anxiety standards for Army aircraft and cites the requirement for a reduction in operator workload as stated in the RFP.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Single pilot, multiple shift operations (ROC, p. 3). Air-to-air combat, deep attack, continuous day and night operations on an integrated battlefield (ROC, p. B-2). Ability to defend itself against both ground and air threats (ROC, p. B-3 and B-2-43).

RESOURCES REQUIRED FOR ANSWER: This question remains valid. The results of the 1) ARTI contractor simulations and 2) additional simulation information from studies conducted by Aeroflight Dynamics Directorate, Ames Research Center, on their Crew Station Research and Development Facility should be incorporated into the RFP and provisions made for further evaluation during development testing.

CRITICAL QUESTION NUMBER: 6.2

STATEMENT OF CRITICAL QUESTION: Is whole body vibration detrimental to crew performance and mission accomplishment?

RATIONALE: The TOA reports that vibration has been related to pilot fatigue and loss of effectiveness. The HFEA, number 4-1/17/86, notes the same concern and recommends the LHX be designed to limit whole body vibration to below the limits specified in MIL-STD-1472C, para 5.8.9.1.1. The LHX PM responds that the RFP requirement will result in a 50 percent reduction in vibration as compared with the UH-60A and that additional vibration survey will be conducted to verify acceptable levels.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Meet latest aeronautical design standards with acoustic noise limits, vibration levels and comfort zone temperatures (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Statement of the requirement does not in and of itself provide assurance that adequate performance will be achieved. No research efforts identified with the exception of those cited by the LHX PM.

CRITICAL QUESTION NUMBER: 6.3

STATEMENT OF CRITICAL QUESTION: How much degradation in unit performance will occur when people are drawn off for combat, self-defense, and casualties?

RATIONALE: The HFEA, number 31-1/17/86, questions the impact of reduced manning on sustained operations, and raises the issue of whether or not LHX units will be dependent upon external support organizations to provide critical functions. The LHX PM responds that maintenance man-hour per flight hour requirements will be used to develop Tables of Organization and Equipment using MARC methodology. This methodology reflects differences in productivity by type unit to include such activities as perimeter defense, additionally assigned duties, etc. The PM also indicates that the LHX test unit effectiveness will be evaluated during operational testing.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Not applicable.

RESOURCES REQUIRED FOR ANSWER: In addition to operational testing, the organizational modeling analysis is expected to project unit effectiveness for varying levels of degradation.

MANPRINT CRITICAL ISSUE NUMBER SEVEN

CAN OPERATIONS BE SUSTAINED IN A HOSTILE ENVIRONMENT (NBC, LASER) WITHOUT UNDUE BIOMEDICAL AND HEALTH HAZARD OR SAFETY COMPROMISE?

The focus of this issue is on the environment in which the operators and maintainers associated with LHX must perform. Potential hazards include various cockpit contaminants, noise, directed energy, hard or uncontrolled landings, and the collective effects of fatigue, stress, and anxiety associated with operation and maintenance of a complex system in a hostile environment. While individual questions may be resolved satisfactorily, some hazards (particularly those with interactive effects) will require progressive analysis and resolution. Development testing of the system should include provisions for evaluation of these questions to ensure resolution prior to production.

CRITICAL QUESTION NUMBER: 7.1

STATEMENT OF CRITICAL QUESTION: Is there a reasonable potential for exposure of occupants to excessive quantities of Halon 1301 fire extinguishing agents?

RATIONALE: The HFEA, number 5-1/17/86, states that current fire extinguishing systems, which employ Halon 1301, can have adverse affects on the aircraft occupants. The LHX PM responds that Halon 1301 is particularly effective in extinguishing aircraft fires, and that no other effective alternative agents are available. In addition, the PM indicates that automatically activated Halon 1301 fire extinguishers will be prohibited from use in the crew and passenger compartments.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Unknown

RESOURCES REQUIRED FOR ANSWER: Operation of the fire extinguishing system should be evaluated during developmental testing, and any cited deficiencies resolved prior to operational testing (OT). No existing or planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 7.2

STATEMENT OF CRITICAL QUESTION: Does the design of the LHX provide an environmental control system sufficient to protect the crew and passengers from combat contaminants and environmental elements?

RATIONALE: The HFEA, number 6-1/17/86a, states that combat contamination and excessive temperature extremes will impact crew health, performance, and mission accomplishment. The HFEA recommends a hybrid protective pressurized cooling, ventilation and heating system to prevent these factors from adversely affecting aircraft occupants. The LHX PM response is that there is an RFP requirement for both SCAT and utility. Both would have heating and ventilation and would also have hybrid NBC protection. In addition, there is a requirement for a crew survey to be conducted during flight tests.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Increased survivability through NBC protection and ballistic protection (ROC, p. 3). Have space, weight and power for point detection of nuclear and biological contaminants and for look-down, look-ahead detection of nuclear and chemical contaminants (ROC, p. A-4). The LHX ROC states that adverse weather pilotage and NBC operability are requirements.

RESOURCES REQUIRED FOR ANSWER: The performance of the environmental system should be evaluated during developmental testing and any cited deficiencies corrected prior to OT. No existing or planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 7.3

STATEMENT OF CRITICAL QUESTION: Is personal and protective equipment compatible with the task and the equipment interfaces to permit personnel to accomplish functions?

RATIONALE: The HFEA, number 7-1/17/86a, states that current NBC and cold weather protective clothing and equipment have an adverse effect on soldier performance. The HFEA recommends placing a high priority on development of such clothing and equipment to reduce adverse effects and to assure the LHX design is compatible with the clothing and equipment developed. The LHX PM response cites the RFP requirement for the contractor to place emphasis on design, development and testing of LHX to verify operational effectiveness under NBC conditions. The contractor must also demonstrate the capability of both variants to be operated and maintained under cold weather conditions.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Capable of conducting NOE operations continuously throughout the entire battlefield against a sophisticated threat who has the capability to use NBC and directed energy weapons (ROC, p. B-1 and B-2-55). Ability to conduct day and night, adverse weather operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: Deficiencies noted during demonstrations and DT should be resolved prior to production. No existing or planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 7.4

STATEMENT OF CRITICAL QUESTION: Does the crashworthiness of the LHX meet acceptable standards for injury and death avoidance?

RATIONALE: The HFEA, number 8-1/17/86a, has requested that the "modified" MIL-STD-1290 be operationally defined so as to clarify the crashworthiness design standards to which LHX will adhere. The LHX PM indicated that the reference to MIL-STD-1290 was in error, and that LHX crashworthiness would be equal to or better that the UH-60A Black Hawk.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Improved safety characteristics to include hazard avoidance, tail rotor protection, antitorque control, crashworthiness, twin engines, and will meet MIL-STD-1290B (revised) (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: All government-cited standards should be clarified prior to release of the RFP. No existing or planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 7.5

STATEMENT OF CRITICAL QUESTION: Is excessive noise environment present that will reduce personnel performance or create a health hazard?

RATIONALE: The HFEA, number 9-1/17/86a, recommends the design of LHX be in accordance with MIL-STD-1294, TB-MED-251, and noise limits of MIL-STD-1294, and provision of hearing protection to air and ground crews equal to or better than the SPH-4 helmet. The LHX PM responds that the LHX RFP specifies internal noise requirements, and a stringent internal noise survey will be conducted during contractor flight qualification.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Meet latest aeronautical design standards with acoustic noise limits, vibration levels and comfort zone temperatures (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: Use of government standards should be resolved prior to release of RFP. Deficiencies noted during the internal noise survey should be corrected prior to production. See "survey" cited by PM above.

CRITICAL QUESTION NUMBER: 7.6

STATEMENT OF CRITICAL QUESTION: Is the protection of personnel from lasers, radio frequency and microwave sufficient to preclude health safety hazard?

RATIONALE: The HFEA, number 10-1/17/86, expresses concern over the potential increase in casualties and degraded aircrew and mission performance due to high power lasers, infrared radiation, radio frequency and microwave exposure. The HFEA recommends the design of LHX components employing these type energy emitters comply with MIL-STD-1425, AR 40-46 and AR 40-583, a "safe" mode capability be provided, and adequate training for soldiers be delivered. The LHX PM response indicates general compliance with the HFEA recommendations.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Capable of conducting NOE operations continuously throughout the entire battlefield against a sophisticated threat who has the capability to use NBC and directed energy weapons (ROC, p. B-1 and B-2-55).

RESOURCES REQUIRED FOR ANSWER: Use of government standards and other requirements should be resolved prior to RFP release. Performance of protection systems should be evaluated at DT and deficiencies corrected prior to OT. No existing or planned research efforts currently identified.

CRITICAL QUESTION NUMBER: 7.7

STATEMENT OF CRITICAL QUESTION: Is the single crewmember LHX more or less survivable than a two-crewmember aircraft?

RATIONALE: The TOA states that "Given the reduced number of crew members and requirement for longer mission, we can expect a significant increase in fatigue related mishaps" (p. R-37). The TOA also cites findings that "The two-place LHX was approximately 25 percent more survivable against all threats modeled" (p. R-36). The HFEA, number 21-1/17/86, echoes these same concerns. The PM asserts that this issue is being addressed by the COEA and that the results will available to support the crew complement decision during ASARC.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The ROC (p. 3) states that single pilot operability is a requirement.

RESOURCES REQUIRED FOR ANSWER: This question should remain open. Given that maturation of individual technologies and overall system integration will have a significant impact on single pilot feasibility, success of this requirement is currently uncertain. As stated above, the 1) COEA is expected to address the issue of survivability, and 2) ARTI may provide some additional data on areas related to pilot error.

CRITICAL QUESTION NUMBER: 7.8

STATEMENT OF THE CRITICAL QUESTION: Can the night vision pilotage system allow a single pilot to fly NOE at night and in adverse to accomplish the mission with an acceptable level of safety?

This is a repeat of critical question number 1.18.

CRITICAL QUESTION NUMBER: 7.9

STATEMENT OF CRITICAL QUESTION: What will be the effect of fatigue and stress on LHX maintenance?

RATIONALE: The HFEA, number 39-1/17/86a, expresses concern that continuous operations will create undue fatigue and stress ultimately impairing mission capability. The HFEA recommends continued monitoring of the following efforts: HARDMAN, LSA, two-level maintenance study, and the LHX contractors' training analyses to determine if a problem exists.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: Improved capability for continuous operations through single pilot, multiple shift operations (ROC, p. 3).

RESOURCES REQUIRED FOR ANSWER: This question should remain open. The efforts cited below are expected to provide some guidance, however, actual performance will not be validated until OT. 1) HARDMAN, 2) LSA, 3) two-level maintenance study, and 4) LHX contractor training analyses.

CRITICAL QUESTION NUMBER: 7.10

STATEMENT OF CRITICAL QUESTION: How much will stress and fatigue affect mission accomplishment?

RATIONALE: A discussion of stress, fatigue and anxiety effects on operators was presented in critical question number 6.1. A discussion of fatigue and stress effects on maintainers was presented in critical question number 7.9.

APPLICABLE SYSTEM PERFORMANCE REQUIREMENTS PARAGRAPH NUMBER: The ROC (p. B-1) states that continuous operations are a requirement. Other requirements may be stress and fatigue related such as all-weather operability, single pilot operations, etc.

RESOURCES REQUIRED FOR ANSWER: See critical question numbers 6.1 and 7.9.

CRITICAL QUESTION NUMBER: 7.11

STATEMENT OF CRITICAL QUESTION: Can a single pilot complete the mission, given single point failures?

This is a Repeat of critical question number 1.10.

APPENDIX D

PRE-ASARC MANPRINT REVIEW

The following presents the LHX MANPRINT data discussed in the MANPRINT Affordability Section in a draft Deputy Chief of Staff for Personnel Pre-ASARC MANPRINT Review format.

I. Background/Overview

No information is provided in this section as the most current information reflecting adjustments to the acquisition strategy, program goals and objectives and the technical approach was not available.

II. System Definition

A. System equipment

1. Principal item

Scout attack helicopter

Utility helicopter

T-800 engine (GFE)

2. Training devices

Includes embedded devices, simulators and training aids distributed according to Annex F of the ROC.

3. Associated support equipment

The LHX is restricted from proliferating support equipment.

4. Other support equipment

None identified.

5. Pre-planned product improvements

To date, there have been no specific pre-planned product improvements (P^3Is). The design of the LHX is required to include provisions for incorporating P^3I. Additionally, the fire control system is required to be able to function with future weapons systems.

B. OP mode mission profile summary

This information should be in the COEA which was not available to the research team.

C. Force structure/organizational system

1. Total Army aviation structure

The aircraft will be integrated into the aviation units in the Army of Excellence Force Structure as replacements for OH-58A and C and AH-1 aircraft. The LHX will not replace the OH-58D aircraft in units equipped with AH-64 aircraft. However, the total demand for MOS cannot be determined due to the insufficiency of technological information from which personnel workloading will be derived.

2. Basis of Issue Plan (BOIP)

The latest BOIP was not available. However, the BOIP is of minimal value until the MOS decision is made. The most recent MOS decision memorandum that the research team is aware of does not foresee any new MOS nor does it discuss the potential consolidation of MOS. Our research indicates that there will be a requirement for at least two new MOS, LHX repairer and LHX technical inspector, as well as numerous ASI and SQI for such things as instructor pilots, instrument examiners and to identify those soldiers holding aviation trades MOS (68 series) who have been trained on the LHX.

3. Support organization impacts

The combat service support (CSS) impact appears to be minimal although not yet quantified. It is not possible to assess the CSS impact fully until the maintenance concept and MOS decisions are made.

D. Best Technical Approach (BTA)

The BTA was not available to the research team at the time the report was written.

E. Target Audience Description (TAD)

The TAD describes the categories of soldiers currently found in units planned to receive the LHX without regard for new or consolidated MOS. Neither does it address additional existing MOS not currently found in the aviation force structure such as computer operations specialists.

III. Facts/Constraints/Assumptions

Current information in this area particularly as it relates to adjustments to the acquisition strategy and goals was not available.

IV. MANPRINT Issues/Concerns

A. Human Performance

1. Crew size

The crew compliment decision has not been made.

(a) Total system performance requirement

The LHX is to perform all missions of the predecessor aircraft with the addition of an air-to-air engagement capability for the utility aircraft.

(b) Human performance standards

Detailed standards for human performance have not been published. The general statement that skills and skill levels shall not be increased implies that the standards of performance are also the same. Therefore, although the need to present the performance standards has been minimally satisfied, any shortcomings in the existing shortcomings has been perpetuated.

(c) Human error analysis

No analysis of human errors pertinent to the LHX was located by the research team.

(d) Operator workload

There appears to be considerable risk that the pilot workload will be excessive for the more complex mission and environment combinations

(e) National Guard, Army Reserve issues

No issues pertinent exclusively to crew size in the reserve components were identified.

2. Maintenance/maintainer, civilian maintainer, and supporter

(a) Total system performance requirement

The total maintenance system requirement is to sustain the stated aviation mission capability with substantial reductions in manpower. To date it appears as if all maintenance planning has been based upon reliability failures only. Therefore, if the maintenance system is organized, equipped and staffed only to meet the requirements of reliability failures, by definition it will not be able to sustain the mission capability if any combat damage is sustained.

(b) Human performance standards

The discussion of performance standards for pilots applies to Army maintenance personnel in tactical units. The situation is complicated by the stated intent to consolidate maintenance MOS. Consolidation will affect performance standards as they currently apply to CMF 67 personnel but the degree of change cannot be estimated until the direction that consolidation will take is known. Additionally, meaningful discussion of performance standards for depot personnel is not possible until the maintenance concept is defined.

(c) Human error analysis

There were no human error analyses identified.

(d) Impact of degraded built-in test automate diagnostic equipment

Degraded BIT/BITE (built-in test/built-in test equipment) will cause a concomitant degradation in aircraft availability. An Army Research Institute research effort on this subject indicates that historically BIT/BITE has not performed up to expectations.

With the information available it is not possible to estimate with any precision the probable performance of the BIT/BITE for LHX. Among other things it has not been determined what systems other than electronics will be monitored by BITE. It does appear however that if the BITE performance approximates the performance of the AH-64 fault detection and location system (FDLS), it may degrade aircraft availability by as much as 15%. That investigation also indicated that the impact of BITE on aircraft availability is most sensitive to the delay time and maintenance time required to perform manual fault isolation and repair.

(e) National Guard, Army Reserve issues

Two issues pertinent to the reserve components present themselves. First, how will the reserve component maintenance personnel be trained? In spite of the fact that planning for reserve component training has been touted as a major Army and TRADOC program since 1984 (Letter from General Richardson, Commanding General TRADOC, subject: Army Action Plan for Reserve Component Training, 27 August 1984), no special provisions have been made for accommodating the peculiarities of the reserve component training schedules and training opportunities.

The second issue is the impact of two level maintenance on the reserve components particularly as it pertains to those personnel working as full time maintenance technicians and secondly as it pertains to training and support of the AVCRADs in peacetime and after mobilization.

3. Environmental impacts on human performance

(a) Physical environment

There do not appear to be any substantive concerns pertaining to the physical aspects of the environment. The noise, vibration, lighting, air exchange rates, and accessibility requirements have been clearly stated and appear to be attainable.

(b) Operational Environment

The operator workload is not yet under control. Indications are that systems are operable independently but that when used in combination the single pilot will at best be subject to extremely high stress. The stress will induce fatigue and those two in combination will increase the rates of human error. This research effort did not locate any empirical data on the projected frequency of human error under the varying mission scenarios.

Although the impact of protective clothing is discussed in the HFEA and other documents it does not seem to be a serious problem. There is no indication that performance would be degraded below current levels and it appears that the applications of technology to simplify maintenance and to build in environmental protection will improve performance.

(c) Social environment

Although it has been mentioned in some of the earlier documents, it does not appear that the LHX will introduce any significant changes in performance due to the social environment.

B. Other Issues

None identified.

V. Specific MANPRINT Domain Issues

See the MANPRINT Affordability Section of the report. That section discusses each domain independently.

IV. O&S Cost Savings

This research effort did not address O&S costs.

MANNED SYSTEMS GROUP

Systems Research Laboratory

Working Paper MSG 88-01

PROPOSED MILITARY STANDARD

MIL-STD-ABC
TASK ANALYSIS

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16 March 1988

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MIL-STD-ABC
March 16, 1988

DEPARTMENT OF DEFENSE
Washington, DC 20301

Task Analysis

MIL-STD-ABC

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, US Army Materiel Readiness Support Activity, ATTN: AMXMD-EI, Lexington, KY 40511, by letter or by completing the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document.

FOREWORD

This standard is the result of more than a decade of work by personnel in all three armed services and industry. Impetus for the work was provided originally by the Commanding General, U.S. Army Operational Test and Evaluation Agency. However, the increasing cost and complexity of military materiel attracted other participants to the effort, since task analysis is a fundamental tool of a variety of engineering specialty programs.

Precisely because task analysis has so many users and practitioners, it also suffers from a profusion of technical usages. Workers early in the program leading to this standard found that, while they used the same terms, they often intended different meanings. The principal effort in producing this document was obtaining agreement among the many different specialties within each of the armed services on one common concept for task analysis.

As more and more military materiel contains sophisticated electronics, and as descriptions of human behavior with regard to that materiel involve less gross muscle-movement and more cognitive tasks (whose performance is more difficult to describe), there has been a need to provide flexibility for innovation and further development in the art of task analysis. While this standard allows for that flexibility (by permitting users to select virtually any means of conducting a task analysis from stubby pencil to sophisticated software), the format and content of a task analysis product is described with specificity.

This standard also accommodates recent specialty programs in all services concerned with manpower, personnel and training (including embedded training) [MANPRINT in the Army, HARDMAN in the Navy, and RAMPARTS in the Air Force].

1. SCOPE

1.1 Purpose. This standard defines the requirements for performing a task analysis where such analysis is required in the development or acquisition of military systems, equipment and facilities.

1.2 Application of Standard. This standard prescribes the requirements and deliverable products of task analysis throughout the Department of Defense in all engineering and support functions including training, human engineering, manpower, personnel, system safety, workload analysis, logistic support analysis, and test and evaluation.

1.2.1 Tailoring of Task Descriptions. Where this standard is applied in a procurement document, the procuring activity shall tailor the requirements of Paragraphs 4 and 5 below to the specific acquisition program, considering the previous development of the system (if any) and the specific tailoring guidance given in Appendix B.

2. REFERENCED DOCUMENTS

In accordance with DoD Directive 5000.43, Acquisition Streamlining (dated January 15, 1986), this standard incorporates by reference no additional Department of Defense Index of Specifications and Standards (DoDISS) documents as necessary for the full completion of the tasks stated herein. Users of this standard may, however, elect to consult MIL-HDBK-XXY (December 1985) for background explanations of technical procedures and examples of task analysis products.

3. DEFINITIONS

Because the process of task analysis is an old one, there are a number of historical precedents and many technical documents (government and commercial) proposing ways to do it. Terminology from document to document is often inconsistent. For the purposes of clarity and cost-control, certain "key terms" are operationally defined in the Glossary (Appendix A) of this standard. Although stated in an appendix for ease of presentation, those definitions are mandatory where this standard is applied.

5.2.3 INPUTS TO TASK INVENTORY. Mission analysis, scenarios/conditions (such as mission profiles and operational mode summaries) shall be prepared and documented prior to beginning preparation of the task inventory. The task inventory shall thereafter be developed by examining each system function allocated to personnel and determining what operator, maintainer and support personnel tasks are involved in the completion of each such function. The structure of the task inventory shall conform to the task taxonomy stated in Appendix A of this standard and shall be maintained in accordance with the format requirements of DI-HFAC-999X. A task statement should exhibit the properties of clarity, completeness, conciseness, and relevance. Clarity is enhanced when easily understood wording is used, when the task statement is precise enough that it means the same thing to all intended users, and when vague statements of activities, skill, knowledge, or responsibility are avoided. A complete task statement contains sufficient detail to meet the needs of all intended users of such data. Concise task statements are brief, begin with an action verb selected from Appendix D (the subject "I" or "you" is understood), and employ commonly used and well understood terminology, abbreviations, and acronyms. Finally, a relevant task statement contains only information germane to describing the task, not the qualifications of the operator, maintainer or support personnel, necessary tools or job aids, and so forth.

5.2.4 MARKING OF SPECIAL TASKS. The following tasks within the task inventory shall be specially coded (for ease of retrieval and analysis):

5.2.4.1 Critical Tasks. (See Appendix A.)

5.2.4.2 Logistics Tasks. Those tasks which are not critical tasks, but which are unique to the new manned system due to new technology or operational concepts, or which are system performance, supportability, cost, or readiness drivers.

5.3 <u>Task 201 - Conduct of Task Analysis</u>.

5.3.1 PURPOSE. To conduct an analysis of the data in the task inventory. This analysis will address the lowest taxonomic level specified by the procuring activity and will describe task performance in terms of human performance time and accuracy. The product of the analytic effort is intended for use in the system acquisition process in support of equipment design, testing and evaluation planning, training requirements identification, manning and workload assessment, development of training and maintenance manuals, and other documentation and reporting. In addition, it will support LSA requirements to (1) identify logistic support resource requirements, (2) identify new or critical logistic support resource requirements, (3) identify transportability requirements, (4) identify support requirements which exceed established goals, thresholds or constraints, (5) provide data to support participation in the development of design alternatives to reduce O&S costs, optimize logistic support resource requirements,

GLOSSARY

1. Task Taxonomy. The structure of the performance description of a manned system, consisting of the following elements:

a. Mission. What the manned system is supposed to accomplish (e.g., combat reconnaissance).

b. Scenario/Conditions. Categories of factors for constraints under which the manned system will be expected to be operated and maintained (e.g., day/night, all-weather, all-terrain operation).

c. Function. A broad category of activity performed by a manned system (e.g., transportation).

d. Job. The combination of all human performance tasks required for operations and maintenance by one personnel position in a manned system (e.g., driver).

e. Duty. A set of operationally related tasks within a job (e.g., emergency repair).

f. Task. A composite of related activities (perceptions, decisions, and responses) performed for an immediate purpose (e.g., change a tire).

g. Subtask. Activities (perceptions, decisions, and responses) which fulfill a portion of the immediate purpose within a task (e.g., remove lug nuts).

h. Task Element. The smallest logically and reasonably definable unit of behavior required in completing a task or subtask (e.g., apply counterclockwise torque to lug nut with lug wrench).

2. Task Analysis. A process performed on a task inventory whose component steps are left to the selection of the user (based on the nature of the acquisition, the complexity of the human performance requirements, and the stage of design maturity) resulting in a product by the same name whose content is specified in MIL-STD-ABC and whose format is prescribed by data item descriptions contained therein.

3. Task Inventory. A comprehensive listing of all tasks performed upon system hardware by operations, maintenance and support personnel.

4. Task Statement. The way in which any task is described in the

TAILORING GUIDE FOR MIL-STD-ABC

> NOTE: This appendix provides guidance primarily to government employees who will be determining the extent to which the provisions of this standard shall apply to a specific procurement. This portion of MIL-STD-ABC is therefore not intended to be binding upon a contractor.

10. SCOPE

This appendix provides guidance for the technical personnel within the procuring activity for the selection of provisions within this standard to be applied to a specific procurement.

20.0 APPLICABLE DOCUMENTS

In addition to the foregoing provisions, the following documents should be consulted:

MIL-STD-882	System Safety
MIL-STD-1379	Military Training Programs
MIL-STD-1388	Logistic Support Analysis
MIL-H-46855	Human Engineering
MIL-P-28700	Personnel Planning Data
MIL-T-29053	Requirements for Training System Development

30.0 TAILORING GUIDE

30.1 General. This military standard on task analysis has been written with two primary goals: (1) to meet in all respects every detailed requirement of task analysis which could reasonably be proposed by engineering specialty programs (such as logistics and human factors) and other supporting programs (such as training, manning, workload, and safety); and (2) to meet both the spirit and the letter of Department of Defense Directive 5000.43 (which restricts the application of specifications and standards). To meet both goals required the creation of a formidable document with highly elaborate specifications. It was never the intent of its many authors that all of the provisions of this standard would be casually applied to procurement after procurement. Instead, the government technical personnel who have identified needs for task analysis data on a particular project involving a procurement should identify the minimum tasks and data required to satisfy all of the needs and then line out all other provisions, specifications and descriptions.

MIL-STD-ABC Paragraph	PHASE OF SYSTEM DEVELOPMENT				
	Requirements and Tech Base	Proof of Principle	Demonstration and Proveout	Production and Deployment	Product Improvement
A1. Task Taxonomy					
a. Mission	E	E	E	E	E
b. Scenario/Conditions	R	R	E	E	E
c. Function	O	R	E	E	E
d. Job	O	O	R	E	E
e. Duty	O	O	R	E	E
f. Task	R	E	E	E	E
g. Subtask	O	O	O	R	R
h. Task Element	O	O	O	O	O
5.1 General					
5.2 Task 101	O	R	R	E	R
5.2.1 Purpose	O	R	R	E	R
5.2.2 Task Inventory	O	R	R	E	R
5.2.3 Inputs to Task Inventory	O	R	R	E	R
5.2.4 Marking of Special Tasks	O	O	R	R	R
5.2.4.1 Critical Tasks	R	E	E	E	E

Figure 1. Tailoring Matrix for MIL-STD-ABC

APPENDIX C

Data Item Descriptions

DATA ITEM DESCRIPTION			Form Approved OMB No. 0704-0188 Exp. Date: Jun 30, 1986

1. TITLE	2. IDENTIFICATION NUMBER
TASK INVENTORY REPORT	DI-HFAC-999X

3. DESCRIPTION/PURPOSE

3.1 A task inventory is a comprehensive listing of all human tasks associated with a system, equipment, or facility. Its purpose is to itemize all human activity to be performed for operations, maintenance and support of a system in a standardized manner permitting subsequent analysis for issues of training, human engineering, logistics, manpower, personnel, workload and system safety.

4. APPROVAL DATE (YYMMDD)	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR)	6a. DTIC REQUIRED	6b. GIDEP REQUIRED
	A/AMXMD-EI		

7. APPLICATION / INTERRELATIONSHIP

7.1 This Data Item Description (DID) contains the preparation instructions for the task inventory data required by Task 101 of MIL-STD-ABC.

7.2 This DID is applicable to the acquisition of military systems, equipment and facilities.

8. APPROVAL LIMITATION	9a. APPLICABLE FORMS	9b. AMSC NUMBER

10. PREPARATION INSTRUCTIONS

10.1 Source document. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments and revisions, shall be as reflected in the contract.

10.2 Media. The task inventory shall be prepared in each of the media not lined out below:

a. typewritten, on 8½ x 11" paper
b. typewritten, on 8½ x 14" paper
c. diskette (size: ________________)
d. magnetic cassette (type: ______________)

10.3 Format. The task inventory shall be structured in accordance with the task taxonomy stated in Appendix A of MIL-STD-ABC, and shall contain for each task the elements specified in paragraph 4 of Appendix A.

DD Form 1664, FEB 85   *Previous edition is obsolete*   PAGE 1 OF 1 PAGES

DATA ITEM DESCRIPTION

Form Approved
OMB No. 0704-0188
Exp. Date: Jun 30, 1986

1. TITLE	2. IDENTIFICATION NUMBER
TASK ANALYSIS REPORT	DI-HFAC-999Y

3. DESCRIPTION/PURPOSE

3.1 A task analysis is used by trainers, logisticians, human engineers, and specialists in health and safety, and manpower and personnel to make decisions regarding the design, performance and support of a manned system.

4. APPROVAL DATE (YYMMDD)	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR)	6a. DTIC REQUIRED	6b. GIDEP REQUIRED
	A/AMXMD-EI		

7. APPLICATION / INTERRELATIONSHIP

7.1 This Data Item Description (DID) contains the preparation instructions for the task analysis data required by Task 201 of MIL-STD-ABC.

7.2 This DID is applicable to the acquisition of military systems, equipment and facilities.

8. APPROVAL LIMITATION	9a. APPLICABLE FORMS	9b. AMSC NUMBER

10. PREPARATION INSTRUCTIONS

10.1 Source document. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments and revisions, shall be as reflected in the contract.

10.2 Media. The report of task analysis shall be prepared in each of the media not lined out below:

a. typewritten, on 8 1/2 x 11" paper
b. typewritten, on 8 1/2 x 14" paper
c. diskette (size: ________)
d. magnetic cassette (type: ________)

10.3 Format.

a. The report of task analysis shall be presented in both graphic and textual form, as follows:

(1) Graphic: The graphic presentation shall be time-based and shall have the cumulative time shown in the selected units (hours, minutes or seconds) clearly marked at the bottom of each page or frame of display. Tasks shall be indicated in the space above the time markings in Gantt-type format with each task occupying that amount of time it required for criterion performance. All critical tasks shall appear on the illustration and shall be differentiated from non-critical tasks by means of some graphic technique appropriate to the medium selected (in paragraph 10.2 above). Tasks whose performance is unscheduled shall be illustrated by reference to a scenario in which the task reasonably appears. Each page or frame of display shall be consecutively numbered at a location which does not interfere with the technical information being presented.

(2) Textual: The format for this portion of the report of task analysis shall be selected by the contractor for maximum clarity of presentation based on:

(a) the medium selected in paragraph 10.2 above, and
(b) the number of data elements selected from the list in subparagraph 10.3b below.

10. PREPARATION INSTRUCTIONS (Cont'd)

(d) Logistics considerations
(1) Skills required
(a) Skill level code
(b) Skill specialty code
(c) Skill specialty evaluation code
(2) Tools required
(3) Job aids and manuals required
(4) Support and test equipment identification
(a) Support item sequence code
(b) Item category code
(5) Electric power requirements
(6) Spares and expendables required
(7) Number of persons per skill specialty code
(8) Number of manhours per skill specialty code
(9) LSA control number
(e) Manpower and personnel considerations
(1) Physical characteristics of task performers (PULHES codes)
(2) Aptitude characteristics of task performers (ASVAB scores)
(3) Planned MOS of task performers
(4) Range of criterion ASVAB scores for lower 20% of personnel currently assigned to MOS identified in subparagraph (3) above
(f) Safety considerations
(1) Special protective equipment required
(2) Hazards encountered
(a) Frequency
(b) Cause
(c) Consequence
(3) Weights to be lifted or transported
(g) Training Considerations
(1) Type of training given to task performers
(2) Length of training (in hours)
(3) Estimated cost/trainee/hour
(4) End of training comprehension and performance test score for each trainee
(h) Discussion
(1) Identification of problem areas by concern
(a) Performance and workload
(b) Health
(c) Human engineering
(d) Logistics
(e) Manpower and personnel
(f) Safety
(g) Training
(2) Proposed alternatives for solving the problem areas identified above.
(3) Estimated impact upon manned system performance requirements of the time and accuracy measures of task performance.
(i) Conclusions. State whether the above analysis does or does not support the projected attainment of manned system performance requirements (effectiveness and availability) given the present design of system hardware and software, the present criteria for personnel selection and affordability, and the present training concept.

RECOMMENDED VERBS FOR TASK INVENTORY

INTRODUCTION

This Appendix lists recommended action verbs to be used in preparing a task inventory. Some specialized verbs, not listed here, may be needed for a particular weapon system. (For example, "lay" is commonly used in tasks describing cannon-type weapon systems, but is not applicable to all weapon systems.) Many of the verbs presented here are synonymous. The user should select the one verb which appears to be closest to the intended meaning on that particular system and use that verb consistently throughout the analysis.

This list of verbs was derived from two sources:

Definitions of Terms for Reliability and Maintainability. Philadelphia, PA: U.S. Naval Publications and Forms Center: MIL-STD-721C. 12 June 1981

Roth, J. Thomas, Implementing Embedded Training: Volume 4 of 10: Identifying ET Requirements. Alexandria, VA: U.S. Army Research Institute Research Product. Draft dated 30 November 1987.

Access
1. To gain visibility of or the ability to manipulate.
2. To cause to be displayed, as with a computer menu.

Accomplish To do, carry out, or bring about; to reach an objective.

Achieve To carry out successfully.

Acknowledge To make known the receipt or existence of.

Actuate To put into mechanical motion or action; to move to action.

Adjust
1. To bring to a specified position or state.
2. To bring to a more satisfactory state; to manipulate controls, levers, linkages, etc.; to return equipment from an out-of-tolerance condition to an in-tolerance condition.

Brief	To give final precise instructions; to coach thoroughly in advance; to give essential information to.
Calculate	To determine by arithmetic processes.
Calibrate	To determine accuracy, deviation, or variation by special measurement or by comparison with a standard.
Camouflage	To conceal or disguise by camouflage.
Cancel	To cause not to occur, as in canceling a command.
Categorize	To put into categories or general classes.
Center	1. To adjust so that axes coincide.
	2. To place in the middle of.
Change	1. To replace one item or assembly with another.
	2. To adjust.
Check	1. To confirm or establish that a proper condition exists; to ascertain that a given operation produces a specified result; to examine for satisfactory accuracy, safety, or performance; to confirm or determine measurements by use of visual or mechanical means.
	2. To perform a critical visual observation or check for specific conditions; to test the condition of.
Chock	To place a blocking device adjacent to, in front of, or behind a wheel to keep it from moving.
Choke	To enrich the fuel mixture of a motor by partially shutting off the air intake of the carburetor.
Choose	To select after consideration.
Chunk	To cause the association of several entities.
Classify	To put into categories or general classes.
Clean	To wash, scrub, or apply solvents to; remove dirt, corrosion, or grease.
Clear	1. To move people and/or objects away from.
	2. To open the throttle of an idling engine to free it from carbon.
Close	1. To block against entry or passage; to turn, push, or pull in the direction in which flow is impeded.

Debug	To detect and remedy an inadequacy in software.
Decide	To arrive at a solution.
De-energize	To take energy from.
Define	1. To determine or identify the essential qualities or meaning. 2. To fix or mark the limits of.
Deflate	To release air or gas from.
Delete	To remove from association with or cause no longer to exist.
Deliver	1. To hand over. 2. To send to an intended target or destination.
Demonstrate	To show clearly.
Depart	To go away; to leave.
Depressurize	To release gas or fluid pressure from.
Derive	To infer or deduce.
Describe	To represent or give an account of in words.
Destroy	To ruin, demolish, or put out of existence; to make unfit for further use.
Detect	To discover or determine the existence, presence, or fact of.
Determine	1. To obtain definite and first-hand knowledge of, to confirm, or establish that a proper condition exists. 2. To investigate and decide to discover by study or experiment.
Develop	To set forth or make clear by degrees or in detail.
Diagnose	To recognize and identify the cause or nature of a condition, situation, or problem by examination or analysis.
Disassemble	To take to pieces; to take apart to the level of the next smaller unit or down to all removable parts.
Disconnect	1. To sever the connection between; to separate keyed or matched equipment parts.

	2. To put on record..
	3. To put in information or data.
Erect	To put up by the fitting together.
Establish	To set on a firm basis.
Estimate	To judge or determine roughly the size, extent, or nature of.
Evaluate	To determine the importance, size, or nature of; to appraise; to give a value or appraisal to on the basis of collected data.
Exchange	To part with or substitute.
Execute	To carry out fully.
Explain	To make something plain and understandable.
Express	To represent in words; to state.
Extract	To draw forth; to pull out forcibly.
Fill out	To enter information on a form.
Find	1. To discover or determine by search; to indicate the place, site, or limits of.
	2. To discover by study or experiment; to investigate and decide.
Fire	To launch a missile or shoot a gun.
Hold	To have or keep in the grasp.
Hypothesize	To develop a prediction or speculation, of some degree of uncertainty, based on incomplete factual information or theory.
Identify	1. To establish the identity of.
	2. To determine the classification of.
Illustrate	To make clear or clarify.
Indicate	To point out.
Inform	To make known to; to give notice or report the occurrence of.
Initialize	To place in an initial or beginning condition.
Input	To enter information into a computer or data system.

interaction with a computer system.

Lubricate	To put lubricant on specified locations.
Maintain	1. To hold or keep in any particular state or condition, especially in a state of efficiency or validity.
	2. To sustain or keep up.
Manage	To handle or direct with a degree of skill.
Maneuver	To make a series of changes in direction and position for a specified purpose.
Manipulate	To operate with the hands.
Measure	To determine the dimensions, capacity, or amount by use of standard instruments or utensils.
Modify	To alter or change somewhat the form or qualities of.
Monitor	1. To visually take note of or to pay attention to in order to check on action or change.
	2. To attend to displays continually or periodically to determine equipment condition or operating status.
Mount	To attach to a support.
Move	To change the location or position of.
Name	To identify by name.
Navigate	To operate and control course of.
Neutralize	To destroy the effectiveness of; to nullify.
Notify	To make known to; to give notice or report the occurrence of.
Observe	1. To conform one's actions or practice to.
	2. To take note of visually; to pay attention to.
Obtain	1. To get or find out by observation or special procedures.
	2. To gain or attain.
Open	1. To move from closed position; to make available for passage by turning in an appropriate direction.
	2. To make available for entry or passage by turning back, removing, or clearing away.

Pull	To exert force upon an object so as to cause motion toward the force.
Pump	1. Raise or lower by operating a device which raises, transfers, or compresses fluids by suction, pressure or both. 2. To move up and down or in and out as if with a pump handle.
Purge	1. To expel unwanted fluids from. 2. To cause to be eliminated or dissociated from.
Push	1. To press against with force so as to cause motion away from the force. 2. To move away or ahead by steady pressure.
Qualify	To declare competent or adequate.
Queue	To cause to be placed in a queue or ordered sequence of similar processes.
Raise	To move or cause to be moved from a lower to a higher position; to elevate.
Read	To derive information from written material.
Recall	To bring forth information from memory.
Receive	To come into possession of; to get.
Recognize	To perceive to be something previously known or designated.
Record	To set down in writing.
Recover	To get back; to regain.
Refuel	To put fuel into the tanks of a vehicle again.
Release	1. To set free from an inactive or fixed position; to unfasten or detach interlocking parts. 2. To let go of. 3. To set free from restraint or confinement.
Remove	1. To perform operations necessary to take an equipment unit out of the next larger assembly or system. 2. To take off or eliminate.

Search	To examine a context to determine the presence of a particular entity or type of entity.
Secure	To make fast or safe.
Select	To take by preference or fitness from a number or group; to pick out; to choose.
Send	To dispatch by means of communication.
Service	To perform such operations as cleanup, lubrication, and replenishment to prepare for use.
Set	1. To put a switch, pointer, or knob into a given position; to put equipment into a given adjustment, condition or mode. 2. To put or place in a desired orientation, condition, or location.
Set up	To prepare or make ready for use.
Show	To point out or explain.
Shut down	To perform operations necessary to cause equipment to cease or suspend operation.
Sight	1. To look at through or as if through a sight. 2. To aim by means of sights.
Signal	To notify or communicate by signals (i.e., a prearranged sign, notice or symbol conveying a command, warning, direction or other message).
Solve	To find a solution for.
Specify	To name or state explicitly or in detail.
Squeeze	To force or thrust together by compression.
Start	To perform actions necessary to set into operation; to set going; to begin.
State	To express the particulars of in words.
Stay	To remain; to continue in a place.
Steer	To direct the course of.
Stop	To perform actions necessary to cause equipment to cease or suspend operation.
Store	To cause to be placed in an accessible location.

Turn	To cause to revolve about an axis or center.
Type	To enter information into a device by means of a keyboard.
Unload	To take off.
Update	To replace older, possibly invalid, information with more current information.
Use	To put into action or service; to avail oneself of; to carry out a purpose or action by means of.
Utilize	To put into action or service; to avail oneself of; to carry out a purpose or action by means of.
Validate	To ascertain the correctness of, using an independent source of information.
Verify	1. To confirm or establish that a proper condition exists. 2. To establish the truth or accuracy of.
Visualize	To create a mental picture or concept of.
Wait	To suspend activity in a sequence of activities until a given condition occurs or a set time has elapsed.
Write	To inscribe words on a surface.
Zero	To bring to a desired level or null position.

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)* ☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER *(Specify)*: ______
b. ADDRESS *(Street, City, State, ZIP Code)*	

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 1426, 82 MAR

PREVIOUS EDITION IS OBSOLETE.

MANNED SYSTEMS GROUP

Systems Research Laboratory

Working Paper MSG 89-01

PROPOSED MILITARY STANDARD

MIL-STD-TASK
TASK ANALYSIS

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24 March 1989

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MIL-STD-TASK
March 24, 1989

DEPARTMENT OF DEFENSE
Washington, DC 20301

Task Analysis

MIL-STD-TASK

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, Humman Engineering Laboratory, U.S. Army Laboratory Command, ATTN: SLCHE-FH, Aberdeen Proving Ground, MD 21005-5001, by letter or by completing the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document.

FOREWORD

This standard is the result of more than a decade of work by personnel in all three armed services and industry. Impetus for the work was provided originally by the Commanding General, U.S. Army Operational Test and Evaluation Agency. However, the increasing cost and complexity of military materiel attracted other participants to the effort, since task analysis is a fundamental tool of a variety of engineering specialty programs.

Precisely because task analysis has so many users and practitioners, it also suffers from a profusion of technical usages. Workers early in the program leading to this standard found that, while they used the same terms, they often intended different meanings. The most difficult part of the effort in producing this document was obtaining agreement among the many different specialties within each of the armed services on one common concept for task analysis.

As more and more military materiel contains sophisticated electronics, and as descriptions of human behavior with regard to that materiel involve less gross muscle-movement and more cognitive tasks (whose performance is more difficult to describe), there has been a need to provide flexibility for innovation and further development in the art of task analysis. While this standard allows for that flexibility (by permitting users to select virtually any means of conducting a task analysis from stubby pencil to sophisticated software), the format and content of a task analysis product are described with specificity.

This standard also accommodates recent specialty programs in all services concerned with manpower, personnel and training (including embedded training) [MANPRINT in the Army, HARDMAN in the Navy, and IMPACTS in the Air Force], and is consistent with DoD Directive 5000.53 (Manpower, Personnel, Training and Safety (MPTS) in the Defense System Acquisition Process), dated 30 December 1988.

CONTENTS

FIGURES

1. SCOPE

1.1 Purpose. This standard defines the requirements for performing a task analysis where such analysis is required in the development or acquisition of military systems, equipment and facilities.

1.2 Application of Standard. This standard prescribes the requirements and deliverable products of task analysis throughout the Department of Defense in all engineering and support functions including training, human engineering, manpower, personnel, system safety, workload analysis, logistic support analysis, and test and evaluation.

1.2.1 Tailoring of Task Descriptions. Where this standard is applied in a procurement document, the procuring activity shall tailor the requirements of Paragraphs 4 and 5 below to the specific acquisition program, considering the previous development of the system (if any) and the specific tailoring guidance given in Appendix B.

2. REFERENCED DOCUMENTS

In accordance with DoD Directive 5000.43, Acquisition Streamlining (dated January 15, 1986), this standard incorporates by reference no additional Department of Defense Index of Specifications and Standards (DoDISS) documents as necessary for the full completion of the tasks stated herein. Users of this standard may, however, elect to consult MIL-HDBK-XXY (December 1985) for background explanations of technical procedures and examples of task analysis products.

3. DEFINITIONS

Because the process of task analysis is an old one, there are a number of historical precedents and many technical documents (government and commercial) proposing ways to do it. Terminology from document to document is often inconsistent. For the purposes of clarity and cost-control, certain "key terms" are operationally defined in the Glossary (Appendix A) of this standard. Although stated in an appendix for ease of presentation, those definitions are mandatory where this standard is applied.

4. GENERAL REQUIREMENTS

4.1 Task analysis shall be conducted as part of the design of hardware components of a manned system so that the human performance requirements occasioned by that design may be identified.

4.2 With each iterative cycle of hardware and software redesign, corresponding changes shall be made to the task inventory and report of task analysis.

4.3 The same task inventory for a given manned system shall be used by all engineering specialties which use task analysis information (including training, test and evaluation, human engineering, logistics, manpower, personnel, workload, and system safety).

4.4 The level of detail in any report of task analysis shall be no greater than is necessary to meet the requirements of the users of that report. The level of detail shall normally be stated by the procuring activity by reference to the level of task taxonomy to be used by the preparer.

4.5 Unless a particular method for conducting a task analysis is required by the statement of work of the contract, the preparer shall select and employ the most cost-effective method which meets the needs of the users identified in the statement of work.

5. DETAILED REQUIREMENTS

5.1 General. The detailed requirements of this standard are organized into two efforts. Each results in a deliverable product, and each therefore has a data item description (see Appendix C). The second cannot be performed without the results of the first.

5.2 Planning.

5.2.1 PURPOSE. To identify the human performance requirements in order for the manned system to meet its operations, maintenance and support requirements in its intended environment.

5.2.2 TASK DESCRIPTION. The human performance requirements will be determined by analysis, described in task statements, and recorded in the form of a task inventory (specified down to the taxonomic level selected and stated by the procuring activity). A task statement should exhibit the properties of clarity, completeness, conciseness, and relevance. Clarity is enhanced when easily understood wording is used, when the task statement is precise enough that it means the same thing to all users, and when vague statements of activities, skill, knowledge, or responsibility are avoided. A complete task statement contains sufficient detail to meet the needs of all users of such data.

Concise task statements are brief, begin with an action verb selected from Appendix D (the subject "I" or "you" is understood), and employ commonly used and well understood terminology, abbreviations, and acronyms. Finally, a relevant task statement contains only information germane to describing the task--not the qualifications of the operator, maintainer or support personnel, necessary tools or job aids, and so forth.

5.2.2.1 INPUTS TO TASK DESCRIPTION. Mission analysis, scenarios and conditions (such as mission profiles and operational mode summaries) shall be obtained and reviewed prior to beginning preparation of the task inventory. The task inventory shall thereafter be developed by examining each system function allocated to personnel by the design of the hardware and software and determining what operator, maintainer and support personnel tasks are involved in the completion of each such function. Where the task description process is started at a time when design is very general, comparability analysis (see Appendix A) may be used to generate likely tasks.

5.2.3 TASK INVENTORY. A task inventory lists <u>all</u> of the tasks that operator, maintainer and support personnel must perform with regard to the system hardware, equipment, or facility being acquired. The task inventory shall include a description of each task in behavioral terms (see Appendix A), and the tasks shall be organized or grouped according to logical criteria (such as immediate purpose). The structure of the task inventory shall conform to the task taxonomy stated in Appendix A of this standard and shall be maintained in accordance with the format requirements of DI-HFAC-999X. The level of detail in the task inventory (e.g., duty, task, subtask, task element) shall be selected and specified by the procuring activity for each delivery of data.

5.2.4 MARKING OF SPECIAL TASKS. The following tasks within the task inventory shall be specially coded (for ease of retrieval and analysis):

5.2.4.1 Critical Tasks. (See Appendix A.)

5.2.4.2 Logistics Tasks. Those tasks which are unique to the new manned system due to new technology or operational concepts, or which are system performance, supportability, cost, or readiness drivers.

5.3 <u>Conduct of Task Analysis</u>.

5.3.1 PURPOSE. To analyze selected tasks, subtasks, and task elements contained in the task inventory. This analysis will address the lowest taxonomic level specified by the procuring activity and will describe task performance in terms of human performance time and accuracy. The product of the analytic effort is intended for use in the system acquisition process in support of equipment design, testing and evaluation planning, training requirements identification, manning and workload assessment, development of training and maintenance manuals, and other documentation and reporting. In addition, it will support LSA requirements to (1) identify logistic support resource requirements, (2) identify new or critical logistic support resource requirements, (3) identify transportability requirements, (4) identify support requirements which exceed established goals, thresholds or constraints, (5) provide data to support participation in the development of design alternatives to reduce O&S costs, optimize logistic support resource requirements, or enhance readiness, and (6) provide source data for preparation of required ILS documents (technical manuals, training programs, manpower and personnel lists, etc.).

5.3.2 TASK ANALYSIS. Conduct a detailed analysis of each operations, maintenance and support task listed in the task inventory, describing each task in terms of the parameters selected by the procuring activity from the list given in DI-HFAC-999Y.

5.3.3 PREPARATION OF REPORT OF TASK ANALYSIS. The report of task analysis shall be in the format shown in DI-HFAC-999Y and shall include those structrual and analytic elements selected by the procuring activity on the face of DI-HFAC-999Y.

GLOSSARY

1. Task Taxonomy. The structure of the performance description of a manned system, consisting of the following elements:

a. Mission. What the manned system is supposed to accomplish (e.g., combat reconnaissance).

b. Scenario/Conditions. Categories of factors for constraints under which the manned system will be expected to be operated and maintained (e.g., day/night, all-weather, all-terrain operation).

c. Function. A broad category of activity performed by a manned system (e.g., transportation).

d. Job. The combination of all human performance tasks required for operations and maintenance by one personnel position in a manned system (e.g., driver).

e. Duty. A set of operationally related tasks within a job (e.g., emergency repair).

f. Task. A composite of related activities (perceptions, decisions, and responses) performed for an immediate purpose (e.g., change a tire).

g. Subtask. Activities (perceptions, decisions, and responses) which fulfill a portion of the immediate purpose within a task (e.g., remove lug nuts).

h. Task Element. The smallest logically and reasonably definable unit of behavior required in completing a task or subtask (e.g., apply counterclockwise torque to lug nut with lug wrench).

2. Task Analysis. A process performed on tasks, subtasks, and task elements selected from the task inventory by the procuring activity. The component steps of a task analysis are left to the selection of the procuring authority (based on the nature of the acquisition, the complexity of the human performance requirements, and the stage of design maturity). The result of the process of task analysis is a product by the same name whose content is specified in MIL-STD-TASK and whose format is prescribed by data item description DI-HFAC-999Y.

3. Task Definition. The process of preparing a task inventory.

4. Task Inventory. A comprehensive listing of all tasks performed upon system hardware by operations, maintenance and support personnel. The format of a task inventory is prescribed by DI-HFAC-999X.

5. Task Statement. The way in which any task is described in the task inventory. The task statement consists of three basic elements: (1) an action verb [from Appendix D] that states what is to be accomplished, (2) an object that identifies what is to be acted upon, and (3) qualifying phrases to distinguish or limit the task. A task statement describes describes specific work behavior with clear beginning and ending points. A critical task has a fourth element: performance standard (given in time and accuracy dimensions). Completion of any task results in a product, condition or result that can be evaluated for quantity, quality, accuracy, timeliness or fitness in the work environment (DOD-HDBK-92-1).

6. Critical Task. A task which, if not accomplished to the specified standard, results in a serious adverse effect upon mission achievement, survivability, or safety.

7. Comparability Analysis. An analytic process, which can be performed by any one of a number of different techniques, for estimating human performance requirements of a new system by aggregating the human performance requirements of one or more predecessor systems (or hardware and software components of systems thought to be "like" the new system).

APPENDIX B
March 24, 1989

TAILORING GUIDE FOR MIL-STD-TASK

NOTE: This appendix provides guidance primarily to government employees who will be determining the extent to which the provisions of this standard shall apply to a specific procurement. This portion of MIL-STD-TASK is therefore not intended to be binding upon a contractor or cited within a contract.

10. SCOPE

This appendix provides guidance for the technical personnel within the procuring activity for the selection of provisions within this standard to be applied to a specific procurement.

20.0 APPLICABLE DOCUMENTS

In addition to the foregoing provisions, the following documents may be consulted for additional information:

MIL-STD-882	System Safety
MIL-STD-1379	Military Training Programs
MIL-STD-1388	Logistic Support Analysis
MIL-H-46855	Human Engineering
MIL-P-28700	Personnel Planning Data
MIL-T-29053	Requirements for Training System Development
DOD-HDBK-292	Training Materials Development

30.0 TAILORING GUIDE

30.1 General. This military standard on task analysis has been written with two primary goals: (1) to meet in all respects every detailed requirement of task analysis which could reasonably be proposed by engineering specialty programs (such as logistics and human factors) and other supporting programs (such as training, manning, workload, and safety); and (2) to meet both the spirit and the letter of Department of Defense Directive 5000.43 (which restricts the application of specifications and standards). To meet both goals required the creation of a formidable document with highly elaborate specifications. It was never the intent of its many authors that all of the provisions of this standard should be casually applied to every procurement. Instead, the government technical personnel who have identified needs for task analysis data on a particular project involving a procurement should identify the minimum effort and data required to satisfy all of the needs and then line out all other provisions, specifications and descriptions.

30.2 Description and Use. Figure 1 is a matrix intended to guide the tailoring of the provisions of this standard. It compares the detailed requirements (by paragraph number) of task inventory and task analysis with the phases of system development. At the points of intersection are symbols indicating the appropriateness of certain requirements at certain times. The symbols used and their meanings are given in Table 1.

Symbol	Meaning
E	Essential
R	Recommended
O	Optional

Table 1. Symbols Used In Tailoring Matrix

30.3 Limitations of Tailoring Matrix. Figure 1 should be understood to be general guidance only. Its provisions represent a trade-off between cost-effectiveness and ultimate performance of the manned system. It provides visibility of critical operations, maintenance and support tasks throughout the design history of the system, and it interweaves the specific concerns of para 5.3.2 at appropriate times. Where the procuring activity's technical personnel determine that the needs of a specific procurement differ from the general guidance in Figure 1, they should tailor this standard in accordance with their identified needs.

MIL-STD-ABC Paragraph	PHASE OF SYSTEM DEVELOPMENT				
	Requirements and Tech Base	Proof of Principle	Demonstration and Proveout	Production and Deployment	Product Improvement
A1. Task Taxonomy					
a. Mission	E	E	E	E	E
b. Scenario/Conditions	R	R	E	E	E
c. Function	O	R	E	E	E
d. Job	O	O	R	E	E
e. Duty	O	O	R	E	E
f. Task	R	E	E	E	E
g. Subtask	O	O	O	R	R
h. Task Element	O	O	O	O	O
5.1 General					
5.2 Task 101	O	R	R	E	R
5.2.1 Purpose	O	R	R	E	R
5.2.2 Task Inventory	O	R	R	E	R
5.2.3 Inputs to Task Inventory	O	R	R	E	R
5.2.4 Marking of Special Tasks	O	O	R	R	R
5.2.4.1 Critical Tasks	R	E	E	E	E

Figure 1. Tailoring Matrix for MIL-STD-TASK

MIL-STD-ABC Paragraph	PHASE OF SYSTEM DEVELOPMENT				
	Requirements and Tech Base	Proof of Principle	Demonstration and Proveout	Production and Deployment	Product Improvement
5.2.4.2 Logistics Tasks	O	R	R	E	R
5.3 Task 201	O	R	E	E	E
5.3.1 Purpose	O	R	E	E	E
5.3.2 Task Analysis	O	R	E	E	E
5.3.3 Preparation of Report of Task Analysis	O	R	E	E	E

Figure 1. Tailoring Matrix for MIL-STD-TASK (continued)

APPENDIX C

<u>Data Item Descriptions</u>

DATA ITEM DESCRIPTION

Form Approved
OMB No. 0704-0188
Exp. Date: Jun 30, 1986

1. TITLE	2. IDENTIFICATION NUMBER
TASK INVENTORY REPORT	DI-HFAC-999X

3. DESCRIPTION/PURPOSE

3.1 A task inventory is a comprehensive listing of all tasks performed upon system hardware by operations, maintenance, and support personnel. Its purpose is to itemize human activity required for a system in a standardized manner, permitting subsequent analysis for issues of training, human engineering, logistics, manpower, personnel, workload and

4. APPROVAL DATE (YYMMDD)	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR)	6a. DTIC REQUIRED	6b. GIDEP REQUIRED
	A/SLCHE-FH		

7. APPLICATION / INTERRELATIONSHIP

7.1 This data item description (DID) contains the preparation instructions for the task inventory data required by the planning task of MIL-STD-TASK.

7.2 This DID is applicable to the acquisition of military systems, equipment, and facilities.

8. APPROVAL LIMITATION	9a. APPLICABLE FORMS	9b. AMSC NUMBER

10. PREPARATION INSTRUCTIONS

10.1 Source document. The applicable issue of the document cited herein, including its approval date and date of any applicable amendments and revisions, shall be as reflected in the contract.

10.2 Media. The task inventory shall be prepared in each of the media not lined out below:

a. typewritten, on 8½ x 11" paper
b. typewritten, on 8½ x 14" paper
c. computer printout, on 11 x 15" paper
d. diskette (size: ____________________)
e. magnetic tape (type: ________________)

10.3 Format. The task inventory shall be structured in accordance with the task taxonomy stated in Appendix A of MIL-STD-TASK, and shall contain for each task included in the inventory the elements described in paragraph 4.4 of MIL-STD-TASK and selected by the procuring activity.

DD Form 1664, FEB 85 Previous edition is obsolete PAGE 1 OF 2 PAGES

3.1 (continued)
system safety.

DATA ITEM DESCRIPTION			Form Approved OMB No. 0704-0188 Exp. Date: Jun 30, 1986
1. TITLE TASK ANALYSIS REPORT		2. IDENTIFICATION NUMBER DI-HFAC-999Y	

3. DESCRIPTION/PURPOSE

3.1 A task analysis is used by trainers, logisticians, human engineers, and specialists in health and safety, and manpower and personnel to make decisions regarding the design, performance, and support of a manned system.

4. APPROVAL DATE (YYMMDD)	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR)	6a. DTIC REQUIRED	6b. GIDEP REQUIRED
	A/SLCHE-FH		

7. APPLICATION/INTERRELATIONSHIP

7.1 This data item description (DID) contains the preparation instructions for the task analysis report required by paragraph 5.3.3 of MIL-STD-TASK.

7.2 This DID is applicable to the acquisition of military systems, equipment and facilities.

8. APPROVAL LIMITATION	9a. APPLICABLE FORMS	9b. AMSC NUMBER

10. PREPARATION INSTRUCTIONS

10.1 Source document. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments and revisions, shall be as reflected in the contract.

10.2 Media. The report of task analysis shall be prepared in each of the media not lined out below:

a. typewritten, on 8 1/2 x 11" paper
b. typewritten, on 8 1/2 x 14" paper
c. computer printout, on 11 x 15" paper
d. diskette (size: ________)
e. magnetic cassette (type: ________)

10.3 Format.

a. The report of task analysis shall be presented in both graphic and textual form, as follows:

(1) Graphic: The graphic presentation shall be time-based and shall have the cumulative time shown in the selected units (hours, minutes or seconds) clearly marked at the bottom of each page or frame of display. Tasks shall be indicated in the space above the time markings in Gantt-type format with each task occupying that amount of time it required for criterion performance. All critical tasks shall appear on the illustration and shall be differentiated from non-critical tasks by means of some graphic technique appropriate to the medium selected (in paragraph 10.2 above). Tasks whose performance is unscheduled shall be illustrated by reference to a scenario in which the task reasonably appears. Each page or frame of display shall be consecutively numbered at a location which does not interfere with the technical information being presented.

(2) Textual: The format for this portion of the report of task analysis shall be selected by the contractor for maximum clarity of presentation based on:

(a) the medium selected in paragraph 10.2 above, and

(b) the number of data elements selected from the list in subparagraph 10.3b below.

b. Data Elements. The report of task analysis shall include all of those data elements not lined out below:

(1) Structural elements, which shall be shown in left-most columns on each page or display frame, are:

(a) System name
(b) Mission (shown on only the first page or display frame)
(c) Scenario/conditions (which may be indicated by reference to a specific passage of an external document)
(d) Function
(e) Job title
(f) Duty title
(g) Task title
(h) Task standards (both time and accuracy dimensions)
(i) Subtask title
(j) Task element title

(2) Analysis elements, which shall be reported for each of the structural elements not lined out in subparagraph 10.3b(1) above, are:

(a) Performance concerns
(1) Criticality of task (Y or N)
(2) Performance of task
(a) Source of data
[1] SME opinion
[2] Comparability analysis
[3] Objective measurement
(b) Task performance measures (time and accuracy; calculated variance, number of observations)
(c) Workload measure (name and numerical score)
(d) Identification of human errors (expected or encountered)

(b) Health considerations (expected or encountered)
(1) Temperature and humidity (WBGT) at performance site
(2) Exposure to ambient noise
(3) Exposure to shock, vibration, motion, recoil
(4) Exposure to windblast
(5) Exposure to pressure fluctuations
(6) Exposure to surface heat or cold
(7) Exposure to electromagnetic radiation
(8) Exposure to toxins (bacteria, chemicals, dust, fuel, fumes, fungi, liquids, smoke, vapors)
(9) Conditions of psychological stress
(a) Confined spaces
(b) Isolation
(c) Sensory or cognitive overload
(d) Body disorientation (vestibular or kinesthetic)
(e) Sustained or continuous operations (implying sleep deprivation)
(f) Human waste elimination constraints

c. Human engineering considerations
(1) Input parameters
(a) Information required
(b) Information available
(c) Initiating cues
(d) Data display format

(2) Response parameters
(a) Action taken
(b) Body movements required by action taken
(c) Workspace envelope required by action taken
(d) Workspace envelope available
(3) Feedback parameters
(a) Feedback required
(b) Feedback available
(c) Cues indicating task completion
(d) Relative rate of feedback update
(e) Form of feedback
(4) Ambient lighting (in foot-candles)
(5) Ventilation
(d) Logistics considerations
(1) Skills required
(a) Skill level code
(b) Skill specialty code
(c) Skill specialty evaluation code
(2) Tools required
(3) Job aids and manuals required
(4) Support and test equipment identification
(a) Support item sequence code
(b) Item category code
(5) Electric power requirements
(6) Spares and expendables required
(7) Number of persons per skill specialty code
(8) Number of manhours per skill specialty code
(9) LSA control number
(e) Manpower and personnel considerations
(1) Physical characteristics of task performers (PULHES codes)
(2) Aptitude characteristics of task performers (ASVAB scores)
(3) Planned MOS of task performers
(4) Range of criterion ASVAB scores for lower 20% of personnel currently assigned to MOS identified in subparagraph (3) above
(f) Safety considerations
(1) Special protective equipment required
(2) Hazards encountered
(a) Frequency
(b) Cause
(c) Consequence
(3) Weights to be lifted or transported
(g) Training Considerations
(1) Type of training given to task performers
(2) Length of training (in hours)
(3) Estimated cost/trainee/hour
(4) End of training comprehension and performance test score for each trainee
(h) Discussion
(1) Identification of problem areas by concern
(a) Performance and workload
(b) Health
(c) Human engineering
(d) Logistics
(e) Manpower and personnel
(f) Safety
(g) Training
(2) Proposed alternatives for solving the problem areas identified above.
(3) Estimated impact upon manned system performance requirements of the time and accuracy measures of task performance.
(i) Conclusions. State whether the above analysis does or does not support the projected attainment of manned system performance requirements (effectiveness and availability) given the present design of system hardware and software, the present criteria for personnel selection and affordability, and the present training concept.

RECOMMENDED VERBS FOR TASK INVENTORY

INTRODUCTION

This Appendix lists recommended action verbs to be used in preparing a task inventory. Some specialized verbs, not listed here, may be needed for a particular weapon system. (For example, "lay" is commonly used in tasks describing cannon-type weapon systems, but is not applicable to all weapon systems.) Many of the verbs presented here are synonymous. The user should select the one verb which appears to be closest to the intended meaning on that particular system and use that verb consistently throughout the analysis. Not all of the verbs in this list are appropriate for the taxonomic level of "task." Some verbs in this list are more appropriate for writing statements of subtasks or task elements. (See Appendix A for illustrations of these differences.)

This list of verbs was derived from two sources:

Definitions of Terms for Reliability and Maintainability. Philadelphia, PA: U.S. Naval Publications and Forms Center: MIL-STD-721C. 12 June 1981

Roth, J. Thomas, Implementing Embedded Training: Volume 4 of 10: Identifying ET Requirements. Alexandria, VA: U.S. Army Research Institute Research Product 88-29. 1988.

Access	1. To gain visibility of or the ability to manipulate.
	2. To cause to be displayed, as with a computer menu.
Accomplish	To do, carry out, or bring about; to reach an objective.
Achieve	To carry out successfully.
Acknowledge	To make known the receipt or existence of.
Actuate	To put into mechanical motion or action; to move to action.
Adjust	1. To bring to a specified position or state.

	2. To bring to a more satisfactory state; to manipulate controls, levers, linkages, etc.; to return equipment from an out-of-tolerance condition to an in-tolerance condition.
Administer	To manage or supervise the execution, use, or conduct of.
Advance	To move forward; to move ahead.
Advise	To give information or notice to.
Alert	To warn; to call to a state of readiness or watchfulness; to notify (a person) of an impending action.
Align	To bring into line; to line up; to bring into precise adjustment, correct relative position; or coincidence.
Allocate	To apportion for a specific purpose or to particular persons or things.
Allow	1. To permit; to give opportunity to.
	2. To allot or provide for.
	3. To carry out a procedure.
Analyze	To examine and interpret information.
Annotate	To append explanatory information to a text or graphic summary of information.
Announce	To make known.
Apply	1. To lay or spread on.
	2. To energize.
Archive	To make an archival copy of.
Arrange	To group according to quality, value, or other characteristics; to put in proper order.
Assemble	To fit and secure together the several parts of; to make or form by combining parts.
Assess	To determine the importance, size, or value of; to evaluate.
Assign	To apportion to for a specific purpose or to particular persons or things; to appoint to a duty.
Assist	To give support or help; to aid.

Attach	To join or fasten to.
Authenticate	To prove or serve to prove the authenticity of.
Balance	To equalize in weight, height, number, or proportion.
Brief	To give final precise instructions; to coach thoroughly in advance; to give essential information to.
Calculate	To determine by arithmetic processes.
Calibrate	To determine accuracy, deviation, or variation by special measurement or by comparison with a standard.
Camouflage	To conceal or disguise.
Cancel	To cause not to occur, as in canceling a command.
Categorize	To put into categories or general classes.
Center	1. To adjust so that axes coincide.
	2. To place in the middle of.
Check	1. To confirm or establish that a proper condition exists; to ascertain that a given operation produces a specified result; to examine for satisfactory accuracy, safety, or performance; to confirm or determine measurements by use of visual or mechanical means.
	2. To perform a critical visual observation or check for specific conditions; to test the condition of.
Chock	To place a blocking device adjacent to, in front of, or behind a wheel to keep it from moving.
Choke	To enrich the fuel mixture of a motor by partially shutting off the air intake of the carburetor.
Choose	To select after consideration.
Chunk	To cause the association of several entities.
Classify	To put into categories or general classes.
Clean	To wash, scrub, or apply solvents to; remove dirt, corrosion, or grease.
Clear	1. To move people and/or objects away from.
	2. To open the throttle of an idling engine to free it from carbon.
Close	1. To block against entry or passage; to turn, push,

	or pull in the direction in which flow is impeded.
	2. To set a circuit breaker into the position allowing current to flow through.
Collect	To bring together into one body or place; to accumulate.
Command	To direct authoritatively.
Communicate	1. To exchange information.
	2. To make known.
Compare	To examine the character or qualities of two or more items; to discover resemblances or differences.
Complete	1. To bring to an end.
	2. To supply missing or needed information, normally in a prescribed format.
Comply	To conform with directions or rules; to accept as authority; to obey.
Compute	To determine by arithmetic process.
Condense	To make denser, more brief, or more compact.
Connect	1. To bring or fit together so as to form a unit; to couple keyed or matched equipment items.
	2. To attach or mate (an electrical device) to a service outlet.
Construct	1. To make or form by combining parts; to fit and secure together the several parts of.
	2. To assemble information elements or entities in a specified fashion.
Control	To exercise restraining or directing influence over; to fix or adjust the time, amount, or rate of.
Coordinate	To bring into a common action, movement, or condition.
Correct	To make or set right, to alter or adjust so as to bring to some standard or required condition.
Correlate	To establish a mutual or reciprocal relation between.
Cover	To protect or shelter by placing something over or around.
Create	To cause to come into being, normally based on some

established criterion.

Debug	To detect and remedy an inadequacy in software.
Decide	To arrive at a solution.
De-energize	To take energy from.
Define	1. To determine or identify the essential qualities or meaning.
	2. To fix or mark the limits of.
Deflate	To release air or gas from.
Delete	To remove from association with or cause no longer to exist.
Deliver	1. To hand over.
	2. To send to an intended target or destination.
Demonstrate	To show clearly.
Depart	To go away; to leave.
Depressurize	To release gas or fluid pressure from.
Derive	To infer or deduce.
Describe	To represent or give an account of in words.
Destroy	To ruin, demolish, or put out of existence; to make unfit for further use.
Detect	To discover or determine the existence, presence, or fact of.
Determine	1. To obtain definite and first-hand knowledge of, to confirm, or establish that a proper condition exists.
	2. To investigate and decide to discover by study or experiment.
Develop	To set forth or make clear by degrees or in detail.
Diagnose	To recognize and identify the cause or nature of a condition, situation, or problem by examination or analysis.
Disassemble	To take to pieces; to take apart to the level of the next smaller unit or down to all removable parts.
Disconnect	1. To sever the connection between; to separate keyed

or matched equipment parts.

2. To detach or separate (an electrical device) from a service outlet.

Discriminate	To distinguish or differentiate by discerning or exposing differences.
Disengage	To release or detach interlocking parts; to unfasten; to set free from an inactive or fixed position.
Display	To cause a visual image to be presented on some medium.
Dispose of	To get rid of.
Distinguish	To perceive a difference in.
Distribute	1. To apportion for a specific purpose or to particular persons or things.
	2. To divide among several or many; to divide or separate, especially into kinds.
Drain	To draw off (liquid) gradually or completely.
Draw	To produce a likeness or representation of.
Drive	To direct the course and motions of a vehicle.
Edit	To correct errors of grammar, syntax, and content in text material.
Egress	To go out.
Elaborate	To provide more detail regarding.
Elevate	To lift up; to raise.
Eliminate	To expel; to ignore or set aside as unimportant.
Emplace	To put into position.
Employ	To put into action or service; to carry out a purpose or action by means of; to avail oneself of.
Energize	To impart energy to.
Enforce	To compel or constrain.
Engage	1. To cause to interlock or mesh.
	2. To enter into conflict.
Enter	1. To go or come in.

	2. To put on record..
	3. To put in information or data.
Erect	To put up by the fitting together.
Establish	To set on a firm basis.
Estimate	To judge or determine roughly the size, extent, or nature of.
Evaluate	To determine the importance, size, or nature of; to appraise; to give a value or appraisal to on the basis of collected data.
Exchange	To part with or substitute.
Execute	To carry out fully.
Explain	To make something plain and understandable.
Express	To represent in words; to state.
Extract	To draw forth; to pull out forcibly.
Fill out	To enter information on a form.
Find	1. To discover or determine by search; to indicate the place, site, or limits of.
	2. To discover by study or experiment; to investigate and decide.
Fire	To launch a missile or shoot a gun.
Hold	To have or keep in the grasp.
Hypothesize	To develop a prediction or speculation, of some degree of uncertainty, based on incomplete factual information or theory.
Identify	1. To establish the identity of.
	2. To determine the classification of.
Illustrate	To make clear or clarify.
Indicate	To point out.
Inform	To make known to; to give notice or report the occurrence of.
Initialize	To place in an initial or beginning condition.

Input	To enter information into a computer or data system.
Insert	To put or thrust in, into, or through.
Inspect	To perform a critical visual observation or check for specific conditions; to test the condition of.
Install	1. To perform operations necessary to properly fit an equipment unit into the next larger assembly or system. 2. To place and attach.
Instruct	To provide with authoritative information or advice.
Integrate	To bring together information from two or more different sources for the purpose of combined analysis or presentation.
Intercept	To stop or interrupt the progress or course of.
Interchange	To remove one item from an assembly and install a like item in the same assembly.
Interpret	1. To conceive in the light of individual belief, judgment, or circumstance. 2. To explain the meaning of.
Investigate	To observe or study by close examination and systematic inquiry.
Isolate	To use test equipment to identify or select a source of trouble.
Issue	To put forth or distribute.
Lift	To move or cause to be moved from a lower to a higher position; to elevate.
List	To enumerate; to write the names of a group of items together.
Listen	To hear something with thoughtful attention.
Load	To place in or on; to place cargo or components on an airplane or other vehicle.
Locate	1. To find, determine, or indicate the place, site, or limits of. 2. To set or establish in a particular spot; to station.
Log	1. To record for purposes of keeping records.

2. To gain access to a computer system or terminate interaction with a computer system.

Lubricate To put lubricant on specified locations.

Maintain
1. To hold or keep in any particular state or condition, especially in a state of efficiency or validity.
2. To sustain or keep up.

Manage To handle or direct with a degree of skill.

Maneuver To make a series of changes in direction and position for a specified purpose.

Manipulate To operate with the hands.

Measure To determine the dimensions, capacity, or amount by use of standard instruments or utensils.

Modify To alter or change somewhat the form or qualities of.

Monitor
1. Visually to take note of or to pay attention to in order to check on action or change.
2. To attend to displays continually or periodically to determine equipment condition or operating status.

Mount To attach to a support.

Move To change the location or position of.

Name To identify by name.

Navigate To operate and control course of.

Neutralize To destroy the effectiveness of; to nullify.

Notify To make known to; to give notice or report the occurrence of.

Observe
1. To conform one's actions or practice to.
2. To take note of visually; to pay attention to.

Obtain
1. To get or find out by observation or special procedures.
2. To gain or attain.

Open
1. To move from closed position; to make available for passage by turning in an appropriate direction.
2. To make available for entry or passage by turning

	back, removing, or clearing away.
	3. To disengage or pull out a circuit breaker.
Operate	To control equipment in order to accomplish a specific purpose.
Organize	To arrange elements into a whole of interdependent parts; to form into a coherent unity; to integrate.
Orient	1. To acquaint with the existing situation or environment.
	2. To set or arrange in any determinate position.
Originate	To give rise to, to set going, to begin.
Park	To bring a vehicle to a stop and leave it standing for a time in a specified area.
Perform	To do, carry out, or bring about; to reach an objective.
Place	To put or set in a desired location or position.
Plan	To devise or project the achievement of.
Plot	To mark or note on or as if on a map or chart; to locate by means of coordinates.
Position	To put or set in a given place.
Post	To station at a given place.
Prepare	To make ready; to arrange things in readiness.
Prescribe	To lay down as a guide, direction, or rule of action; to specify with authority.
Press	To act upon through thrusting force exerted in contact.
Pressurize	To apply pressure within by filling with gas or liquid.
Prevent	To keep from happening or existing.
Prioritize	To arrange or list in order of priority or importance.
Process	To submit to a series of actions or operations leading to a particular end.
Produce	To cause to come into being or visibility.
Program	To work out a plan or procedure or a sequence of operations to be performed.

Provide	To supply what is needed, to equip.
Pull	To exert force upon an object so as to cause motion toward the force.
Pump	1. Raise or lower by operating a device which raises, transfers, or compresses fluids by suction, pressure or both.
	2. To move up and down or in and out as if with a pump handle.
Purge	1. To expel unwanted fluids from.
	2. To cause to be eliminated or dissociated from.
Push	1. To press against with force so as to cause motion away from the force.
	2. To move away or ahead by steady pressure.
Qualify	To declare competent or adequate.
Queue	To cause to be placed in a queue or ordered sequence of similar processes.
Raise	To move or cause to be moved from a lower to a higher position; to elevate.
Read	To derive information from written material.
Recall	To bring forth information from memory.
Receive	To come into possession of; to get.
Recognize	To perceive to be something previously known or designated.
Record	To set down in writing.
Recover	To get back; to regain.
Refuel	To put fuel into the tanks of a vehicle again.
Release	1. To set free from an inactive or fixed position; to unfasten or detach interlocking parts.
	2. To let go of.
	3. To set free from restraint or confinement.
Remove	1. To perform operations necessary to take an equipment unit out of the next larger assembly or system.
	2. To take off or eliminate.

3. To take or move away.

4. To take off devices for closing off the end of a tube.

Repair — To restore damaged, wornout, or malfunctioning equipment to a serviceable, usable, or operable condition.

Repeat — To make, do, or perform again.

Replace
1. To restore to a former place of position.
2. To substitute serviceable equipment for malfunctioning, wornout, or damaged equipment.

Report
1. To describe as being in a specified state.
2. To make known to; to give notice or report the occurrence of.

Represent — To cause information to be conveyed in a fashion different from the original.

Request — To ask for.

Reset — To put back into a desired position, adjustment, or condition.

Resolve — To eliminate discrepancies from two or more sources of information.

Respond — To react.

Retrieve — To cause to be removed from storage or other unavailable state and made accessible.

Review — To examine again; to go over or examine critically or deliberately.

Rotate — To cause to revolve about an axis or center.

Route — To send by a selected course of travel; to divert in a specified direction.

Run — To cause a computer program to be executed by a computer.

Save — To cause to be stored or placed in an accessible location.

Scan — To make a wide, sweeping search of; to look through or over hastily.

Schedule — To appoint, assign, or designate for a fixed future time;

to make a timetable of.

Search	To examine a context to determine the presence of a particular entity or type of entity.
Secure	To make fast or safe.
Select	To take by preference or fitness from a number or group; to pick out; to choose.
Send	To dispatch by means of communication.
Service	To perform such operations as cleanup, lubrication, and replenishment to prepare for use.
Set	1. To put a switch, pointer, or knob into a given position; to put equipment into a given adjustment, condition or mode.
	2. To put or place in a desired orientation, condition, or location.
Set up	To prepare or make ready for use.
Show	To point out or explain.
Shut down	To perform operations necessary to cause equipment to cease or suspend operation.
Sight	1. To look at through or as if through a sight.
	2. To aim by means of sights.
Signal	To notify or communicate by signals (i.e., a prearranged sign, notice or symbol conveying a command, warning, direction or other message).
Solve	To find a solution for.
Specify	To name or state explicitly or in detail.
Squeeze	To force or thrust together by compression.
Start	To perform actions necessary to set into operation; to set going; to begin.
State	To express the particulars of in words.
Stay	To remain; to continue in a place.
Steer	To direct the course of.
Stop	To perform actions necessary to cause equipment to cease or suspend operation.

Store	To cause to be placed in an accessible location.
Stow	To deposit or leave in a specified place for future use.
Strike	To deliver or aim a blow or thrust; to hit.
Submit	To make available; to offer.
Summarize	To tell in or reduce to a summary.
Supervise	To oversee; to have or exercise the charge of.
Synthesize	To combine or produce by synthesis.
Take	1. To get into or carry in one's hands or one's possession. 2. To get or find out by observation or special procedures.
Tap	To strike lightly.
Tell	To express in words.
Test	To perform specified operations to verify operational readiness of a component, subcomponent, system, or subsystem.
Tighten	1. To perform necessary operations to fix more firmly in place. 2. To apply a specified amount of force to produce a rotation or twisting motion to fix more firmly in place.
Trace	To follow or study out in detail or step by step.
Transfer	To cause an entity to change location or association with other entities.
Transmit	1. To convey or cause to pass from one place to another. 2. To send out a signal by radio waves or wire.
Transport	1. To convey or cause to pass from one place to another. 2. To carry by hand or in a vehicle or hoist, or in a container, etc.
Traverse	To move from side to side.
Troubleshoot	To localize and isolate the source of a malfunction or break down.

Turn	To cause to revolve about an axis or center.
Type	To enter information into a device by means of a keyboard.
Unload	To take off.
Update	To replace older, possibly invalid, information with more current information.
Use	To put into action or service; to avail oneself of; to carry out a purpose or action by means of.
Utilize	To put into action or service; to avail oneself of; to carry out a purpose or action by means of.
Validate	To ascertain the correctness of, using an independent source of information.
Verify	1. To confirm or establish that a proper condition exists. 2. To establish the truth or accuracy of.
Visualize	To create a mental picture or concept of.
Wait	To suspend activity in a sequence of activities until a given condition occurs or a set time has elapsed.
Write	To inscribe words on a surface.
Zero	To bring to a desired level or null position.

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(See Instructions – Reverse Side)

1. DOCUMENT NUMBER

2. DOCUMENT TITLE

3a. NAME OF SUBMITTING ORGANIZATION

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b. ADDRESS *(Street, City, State, ZIP Code)*

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a. Paragraph Number and Wording:

b. Recommended Wording:

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MANNED SYSTEMS GROUP
Systems Research Laboratory

Working Paper MSG 89-02

PROPOSED NOTICE 2 TO

MIL-STD-1388-1A

Logistic Support Analysis

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24 March 1989

U.S. Army Research Institute
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PROPOSED NOTICE 2 TO MIL-STD-1388-1A
Logistics Support Analysis

EXECUTIVE SUMMARY

Background

Two Department of Defense Directives in the last three years have significantly changed the way existing technologies can be applied in materiel system development projects. The earlier, DoDD 5000.43, precluded contractual application of specifications and standards prior to full-scale development. While specifications and standards could be cited "for guidance" in earlier phases of development, contractors in those phases were largely freed from strict compliance with the provisions of those documents. Although arguments have been advanced that the early stages of equipment design are most sensitive to considerations of human factors and logistics (see, for example, GAO, 1981), it was concluded that the cost of "full mil spec compliance" was simply too great in the early stages of all system development projects.

More recently, DoDD 5000.53 announced new policy concerning "the design process" of military systems. Reciting a goal of "enhanced operational suitability and effectiveness," this directive requires fresh attention to human participation in military systems--particularly with regard to the dimension of manned system performance. It is unlikely to come as a surprise to a reader familiar with human factors technology that the very first subparagraph of new policy addresses the issue of "Standardization of MPTS Data." While there are a variety of new techniques and methodologies for measuring and quantifying soldier and system performance (see, for example, Lowry and Seaver, 1988), virtually all require task analysis data as input. Consequently, the form and structure of task analysis data are of immense importance to the policy goals of DoDD 5000.53.

For many years, logisticians sponsored in MIL-STD-1388 a process of systematic examination of human behavior which they called "task analysis" and described in Task 401. During the same time, the human factors community maintained its own similar-but-different systematic analysis of human behavior in MIL-H-46855. The press of new technology led to a series of refinements of task analysis methods in human factors (see summary in Appendix).

In 1988, the Army Materiel Command sponsored an ILS/MANPRINT Technical Working Group (TWG) to examine the interface between these two disciplines. As a result of efforts by the Task Analysis Subgroup of the TWG, this document was created to allow both the human factors and logistics communities to pursue their legitimate concerns about task analysis without creating duplication or overlap on the part of contractors. Proposed Notice 2 to MIL-STD-1388 is designed to interface that standard with the latest version of the human factors task analysis standard (MIL-STD-TASK) referenced below.

<u>Proposed Changes to MIL-STD-1388-1A</u>

The changes proposed in this draft of Notice 2 are to the content of Task 301 (Functional Requirements Identification) and Task 401 (Task Analysis). If approved, these changes would allow MIL-STD-1388-1A to continue to fulfill its supportability role in full, while avoiding any duplication with the provisions of MIL-STD-TASK. Although some close editing of the material in the 11 April 1983 version of MIL-STD-1388-1A has been accomplished in the pages that follow, this material has been checked and rechecked to verify that the ILS process can operate entirely undisturbed by the effects of these changes.

The intent of changes to Task 301 was to: (1) preserve the logistics character of the prose, (2) make more precise the identification of inputs and outputs, (3) bring to the process of task identification the same behavioral framework that has been employed by the non-ILS part of the DoD R&D community, and (4) avoid any duplication of effort on the part of a contractor charged with performing both ILS and MPTS tasks, and (5) provide the procuring activity not only with the flexibility to tailor MIL-STD-1388-1A more easily, but to interface the ILS and MPTS programs more effectively.

The changes to paragraph 301.1 maintain the original purpose, but with more modern terminology. The bulk of changes to paragraph 301.2 separates content and format requirements into different paragraphs. The changes to the input and output paragraphs consolidate redundancies and maintain uniform terminology.

The intent of changes to Task 401 was to permit the current practices of task analysis in the logistics community to continue without interruption or interference, but to identify an alternative, interdisciplinary means of performing task analysis (contained in MIL-STD-TASK)--and to let the procuring activity select which means was more appropriate for the project at hand. Consequently, the title of Task 401 was modified to reflect its content more clearly.

The changes to paragraph 401.2 added the alternative source document provision, moved the requirement of current paragraph 401.2.2 to 401.2.1, and improved the syntax of paragraph 401.2.3.

REFERENCES

Acquisition Streamlining, Washington, DC: Department of Defense Directive 5000.43, January 15, 1986.

Effectiveness of U.S. Forces Can Be Increased Through Improved Weapon System Design (Report PSAD-81-17). Washington, DC: United States General Accounting Office, January 29, 1981.

Human Engineering Requirements for Military Systems, Equipment and Facilities (MIL-H-46855). Philadelphia, PA: U.S. Naval Publications and Forms Center, 2 May 1972.

Lowry, John C. and Seaver, David A., Handbook for Quantitative Analysis of MANPRINT Concerns in Army Systems (Research Product 88-15). Alexandria, VA: U.S. Army Research Institute, June, 1988.

Manpower, Personnel, Training, and Safety (MPTS) in the Defense System Acquisition Process, Washington, DC: Department of Defense Directive 5000.53, December 30, 1988.

Miles, John L. Jr. and Geddie, James C., Proposed Military Standard MIL-STD-TASK, Task Analysis (Working Paper MSG 89-01). Alexandria, VA: U.S. Army Research Institute, 24 March 1989.

MILITARY STANDARD

MIL-STD-1388-1A
Notice 2
24 Mar 89

LOGISTIC SUPPORT ANALYSIS

TO ALL HOLDERS OF MIL-STD-1388-1A

1. THE FOLLOWING PAGES OF MIL-STD-1388-1A HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE(S)	DATE	SUPERSEDED PAGE(S)	DATE
31	24 March 1989	31	11 April 1983
32	24 March 1989	32	11 April 1983
33	24 March 1989	33	11 April 1983
41	24 March 1989	41	11 April 1983

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-STD-1388-1A will verify that the page changes indicated herein have been entered. This notice will be retained as a check sheet. This issuance is a separate publication. Each notice is to be retained by stocking points until the military standard is completely revised or canceled.

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TASK 301

FUNCTIONAL REQUIREMENTS IDENTIFICATION

301.1 PURPOSE. To identify the operations, maintenance and support functions that must be performed for each system concept or equipment design alternative under consideration; then to identify the human performance tasks for operations, maintenance and support of the system or equipment in its designated environments.

301.2 TASK DESCRIPTION

301.2.1 Identify the functions that must be performed for the manned system (in each design alternative under consideration) to accomplish its intended mission in the designated environments. These functions shall be identified to a level commensurate with the state of design and with operational scenario development, and shall include all functions concerned with wartime and peacetime employments.

301.2.2 Mark (or otherwise specially identify) those functional requirements which are unique to any system concept or design alternative because of use of new technology or operational concepts; also mark those which are likely to be drivers of cost or supportability, and those which are likely to be major determiners of system effectiveness and readiness.

301.2.3 Identify any risks involved in satisfying the functional requirements of the manned system (in each design alternative under consideration).

301.2.4 Examine each system function allocated to personnel by the design of hardware and software and determine what operator, maintainer and support tasks are involved in the completion of each such function.

301.2.4.1 Maintenance tasks shall be categorized as corrective or preventative, and shall be checked for completeness and accuracy against the results of the failure modes, effects and criticality analysis (FMECA) and the reliability centered maintenance (RCM) analysis. 301.2.4.2 Operations, maintenance, and support tasks shall be listed in the format specified in MIL-STD-1388-2A or in the format specified in MIL-STD-TASK, as designated by the procuring authority. Tasks listed in either format shall use the task taxonomy (behavioral classification structure) given in Appendix A to MIL-STD-TASK.

Supersedes page 31 of 11 April 1983.

301.2.5 Participate in formulating design alternatives to correct design deficiencies disclosed during the identification of functional requirements or of operations, maintenance, and support tasks.

301.2.6 With each iterative cycle of hardware and software redesign, corresponding changes shall be made to the list of functional requirements and to the list of operations, maintenance, and support tasks.

301.3 TASK INPUT

301.3.1 Mission analysis, scenarios and conditions (such as mission profiles and operational mode summaries).

301.3.2 Descriptions (illustrations, functional flow diagrams, engineering drawings, or narratives) of system concepts and design alternatives.

301.3.3 Procedures for conducting the RCM analysis.

301.3.4 Results of FMECA in accordance with MIL-STD-1629.

301.3.6 Results of Tasks 201, 202, and 203.

301.3.7 Delivery identification of any data item required.

301.3.8 Selection by the procuring authority of the format for the output of this task and selection by the procuring authority of the behavioral level of detail within the task taxonomy (in Appendix A of MIL-STD-TASK).

301.4 TASK OUTPUT

301.4.1 Documented functional requirements for each system concept or design alternative under consideration, in designated environments and in wartime and peacetime employments.

301.4.2 List of unique functional requirements, drivers of cost or supportability, and major determiners of system effectiveness and readiness.

301.4.3 Identification of any risks involved in satisfying the functional requirements considered.

301.4.4 List of human performance tasks, structured according to the behavioral task taxonomy (in Appendix A of MIL-STD-TASK) for operations, maintenance, and support for each function allocated by system design to human performance.

301.4.5 Identification of potential design deficiencies, with proposed design alternatives correcting the deficiencies.

301.4.6 Revisions to the lists of functional requirements and human performance tasks following each iteration of hardware and software redesign.

TASK 401

LOGISTICS TASK ANALYSIS

401.1 PURPOSE. To analyze the human performance requirements of the manned system or design alternative to (1) identify logistic support resource requirements for each task; (2) identify new or critical logistic support resource requirements; (3) identify transportability requirements; (4) identify support requirements which exceed established goals, thresholds, or constraints; (5) provide data to support participation in the development of design alternatives to reduce O&S costs, optimize logistic support resource requirements, or enhance readiness; and (6) provide source data for preparation of required ILS documents.

401.2 TASK DESCRIPTION

401.2.1 Alternative Uses. If the purpose of the task analysis is solely for logistics use, follow the procedures described below and report the data in the format prescribed in MIL-STD-1388-2. If the purpose of the task analysis is for interdisciplinary use, follow the procedures described in MIL-STD-TASK and report the data in the format prescribed by its data item descriptions.

401.2.2 Conduct a detailed analysis of each operations and maintenance task identified for the new system or item of equipment (Task 301), and determine the following:

a. Procedural steps required to perform the task to include identification of those tasks that are duty position specific (performed principally by only one individual) or collective tasks (performed by two or more individuals as a team or crew).

b. Logistic support resources required (considering all ILS elements) to perform the task.

c. Task frequency, task interval, elapsed time, and manhours in the system or item of equipment's intended operational environment and considering the specified annual operating base.

d. Maintenance level assignment based on the established support plan (Task 303).

401.2.3 Identify those logistic support resources required to perform each task which is new or critical. New resources are those which require development to operate or maintain the new

Supersedes page 41 of 11 April 1983

system or item of equipment. These can include support and test equipment, facilities, new or restructured personnel skills, training devices, new or special transportation systems, new computer resources, and new repair, test, or inspection techniques or procedures to support new design plans or technology. Critical resources are those which are not new but require special management attention due to schedule constraints, cost implications, or known scarcities.

[continuation of new page 41]

APPENDIX

SYNOPSIS OF DEVELOPMENTS
Task Analysis in the Human Factors Community

For more than 15 years, the human factors community, led by the Army's Human Engineering Laboratory (HEL), has been active in developing the art of task analysis and applying that art to Army and DoD programs. Highlights:

1973 - A program was begun in the Weapons Branch of HEL's Systems Research Laboratory in support of an AMC initiative to examine soldier performance reliability.

1974 - The need for task taxonomies for describing soldier performance was shown, and preliminary examinations were made for infantry small arms (HEL TMs 2-74, 6-74 and 22-74).

1976 - The application of primitive task taxonomies was made to communications and aerial surveillance systems (HEL TM 29-76).

1978 - CG, OTEA sends memorandum (28 Feb 78) to the VCSA pointing out current problems with major system testing and identifying the need for a military standard on task analysis.*

1979 - HEL leads a tri-service group in the development of a standardized task taxonomy which was coordinated within the research community.

1980 - HEL publishes what is still the most widely followed example of operations and maintenance tasks (HEL TM 7-80); HEL completes a joint effort with MRSA reforming and revising the LSAR task analysis system (HEL TM 24-80); however, the majority of that product is never incorporated into MIL-STD-1388. The second draft of a proposed tri-service military standard on Task Analysis is published.

1981 - HEL publishes the Army/Navy Self-Paced Human Factors Engineering Training Course, Lessons 23 and 24 of which explained use of the new standardized task taxonomy.

1984 - HEL's task taxonomy is incorporated (as Amendment 2) in the tri-service military specification MIL-H-46855.

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*DA IG Finding 638, dtd 30 Oct 78, notes lack of a military standard on task analysis has an adverse impact on OTEA performance of "Human Resources Testing in Materiel Development."

1985 - The third draft of a tri-service proposed military standard and the first draft of a proposed military handbook on Task Analysis are delivered to HEL by Battelle.

1987 - HEL publishes the fifth draft of the proposed military standard on task analysis (HEL TM 13-87); DCGMD of AMC directs HEL to publish that standard as "Army only" document.

1988 - ILS community opposes the human factors military standard on task analysis, and prevents its publication. ILS community proposes instead to add "operations" provisions to its existing supportability military standard. The Technical Society/Industry (TS/I) Subgroup of the DoD Human Factors Engineering Technical Group sends letter to MICOM expressing "deep concern" over the delay in release of the human factors task analysis standard. A revision of that standard (MIL-STD-ABC) is proposed which is thought to overcome principal ILS objections, but ILS opposition continues. A joint ILS/MANPRINT Technical Working Group (TWG) is convened to explore possible technical duplication and overlap between the technologies of ILS and MANPRINT.

1989 - HEL and ARI offer still another version of a stand-alone task analysis standard (MIL-STD-TASK) which is designed not to conflict or overlap with ILS concerns about soldier performance.

Working Paper

WP MSG 91-02

STRAWMAN FUNCTIONAL CONFIGURATION IDENTIFICATION OF ATTD VEHICLE FOR INTEGRATED TWO-MAN CREW STATION (ITCS)

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"The Abrams may be the best heavy tank in the world, but perhaps its successor should be half the size, with new kinds of armor and armament."

Insight, March 25, 1991, p. 12

ACKNOWLEDGEMENTS

We wish to acknowledge all those who provided helpful information to us in the completion of this task in a very short time. We especially appreciate the assistance of Ms. **Barbara Howard** of the Logistics Engineering Branch of the Belvoir Research, Development and Engineering Center, and Mr. **Bob Orendas** at the AMC Materiel Readiness Support Activity.

TABLE OF CONTENTS

DISCLAIMER

The purpose of this Working Paper is to lay the groundwork for the preparation of a performance baseline for the advanced technology transition demonstration (ATTD) vehicle which will carry the integrated two-man crew station (ITCS).

Parts of this Working Paper will appear similar to the requirements documents customarily associated with actual weapon system acquisitions. That similarity is deliberate; but its purpose is to provide a means to exercise recent technology--and not to imply that any of the requirements recited are correct, ought to be in new real acquisition documents, or should have been in prior real acquisition documents.

The strawman functional configuration identification (FCI) presented in this Working Paper is a "place-holder" for the FCI which we think ought to be developed by the full ITCS Working Group through application of the analysis techniques described in the final section.

OBJECTIVES

1. To document at an early stage what is and what is not included in the ITCS ATTD vehicular system and why.

2. To provide the means for developing a performance baseline for the ITCS ATTD vehicle in which both human and machine performance are objectively measured, and which will permit trade-offs (in terms of cost and performance) among proposed subsystem design concepts.

3. To provide a means for identifying and documenting the complex interactions among the operators, tasks, equipment, environment, threats, and doctrine.

4. To identify what analyses, by what means, and for what purpose(s) need to be performed by whom, when.

VIEWPOINT

"The operator has been traditionally used as the adaptive, integrating, and interpreting element for the increasingly complex controls and displays contained in new...systems."

- Army-NASA A^{3}I Program Executive Summary
1 September 1990, page 2

The approach to system design presented in this document is that of both the human factors community (as represented in para 3.1.1a of MIL-H-46855 [Ref. 12]) and the integrated logistics support community (as represented in para 301.2.1 of MIL-STD-1388 [Ref. 13]). Both these communities hold that the application of their technologies to the creation of a new system should be through a reasoned process of functional identification directly related to mission analysis (as required by Ref. 14 and explained in Refs. 2 and 3). This approach specifically rejects the alternative design notion that "windows of opportunity" will open during which ITCS Working Group participants can throw recent hardware willy-nilly aboard whatever platform exists and assume that, somehow, the human operators will figure out how to make it all work.

"...the complex crew station development process ...fundamentally starts with some form of mission analysis and requirements definition."

- Army-NASA A^{3}I Program Executive Summary
1 September 1990, page 3

Communicating is something that, as a general rule, humans do not do well. Yet, in any group endeavor, communication of what it is we are doing, how, and for what purpose, is essential to project success. The *functional configuration identification* (FCI) step of the Logistic Support Analysis process provides the structure and guidance for drafting a single document which contains the functional baseline of a system and which can be used as the single source for authenticating the design of each subsystem.

GENERAL ASSUMPTIONS

1. The performance requirements written for the Block 3 version of the Army's Main Battle Tank should serve as the basis for the requirements presented here, for the principal reason that the Block 3 requirements contain some of the most recent thinking on armored vehicle operations. Moreover, the Block 3 requirements have been scrubbed during the approval process. However, the ITCS ATTD is not intended to duplicate the Block 3; hence, the requirements for the ICTS ATTD vehicle are a derivation from the requirements stated for the Block 3.

2. It is possible to model human and equipment performance in a complex activity (like war-fighting) and to determine before any complete system prototypes are actually built which established and proven subsystems will work together and which won't work--and to make performance assessments with objective metrics.

3. With the possible exception of robotics, the human operator is the ultimate integrator of hardware subsystems and, therefore, the ultimate author of "system performance."

4. Before the orderly process of design of a crew-station can begin, there needs to be general agreement within the supporting R&D community concerning (1) what the overall functions of the manned system will be, and (2) which functions will initially be allocated to human performance.

MISSION ASSUMPTIONS

1. The mission of the ATTD vehicle is:

a. To damage or destroy fixed emplacements, unarmored or lightly-armored vehicles, and rotary wing aircraft within 2000 meters.

b. To inflict casualties upon enemy personnel.

c. To perform reconnaissance over unforested terrain.

d. To provide protection for the crew of two from chemical agents, small arms fire, onboard fires, and lasers powered less than _________.

e. To provide primary detection of enemy vehicles (including towed artillery) in the open 95% of the time in the first 90 seconds when they are within 2000 meters of the ATTD vehicle and those in fully camouflaged positions 90% of the time in the first 90 seconds when they are within 1500 meters of the ATTD vehicle during bright daylight hours.

f. To provide secondary detection of enemy vehicles (including towed artillery) 80% of the time when they are within 2000 meters of the ATTD vehicle in the first 120 seconds when operating in the hours of darkness or in environments (such as precipitation, blowing dust, or the deliberate use of obscurants) other than bright daylight.

g. To communicate by radio with its parent unit when that unit is within 10 km of the ATTD vehicle under non-EW conditions.

h. To have a "manned system availability" (as calculated by the formula in Ref. 5, page 16) of .88 under the Condition Assumptions.

i. To be undetectable by radar, thermal, or acoustic signature at ranges in excess of 2000 meters from the detector.

j. To be operable by a crew (one sergeant, one specialist fourth class; MOS 19K) drawn from the Target Audience Description who are able to achieve performance standards on critical tasks after no more training than ____ hours.

2. The mission diagram (derived from Ref. 6, page 11) for the ATTD Vehicle is shown in Figure 1.

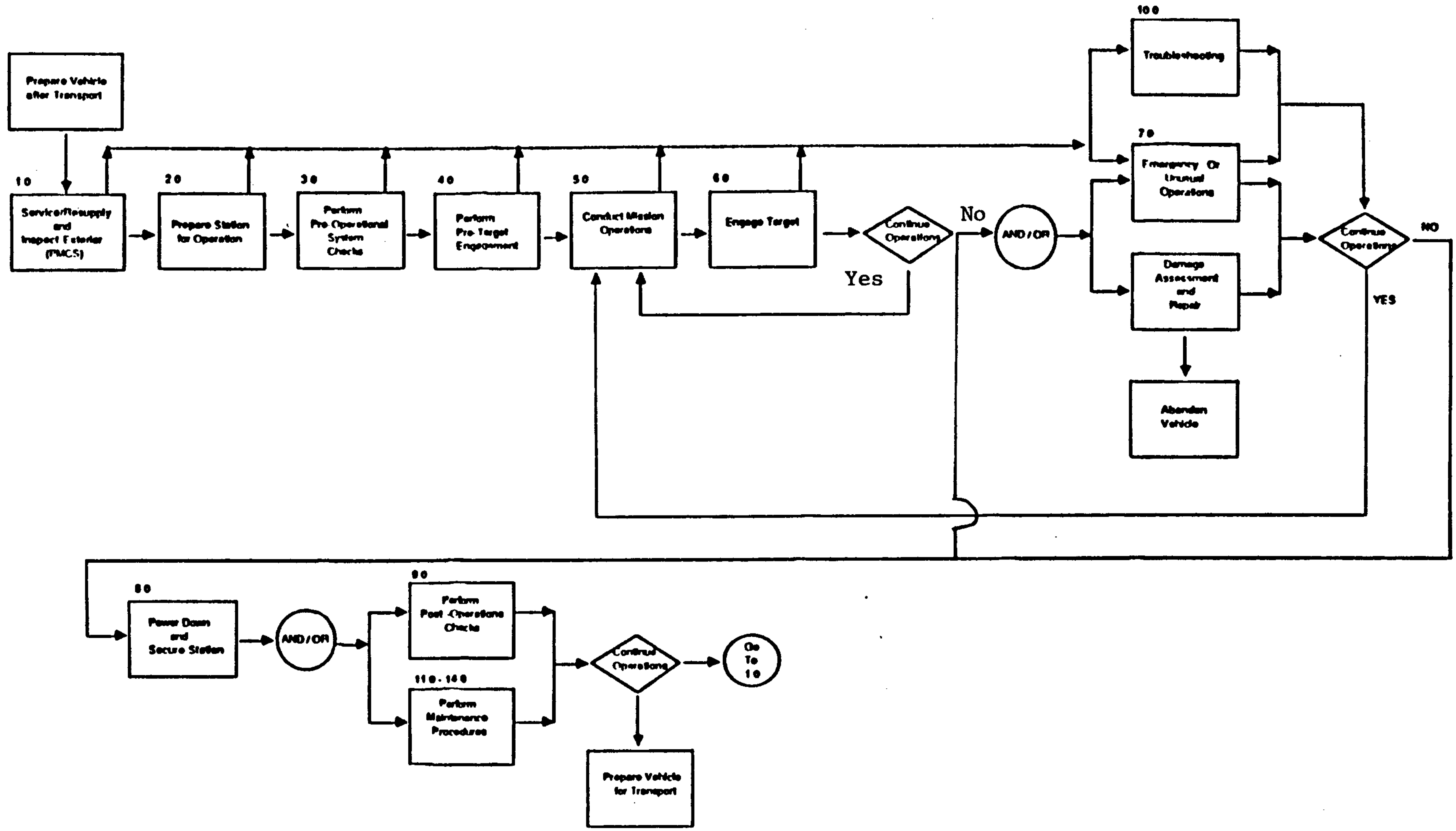


Figure 1. ATTD Vehicle Mission Diagram

3. The BOIP for the ATTD vehicle is: If there were a requirement for this vehicle, it would be assigned to the scout section of a recon platoon of armored cavalry units.

4. Doctrinal Assumptions.

a. The particular vehicle for which this FCI is written would be controlled in the field by a section or platoon sergeant in an accompanying vehicle of a similar (but not necessarily the same) type.

b. There will be a crew change in a non-contaminated environment after every twelve hours.

CONDITION ASSUMPTIONS

1. The ATTD vehicle must perform its operational mission under the following conditions:

a. Tempo. No mission to exceed 24 hours; average mission length of 5 hours. All missions by definition end in an area uncontaminated by chemical munitions.

b. Climate. Ambient temperatures in which the vehicle will be operated range from -20°F to 110°F. Humidity range from 0-100%. For planning purposes, 20% of all missions will be conducted in precipitation (rain, snow, sleet).

c. Light Level. From moonless night with low clouds to bright sunny day.

d. Hazards. The vehicle will be expected to traverse into, through, and out of terrain where chemical munitions have been employed.

e. Electronic Warfare. The hostile force will have and use offensive and defensive EW devices.

2. All scheduled and preventive maintenance tasks and all corrective maintenance tasks to be performed *above* crew level will be performed in a benign environment. Any corrective maintenance task to be performed <u>by the crew</u> should be capable of being performed in the operational environment.

Manned System

FUNCTIONAL CONFIGURATION IDENTIFICATION

ATTD Vehicle

with

Integrated Two-Man Crew Station

ATTD VEHICLE CHARACTERISTICS
(Derived from Mission Assumptions)

1. Mobility.

a. To have a sustained speed over flat, unforested terrain of 35 km/hr.

b. To achieve a peak speed of 62 km/hr, and to sustain that speed for 8 minutes.

2. Firepower.

a. [performance spec for destroying enemy bunker]

b. [performance spec for destroying armored vehicles]

c. [performance spec for anti-personnel fire]

3. Communications.

a. [performance spec for intra-vehicle communications]

b. [performance spec for inter-vehicle communications]

c. [performance spec for direct communications with unit base]

d. [performance spec for indirect communications with unit base] (Something like, "Base unit shall be able to query the onboard computer concerning location, fuel and ammunition status, heading and speed while the ATTD vehicle is within a 10 km range in open terrain and without the need for interacting with the crewmembers, and shall obtain correct information 90% of the time.")

4. Survivability.

a. The crewstation shall provide primary chemical protection by means of a positive pressure subsystem. Nuclear survivability is not required.

b. [performance spec for on-board fire protection]

c. [performance spec for ballistic protection]

d. [performance spec for laser eye protection, including prohibition against disrupting crew's color vision.]

e. Stowage space will be provided somewhere on the vehicle for two M16A1 rifles Soldier Integrated Protective Ensemble (SIPE), and such other personal equipment as may be necessary if the crewmen are required to evacuate the vehicle during a mission.

f. A separate "crew entry capsule," transportable on an M1069 (HMMWV) shall be designed which will permit a safe crewchange within five minutes without decontaminating more than 10% of the outer surface of the ATTD vehicle.

5. Navigation.

a. [performance spec for knowing where in the world they are]

b. [performance spec for travel aid]

6. Crew Station.

a. The crewstation shall provide comfortable seating for two personnel only.

b. Either crew position shall provide access to the full range of input information and the full range of output soldier actions (but the two stations shall not *necessarily* be of the exact same design).

c. The vehicle shall be safely drivable by one crewman.

d. Displays in the crewstation shall not cause asthenopia in missions up to five hours in length.

e. The crewstation shall accommodate male personnel with 5th through 95th percentile anthropometry.

f. "Immediate action" to clear weapon stoppages shall be performable by one crewman without torso exposure and without disrupting the chemical protection afforded by the positive pressure subsystem.

g. The crewstation shall have no mechanical control devices (e.g., pedals) any portions of which can enter the crewstation from an area of the vehicle not protected by the positive pressure subsystem.

h. Any hatches proposed for the crewstation shall have "knife edge," not "flat plate" seals.

i. Any optics proposed for the crewstation shall not require "right eye dominance" for successful operation.

FUNCTIONAL CONFIGURATION IDENTIFICATION

1. General.

1.1 Purpose and Scope. This functional configuration identification (FCI) is prepared in accordance with para 301.2.1 of MIL-STD-1388-1 [Ref. 13]. That document prescribes content, but not format. The format used is that proposed in Ref. 6 as automated in *System Performance and RAM Criteria* (SPARC) [Ref. 1].

1.1.1 SPARC Conventions. SPARC permits the user to enter the system mission in segments, and to develop hierarchically-based functions and subfunctions. No allocation to human or machine performance is required in either the input or the output; all performance criteria are for the "manned system." (However, for convenience of the user, some subfunctions are customarily written for human performance when those subfunctions are traditionally regarded as soldier tasks. See example, below.) Time and accuracy criteria [Ref. 4] are developed for each mission segment and each subfunction.

1.1.2 SPARC Selections. The mission segment selected for presentation in this FCI is "movement to contact," and the function illustrated is "fire while moving." [Before a performance baseline can be established for the manned ATTD vehicle, all mission segments should be established with appropriate success criteria (expressed in time and accuracy).

1.2 Limitation. The FCI presented in this Working Paper is based on the M1A1 tank model in the SPARC library. <u>It is presented here without modification to the library data,</u> although such modifications are proposed (in the following section) to link the FCI more closely with the Mission and Condition Assumptions (in previous sections).

2. Functional Configuration.

2.1 Identifications. The output of the SPARC model reports both a narrative list of functions and subfunctions supporting each mission segment and functional-flow block diagrams (FFBDs) of the relationships among the parts.

2.1.1 Mission

2.1.2 Function Sequence Report

2.1.3 Subfunction Sequence Report

(Initialization of SPARC Model)

```
03/25/1991                    System Description Report                  06:26:08

Mission Area        : Close Combat Heavy
System Type         : Tanks
System Name         : M-1 Abrams
Version Name        :
Comparable Mission  :  << LIBRARY >>
Comparable Type     :  << LIBRARY >>
System Mission      : Movement to Contact
```

```
PATH: SPARC>Set Mission Requirements

Mission Area        : Close Combat Heavy
System Type         : Tanks
System Name         : M-1 Abrams
Version Name        :
Comparable Mission  :  << LIBRARY >>
Comparable Type     :  << LIBRARY >>
System Mission      : Movement to Contact

          Set Mission Level Time and Accuracy Requi   ents

Mission Time        : <=      60.00 minutes
Mission Accuracy    : Move to start point(2km)then to che   point L(3km)
                      From there move to release point(2kr  then to line
                      of departure(3km).Once beyond the LI  a threat may
                      be encountered. Threats are T-72 tanks at a range
                      of 1200-1400 meters in an open field. The tank is
                      facing threat but may be moving.One-on-one battle.
Mission Criterion   : Meet standards with a probability of  70.00 %

    Change Time     Change Accuracy     Change Criterion     Save & Exit
```

2.1.1

03/25/1991	Mission Description Report 06:26:08
Functions	**Subfunctions**
Move to Start Point	Steer Tank Power Tank Monitor Instruments Monitor Forward Terrain Assign Sector Searches Conduct Surveillance-TC Conduct Surveillance-Gunner Conduct Surveillance-Loader
Move to Check Point	Steer Tank Power Tank Monitor Instruments Monitor Forward Terrain Assign Sector Searches Conduct Surveillance-TC Conduct Surveillance-Gunner Conduct Surveillance-Loader
Move to Release Point	Steer Tank Power Tank Monitor Instruments Monitor Forward Terrain Assign Sector Searches Conduct Surveillance-TC Conduct Surveillance-Gunner Conduct Surveillance-Loader
Move to Line of Departure	Steer Tank Power Tank Monitor Instruments Monitor Forward Terrain Assign Sector Searches Conduct Surveillance-TC Conduct Surveillance-Gunner Conduct Surveillance-Loader
Pass Line of Departure	Pass Line of Departure
Targets Appear Within FOV	Targets Appear within FOV
Targets Do Not Appear Within FOV	Targets Do Not Appear within FOV
Move Beyond LD-No Firing	Steer Tank Power Tank Monitor Instruments Monitor Forward Terrain Assign Sector Searches Conduct Surveillance-TC Conduct Surveillance-Gunner Conduct Surveillance-Loader
Continue Moving	Continue Moving
Target is Not Detected	Target is not Detected

Target is Detected	Target is Detected
Target Selected by Section Leader	Target Selected by Section Leader
Target Not Selected by Section Leader	Target is not Selected by Section Lea
Identify/Select Target	Identify Target Select Target
Select Firing Position	Select Firing Position
Move Without Firing During Engagement	Steer Tank Power Tank Monitor Instruments Monitor Forward Terrain Assign Sector Searches Conduct Surveillance-TC Conduct Surveillance-Gunner Conduct Surveillance-Loader
Fire While Stationary	Steer Tank (from defilade) Power Tank (from defilade) Initiate Fire Command Begin Alert Segment Lay Gun in Direction of Target Select Weapon/Announce Alert Check/Change Fire Control Switch Check/Change LRF Switch End Alert Segment Check/Change Gun Turret Switch Select/Announce Ammunition Announce Target Check/Change Gun Select Switch Check/Change Ammo Select Switch Check/Change Spent Case Rejection Swi Check Path of Recoil Load Ammo Release Override Gunner Acquires Target TC Gives Fire Command Gunner Fires End Fire Segment Steer Tank (back to defilade) Power Tank (back from defilade) Gunner Observes Effects TC Observes Effects
Fire While Moving	Initiate Fire Command Begin Alert Segment Lay Gun Select Weapon/Announce Alert Check/Change Fire Control Switch Check/Change Gun Turret Switch Release Override Check/Change LRF Switch End Alert Segment Select/Announce Ammunition Check/Change Gun Select Switch

	Check/Change Spent Case Rejection Swi Load Ammo Announce Target Check/Change Ammo Select Switch Check Path of Recoil Gunner Acquires Target TC Gives Fire Command Gunner Fires Gunner Observes Effects TC Observes Effects Move Tank During Firing Steer Tank During Firing Power Tank During Firing
Target Not Hit (While Stationary)	Target not Hit (While Stationary)
Target Hit (While Stationary)	Target Hit (While Stationary)
Target Survives	Target Survives
Target Does Not Survive	Target Does Not Survive
Another Target is Present	Another Target is Present
No More Targets	No More Targets
Tank Engages Again	Tank Engages Again
Threat Fires	Threat Fires
System Hit	System Hit
System Not Hit	System Not Hit
System Does Not Survive	System Does Not Survive Hit
System Survives	System Does Survive
Target Hit (While Moving)	Target Hit (While Moving)
Target Not Hit (While Moving)	Target not Hit (While Moving)
Perform External Communication	Transmit Message-TC Receive Message-TC Transmit Message-Loader Receive Message-Loader
Perform Crew Communication	TC Initiates Communication Gunner Initiates Communication Driver Initiates Communication Loader Initiates Communication TC Transmits Communication Gunner Receives Communication Loader Receives Communication Driver Receives Communication Gunner Transmits Communication TC Receives Communication Loader Receives Communication from Gu Driver Receives Communication from Gu

	Driver Transmits Communication TC Receives Communication from Driver Gunner Receives Communication from Dr Loader Receives Communication from Dr Loader Transmits Communication TC Receives Communication from Loader Gunner Receives Communication from Lo Driver Receives Communication from Lo
Adjust Internal Environment	Adjust Personnel Heater

2.1.2

03/25/1991	Function Sequence Report		08:42:22
System Mission: Movement to Contact			

Functions Following Functions	Func Type	Decision Type	Prob, Repeat or Converge
START	D	Sing	
1) Move to Start Point			
1) Move to Start Point	D	Rept	2
2) Move to Check Point			
2) Move to Check Point	D	Rept	3
3) Move to Release Point			
3) Move to Release Point	D	Rept	2
4) Move to Line of Departure			
4) Move to Line of Departure	D	Rept	3
5) Pass Line of Departure			
5) Pass Line of Departure	D	Prob	
6) Targets Appear Within FOV			0.70
7) Targets Do Not Appear Within FOV			0.30
6) Targets Appear Within FOV	D	Prob	
10) Target is Not Detected			0.30
11) Target is Detected			0.70
7) Targets Do Not Appear Within FOV	D	Sing	
8) Move Beyond LD-No Firing			
8) Move Beyond LD-No Firing	D	Rept	2
9) Continue Moving			
9) Continue Moving	D	Prob	
6) Targets Appear Within FOV			0.70
7) Targets Do Not Appear Within FOV			0.30
10) Target is Not Detected	D	Prob	
8) Move Beyond LD-No Firing			0.80
26) Threat Fires			0.20
11) Target is Detected	D	Prob	
12) Target Selected by Section Leader			0.70
13) Target Not Selected by Section Leader			0.30
12) Target Selected by Section Leader	D	Sing	
15) Select Firing Position			
13) Target Not Selected by Section Leader	D	Sing	
14) Identify/Select Target			
14) Identify/Select Target	D	Sing	
15) Select Firing Position			
15) Select Firing Position	D	Prob	
16) Move Without Firing During Engagement			0.30
17) Fire While Stationary			0.10
18) Fire While Moving			0.60
16) Move Without Firing During Engagement	D	Sing	
15) Select Firing Position			
17) Fire While Stationary	D	Prob	
19) Target Not Hit (While Stationary)			0.30
20) Target Hit (While Stationary)			0.70
18) Fire While Moving	D	Prob	
31) Target Hit (While Moving)			0.50
32) Target Not Hit (While Moving)			0.50
19) Target Not Hit (While Stationary)	D	Prob	
25) Tank Engages Again			0.80
26) Threat Fires			0.20
20) Target Hit (While Stationary)	D	Prob	

21) Target Survives			0.40
22) Target Does Not Survive			0.60
21) Target Survives	D	Prob	
25) Tank Engages Again			0.80
26) Threat Fires			0.20
22) Target Does Not Survive	D	Prob	
23) Another Target is Present			0.83
24) No More Targets			0.17
23) Another Target is Present	D	Sing	
11) Target is Detected			
24) No More Targets	D	Sing	
99) END			
25) Tank Engages Again	D	Sing	
15) Select Firing Position			
26) Threat Fires	D	Prob	
27) System Hit			0.50
28) System Not Hit			0.50
27) System Hit	D	Prob	
29) System Does Not Survive			0.50
30) System Survives			0.50
28) System Not Hit	D	Prob	
25) Tank Engages Again			0.80
26) Threat Fires			0.20
29) System Does Not Survive	D	Sing	
99) END			
30) System Survives	D	Prob	
25) Tank Engages Again			0.80
26) Threat Fires			0.20
31) Target Hit (While Moving)	D	Prob	
21) Target Survives			0.40
22) Target Does Not Survive			0.60
32) Target Not Hit (While Moving)	D	Prob	
25) Tank Engages Again			0.80
26) Threat Fires			0.20
33) Perform External Communication	C	Sing	
33) Perform External Communication			
34) Perform Crew Communication	C	Sing	
34) Perform Crew Communication			
35) Adjust Internal Environment	C	Sing	
35) Adjust Internal Environment			

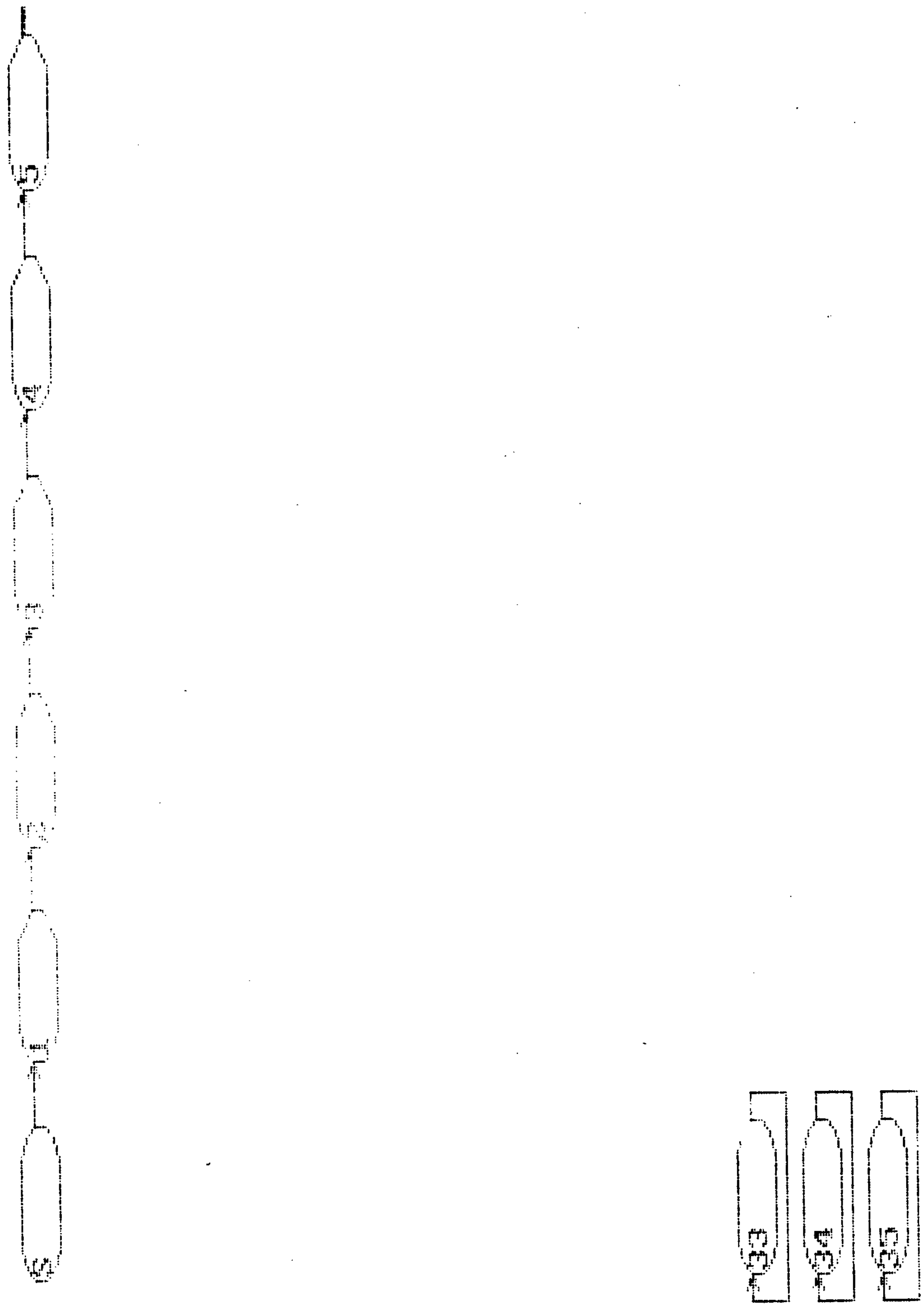
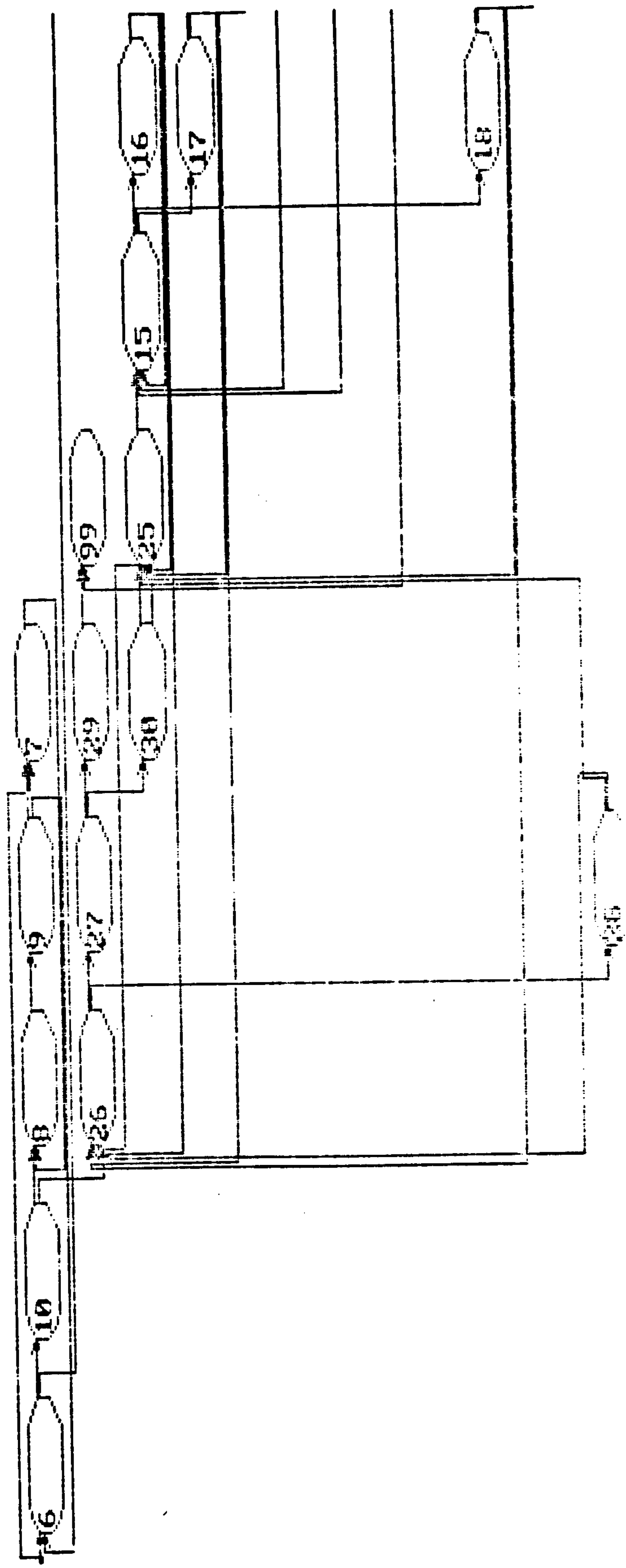
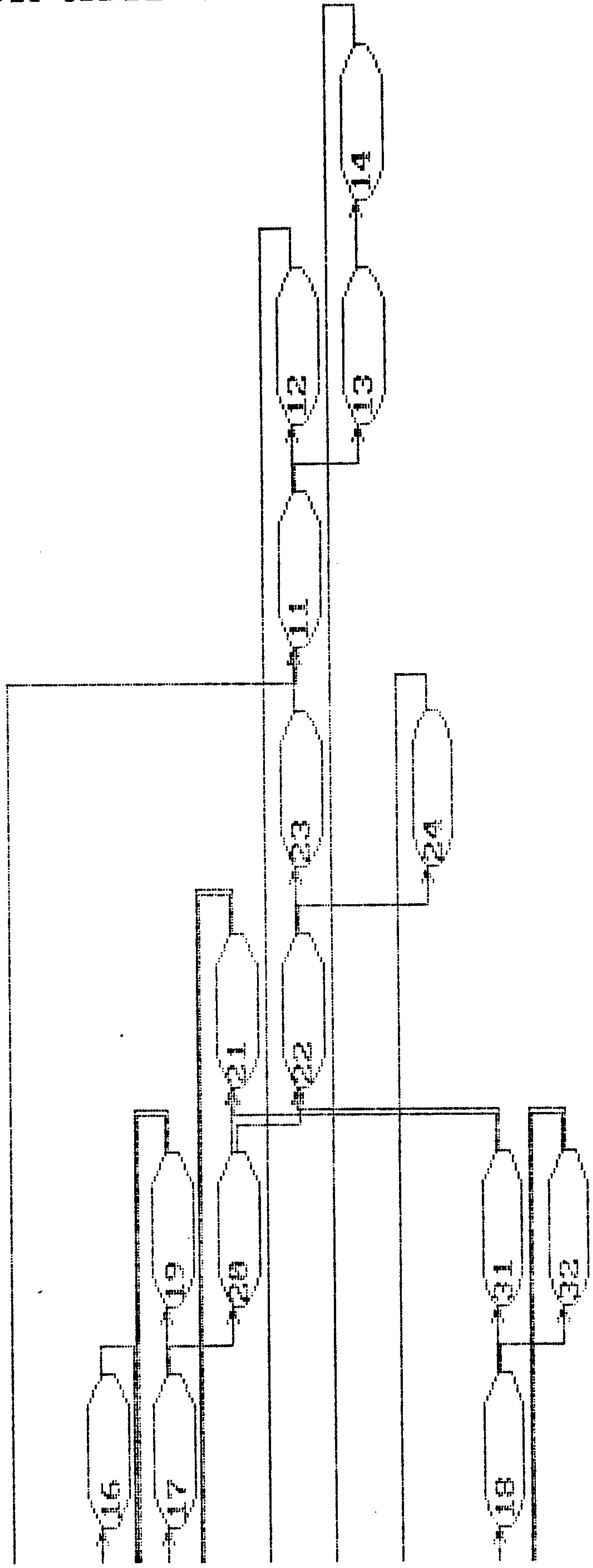


Figure 2. Functional Flow Block Diagram at Function Level



FOR ATTD PURPOSES ONLY



FOR ATTD PURP SES ONLY

2.1.3

03/25/1991	Subfunction Sequence Report	09:17:43

Function: Fire While Moving

Subfunctions Following Subfunction	Decision Type	Prob, Repeat or Converge
START	Mult	99
1) Initiate Fire Command		
22) Move Tank During Firing		
1) Initiate Fire Command	Mult	17
2) Begin Alert Segment		
3) Lay Gun		
4) Select Weapon/Announce Alert		
5) Check/Change Fire Control Switch		
2) Begin Alert Segment	Mult	17
4) Select Weapon/Announce Alert		
5) Check/Change Fire Control Switch		
6) Check/Change Gun Turret Switch		
3) Lay Gun	Sing	
7) Release Override		
4) Select Weapon/Announce Alert	Sing	
9) End Alert Segment		
5) Check/Change Fire Control Switch	Sing	
8) Check/Change LRF Switch		
6) Check/Change Gun Turret Switch	Sing	
9) End Alert Segment		
7) Release Override	Sing	
17) Gunner Acquires Target		
8) Check/Change LRF Switch	Sing	
9) End Alert Segment		
9) End Alert Segment	Mult	17
10) Select/Announce Ammunition		
11) Check/Change Gun Select Switch		
12) Check/Change Spent Case Rejection Swit		
13) Load Ammo		
10) Select/Announce Ammunition	Sing	
14) Announce Target		
11) Check/Change Gun Select Switch	Sing	
15) Check/Change Ammo Select Switch		
12) Check/Change Spent Case Rejection Switch	Sing	
16) Check Path of Recoil		
13) Load Ammo	Sing	
17) Gunner Acquires Target		
14) Announce Target	Sing	
17) Gunner Acquires Target		
15) Check/Change Ammo Select Switch	Sing	
17) Gunner Acquires Target		
16) Check Path of Recoil	Sing	
17) Gunner Acquires Target		
17) Gunner Acquires Target	Sing	
18) TC Gives Fire Command		
18) TC Gives Fire Command	Sing	
19) Gunner Fires		
19) Gunner Fires	Mult	99
20) Gunner Observes Effects		
21) TC Observes Effects		
20) Gunner Observes Effects	Sing	
99) END		
21) TC Observes Effects	Sing	
99) END		
22) Move Tank During Firing	Mult	99
23) Steer Tank During Firing		
24) Power Tank During Firing		
23) Steer Tank During Firing	Sing	
99) END		
24) Power Tank During Firing	Sing	
99) END		

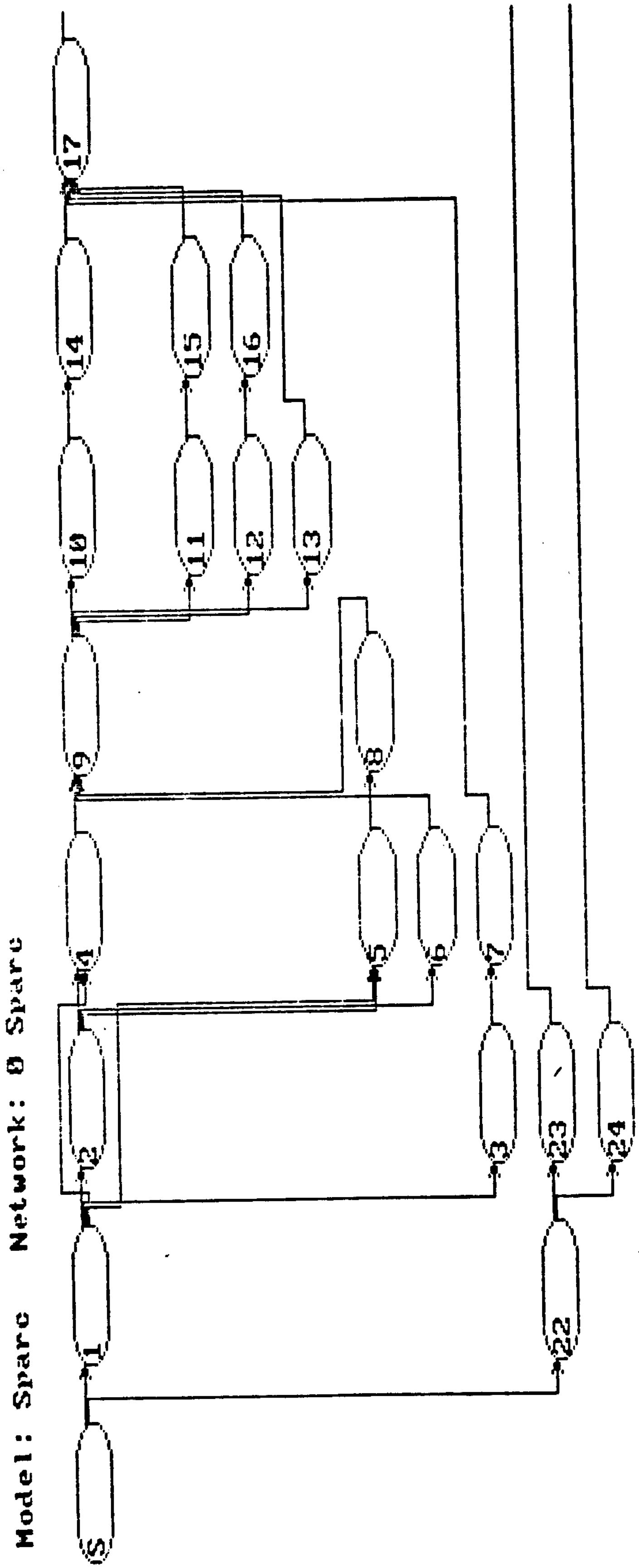
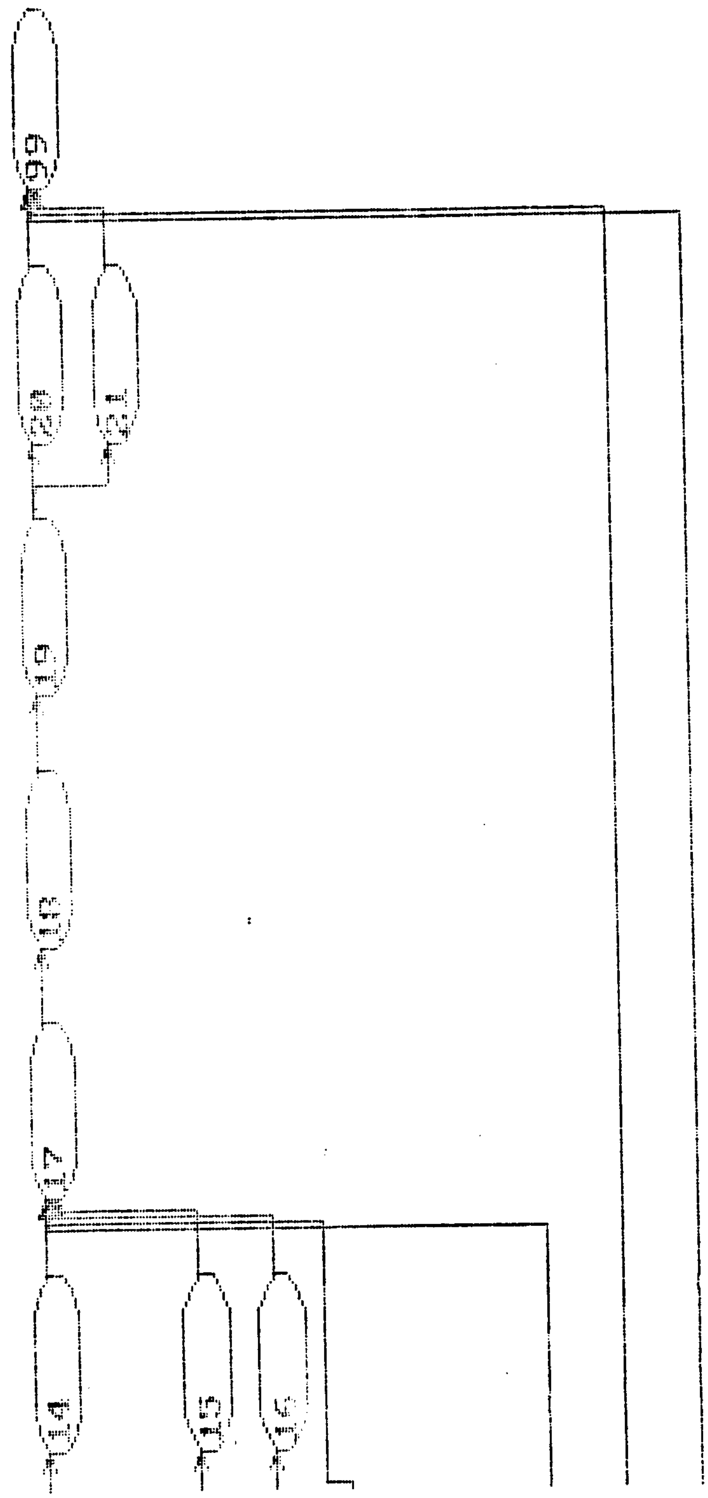


Figure 3. Functional Flow Block Diagram at Subfunction Level

FOR ATTD PURPOSES ONLY



ADDITIONAL ANALYSES RECOMMENDED

To develop a formal performance baseline for the ATTD vehicle which can be used for subsequent trade-off analyses, the following efforts should be undertaken by the ITCS Working Group. Those efforts should be based on the best available data, rather than "strawman data" used in the preceding sections of this working paper.

1. Development of a realistic mission scenario for the ATTD vehicle, based upon Refs. 10 and 15.

2. Statement of the full range of conditions under which the ATTD vehicle would be expected to operate, based upon Refs. 9 and 11.

3. Selection of operational tank model. This model should be either an M1 or Block 3 model which permits full play of human performance [Refs. 3 and 8] and which is adaptable to personal computer RAM requirements. The likeliest candidate appears to be the CREWCUT M1A1 model (due to be available at the end of March, 1991).

4. Adaptation of the selected model for a 2-man tank. Adaptation should be performed by a working group consisting of personnel from the appropriate modelling and subject matter organizations. The likely candidate organizations for this working group are TACOM, ARI, HEL, and the Armor School. The SME organization in particular must provide plausible details about the operation and functioning of a 2-man tank, including -

a. Mission(s), functions, tasks and conditions that are projected for the new system.

b. Maximum acceptable mission time.

c. Minimum acceptable mission accuracy

d. Sequence of function performance for a given mission.

e. Sequence of task performance for a given function.

f. If two or more functions follow another function probabilistically--estimates of those probabilities.

g. If two or more tasks follow another task probabilistically--estimates of those probabilities.

h. Initial estimate of maximum acceptable function time.

i. Initial estimate of maximum acceptable task time.

j. Probable task time.

k. Initial estimate of minimum acceptable task accuracy.

l. Probable task accuracy.

m. Workload assignments for each task according to WINDEX and McCracken-Aldrich approaches.

5. Select appropriate methods for developing performance criteria and evaluating design. The likely candidate methods are: SPARC, CREWCUT, the Workload Analysis Aid of MAN-SEVAL.

6. Insertion of the 2-man tank model into appropriate methods.

7. Development of 2-man tank performance criteria, based upon runs of the methods (selected above). These criteria need to include function and subfunction time and accuracy) requirements for mission success. Mission success criteria should be developed in the working group.

8. Evaluation of the crew workload in the conceptual design, including: time-lines with workload estimates for each job; points during time-line in which overload takes place; potential task allocations that will reduce workload; automation recommendations.

9. Alter the aptitude requirements of the crew selection criteria or increase the training if performance with average soldiers is predicted to be mission-inadequate.

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APPENDIX

TARGET AUDIENCE DESCRIPTION

ATTD Vehicle

with

Integrated Two-Man Crew Station

(To Be Completed)

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REMARKS

This is "Read-Ahead" package for ITCS subgroup meeting at Ft Knox 9-10 Apr 91.

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for ROBIN L. KEESEE, Director Systems Research Laboratory	Rene J. deBurrilleron

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Commandant, U.S. Army Armor School, ATTN: ATSB-CDT (MAJ Szydloski), Ft. Knox, KY 40121-5215

Working Paper

WP MSG 90-13

AN ASSESSMENT OF THE USE OF THE MANPOWER CONSTRAINTS (M-CON) SOFTWARE AID

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28 SEPTEMBER 1990

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AN ASSESSMENT OF THE USE OF THE MANPOWER CONSTRAINTS (M-CON) SOFTWARE AID.

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LIST OF TABLES

LIST OF FIGURES

AN ASSESSMENT OF THE USE OF THE MANPOWER CONSTRAINTS (M-CON) SOFTWARE AID.

INTRODUCTION

In developing a new system, the emerging requirements for manpower which will be necessary to operate and maintain that system must be compared with the manpower resources which will be available when the system is fielded. If a "fit" is not found between the two, adjustments must be made in one or the other.

The Army Research Institute is engaged in the development of analytical tools for both the assessment of manpower requirements and manpower constraints, or availability. On the requirements side, the HARDMAN II series of tools is being developed to implement the HARDMAN comparability methodology (HCM). HCM provides a structured approach to the determination of manpower, personnel and training (MPT) requirements early in the system development cycle. On the constraints side, the HARDMAN III series of tools provides estimates of the quantitative and qualitative characteristics of the personnel who will likely be available to support an emerging weapon system. One of these tools, the Manpower Constraints Aid (M-CON) generates estimates of the maximum manpower that is likely to be available for assignment to a newly fielded system. The early estimation of availability of manpower can serve as a system design constraint.

An overview of M-CON is given in Figure 1, taken from Herring and O'Brian (1989). Initially, the estimated pool of available manpower, both operators and maintainers, is based upon the manpower presently supporting the system to be replaced. Estimation of available maintenance manpower is based upon the annual maintenance manhours required to support a single baseline weapon system, derived from the MARC maintenance data base. Algorithms translate the system maintenance manhours to productive maintenance manhours for each MOS by skill level at each maintenance level, and subsequently to maintenance manpower spaces required for each MOS. Maintenance MOSs may be maintaining more than one type of system while a operational crew's time is committed to one system type. Estimates of available manpower may be adjusted to reflect authorized strength rather than system-driven required strength through the use of an adjustment factor, either across all MOSs or for selected MOSs, which simulates the use of an authorized data base rather than the MARC data base. Similarly, an estimation may be made for actual manpower availability rather than available authorized strength through use of an adjustment factor, either across MOSs or for selected MOSs, simulating the use of an operating data base rather than an authorized data base. Total available manpower, either adjusted or unadjusted, is then divided by the system density of the new system to determine the manpower constraints per system, either in terms of maximum crew size or maximum maintenance manpower. These manpower constraints may

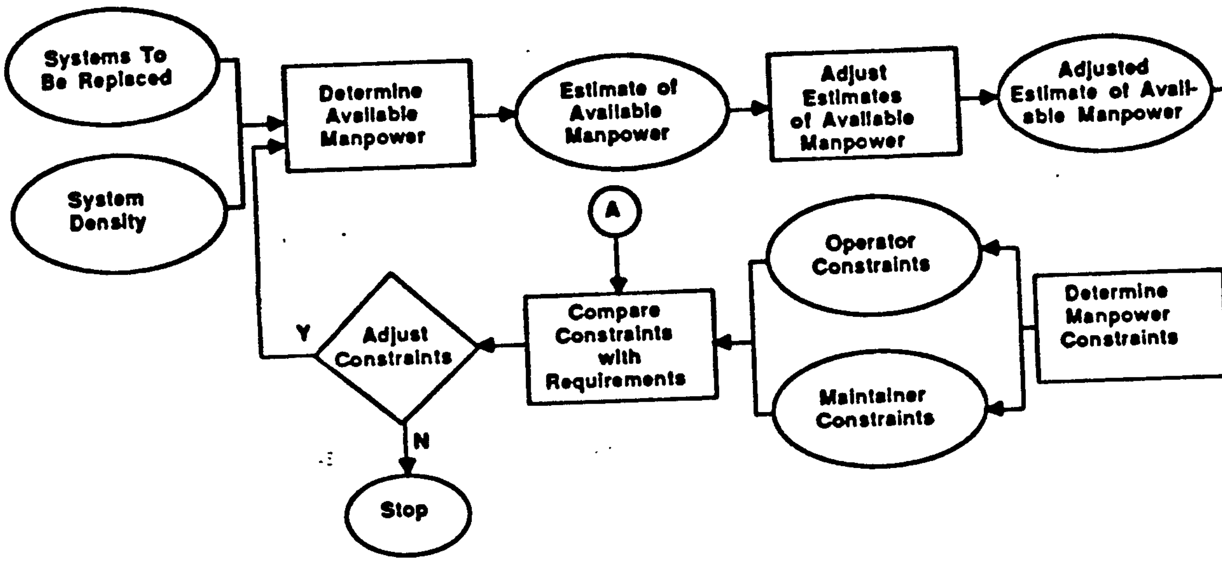

Figure 1. Overview of M-CON Aid Logic

then be compared with manpower requirements, such as may be derived from a HCM analysis. If estimated requirements are found to exceed the constraints, they may be balanced through such alternatives as decreasing the system density of the emerging system or changing the system design to reduce required manpower.

The objective of this effort was to apply the available prototype of the M-CON tool to derive manpower constraints and compare them to manpower requirements obtained in a previous HCM analysis of the Future Armored Combat System (FACS). The results of the HCM analysis have been presented in the report "Apply the Army HARDMAN Comparability Methodology (HCM) to the Future Armored Combat System (FACS), Volume 1." by Hay Systems, Inc. (Shotzbarger, 1989). (The FACS is a variant included within the Armored Family of Vehicles (AFV). The AFV program having been superseded by and incorporated into the Armored Systems Modernization (ASM) program, the FACS is now known as the Block III tank. However, FACS shall be the designation used in this report.)

The assumptions and constraints used in estimating the manpower requirements in the HCM for the FACS were as follows:

o The FACS will replace the M1A1 on a one-for-one basis.

o Crew manpower requirements were determined by Army manning standards. The introduction of an autoloader permits reduction of crew size from 4 men in the M1 (the predecessor system) to 3 men in the FACS.

o Maintenance will be performed in accordance with the conventional Army maintenance concept, i. e. at the organizational and intermediate levels.

o A representative FACS configuration, consisting of selected subsystem alternatives, was used.

o The FACS force structure consists of 54 armored battalions, of 58 tanks each, and 9 armored calvary squadrons, each with 41 tanks, giving a total of 3501 tanks for the active force.

o Only manpower spaces directly attributable to the FACS were estimated.

o Officer spaces were not included.

The manpower requirements found in the HCM analysis for both the M1A1 and the FACS are shown in Table 1. It is to be noted that manpower requirements are expressed in whole spaces for the crew and organizational level MOSs, as each soldier at these levels is totally committed to one system (e. g., M1). For maintainers at the intermediate level, fractional spaces are used as maintainers at this level may also deal with systems other

Table 1. HCM Active Force Manpower Requirements

MAINTENANCE LEVEL	MOS	M1A1 MPR	FACS MPR
Crew	19K	13,275.00	9,774.00
Organization	31V	378.00	378.00
	45E	666.00	315.00
	63E	1,089.00	1,089.00
Subtotal		2,133.00	1,782.00
Intermediate	29E	28.44	15.29
	39E	7.83	1.75
	41C	144.27	13.15
	44B	0.00	20.63
	44E	0.00	0.87
	45G	178.65	173.16
	45K	980.91	469.72
	63G	74.25	118.04
	63H	1,158.39	439.55
	63J	9.63	1.33
Subtotal		2,582.37	1,253.49
Total, All Levels		17,990.37	12,809.49

than the one being analyzed. It should also be recalled that the active force represents 3501 tanks.

APPROACH

The approach consisted of familiarization with the operation of the M-CON software, use of M-CON to derive the various measures of manpower availability, or constraints, for the FACS, based on the predecessor system (M1), and comparison of the constraints from M-CON with the requirements from the HCM. Successive versions of the software were used as they became available, with version .91 being the most recent.

The utilization of an early prototype of the M-CON software uncovered numerous difficulties in achieving the desired comparison of FACS manpower requirements and constraints and its interpretation. Therefore, these difficulties were noted, with the objective of highlighting areas which appear to be candidates for the introduction of subsequent improvements.

A narrative of the use of the M-CON software aid as applied to the FACS HCM, together with associated observations, is presented in the Appendix. A summary of these observations, selected for their frequency of occurrence and importance to successful use of the aid, is included in the following Results section.

RESULTS AND DISCUSSION

FACS HCM manpower requirements and M-CON constraints.

Table 2 summarizes the manpower spaces for maintenance MOSs, as derived by the HCM and M-CON analyses. All analyses are those associated with support of 3501 tanks. The results for the M1 and the FACS HCM analyses are the same as those previously presented in Table 1. The first M-CON analysis is that based on the system-driven annual maintenance manhours as given in the MARC database, converted to manpower spaces. The next M-CON analysis (M-CON M1 AUTH) is that which has adjusted the MARC-based manpower estimates to reflect manpower which can be expected to be authorized to support the system, according to the Table of Organization and Equipment (TOE). The M-CON M1 OPST column gives the authorized estimate adjusted to reflect manpower which can be expected to actually be operational with the M1, based on the operating database.

It should first be noted that there was a lack of commonality between the MOS components for the FACS HCM and the M-CON analyses. For three MOSs, a requirement was identified in the FACS HCM but zero availability was reported in the M-CON analyses. This was the case for the following MOSs: 39E (Special Electronics Devices Repairer) which was not in the M-CON MOS

Table 2. Summary of Manpower Requirements and Constraints

MOS	[1]HCM FACS	HCM M1	[2]MCON M1 MARC	MCON M1 AUTH	MCON M1 OPST
29E	15.29	28.44	26.57	22.06	24.25
31V	[3]378	378	24.88	28.37	34.61
35H	[4] -	-	5.66	4.69	5.35
39E	1.75	7.83	[5] -	-	-
41C	13.15	144.27	141.74	144.58	167.71
44B	20.63	-	-	-	-
44E	.87	-	-	-	-
45B	-	-	6.98	5.39	7.58
45E	315	666	538.61	490.14	632.29
45G	173.16	178.65	165.67	127.58	174.77
45K	469.72	980.91	961.16	797.77	909.46
63E	1089	1089	899.29	818.36	908.38
63G	118.04	74.25	69.78	57.91	60.23
63H	439.55	1158.39	1122.79	1538.23	1599.75
63J	1.33	9.63	60.06	54.65	67.78
TOTAL	3035.49	4715.37	4023.19	4089.73	4592.16

NOTES:

1 HCM - HARDMAN Comparability Methodology
2 MCON - Manpower Constraints (Availability) Aid
3 Integer numbers indicate organizational level
4 "-" under HCM indicates no requirement was identified.
5 "-" indicates MCON reports zero availability.

database for the M1, but was included in the required MOSs for both the M1 and FACS HCM analyses; 44B (Metal Worker), and 44E (Machinist), both of which were found to be required in the FACS HCM but not to be required in the original M1 HCM analysis. For two MOSs, no requirement was identified in the FACS HCM (and the M1 HCM) but availability was assessed in the M-CON analyses as these MOSs were included in the MOS database for the M1. This was the case for the 35H (Calibration Specialist), and the 45B (Small Arms Repairer).

Among the other ten MOSs, which had been identified as being required both in the original FACS and M1 HCM analyses, the results of the comparison of requirements for the FACS with the constraints imposed by the M-CON availability analysis were as follows. For the following six MOSs, the FACS manpower requirement was found to be less than any of the M-CON constraints: 29E (Communications Electronic Radio Repairer), 41C (Fire Control Instrument Repairer), 45E (M1 Tank Turret Mechanic), 45K (Tank Turret Repairer), 63H (Track Vehicle Repairer), and 63J (Quartermaster and Chemical Equipment Repairer). For the following three MOSs, the FACS manpower requirement was found to exceed any of the three M-CON constraints: 31V (Unit Level Communications Maintainer), 63E (M1 Tank Systems Mechanic), and 63G (Fuel and Electrical System Repairer). For the remaining MOS, 45G (Fire Control Systems Repairer), the FACS manpower requirement was found to exceed the MARC and authorized M-CON constraints but to be slightly less than the operationally based constraint.

In summary, for the thirteen MOSs for which a requirement had been identified in the FACS HCM, six were found to have a requirement that was less than any of the M-CON constraints, six were found to have a requirement greater than any of the M-CON constraints, and one MOS was found to have a requirement greater than all but one M-CON constraint.

Table 3 presents the results in terms of the differences which were found between the manpower requirements from the FACS HCM analysis and the various manpower constraints found in the M-CON analysis. The MOSs are listed in descending order, within organizational and intermediate levels of maintenance, of the manpower requirements from the FACS HCM analysis. The requirements are given in the first column for each MOS, while the differences between these requirements and the MARC, authorized and operational constraints from the M-CON analysis are given in the second, third and fourth columns respectively. A shortfall in estimated availability relative to requirements is indicated by the difference being in a parenthesis; lack of a parenthesis indicates sufficient availability to meet requirements. Presentation of the results in this manner serves to highlight the presence of shortfalls in manpower availability.

Through examination of Table 3, it may be seen that two of the three maintenance MOSs committed to the system at the

Table 3. Differences between Requirements and Constraints.

MOS	Req.	MARC-Req.	AUTH-Req.	OPST-Req.
Organizational				
63E M1 Tank Sys Mech	1089	(189.71)	(270.64)	(180.62)
31V Unt Lvl Comm. Maintr	378	(353.12)	(349.63)	(343.39)
45E M1 Tank Turret Mech	315	223.61	175.14	317.29
Intermediate				
45K Tank Turret Repar	469.72	491.44	328.05	439.74
63H Track Vehicle Repar	439.55	683.24	1098.68	1160.20
45G Fire Cntl Sys Repar	173.16	(7.49)	(45.58)	1.61
63G Ful & Elec Sys Repar	118.04	(48.26)	(60.13)	(57.81)
44B Metal Worker	20.63	(20.63)	(20.63)	(20.63)
29E Com Elet Rad Repar	15.29	11.28	6.77	8.96
41C Fire Cntl Ins Repar	13.15	128.59	131.43	154.56
39E Spec Elet Dev Repar	1.75	(1.75)	(1.75)	(1.75)
63J QM & Chem Eqp Repar	1.33	58.73	53.32	66.45
44E Machinist	.87	(.87)	(.87)	(.87)

organizational level, 63E (M1 Tank System Mechanic) and 31V (Unit Level Communications Maintainer) have shortfalls. The shortfall is particularly acute for the 31V, with almost a complete lack of availability. The lack of availability of these two MOSs at the organizational level should be of concern, as they would be the maintenance MOSs committed to this one system and the only ones available for quick response reaction under combat operational tempos. There are five MOSs at the intermediate level (which is assumed to include the DS/GS levels) showing a shortfall. Three of these (44B, 39E, and 44E) show complete shortfalls as they were not included in the M-CON MOS database for the M1. The shortfalls for the other two MOSs (45G and 63G) are at 50% or less of the required manpower. For six of the 13 MOSs involved over both levels, no shortfalls are indicated.

However, these findings must be treated with caution until the comparability of the procedures and parameters used in estimating the requirements and constraints are demonstrated. Referring back to Table 2, it can be seen that the HCM and MCON estimates of the manpower requirements for the same baseline system, the M1, are considerably different, i.e. 4716 versus 4023 or a difference of 692. Three MOSs account for 670 of this difference; MOSs 31V, 45E and 63E, all at the organizational level. The source of this difference may be in the conversion from maintenance manhours to manyears; MCON uses 2080 hours but the HCM uses 2500 at the unit, 2700 for direct support and 3100 for general support. However, if this conversion accounted for the differences, the greater difference would not be found only at the organizational level where the difference between the conversion factors is less than the other two. As mentioned previously, the lack of commonality of the MOS lists between HCM and M-CON for the M1 may be a contributor. In addition, two other potential sources of the discrepancy may by cited but can not be explored since they are speculative in the absence of definitive information about the MCON computations. HCM uses the Army MARC Maintenance Data Base (AMMDB) for the M1A1; MCON is assumed to use the same data base but it is not clear if the data for the A1 version of the M1 is being used, as most of the necessary documentation in the most recent version (.91) was not available for this effort. Another possible source of the discrepancy is a difference in the operating tempo or intensity which may influence the maintenance requirements. Based on the preceding observations, the lack of comparability in the bases for estimating manpower requirements and availability can lead to unrealistic estimates. As indicated below in the section on the user interface, there is a need for a clear indication of the data specifications in each measure; the model parameters and how they are computed. These need to be provided to permit an assessment of comparability and any possible biasing of results.

overview of user interface.

Appendix A provides a detailed screen-by-screen description of user procedures and identifies potential improvements. They are based on the MCON prototype software package version .91.

Familiarization. The introduction to MCON is an option on screen 0.0 with a default to skipping the introduction. The introduction is important (and rather lengthy) and should be read by all first time users. The introduction would be more valuable if a short table were provided on the first screen to alert the user to its contents. A print-out feature is available, provided a printer is available and MCON has been set up for it. A useful feature would be a list of information or data that is required for input to run the model. This would minimize the user's need to obtain the necessary data while in the middle of a model run while relatively unfamiliar with the use of the model. Additional information that would assist the user during early familiarization include a general flow diagram showing the model processes and a detailed listing of the steps and substeps sequence.

Navigation. Help screens are provided (although many, if not most, were incomplete or simply place holders in this version) and the step screens include a path description. Unfortunately, the path description is useful only in the context of the overall process which would be available from a diagram such as suggested above. Screen prompts for key functions are provided at the bottom of the screen. However, these are ambiguous and not always applicable to the particular screen. For example, the "General Keystroke and Program Instructions" help file lists three functions by pressing the Escape key and three by pressing the Enter key. Their definitions suggest they are context sensitive but their screen prompts do not define the context. Many of the input screens include options for the various actions. In some cases the options include "continue" which appears to duplicate a screen prompts. For example, the presence of "Enter to continue" as a screen prompt and the "continue" option for selection is confusing. In others, the user may select one or many from a list. No instructions are provided on how this is to be accomplished leading to errors and great frustration.

Warnings. Several screens are preceded by warning windows. Although the warning is explicit, the reason for it is not and the user is not given the consequences or purpose on which to base a decision. For example, if an existing analysis is selected, the user is warned that resuming an analysis will modify the current values stored for the analysis. Repeated test of this assertion indicated that the "Date Accessed" on the step menu is changed but the model parameters are not unless the some action is taken. It would be more useful to record the date on which any of the parameters within the step were changed but not if the screens were only viewed. In addition, warnings should be provided, and possibly interlocks, to preclude resetting parameters to unrealistic values. An example of this are the adjustment factors. If the adjustment from MARC to Authorized is enabled once and then enabled a second time, the adjustment factor is squared resulting in an error. This error would not be easily detectable unless the user had some expectation for the actual value.

Input and Output. Screens are used to display data for editing or to report results from the model. Data to be edited include "0" entries which may represent no availability or the lack of data. The no data condition should be flagged for the user. Editing data arrays should provide definitive descriptions of the data to include a label, format, dimensions and whether the numbers are real or integer. Starting and ending dates are required to start an analysis but there is no evidence that these dates are used. Even when the fielding plan is entered the availability estimates do not appear to reflect changes in availability. Model output may be displayed on the screen and printed at the users option. Reported values should be clearly defined and labeled. Two reports (Annual MMH Constraint and the "Annual" Maintenance Manhours Per System) have columns with identical labels but different totals. However, the comparison screen requires user input of the requirements in integer form which usually requires rounding the values. MCON rounds down to the integer value which may introduce a relatively large error in MOSs with small availability. The comparison screen represents an analytic goal providing a comparison of required and available spaces. This screen is the only MCON screen that is not saved. Returning to the screen after exiting will not restore the requirements and the user if forced into entering the data again.

A continuing problem during an analysis is knowledge of model parameter settings. Although the reports represent the results of a model run, there is a need for the user to identify the values used in generating the output. A very valuable and useful feature would be a status screen showing all of the model parameters and their values for the current analysis. In addition, a scratch pad that is available at all times and includes a notation for each time an entry is made showing the step and substep would prove most useful to the user in interpreting the results.

SUMMARY AND CONCLUSIONS

The utilization of the Manpower Constraints (M-CON) aid as applied to the assessment of the availability of manpower from the predecessor system (M1) to satisfy the manpower requirements for the FACS is discussed. Both a general and screen-by-screen discussion of the use of the aid are given. The findings relative to the availability of maintenance MOSs estimate shortfalls for two of the three MOSs at the organizational level and shortfalls for five of the ten MOSs at the intermediate level. M-CON appears to have considerable potential for the early and continuous integration of manpower constraints throughout the system design process. However, problems were encountered in the use of the aid in achieving the desired assessments of availability. These difficulties are discussed, with the objective of highlighting candidates for improvements. Difficulties with the comparability of data specifications are also discussed.

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APPENDIX

DISCUSSION OF SCREENS

The screens shall be organized and numbered to correspond to the steps involved in the use of M-CON. These steps are as follows:

0. Introduction
1. Identifying systems to be replaced
2. Adjusting the MOSs involved
3. Determining the system density
4. Calculating manpower constraints
5. Running a projection model
6. Adjusting manpower constraints
7. Comparing constraints with requirements
8. Printing or displaying reports
9. Returning to the initial menu

The screens are presented on separate pages following associated comments.

Step 0. Introduction.

This step serves as an initial entry into the system, or as a reentry to resume an analysis. It affords the user an opportunity to view a discussion of the process or become familiar with the process involved.

A series of help screens is being developed to assist the user, but most of these were not yet available when this report was written.

Screen 0.0, M-CON Introduction Menu

Purpose: Initial screen presented when user first enters the system. Affords the user the opportunity to view an introduction to M-CON or skip it.

Comments: While this introduction is written at a fairly superficial level, no assistance is given in gaining an understanding of how the results of the M-CON analysis may be used in conjunction with analyses concerned with the development of manpower requirements, such as HCM. What is needed is the option of selecting more detailed discussions of the concordance of findings with the M-CON and other analytical procedures, such as HCM. While it is stated that analyses may be done at a "detailed" or "rapid response" level, there is no guidance to how either may be used in conjunction with another analysis, such as HCM.

PATH:> Manpower Constraints(M-CON) version 1.0 M-CON Ver 1.0

P R O T O T Y P E

M-CON Introduction Menu
1. Skip Introduction to M-CON 2. View Introduction to M-CON
Select

] to highlight . [Enter] to select
[F1] for help

Screen 0.0

Screen 0.1, M-CON Initial Menu

Purpose: Presentation of initial analysis options. If a new analysis is not being initiated, an existing analysis may be resumed or changed.

Comments: Provision is made here to perform utilities, such as importing requirements from another analysis. However, more information is needed as to how to use this and what the options are. The "help" screen associated with this screen discusses the possibility of importing requirements from MAN-SEVAL. More information is needed concerning the steps needed to make valid comparisons between such requirements and the constraints generated by M-CON.

Screen 0.2, Starting a New Analysis

Purpose: Identification of an analysis and annotation with comments.

Comments: Since the objective here was to compare the requirements derived for the FACS with constraints, this analysis was labeled "FACS". Notes were made concerning details of how the analysis was to be handled, such as how to achieve the number of tanks, 3501, which were used in the FACS HCM. The assumption was made that all replacement would take place the first year, using a one-on-one or 1:1 replacement ratio.

Screen 0.3, Starting Year for Analysis.

Purpose: Select starting year for analysis.

Comments: As the assumption was made that all replacements would be made the first year, 1989 was chosen as the starting year, and also as the ending year, However, the years covered by the analysis can be different from the years involved in the phasing in and out of the weapon systems being analyzed.

Screen 0.4, Ending Year for Analysis.

Purpose: Select ending year for analysis.

Comments: See screen 0.3.

Step 1. Identifying systems to be replaced.

This step establishes the baseline system, or the system to be replaced by the new or emerging system. As the predecessor system in the FACS HCM was the M1A1, this is the system to be replaced. This is the system which will furnish the manpower pool for the FACS. One assumption followed in the FACS HCM was a one-for-one replacement of the M1A1 with the FACS.

PATH:> Manpower Constraints(M-CON) version 1.0 M-CON Ver 1.0

P R O T O T Y P E

M-CON Initial Menu
1. Start a new analysis 2. Resume or change an analysis 3. Perform utilities 4. Quit
Select

] to highlight [Enter] to select

[F1] for help

Screen 0.1

PATH:> Starting a New Analysis

M-CON Ver 1.0

P R O T O T Y P E

Starting a New Analysis
Enter system name: FACS Enter version: 1.0 Description or comments: Baseline Conditions: No adjustments to MARC data, standard deletion of units for total of 3501, 1:1 replacement, 1 year fielding.
Edit

[TAB] and [Shift-TAB] to move
[F1] for help

[Esc] when finished

Screen 0.2

PATH:> Starting a New Analysis

M-CON Ver 1.0

P R O T O T Y P E

Starting Year for Analysis
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
More
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 0.3

PATH:> Starting a New Analysis

M-CON Ver 1.0

P R O T O T Y P E

Ending Year for Analysis
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
More
Select

] to highlight [Enter] to select [Esc] when finished

[F1] for help

Screen 0.4

Screen 1.0, M-CON Step Menu

Purpose: The step menu serves as the entry to each step in the analysis beyond the introduction.

Comments: The asterisks beside steps 5, 6, and 7 indicate that these are more detailed or supplementary analyses which may be performed to supplement or adjust the main, "rapid", analysis , which may be executed with the other steps.

Screen 1.1, Mission Area Menu

Purpose: Select mission area for the system to be replaced.

Comments: As the system being replaced, the M1A1, is a tank, the Close Combat Heavy mission area was selected.

Screen 1.2, Mission Area, System Type, Baseline System Menu

Purpose: Select system type and baseline system.

Comments: Having selected the mission area (Close Combat Heavy) from the previous mission area menu, the system type (Tank) and the baseline system (M1A1) were selected and confirmed.

Screen 1.3, Baseline Systems for the Analysis

Purpose: Confirm the baseline system

Comments: The M1 was confirmed as being the baseline system which was used for the FACS HCM. More information is needed as to how multiple baseline systems may be utilized in such an analysis.

Screen 1.4, Manpower for System

Purpose: Present the maintenance manhours for each MOS associated with the maintenance of the baseline system.

Comments: In this screen, which is automatically displayed after selection of the baseline system, the manpower associated with the baseline system (in this case, the M1) is displayed. A help screen informs that these are annual maintenance manhours per system. It is assumed that this is based on MARC data. More information is needed to support this assumption. More information also is needed as to how to relate such data to requirements data concerning the predecessor system (M1) found in the HCM, such as given in Table 1. The data in Table 1 are for 3501 tanks and could be converted to a single system through simple division by 3501. However, the data from the HCM on Table 1 are in terms of manpower spaces and information is needed on conversion of maintenance manhours to maintenance spaces. Perhaps an option could be made available to activate an algorithm which would convert MMH to manpower space requirements. Another source

PATH:> Selecting Steps for Analysis   M-CON Ver 1.0

P R O T O T Y P E

M-CON Step Menu System: DEMO Version: STEPS	Latest Access Date
1. Identify Systems to be replaced	NA
2. Identify Additional MOSs	NA
3. Determine System Density	NA
4. Calculate Manpower Constraints	NA
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight   [Enter] to select
[F1] for help

Screen 1.0

PATH:dentifying systems to be replaced> Defining baseline systems M-CON Ver 1.0
P R O T O T Y P E

SYSTEM : FACS
VERSION: 1.0

Mission Area Menu

1. Air Defense
2. Aviation
3. Close Combat Heavy
4. Close Combat Light
5. Combat Service Support
6. Command and Control
7. Communications
8. Engineering and Mine Warfare
9. Fire Support
10. Intelligence and Electronic Warfare
11. Nuclear, Biological and Chemical
12. Special Operations

Select

] to highlight [Enter] to select
[F1] for help

Screen 1.1

PATH:dentifying systems to be replaced> Defining baseline systems M-CON Ver 1.Ø

P R O T O T Y P E

SYSTEM : FACS
VERSION: 1.Ø

Mission Area Menu

3. Close Combat Heavy

System Type Menu

2. Tank

Baseline System M

1. M1

Confirm (Y/N)

Screen 1.2

PATH:> Identifying systems to be replaced

M-CON Ver 1.0

P R O T O T Y P E

Baseline Systems for this Analysis		
Mission Area	System Type	Baseline Systems
Close Combat Heavy	Tank	M1

Add Delete Modify Continue

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 1.3

PATH:> Identifying systems to be replaced> Editing MMHs M-CON Ver 1.0

P R O T O T Y P E

Manpower for System: FACS Version: 1.0

Baseline System	Oper MOS (#/sys)	Maint MOS	Total	ORG# (MMHs/sys)	DS# (MMHs/sys)	GS# (MMHs/sys)
M1	19K(4)					
M1		29E		0.00	22.10	0.00
M1		31V		20.70	0.00	0.00
M1		35H		0.00	0.00	4.10
M1		41C		0.00	68.90	42.70
M1		44B		0.00	0.00	0.00
M1		45B		0.00	3.40	2.10

Edit Adjust Accept

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 1.4

of difficulty in moving from the FACS HCM to the M-CON analysis is the different manner of designating maintenance levels. The HCM analysis uses the organizational and intermediate levels, while M-CON uses the organizational , direct support (DS) and general support (GS) levels. It is assumed that the direct support and general support levels together constitute the intermediate level of maintenance.

In comparing the MOSs listed for the M1 and those listed in the HCM some discrepancies were noted and some of the MMHs were questioned. Therefore, adjustments for these items were explored.

Screen 1.5, Baseline Systems for MMH Adjustments.

Purpose: Select baseline system(s) for adjustments to the MMHs involved.
Comments: The M1 was selected.

Screen 1.6, Maintenance Level for Annual MMH Adjustment.

Purpose: Select maintenance level(s) to adjust the MMH.
Comments: All maintenance levels were selected to make an adjustment.

Screen 1.7, Adjustment factor.

Purpose: To put in the adjustment factor for the MHHs selected.
Comments: As it was decided not to change the MMHs which had come out of the MMH data base for the M1, a "1" was put in as the adjustment factor. More information is needed concerning the meaning and use of this adjustment factor.

Screen 1.8, Warning Window.

Purpose: To alert to MOSs listed which have zero manpower assigned.
Comments: As discrepancies were noted between the MOSs listed here and those listed for the M1A1 in the HCM analysis, it was decided to explore the possibility of adjusting the MOSs through use of step 2.

Step 2, Adjusting the MOSs involved.

As discrepancies were noted between the MOSs listed in the M-CON M1A1 baseline system and those listed for the M1A1 in the HCM analysis, step 2 was explored for the possibility of adjusting the MOSs.

PATH:ems to be replaced> Editing MMHs> Adjusting MMHs by a factor M-CON Ver 1.0
P R O T O T Y P E

Baseline Systems for MMH Adjustments
M1
Select(s)

] to highlight [Space] to select or deselect
[Enter] when finished [Esc] to quit
[F1] for help

Screen 1.5

PATH:ems to be replaced> Editing MMHs> Adjusting MMHs by a factor M-CON Ver 1.0
P R O T O T Y P E

Maintenance Level for Annual MMH Adjustment
1. All levels 2. ORG/AVUM 3. DS/AVIM 4. GS
Select

] to highlight [Enter] to select [Esc] to quit
[F1] for help

Screen 1.6

PATH:ems to be replaced> Editing MMHs> Adjusting MMHs by a factor M-CON Ver 1.0

P R O T O T Y P E

Adjustment Factor
Baseline system : M1 Maintenance level: All levels Adjustment factor: 1
Edit

[Enter] when finished.   [Esc] to quit

[F1] for help

Screen 1.7

PATH:> Identifying systems to be replaced> Editing MMHs M-CON Ver 1.0

PROTOTYPE

Manpower for System: FACS Version: 1.0

Baseline System	Oper MOS (#/sys)	Maint MOS	Total	ORG# (MMHs/sys)	DS# (MMHs/sys)	GS# (MMHs/sys)
M1	19					0.00
M1						0.00
M1						4.10
M1						42.70
M1						0.00
M1						2.10
M1						

WARNING

One or more MOSs has zero Manpower assigned.
You should consider either assigning Manpower
in this step or deleting the MOS in Step 2.

Do you want to continue (Y/N)?

Edit Adjust Accept

Screen 1.8

Screen 2.0, M-CON Step Menu.

Purpose: To present menu of steps.
Comments: Step 2 was selected.

Screen 2.1, Manpower for System.

Purpose: Present list of MOSs.
Comments: When step 2 is chosen, this screen (the same as screen 1.4) is displayed in order to add MOSs. It is to noted that the listing is labeled FACS. However, the manhours are those for the baseline system, which is given in the first column, the M1A1.

Screen 2.2, Options for adding MOSs.

Purpose: Present options for adding MOSs.
Comments: As MOSs were listed for either the M1A1 or the FACS for the HCM which were not listed for the M-CON M1A1 listing and as there were two MOSs listed for the M-CON M1A1 which were not listed for either the HCM M1A1 or FACS, the option of selecting from a directory of all MOSs was chosen.

Screen 2.3, Warning screen.

Purpose: Present warning that baseline system is affected.
Comments: As this warning was presented, it was decided not to change the list of MOSs associated with the M1A1 in M-CON. The situation in which there is a discrepancy, either of commission or omission, between the lists of MOSs used in a requirements analysis, such as HCM, and M-CON needs to be clarified. It was decided not to use this step, but to perform comparisons on an individual MOS basis, using only those common to the two analyses.

"No" is chosen. It was found difficult to get back to the main menu; it was necessary to escape by going back through the previous screens.

Step 3, Determining the system density.

In this step, the density and the phasing in of the new system is determined. The HCM analysis was based upon a total active force of 3501 tanks. This had to reconciled with the list of units and number of tanks in each unit listed in the M-CON data bases.

PATH:> Selecting Steps for Analysis

M-CON Ver 1.0

P R O T O T Y P E

M-CON Step Menu System: DEMO Version: STEPS	Latest Access Date
1. Identify Systems to be replaced	NA
2. Identify Additional MOSs	NA
3. Determine System Density	NA
4. Calculate Manpower Constraints	NA
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight [Enter] to select
[F1] for help

Screen 2.0

PATH:> Identifying additional MOSs

M-CON Ver 1.0

P R O T O T Y P E

Manpower for System: FACS Version: 1.0

Baseline System	Oper MOS (#/sys)	Maint MOS	Total	ORG# (MMHs/sys)	DS# (MMHs/sys)	GS# (MMHs/sys)
M1	19K(4)					
M1		29E		0.00	20.17	0.00
M1		31V		28.79	0.00	0.00
M1		35H		0.00	0.00	3.88
M1		41C		0.00	81.52	50.52
M1		44B		0.00	0.00	0.00
M1		45B		0.00	3.69	2.28

Add Delete Edit View Continue

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 2.1

PATH:> Identifying additional MOSs> Adding MOSs M-CON Ver 1.0

P R O T O T Y P E

Options for adding MOSs
1. Select from a directory of all MOSs 2. Select from a list of MOSs for a specific system 3. Select from a list of MOSs for a subsystem 4. Type in MOSs
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 2.2

PATH:> Identifying additional MOSs> Adding MOSs

M-CON Ver 1.0

PROTOTYPE

WARNING

By adding an MOS here, you are not replacing a baseline system. If you wish to replace a system go to step one.

Do you wish to continue(Y/N)?

Screen 2.3

Screen 3.0, M-Con Step Menu.

Purpose: To present menu of steps.
Comments: Step 3 was selected.

Screen 3.1, Phasing Menu.

Purpose: Present phasing options.
Comments: It was decided to use option 1, Specify units to phase out baseline system, for 1989, eliminating units as needed to achieve a total number of 3501 tanks involved.

Screen 3.2, Phase Out Year Menu.
Purpose: To select phase out year.
Comments: 1989 was chosen as the phase out year.

Screen 3.3, Phase Out Menu Options
Purpose: Present phase out options for year selected, in this case, 1989.
Comments: Option 1 was chosen, Select from Unit List with baseline system.

Screen 3.4, Phase Out Unit List
Purpose: Present units to select for phase out of baseline system.
Comments: Two units, which added up to the number needed to delete to add up to 3501 tanks were selected for deletion. However, considerable difficulty was experienced in determining the correct procedure to execute this. Instructions should be clarified with regard to how to select to delete units. No help screen is presently available, with regard to procedures for select or deselect. (This step was later repeated, but the strategy was followed of highlighting all of the units except the two to be deleted, and selecting these for phase in or out.)

Screen 3.5, Baseline Phase Out Schedule.

Purpose: Present list of units with baseline system to be phased out
Comments: This presents the results of step 3.4.

Screen 3.6, Phasing Menu.

Purpose: Present phasing options.
Comments: As 2 units had been deleted in the phase out menu. option 2 was selected, Specify units to phase in new systems by year, with the idea that the same two units which had

PATH:> Selecting Steps for Analysis M-CON Ver 1.0

P R O T O T Y P E

M-CON Step Menu System: DEMO Version: STEPS	Latest Access Date
1. Identify Systems to be replaced	NA
2. Identify Additional MOSs	NA
3. Determine System Density	NA
4. Calculate Manpower Constraints	NA
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight [Enter] to select
[F1] for help

Screen 3.0

PATH:> Determining system density

M-CON Ver 1.0

P R O T O T Y P E

Phasing Menu
*1. Specify units to phase out baseline systems by year *2. Specify units to phase in new systems by year 3. Replace baseline systems in units without a phasing schedule 4. Specify number of New Systems to be fielded.
Select

] to highlight   [Enter] to select   [Esc] when finished
[F1] for help

Screen 3.1

PATH:ermining system density> Creating Phase out schedule by year M-CON Ver 1.0
P R O T O T Y P E

Phase Out Year Menu
1989
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 3.2

PATH:ermining system density> Creating Phase out schedule by year M-CON Ver 1.0

P R O T O T Y P E

Phase Out Menu Options   Year: 1989
1. Select from Unit List with baseline system 2. Select from Unit Directory 3. Return to Phase Out Schedule
Select

] to highlight   [Enter] to select   [Esc] when finished

[F1] for help

Screen 3.3

PATH:ermining system density> Creating Phase out schedule by year M-CON Ver 1.0
P R O T O T Y P E

Phase Out Unit List Year: 1989

UIC	Unit Name	Baseline System	Quantity
WACUA	1st Armored Division	M1	348
WACVA	1st Cav Division	M1	348
WADQA	2nd Armored Division	M1	348
WAEKA	3rd Armored Division	M1	348
WAG9A	1st Inf (Mech) Division	M1	290
WALGA	177th Armored Brigade	M1	174
WAMHA	3rd Inf (Mech) Division	M1	290
WAPBA	8th Inf (Mech) Division	M1	290
WAQLA	24th Inf (Mech) Division	M1	290
WAR4A	197th Inf (Mech) Brigade	M1	116

– More

Select

] to highlight
[Enter] when finished
[F1] for help

[Space] to select or deselect
[Esc] to quit
[P] to print

Screen 3.4

M-CON System: FACS   Version: 1.0   , Monday, September 3, 1990 4:52 pm

Baseline Phase Out Schedule

UIC	Unit	Baseline	Qty	Year
WACUAA	1st Armored Division	M1	348	1989
WACVAA	1st Cav Division	M1	348	1989
WADQAA	2nd Armored Division	M1	348	1989
WALGAA	177th Armored Brigade	M1	174	1989
WAMHAA	3rd Inf (Mech) Division	M1	290	1989
WAPBAA	8th Inf (Mech) Division	M1	290	1989
WAQLAA	24th Inf (Mech) Division	M1	290	1989
WAR4AA	197th Inf (Mech) Brigade	M1	116	1989
WASBAA	194th Armored Brigade	M1	174	1989
WASUAA	5th Inf (Mech) Division	M1	290	1989
WAY6AA	11th ACR	M1	123	1989
WAY7AA	2nd ACR	M1	123	1989
WAY8AA	3rd ACR	M1	123	1989
WEPUAA	4th Inf (Mech) Division	M1	290	1989
WFBDAA	Berlin Brigade	M1	116	1989
WH3QAA	2nd Inf Division	M1	58	1989

Add

Screen 3.5

PATH:> Determining system density

M-CON Ver 1.0

P R O T O T Y P E

Phasing Menu
*1. Specify units to phase out baseline systems by year *2. Specify units to phase in new systems by year 3. Replace baseline systems in units without a phasing schedule 4. Specify number of New Systems to be fielded.
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 3.6

been eliminated in the phase out schedule would be eliminated in the Phase In schedule.

Screen 3.7, Phase In Options Menu
Purpose: Present phase in options.
Comments: Option 1. Phase in new systems in accordance with Phase Out schedule, was selected.

Screen 3.8, Unit Replacement Ratio.
Purpose: To give option of changing unit replacement ratio.
Comments: As the assumption was being made that there would be a one-on-one replacement of the M1A1 with the FACS, the 1:1 ratio was accepted.

Screen 3.9, Baseline Phase In Schedule
Purpose: Present list of units with baseline systems.
Comments: The same two units were eliminated as were eliminated in the phase out schedule. Considerable difficulty was encountered in getting out of this screen either by using the escape key or the continue key. It was necessary to step through the Phase In Options Menu and the Phasing Menu in order to get back to the step menu. (This step was later repeated, highlighting all of the units to be phased in, with the exception of the two to be eliminated, due to confusion as to how to execute these steps.)

Step 4. Calculate Manpower Constraints.

Having gone through the first three steps, the main "rapid" calculation of the manpower constraints to be faced by the system, in this case the FACS, replacing the baseline system, the M1A1, may be invoked.

It will be recalled that the analysis was done under the following assumptions:

o All replacement of the M1A1 by the FACS is to take place in the first year (1989).
o Two units were eliminated from the phasing, so that 3501 tanks were involved ,as was the case for the HCM.
o Discrepancies were noted between the MOSs in the HCM and M-CON analyses, which were not corrected.

The manpower constraints resulting from this calculation are presumed to be based on MARC data.

Screen 4.0. M-CON Step Menu.
Purpose: Present steps for selection.
Comments: Step 4 was selected.

PATH:> Determining system density

M-CON Ver 1.0

P R O T O T Y P E

Phase In Options Menu
1. Phase in new systems in accordance with Phase out schedule 2. Develop separate Phase in schedule
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 3.7

PATH:nsity> Creating Phase in schedule in accordance to Phase out M-CON Ver 1.0
P R O T O T Y P E

Unit Replacement Ratio			
Baseline Systems		Ratio New : Current	New Systems
M1	3501	1 : 1	3501
		:	
		:	
		:	
		:	
	Edit	Accept	

[ ] to highlight [Enter] to select
[F1] for help [P] to print
M-CON System: FACS Version: 1.0 , Monday, September 3, 1990 5:00 pm

Screen 3.8

PATH:nsity> Creating Phase in schedule in accordance to Phase out M-CON Ver 1.0

P R O T O T Y P E

Baseline Phase In Schedule

UIC	Unit	Baseline (Qty)	New Qty	Date
WACUAA	1st Armored Division	M1(348)	348	1989
WACVAA	1st Cav Division	M1(348)	348	1989
WADQAA	2nd Armored Division	M1(348)	348	1989
WALGAA	177th Armored Brigade	M1(174)	174	1989
WAMHAA	3rd Inf (Mech) Division	M1(290)	290	1989
WAPBAA	8th Inf (Mech) Division	M1(290)	290	1989
WAQLAA	24th Inf (Mech) Division	M1(290)	290	1989
WAR4AA	197th Inf (Mech) Brigade	M1(116)	116	1989
WASBAA	194th Armored Brigade	M1(174)	174	1989
WASUAA	5th Inf (Mech) Division	M1(290)	290	1989

Add Delete Edit View Continue

[ ] to highlight [Enter] to select [Esc] when finished
[F1] for help [P] to print

Screen 3.9

PATH:> Selecting Steps for Analysis

M-CON Ver 1.0

P R O T O T Y P E

M-CON Step Menu System: DEMO Version: STEPS	Latest Access Date
1. Identify Systems to be replaced	NA
2. Identify Additional MOSs	NA
3. Determine System Density	NA
4. Calculate Manpower Constraints	NA
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight [Enter] to select
[F1] for help

Screen 4.0

Screen 4.1, Manpower Constraints Report Menu
Purpose: Present report options.
Comments: Option 4, calling for all three reports was chosen. These reports are presented separately, as are all subsequent reports, but are discussed below.

Report 4.1: Operator Manpower Constraint Report

This report presents the total number of operators (19K) available in the systems to be replaced (M1). This output has been adjusted to reflect 3501 tanks, which is the number used in the HCM FACS analysis. A crew of four is used for the M1, two at skill level 1, one at skill level 2, and one at skill level 3. It will be recalled that the FACS was configured to use a three man crew.

Report 4.2: Annual MMH Constraint Report

This report gives the annual maintenance manhours which will be available per system, and for 3501 systems. As noted previously, two levels (Organizational and Intermediate) were used in the HCM analysis, while M-CON uses three levels (Organizational, Direct Support, and General Support). It should also be noted that adjustments may need to be made for different MOS components used in the two analyses.

Report 4.3, Maintenance Manpower Constraint Report.

It needs to be clarified as to what is presented here and how it is calculated. It is assumed that it is presented in terms of maintenance manpower spaces available to support 3501 tanks. If it is MMH per system, this needs to be reconciled with the information presented initially in step 1. If this is in terms of MMH, means should be presented to convert to manpower spaces, such as used in the HCM analysis. Provision should also be made to combine DS and GS levels to Intermediate level. Provision is also needed to combine the skill levels for each MOS, as the HCM did not split out the manpower requirements in terms of skill level.

All reports should be clearly labeled as to what they represent, rather then depending on the user remembering what steps were followed leading up to the report.

It is possible to place brief labels on the report in the "System" or "Version" field, by going back to the initial menu or by using a "repeat file" utility and assigning another label to the file. Reports resulting from Step 4 were labeled "MARC" in the "Version" field, However, this procedure should be facilitated.

PATH:> Calculating manpower constraints

M-CON Ver 1.0

P R O T O T Y P E

Manpower Constraints Report Menu
1. Operator Manpower Constraint 2. Annual MMH Constraint 3. Maintenance Manpower Constraint 4. ALL Manpower Constraints 5. Exit Reports Menu
Select

] to highlight   [Enter] to select
[F1] for help

Screen 4.1

Operator Manpower Constraint Report

System: FACS Version: MARC

Crew Ratio: 1.00

MOS	Skill level	Number of Operators	Number of Systems	Operators per system
19K	1	7002.00	3501	2.00
19K	2	3501.00	3501	1.00
19K	3	3501.00	3501	1.00

Report 4.1

Annual MMH Constraint Report

System: FACS Version: MARC

Maintenance Level	Annual MMH/System	Number of Systems	Total
ORG/AVUM	887.07	3501	3105637.13
DS/AVIM	988.93	3501	3462239.07
GS	514.26	3501	1800432.27
TOTAL	2390.26	3501	8368308.47

Maintenance Manpower Constraint Report

System: FACS Version: MARC

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
29E	1	0.00	13.41	0.00	13.41
29E	2	0.00	7.49	0.00	7.49
29E	3	0.00	5.67	0.00	5.67
31V	1	18.59	0.00	0.00	18.59
31V	2	6.29	0.00	0.00	6.29
35H	1	0.00	0.00	2.53	2.53
35H	2	0.00	0.00	1.19	1.19
35H	3	0.00	0.00	0.92	0.92
35H	4	0.00	0.00	0.78	0.78
35H	5	0.00	0.00	0.24	0.24
41C	1	0.00	50.76	36.10	86.86
41C	2	0.00	20.96	14.91	35.87
41C	3	0.00	11.11	7.90	19.01
45B	1	0.00	3.05	2.16	5.21
45B	2	0.00	1.04	0.73	1.77
45E	1	388.52	0.00	0.00	388.52
45E	2	150.09	0.00	0.00	150.09
45G	1	0.00	89.91	0.00	89.91
45G	2	0.00	45.79	0.00	45.79
45G	3	0.00	29.97	0.00	29.97
45K	1	0.00	322.94	218.32	541.26
45K	2	0.00	122.16	82.58	204.74
45K	3	0.00	128.38	86.79	215.16
63E	1	417.42	0.00	0.00	417.42
63E	2	223.40	0.00	0.00	223.40
63E	3	135.87	0.00	0.00	135.87
63E	4	105.22	0.00	0.00	105.22
63E	5	17.38	0.00	0.00	17.38

Maintenance Manpower Constraint Report

System: FACS Version: MARC

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
63G	1	0.00	55.06	2.62	57.68
63G	2	0.00	11.55	0.55	12.10
63H	1	0.00	306.00	161.03	467.03
63H	2	0.00	121.51	63.94	185.45
63H	3	0.00	179.76	94.59	274.35
63H	4	0.00	128.40	67.57	195.96
63J	1	23.82	7.56	15.83	47.21
63J	2	6.48	2.06	4.31	12.85

It will be recalled that it was earlier pointed out that steps 5, 6, and 7 had asterisks, indicating that they were for more advanced analyses supplementary to the main analysis conducted through use of steps 1-4. These steps will now be discussed. However, step 5, running a projection model, will be discussed in a separate report. 4.

Step 6. Adjust manpower constraints.

The main results of step 4 are presumed to be based on MARC data, which represents maintenance manhours which are dictated by system design, and which in turn can be converted into maintenance manpower spaces required. This is what was done in the HCM analysis for the M1A1 and upon which the FACS results were based. However, these results may need to be adjusted to more accurately reflect authorized strength and actual operational strength. This is what step 6 permits.

Screen 6.0, M-CON Steps Menu.
Purpose: Present steps for selection.
Comments: Step 6 was selected.

Screen 6.1, Adjust Manpower Constraints Menu.
Purpose: Present adjustment options.
Comments: Having calculated the manpower constraints , presumably calculated on the basis of MARC data, it was decided to adjust for authorized and operating strength. It was decided to first exercise option 2. This option adjusts for differences in MARC requirements and Authorized spaces, leading to the conclusion that the manpower constraints given in Report 4.3 are in terms of manpower spaces.

Screen 6.2, Warning window.
Purpose: To warn against adjusting flowed MOSs.
Comments: If the projection model has been used with an MOS, adjustments have already been used with that MOS and therefore these adjustments can not be used with that MOS. Therefore, the use of the flow, or projection, model in step 5, needs to be kept separate from the adjustments executed in step 6.

Screen 6.3, MARC Requirements vs. Authorized Spaces
Purpose: Present MOSs and associated adjustment factors for selection.
Comments: The option "ALL" was selected, with all MOSs involved to be adjusted. Instructions need to be clarified as to the steps to be followed to implement the various adjustments.

Screen 6.4, Manpower Constraints Report Menu.
Purpose: To select reports.

PATH:> Selecting Steps for Analysis

M-CON Ver 1.0

P R O T O T Y P E

M-CON Step Menu System: DEMO Version: STEPS	Latest Access Date
1. Identify Systems to be replaced	NA
2. Identify Additional MOSs	NA
3. Determine System Density	NA
4. Calculate Manpower Constraints	NA
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight [Enter] to select
[F1] for help

Screen 6.0

PATH:> Adjusting manpower constraints

M-CON Ver 1.0

P R O T O T Y P E

Adjust Manpower Constraints Menu
1. Adjust for competing manpower requirements of newly fielded systems. 2. Adjust for differences in MARC Requirements vs. Authorized spaces. 3. Adjust for Operating vs. Authorization strengths. 4. Adjust Operator constraints in accordance with crew ratios. 5. Display manpower constraints reports.
Select

] to highlight [Enter] to select [Esc] to quit
[F1] for help

Screen 6.1

PATH:Adjusting manpower constraints> Adjusting MARC vs Authorized M-CON Ver 1.0

P R O T O T Y P E

W A R N I N G
If you have FLOWED an MOS in Step 5 Run Projection Model, you CAN NOT adjust them here. Flowed MOS's already reflect Operating strength.
[Enter] or [Esc] to continue

Screen 6.2

M-CON System: FACS   Version: AUTH   , Sunday, September 9, 1990 6:19 pm

MARC Requirements vs. Authorized Spaces	
System: FACS	Version: AUTH
MOS	Adjustment Factor
ALL	
29E	0.83
31V	1.14
35H	0.83
41C	1.02
44B	0.91
45B	0.77
45E	0.91
45G	0.77
45K	0.83
45Z	1.00
52C	0.83
63E	0.91
63G	0.83
63H	1.37
63J	0.91
63Z	0.83
Select	

Screen 6.3

Comments: Reports results from the previous adjustment invoked can be called up. Option 5, calling for all reports, was selected. This resulted in Reports 6.1, 6.2, 6.3, and 6.4, which are presented separately. The reports resulting from this adjustment were labeled "AUTH" in the "Version" field. Provision should be made to aid the user in keeping track of which adjustment has been done.

Report 6.1. Operator Manpower Constraint Report.

This output is the result of applying the adjustment. It is assumed that these are the results of applying the adjustment for the authorized spaces, but this is not clearly labeled as such. Because of the lack of clear labeling, this report could easily be confused with others. The somewhat convoluted procedure required for labeling reports has been discussed previously.

As did Report 4.1, this report presents the crew required for the operation of the baseline system, the M1A1. The number of operators, which is fixed at 4 per M1A1, is not affected by going from MARC to Authorized.

Report 6.2, Annual MMH Constraint Report.

As did Report 4.2, this report presents the annual maintenance manhours which will be available at each maintenance level, per system and for 3501 systems. However, these figures have been adjusted in keeping with authorized strength.

Report 6.3, Maintenance Manpower Constraint Report.

As did Report 4.3, it is assumed that this report presents the annual maintenance manpower spaces per MOS associated with maintenance of 3501 systems. However, these data have been adjusted to reflect authorized strength.

Report 6.4, Manpower Constraint Adjustment Report

This report presents the adjustment factor that was applied to each MOS, in this case for the adjustment of MARC vs Authorized.

Screen 6.5, Adjust Manpower Constraints Menu.
Purpose: Present adjustment options.
Comments: Having adjusted for MARC vs authorized, it was decided to also exercise the option to adjust for operating vs authorization strengths. Option 3 was selected.

Screen 6.6, Warning
Purpose: To warn against using an adjustment if an MOS has

PATH:> Adjusting manpower constraints> Displaying Reports

M-CON Ver 1.0

P R O T O T Y P E

Manpower Constraints Report Menu
1. Operator Manpower Constraint 2. Annual MMH Constraint 3. Maintenance Manpower Constraint 4. Manpower Constraint Adjustment 5. All Reports 6. Exit Reports Menu
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 6.4

Operator Manpower Constraint Report

System: FACS Version: AUTH

Crew Ratio: 1.30

MOS	Skill level	Number of Operators	Number of Systems	Operators per system
19K	1	9102.60	3501	2.00
19K	2	4551.30	3501	1.00
19K	3	4551.30	3501	1.00

Report 6.1

Annual MMH Constraint Report

System: FACS Version: AUTH

Maintenance Level	Annual MMH/System	Number of Systems	Total
ORG/AVUM	810.64	3501	2838035.65
DS/AVIM	1060.59	3501	3713110.63
GS	558.54	3501	1955451.96
TOTAL	2429.76	3501	8506598.24

Maintenance Manpower Constraint Report

System: FACS Version: AUTH

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
29E	1	0.00	11.13	0.00	11.13
29E	2	0.00	6.22	0.00	6.22
29E	3	0.00	4.71	0.00	4.71
31V	1	21.20	0.00	0.00	21.20
31V	2	7.17	0.00	0.00	7.17
35H	1	0.00	0.00	2.10	2.10
35H	2	0.00	0.00	0.98	0.98
35H	3	0.00	0.00	0.76	0.76
35H	4	0.00	0.00	0.65	0.65
35H	5	0.00	0.00	0.20	0.20
41C	1	0.00	51.78	36.82	88.60
41C	2	0.00	21.38	15.20	36.59
41C	3	0.00	11.33	8.06	19.39
45B	1	0.00	2.35	1.67	4.02
45B	2	0.00	0.80	0.57	1.37
45E	1	353.56	0.00	0.00	353.56
45E	2	136.58	0.00	0.00	136.58
45G	1	0.00	69.24	0.00	69.24
45G	2	0.00	35.26	0.00	35.26
45G	3	0.00	23.08	0.00	23.08
45K	1	0.00	268.04	181.20	449.25
45K	2	0.00	101.39	68.54	169.93
45K	3	0.00	106.55	72.03	178.59
63E	1	379.85	0.00	0.00	379.85
63E	2	203.30	0.00	0.00	203.30
63E	3	123.65	0.00	0.00	123.65
63E	4	95.75	0.00	0.00	95.75
63E	5	15.81	0.00	0.00	15.81

Maintenance Manpower Constraint Report

System: FACS

Version: AUTH

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
63G	1	0.00	45.70	2.18	47.87
63G	2	0.00	9.58	0.46	10.04
63H	1	0.00	419.22	220.61	639.83
63H	2	0.00	166.47	87.60	254.07
63H	3	0.00	246.27	129.59	375.86
63H	4	0.00	175.90	92.57	268.47
63J	1	21.67	6.88	14.41	42.96
63J	2	5.90	1.87	3.92	11.69

Manpower Constraint Adjustment Report

System: FACS Version: AUTH

MOS	Flow Model	New Systems	MARC vs. Authorized	Operating vs. Authorized	Crew Ratio
19K	1.00				1.30
29E	1.00	1.00	0.83	1.00	
31V	1.00	1.00	1.14	1.00	
35H	1.00	1.00	0.83	1.00	
41C	1.00	1.00	1.02	1.00	
44B	1.00	1.00	0.91	1.00	
45B	1.00	1.00	0.77	1.00	
45E	1.00	1.00	0.91	1.00	
45G	1.00	1.00	0.77	1.00	
45K	1.00	1.00	0.83	1.00	
45Z	1.00	1.00	1.00	1.00	
52C	1.00	1.00	0.83	1.00	
63E	1.00	1.00	0.91	1.00	
63G	1.00	1.00	0.83	1.00	
63H	1.00	1.00	1.37	1.00	
63J	1.00	1.00	0.91	1.00	
63Z	1.00	1.00	0.83	1.00	

PATH:> Adjusting manpower constraints

M-CON Ver 1.0

P R O T O T Y P E

Adjust Manpower Constraints Menu
1. Adjust for competing manpower requirements of newly fielded systems. 2. Adjust for differences in MARC Requirements vs. Authorized spaces. 3. Adjust for Operating vs. Authorization strengths. 4. Adjust Operator constraints in accordance with crew ratios. 5. Display manpower constraints reports.
Select

] to highlight [Enter] to select [Esc] to quit
[F1] for help

Screen 6.5

PATH:Adjusting manpower constraints> Adjusting MARC vs Authorized M-CON Ver 1.0
P R O T O T Y P E

W A R N I N G

If you have FLOWED an MOS in Step 5 Run Projection Model, you CAN NOT adjust them here. Flowed MOS's already reflect Operating strength.

[Enter] or [Esc] to continue

Screen 6.6

previously been subjected to the projection model.
Comments: Step 5, the projection model, must be used separately from the other steps.

Screen 6.7, Operating vs. Authorized Spaces
Purpose: Present MOSs and associated adjustment factors for selection.
Comments: The option "ALL" was selected, with all MOSs involved to be adjusted. Instructions need to be clarified as to the steps to be followed to implement the various adjustments.

Screen 6.8, Manpower Constraints Report Menu.
Purpose: Present report options.
Comments: This menu presents the options for the reports resulting from the adjustment invoked. All reports were requested, resulting in Reports 6.5, 6.6, 6.7 and 6.8. which are presented in a separately. The reports resulting from this adjustment were labeled "OPSTR" in the "Version" field. Provision should be made to aid the user in keeping track of which adjustment has been done.

Report 6.5. Operator Manpower Constraint Report.

This output is the result of applying the adjustment. It is assumed that these are the results of applying the adjustment to reflect operational strength, but this is not clearly labeled as such. Because of the lack of clear labeling, this report could easily be confused with others. The somewhat convoluted procedure required for labeling reports has been discussed previously.

As did Report 4.1, this report presents the crew required for the operation of the baseline system, the M1A1. The number of operators, which is fixed at 4 per M1A1, is not affected by going from Authorization to Operating strength.

Report 6.6, Annual MMH Constraint Report.

As did Report 4.2, this report presents the annual maintenance manhours which will be available at each maintenance level, per system and for 3501 systems. However, these figures have been adjusted in keeping with operating strength.

Report 6.7, Maintenance Manpower Constraint Report.

As did Report 4.3, it is assumed that this report presents the annual maintenance manpower spaces per MOS associated with maintenance of 3501 systems. However, these data have been adjusted to reflect operating strength.

PATH:g manpower constraints> Adjusting Operating vs Authorization M-CON Ver 1.0
P R O T O T Y P E

Operating vs. Authorization Strength	
System: FACS	Version: 1.0
MOS	Adjustment Factor
ALL	
29E	1.10
31V	1.22
35H	1.14
41C	1.16
44B	1.23
45B	1.41
More	
Select	

Select/Deselect all menu options
] to highlight
[Space] to select or deselect
[Enter] when finished
[Esc] to quit
[F1] for help
[P] to print

Screen 6.7

PATH:> Adjusting manpower constraints> Displaying Reports M-CON Ver 1.0

P R O T O T Y P E

Manpower Constraints Report Menu
1. Operator Manpower Constraint 2. Annual MMH Constraint 3. Maintenance Manpower Constraint 4. Manpower Constraint Adjustment 5. All Reports 6. Exit Reports Menu
Select

] to highlight [Enter] to select [Esc] when finished
[F1] for help

Screen 6.8

Operator Manpower Constraint Report

System: FACS Version: OPSTR

Crew Ratio: 1.30

MOS	Skill level	Number of Operators	Number of Systems	Operators per system
19K	1	9102.60	3501	2.00
19K	2	4551.30	3501	1.00
19K	3	4551.30	3501	1.00

Annual MMH Constraint Report

System: FACS Version: OPSTR

Maintenance Level	Annual MMH/System	Number of Systems	Total
ORG/AVUM	956.20	3501	3347656.16
DS/AVIM	1164.84	3501	4078089.92
GS	607.24	3501	2125939.13
TOTAL	2728.27	3501	9551685.21

M-CON System: FACS Version: OPSTR , Tuesday, September 11, 1990 5:26 am

Maintenance Manpower Constraint Report

System: FACS Version: OPSTR

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
29E	1	0.00	12.24	0.00	12.24
29E	2	0.00	6.84	0.00	6.84
29E	3	0.00	5.17	0.00	5.17
31V	1	25.86	0.00	0.00	25.86
31V	2	8.75	0.00	0.00	8.75
35H	1	0.00	0.00	2.39	2.39
35H	2	0.00	0.00	1.12	1.12
35H	3	0.00	0.00	0.87	0.87
35H	4	0.00	0.00	0.74	0.74
35H	5	0.00	0.00	0.23	0.23
41C	1	0.00	60.06	42.71	102.77
41C	2	0.00	24.80	17.64	42.44
41C	3	0.00	13.15	9.35	22.50
45B	1	0.00	3.31	2.35	5.66
45B	2	0.00	1.13	0.80	1.92
45E	1	456.09	0.00	0.00	456.09
45E	2	176.20	0.00	0.00	176.20
45G	1	0.00	94.85	0.00	94.85
45G	2	0.00	48.30	0.00	48.30
45G	3	0.00	31.62	0.00	31.62
45K	1	0.00	305.57	206.57	512.14
45K	2	0.00	115.59	78.14	193.73
45K	3	0.00	121.47	82.12	203.59
63E	1	421.63	0.00	0.00	421.63
63E	2	225.66	0.00	0.00	225.66
63E	3	137.25	0.00	0.00	137.25
63E	4	106.29	0.00	0.00	106.29
63E	5	17.55	0.00	0.00	17.55

Maintenance Manpower Constraint Report

System: FACS Version: OPSTR

System Density: 3501

MOS	Skill Level	ORG	DS	GS	TOTAL
63G	1	0.00	47.52	2.27	49.79
63G	2	0.00	9.97	0.48	10.44
63H	1	0.00	435.99	229.43	665.42
63H	2	0.00	173.13	91.11	264.23
63H	3	0.00	256.12	134.78	390.89
63H	4	0.00	182.94	96.27	279.21
63J	1	26.87	8.53	17.87	53.28
63J	2	7.31	2.32	4.86	14.50

Report 6.8, Manpower Constraint Adjustment Report

This report presents the adjustment factor that was applied to each MOS, in this case for the adjustment of Operating vs Authorization strength.

Step 7. Compare Constraints with Requirements.

This step permits the constraints which have been produced during steps 4 and 6 to be compared with requirements produced by such an analysis as HCM. However, more guidance is needed as to the procedure to be followed to select a particular constraint against which to compare requirements.

Screen 7.0 M-CON Step Menu
Purpose: Present M-CON step options.
Comments: Step 7 was selected.

Screen 7.1, Requirement Input Options Menu
Purpose: Present input options.
Comments: As the only import option available is importing data from MAN-SEVAL, it was necessary to type in the numbers from the HCM analysis.

Screen 7.2, Constraints vs Requirements
Purpose: Input of requirements.

Comments: To exercise this option, this screen is presented. The requirements must be input to the Requirement column, per MOS. Only whole numbers could be input, so it was necessary to round the numbers from the HCM analysis.

Report 7.1. MARC Constraints vs Requirements.

Comments: This is the result of typing in the rounded numbers from the HCM analysis in the Requirement column. The difference is automatically calculated. It is assumed that the constraints are those based on MARC data and are spaçes, although this is not clearly labeled. The Help screen for this function states that this step permits the comparison of manpower constraints, either adjusted or not adjusted, with estimated requirements. However, it is not clear as to how the adjustment function is to be performed and then retrieved or utilized for the comparison function. The constraint which is being displayed is not clearly labeled and it is difficult to track what is happening. The procedure needs to be much more clearly

M-CON System: FACS Version: 1.0 , Sunday, September 30, 1990 10:00 am

Manpower Constraint Adjustment Report

System: FACS Version: 1.0

MOS	Flow Model	New Systems	MARC vs. Authorized	Operating vs. Authorized	Crew Ratio
					1.00
19K	1.00				
29E	1.00	1.00	0.83	1.10	
31V	1.00	1.00	1.14	1.22	
35H	1.00	1.00	0.83	1.14	
41C	1.00	1.00	1.02	1.16	
44B	1.00	1.00	0.91	1.23	
45B	1.00	1.00	0.77	1.41	
45E	1.00	1.00	0.91	1.29	
45G	1.00	1.00	0.77	1.37	
45K	1.00	1.00	0.83	1.14	
45Z	1.00	1.00	1.00	1.00	
52C	1.00	1.00	0.83	1.14	
63E	1.00	1.00	0.91	1.11	
63G	1.00	1.00	0.83	1.04	
63H	1.00	1.00	1.37	1.04	
63J	1.00	1.00	0.91	1.24	
63Z	1.00	1.00	0.83	0.97	

PATH:> Selecting Steps for Analysis

M-CON Ver 1.0

P R O T O T Y P E

M-CON Step Menu System: DEMO Version: STEPS	Latest Access Date
1. Identify Systems to be replaced	NA
2. Identify Additional MOSs	NA
3. Determine System Density	NA
4. Calculate Manpower Constraints	NA
*5. Run Projection Model	NA
*6. Adjust Manpower Constraints	NA
*7. Compare Constraints with Requirements	NA
8. Print or Display Reports	NA
9. Return to Initial Menu	
* - optional steps	
Select	

] to highlight [Enter] to select
[F1] for help

Screen 7.0

PATH:> Comparing constraints with requirements

M-CON Ver 1.0

P R O T O T Y P E

Requirement Input Options Menu
1. Type in number required by MOS 2. Use import requirements from MAN-SEVAL
Select

] to highlight   [Enter] to select   [Esc] when finished
[F1] for help

Screen 7.1

M-CON System: FACS Version: MARC , Wednesday, September 26, 1990 9:58 pm

Contraints vs Requirements

System: FACS Version: MARC

MOS	Contraint	Requirement	Difference
19K	14004	9774	4230
29E	26	15	11
31V	24	378	[354]
35H	5	0	5
41C	141	13	128
44B	0	21	[21]
45B	6	0	6
45E	538	315	223
45G	165	173	[8]
45K	961	470	491
45Z	0	0	0
52C	0	0	0
63E	899	1089	[190]
63G	69	118	[49]
63H	1122	440	682
63J	60	1	59
63Z	0	0	0

Edit

Report 7.1

PATH:> Comparing constraints with requirements

M-CON Ver 1.0

P R O T O T Y P E

Contraints vs Requirements

System: FACS

Version: AUTH

MOS	Contraint	Requirement	Difference
19K	18205	0	18205
29E	22	0	22
31V	28	0	28
35H	4	0	4
41C	144	0	144
44B	0	0	0
45B	5	0	5

More

Edit

] to highlight   [Enter] to select   [Esc] when finished
[F1] for help   [P] to print

Screen 7.2

delineated and more aids are needed to facilitate navigation through the procedure.

It is to be noted that Report 7.1 was not made available through use of a function provided in M-CON, but is rather the result of printing the screen. While a series of reports is made available, such as has been already provided or through use of the Report Menu in Step 8, no provision appears to have been made to print out comparisons of constraints with requirements.

Report 7.2. Authorization Constraints vs Requirements.

Comments: See comments for Report 7.1.

Report 7.3. Operational Constraints vs Requirements.

Comments: See comments for Report 7.1.

M-CON System: FACS Version: AUTH , Wednesday, September 26, 1990 10:08 pm

Contraints vs Requirements

System: FACS Version: AUTH

MOS	Contraint	Requirement	Difference
19K	18205	9774	8431
29E	22	15	7
31V	28	378	[350]
35H	4	0	4
41C	144	13	131
44B	0	21	[21]
45B	5	0	5
45E	490	315	175
45G	127	173	[46]
45K	797	470	327
45Z	0	0	0
52C	0	0	0
63E	818	1089	[271]
63G	57	118	[61]
63H	1538	440	1098
63J	54	1	53
63Z	0	0	0

Edit

Report 7.2

M-CON System: FACS Version: OPSTR , Wednesday, September 26, 1990 10:45 pm

Contraints vs Requirements

System: FACS Version: OPSTR

MOS	Contraint	Requirement	Difference
19K	18205	9774	8431
29E	24	15	9
31V	34	378	[344]
35H	5	0	5
41C	167	13	154
44B	0	21	[21]
45B	7	0	7
45E	632	315	317
45G	174	173	1
45K	909	470	439
45Z	0	0	0
52C	0	0	0
63E	908	1089	[181]
63G	60	118	[58]
63H	1599	440	1159
63J	67	1	66
63Z	0	0	0

Edit

Report 7.3

Working Paper

WP MSG 90-02

Systems Design Concepts to Support Embedded Training (ET): Final Report.

George R. Purifoy, Jr.
Applied Science Associates, Inc.

MDA 903-85-C-0078

August 1989

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WORKING PAPER MSG 90-02

Systems Design Concepts to Support Embedded Training (ET): Final Report

August 1989

Prepared by:
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ARMY RESEARCH INSTITUTE

US ARMY
MATERIEL COMMAND
PM TRAINING DEVICES

SUMMARY

This report summarizes the activities and products of Contract MDA903-85-C-0078, "System Design Concepts to Support Embedded Training (ET)." A general introduction to the contract effort, including a working definition of Embedded Training (ET), is provided to set the context for the description of project tasks and activities. Each of the six tasks of the project is listed and discussed. Appendix A itemizes, in chronological order, the major activities, accomplishments, and products which resulted from the four-year effort. Appendix B provides a list of assigned ET report numbers.

SYSTEM DESIGN CONCEPTS TO SUPPORT EMBEDDED TRAINING (ET):
FINAL REPORT

CONTENTS

SYSTEM DESIGN CONCEPTS TO SUPPORT EMBEDDED TRAINING (ET): FINAL REPORT

INTRODUCTION

This is the Final Report for Contract MDA903-85-C-0078, "System Design Concepts to Support Embedded Training (ET)." The co-sponsors of this research effort were the U.S. Army Research Institute for the Behavioral and Social Sciences and the Army's Project Manager for Training Devices (PM TRADE). The prime contractor in conducting this exploratory development work was Applied Science Associates, Inc. (ASA). Subcontractors included Vector Research, Inc. (VRI); Hi-Tech Systems, Inc. (HSI); Bolt, Beranek, and Newman Laboratories (BBN); and Integrated Graphics Systems, Inc. (IGS). The overall objective of this multi-year project was to develop effective and efficient means of defining and specifying the role of ET in, and ET approaches for integrating with, Army systems. In addition, the research was to specify the manner in which ET considerations should be integrated in the life cycle systems management process and in the fielding of systems with effective training capabilities.

ET DEFINED

ET has been defined by the project as that "training which results from features incorporated into the end-item equipment to provide training and practice in operating and/or maintaining that end-item equipment." The features may be completely embedded within the system configuration by software or a combination of both software and systems' hardware configuration, or may be executed by some form of strap-on (e.g., a video disc player) or plug-in (e.g., a floppy disc) resource, or a combination of embedded and appended components. The features MUST include stimuli necessary to support training, and specific provisions for performance assessment capability, appropriate feedback, and record keeping.

PROJECT TASKS

The project was made up of six tasks related directly to the overall project objective. Each of the tasks was open-ended, in that it established a purpose or focus which contributed in an essential way to the evolution of ET methodology, but permitted specific objectives to derive from findings, results, and conditions which emerged. This functional flexibility provided the maximum opportunity for ad hoc investigation of issues and problems related to the ultimate goal of effective integration of ET into the systems development process. The six tasks were:

Task 1. Design an ET package for the Fiber Optic Guided Missile (FOG-M). The FOG-M was then in a technology demonstration phase. This system provided an ideal testbed in which to develop and apply methods and procedures for implementing ET in a systems development program. An ET requirements definition process was developed, applied, and refined. ET content, structure, and support software for the scheduled FY 1987 FOG-M system ET demonstration was prepared. Preliminary guidance was developed for utilization of the FOG-M ET capability in unit training. Finally, Request for Proposal (RFP) sections and specialized Data Item Descriptions (DIDs) to support FOG-M procurement were prepared.

Task 2. Assess the characteristics of existing and planned ET-relevant technologies and operational systems which impact ET implementation and effectiveness. A formal review of computer-based hardware and software technology was performed and documented. Eight operational Army systems and nine tri-service systems involving some type or mode of ET were surveyed to identify effective and non-effective configurations and characteristics. A "Crosswalk" report was prepared to compile common design and acquisition implications. These findings led to a plan for a structured set of ET integrated guideline documents.

Task 3. Support on-going ARI research in the exploration of human factors issues in the development and implementation of ET. The project team worked closely with ARI scientists to design and conduct studies which facilitated experimental research in training for vehicle identification, the effects of fidelity in simulation, and target recognition.

Task 4. Coordinate and manage all contractors and task efforts to meet ultimate project objectives and budget limitations. Objectives were met within budget, and all required reports and project documents were produced.

Task 5. Prepare ET designs for at least two additional exemplar Army systems, and utilize the development experience to further refine the evolving ET decision and design models and procedures. ET development programs were conducted for the Howitzer Improvement Program (HIP), the Maneuver Control System (MCS-2), and the All Source Analysis System (ASAS). In addition, an assessment was made of the proposed SGT YORK Troop Proficiency Trainer, (using ET analysis methods) and a number of "Lessons Learned" working papers were prepared as inputs to the ET development procedures.

Task 6. Develop documentation which will facilitate, support, and procedurally guide the complete integration of ET design and development into the Life Cycle Systems Management Model (LCSMM), including all aspects of system design, development, and acquisition. The results, findings, and implications of all of the ET studies and applications of the preceding five tasks were compiled and organized into a ten-volume series of "Guideline" documents treating each major phase of the LCSMM. The specific volumes of this series have the general title of Implementing Embedded Training (ET), and are subtitled:

Volume 1. Overview

Volume 2. ET as a System Alternative

Volume 3. The Role of ET in the Training System Concept

Volume 4. Identifying ET Requirements

Volume 5. Designing the ET Component

Volume 6. Integrating ET with the Prime System

Volume 7. ET Test and Evaluation

Volume 8. Incorporating ET into Unit Training

Volume 9. Logistics Implications

Volume 10: Integrating ET into Acquisition Documentation

All volumes are available through the National Technical Information Service and the Defense Technical Information Center.

APPENDIX A

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'84	11-12	-Gather status info on FOG-M Gunner's Station & B-5 Spec -Gunner's Task Analysis -Input HF recommendation to Gunner's Station & operational inputs to B-5			-George R. Purifoy, Jr. to be Principal Investigator and Project Director in place of Zita Glasgow		
'85	1	-Kickoff meeting 8-10 Jan -Plan computer task database -Plan FOG-M Operational Description . CRT for DBI . CRT & DMG perspective for flight planning and inflight control -Revision of Deliverable Schedule					
	2	-Task database built using RL-1, Relational Database Management System -Updated Operational Description -Training Requirements Analysis Decision Model for ETRs -FOG-M ET Functional Requirements -FOG-M Technology Review -Task & Training Requirements Analysis Report					

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'85	3	-Submitted "FOG-M Task and Training Requirements Analysis for Embedded Training (ET)" on 15 Mar -Plan for "Design Concepts" report -Technical Review Committee	-Initiation of Tri-Service and Army Systems Reviews				
	4	-Submitted "Design Concepts for FOG-M Embedded Training (ET) on 12 April -Submitted draft working paper "Embedded Training Technology Review for FOG-M" -Working paper revisions	-Development of data gathering instruments. Database development -Data gathering on AEGIS at NTEC		-Quarterly IPR on 8 Apr -SIG meeting at NTEC -Review of BBN responsibilities	-Plans for SGT YORK ET Analysis -Data gathering at Ford Aerospace Corp -Arrangements for Fort Bliss data gathering	
	5	-Initiation of Course Outlines for the 87 Demo (Objectives Hierarchy) -Work on B-5 Specs for 87 Demo -Submitted Technology Review Working Paper (final) -Revised Technology Review planning	-Data gathering trips for: SQQ-89 Sonar MCM-1 Mine Countermeasures Ship AEGIS CSTS SMARTS T-4, 5, 6 Sonar Test/ Training Sets PATRIOT HAWK Missile Minder ALR-46, including IFFC OBEWS SHORAD/SHORAD C2 ADA		-Briefed Army Tank Command on ET	-Data gathering re SGT YORK at Fort Bliss	

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'85	6	-Initiated outline training requirements analysis for the notional objective system	-Technology Review ongoing -Tri-Service Review documentation drafted -Army Systems Review of ARI-selected systems underway			-Submitted "An Assessment of the SGT YORK Troop Proficiency Trainer (TPT)" on 29 June	
	7	-Draft 87 Demo Lesson Plans submitted -MICOM meeting re 87 Demo—little interest	-Descriptive documentation reviewed and revised for Tri-Service Review -Systems selected for Army Systems Review are: AFATDS TACFIRE HIP BRADLEY PATRIOT AH64 APACHE AQUILA ASAS Data were collected				
	8	-Course Outlines for Demo revised. Objectives Hierarchy for fielded system completed -B-5 Spec drafted for ET Demo	-Technology Review Draft under preparation -AWACS data obtained -Tri-Service Review being drafted		-Unit Utilization Plan replaced Fielded System courseware outline and associated B-5 Specification		

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'85		-Initiated preparation of a "Unit Utilization Plan" for FOG-M	-Plans for Crosswalk			-Requirements for HIP ET training and training to be developed: . data collection trip . task analysis initiated	
	9	-Draft submitted of "FOG-M Embedded Training (ET) Demonstration Courseware Outline" -Draft submitted of "Embedded Training Software Specifications for the FOG-M System Demonstration" -Continued analysis for the Unit Utilization Plan for the fielded system	-Draft of the Technology Review submitted -Draft submitted of "Review of Eight Army Systems: Characteristics and Implications for Embedded Training" -Draft submitted of "Tri-Service Review of Embedded Training (ET) Systems" -Additional data collection on WAMMS			-Draft submitted of "Interim Embedded Training (ET) Design Concepts for HIP"	
	10	-Huntsville meeting concluded . Will use perspective view generator & DMG . Targets will be symbolized (no target identification) -Target identification training from videodisk -The UUP document will be a "guideline" document and a generic model	-Revisions under way for the Tri-Service Review and the Review of Army Systems Crosswalk held: . Initial definition of required guidelines . Plans for compilation of common design and acquisition implications			-HIP data gathering at Fort Sill	

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'85	11	-Continual work on: . Requirements procedures . Design procedures . Demo software specs . Unit utilization plan	-Crosswalk computations -Army Systems Review revisions		-Draft Annual Report submitted	-Draft HIP ET Working Paper submitted -Initial data gathering trip on MCS-2 at Fort Lewis, WA -Initial data gathering trip on ASAS to Fort Huachuca, AZ	
	12	-Revisions made to the ET Demo Courseware Outlines -Revisions made to the draft software specs -Work continued on UUP: . UUP development procedures . UUP for FOG-M - Trainer's Guide for 11H MOS - ET Component Operators Guide - ET in collective training	-Revisions ongoing for Army Systems Review and Tri-Service Review -Crosswalk Report in preparation -Revisions to Technology Review	-Task 3 planning	-Annual IPR, 11 Dec -SIG Briefing	-Draft submitted for "Embedded Training (ET) and the Training Devices for the Howitzer Improvement Program (HIP)"	
'86	1	-Data gathering re perspective program -UUP to become "Guide to Integrating ET in Units"	-Final submittal "Review of Eight Army Systems: Characteristics and Implications for Embedded Training -An integrated Crosswalk Report will combine Crosswalk, ETR, and the Design Procedures Report	-Supporting ARI research in training for vehicle identification (Bogner) -Supporting ARI research in effects of fidelity in simulation (Burroughs)	-Proposal to design ET for MCS-2	-HIP ET report revised	

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'86		-FOG-M Demo ET Specs being revised -Submitted draft "Development of Embedded Training Requirements (ETR)"					
	2	-Received info that the FOG-M demo systems (2) will <u>not</u> have a DMG or a videodisk -Submitted draft "Design Procedures for Embedded Training (ET)"	-Ongoing work on "Implementing Embedded Training Within the LCSMM: Preliminary Guidance and Remaining Issues"		-ARI request to replan ET project for completion on 15 Nov 1987		
	3	-Submitted FOG-M ET Training B-5 Spec	-Submitted draft "Crosswalk" report -Submitted draft of revised Tri-Service Review report -Ongoing work on "Integrated Guidelines" report		-Preparation of 3-year plan for ET project completion -Plan for input from MCS-2		-Data collection at PM TRADE for Media Selection Model
	4	-Orders to stop development of FOG-M Demo Courseware -Courseware Outlines to be revised	-Meeting to plan Integrated Guidelines Report. Resulted in initial structuring of "Guidelines" series (Task 6)	-Working Paper "Fidelity Issues in Computer-Generated Imagery (CGI) and Recommendations for Research in Training Impact Studies" -Recommendations to combine both ARI research areas	-Replanning to complete ET in 3 years	-Draft submittal "Unit Training Resources Utilization Concept for New Training Devices for the Howitzer Improvement Program"	

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'86	5	-ET courseware preparation terminated -Submitted final "FOG-M System Embedded Training (ET) Demonstration Courseware Outlines" (assessed DMG & perspective program) -Initiated draft Prime Item Spec (incl. DIDs for FOG-M) -Second draft submitted of "Procedures for Embedded Training (ET) Package Design"	-Final submittal of "Embedded Training Technology Survey" -Ongoing preparation of "Guidelines"	-Recommended terminating support for both ARI research areas	-Meeting re Task 3 commitment of funds	-MCS-2 produced revised models for task classification	-Work continuing on Army Impact Study and Media Selection Model
	6	-Ongoing work on the ET Integration Guide and the FOG-M ET SOW	-ARI review of Technology Survey and Tri-Service Review	-Ongoing work on Media Model		-Initiation of ET work on ASAS -Initiation of work on HIP CTEA	-Study plan for Army Impact study proposed to use MOS 13 BRAVO and 96 BRAVO data
	7	-Draft FOG-M ET SOW submitted			-QQR Briefing	-Planning for HIP CTEA -Data gathering for ASAS	
	8	-Ongoing work: FOG-M ET SOW and ET Integration Guide		-Literature search re cognitive complexity and its impact on visual discrimination and target recognition in training		-Data gathering for HIP CTEA -Prepared draft "Total Training Systems Concept/Model for ASAS" -ET support for ASAS plan revised and resubmitted -ASAS Task Analysis continued	-Structural interview form for Army Impact Study data gathering drafted -Hotline concepts and video tape guideline intro proposal

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'86	9	-Ongoing work: FOG-M ET SOW -Integration Report--Task 6		-Literature search re combat vehicle identification training -Media Model--Task 6		-Data gathering re HIP CTEA -Working paper re evaluation of HIP ET design/ documentation -ASAS task analysis -Request for classified computer database -ET materials for FOG-M Air Defense considered	-Working Paper submitted -"Early System Acquisition Training Media Alternatives Identification" (Model applied to data from FOG-M, HIP, and SGT YORK) -Ongoing work in Guidelines for ET decision procedure an Army Impact Study
	10	-Ongoing revisions to FOG-M ET SOW -Analysis of funding requirements for mods to FOG-M materials to make them applicable to Air Defense		-Final summary of related materials re identification training	-COR Briefing . HIP TEA training test plan development may slip . Move ahead on demo package for FOG-M Air Defense ET-scripts, video material, validation plan, and B-5 spec: - Will have perspective program plus cultural features overlay - Suitable for vehicle-independent ops - Intro ET and Ops ET - Emphasis on flight simulator - Include performance recording, feedback, and training adaptability	-Ongoing work in TEA plans for HIP, proposals for CTEA for the IFCST and the HIP maintenance trainer and ASAS/ENSCE task analysis	-Ongoing work in Army Impact Sutdy, Integrated ET Report, and draft guidelines for impact implications

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'86					- Will have videodisk - Don't include VNS - Color unknown . Reduced scope on Army Impact Study—11B only . Plan for electronic Bulletin Board for Task 6		
	11		-Re-editing of the Tri-Service Review report	-Review technical reports re target recognition		-Submitted proposals for CTEA for IFCST and the HIP maintenance trainer -Planning for ASAS ET schedules -ASAS Task Analysis ongoing	-Revisions to report on incorporation of ET into systems under P^3I, PIP, ECP and other retrofit conditions
	12	-Submitted revised FOG-M ET SOW specs and DIDs				-Revisions submitted for CTEA proposals -Final inputs to the procurement schedule for ASAS ET -ASAS Task Analysis ongoing with input to the classified comuter database	-Training Impact Study being drafted -Guidelines for ET integration being revised -Draft video tape script to introduce Guidelines submitted
'87	1	-FOG-M FAAD NLOS ET demonstration package preparation: . Operational Description . Gunner's Task Analysis . Courseware Outlines	-Revisions being made to Technology Review and Tri-Service Review		- IPR Outline submitted	-ASAS Task Analysis ongoing -R1 software slip	

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'87	2	-Data gathering to determine feasibility and facts re converting original FOG-M materials to fit FAADS role	-Submitted final "Embedded Training Technology Survey" -Submitted final "Tri-Services Embedded Training Systems Review"		-MCS-2 on hold; preparing a Lessons Learned Working Paper -ASA agreed to identify appropriate MILSPEC changes involving ET	-ASAS Task Analysis obstructed somewhat by software slippages	-Submitted "A Study of Training Delivery Issues and Media Impact for the 13B MOS"
	3	-Data gathering to define FOG-M FAAD NLOS role -Revised lesson plans for FOG-M demo prepared		-Task 3 completed		-Draft ASAS Task Analysis submitted	-Guideline Package further defined. Volumes named. -Draft "Incorporating ET into Unit Training" submitted -Revised videotape script submitted
	4	-Task analysis complete -Outlines for all lessons complete -Remedial strategies diagrammed for all lessons -Revised operational description under preparation	-Task 2 completed			-ASAS task database submitted to ARI -CBI tutorial, CBI hardware/software inventory, and an analysis of hardware/software implications of data digitizers initiated -Honeywell ET screens for HIP reviewed. Report prepared -Revised plan for HIP ET evaluation prepared	-Draft submitted of Guideline Vol. 6 "Integrating ET with the Prime System" -Draft submitted of Guideline Vol. 8 "Incorporating ET into Unit Training" -Revised script for Indoctrination video tape submitted
	5	-FOG-M ET Demonstration Lessons and supporting material are in production			-Coordination with ARI Contracts Office re added work on FOG-M and preparation of video tape	-Ongoing ASAS Analysis	-Ongoing Guideline preparation

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'87	6	-Preparation of executive program and pseudocode for FOG-M ET -Continued modifications to the gunner's station have invalidated much of the developed Demo materials			-Discontinue ET Demo material development until FOG-M design becomes firm -Received additional funds for video taping and FOG-M demo	-ASAS Analyses continued	
	7					-Draft submittal, "Vol. I, Preliminary Embedded Training Design and Integration Concepts for ASAS/ENSCE"	-Further video tape script revisions
	8	-Meeting at CSC to resume FOG-M ET materials development			-Rescheduling FOG-M work beyond earlier set date of 15 Nov 87 for project termination	-Draft submittal, "Vol. II, Preliminary Embedded Training Design and Integration Concepts for ASAS/ENSCE, Vol II(U)" -ASAS/ENSCE ET briefing -Initiated Vol. I revisions -Initiated Lessons Learned working paper	-"Vol. 3, The Role of ET in the Training System Concept" outlined -"Vol. 7, ET Test and Evaluation" outlined -ET inputs to AR-71-3, "User Testing" were submitted -Guideline indoctrination videotape shot, edited, and submitted for review

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'87	9	-Revision of materials based on documented design changes initiated. Two lessons revised -ET executive system design specifications revised and submitted			-Guideline development schedule revised and accepted -Estimates prepared for requested revisions to the video tape -HIP ET evaluation dropped	-Draft submitted: "Lessons Learned from ET Design Process for ASAS/ENSCE"	-Continued work on Guideline series -Ongoing work on "Army Impact Study" -Revisions to video tape script
	10	-Revisions to task analysis and lesson materials -Draft submittal "FOG-M Embedded Training Systems Specification"				-Draft submittal, "ASAS Design Concepts" Working Paper -Draft submittal, "Preliminary Embedded Training Design and Integration Concepts for ASAS/ENSCE"	-Final video tape submitted
	11	-Draft submittal, Lesson No 2, "The Gunner's Console" -Development continued on "Introduction to ET" and "Overview of FOG-M" lessons -Informed that the Winchester Disk for ET material storage may not be included in the IOE system				-Revisions made to "Lessons Learned for ET Design Process for ASAS/ENSCE"	-Guideline "Vol. 9: Logistics Implications" outlined -Final draft submittal, "Vol. 2, ET as a System Alternative" -Draft submittal, "Vol. 3, The Role of ET in the Training System" -Revised submittal, "Vol. 4, Identifying ET Requirements" -"Vol. 7, ET Test and Evaluation" drafted

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'87							-Revised submittal, "Vol. 8, Incorporating ET into Unit Training" -Continued preparation of "Vol. 9, Logistics Implications" and "Vol. 10, Integrating ET into Acquisition Documentation"
	12	-Draft submittal, Lesson, "Introduction to Embedded Training" -Continued work on "Introduction to FOG-M" and "Target Recognition" -Investigated alternative CGI simulation to support flight training				-Final submittal, "Lessons Learned for ET Design Process for ASAS/ENSCE"	-"Vol. 6, Integrating ET with the Prime System" initiated -Copies of "Vol. 8, Incorporating ET into Unit Training" sent to TRADOC for review -Ongoing work on Volumes 7, 9, and 10
'88	1	-Final submittal, "Lesson 1: What is FOG-M?" -Revision to "Introduction to ET" and "Gunner's Console" -Revised B-5 Spec received from CSC			-HSI's responsibilities assumed by ASA	-Task completed	-Draft submittal, "Vol. 10, Integrating ET into Acquisition Documentation" -Revisions initiated for Volumes 3, 4, and 5
	2	-ASA instructed to restrict all lesson material to subjects which do not require flight simulation			-Task 1 requirements modified to reflect the lack of FOG-M simulation capability		-Draft submittal, "Vol. 9, Logistics Implications"

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'88	3	-Ongoing preparation of Target Recognition lesson materials					-Draft submittal, "Vol. 7, ET Test and Evaluation" -Final submittal, "Vol. 4, Identifying ET Requirements" and "Vol. 5, Designing the ET Component"
	4	-Ongoing preparation of "Lesson 5: Target Recognition"					-Ongoing revisions to all outstanding volumes -Final submittal, "Vol. 2, ET as a System Alternative" and "Vol. 8, Incorporating ET into Unit Training" -Ongoing revisions for Vols 6, 7, 9, and 10
	6	-"Lesson 5: Target Recognition" submitted					

CHRONOLOGICAL PROJECT ACTIVITIES BY TASK (Continued)

YR	MO	Task 1 Develop an ET Package for FOG-M Missile	Task 2 Technology Applications to ET	Task 3 ET Human Factors Support	Task 4 Contract Management	Task 5 Development of ET Package for Other Army Systems	Task 6 ET Documentation
'88	8						-Final submittal, "Vol. 10, Integrating ET into Acquisition Documentation"
	9						-Final submittal, "Vol. 6, Integrating ET with the Prime System" "Vol. 7, ET Test and Evaluation" and "Vol. 9, Logistics Implications"

APPENDIX B

ASSIGNED ET REPORT NUMBERS

AD A201 401	RP 88-12	Implementing Embedded Training (ET): Volume 1 of 10. Overview.
AD A204 836	RP 88-22	Implementing Embedded Training (ET): Volume 2 of 10. Embedded Training as a System Alternative.
AD A201 427	RP 88-13	Implementing Embedded Training (ET): Volume 3 of 10. The Role of ET in the Training System Concept.
AD A205 752	RP 88-29	Implementing Embedded Training (ET): Volume 4 of 10. Identifying ET Requirements.
AD A205 697	RP 88-28	Implementing Embedded Training (ET): Volume 5 of 10. Designing the ET Component.
AD A207 982	RP 88-33	Implementing Embedded Training (ET): Volume 6 of 10. Integrating ET with the Prime System.
AD A207 290	RP 89-02	Implementing Embedded Training (ET): Volume 7 of 10. ET Test and Evaluation.
AD A207 509	RP 88-24	Implementing Embedded Training (ET): Volume 8 of 10. Incorporating ET into Unit Training.
AD A206 794	RP 88-34	Implementing Embedded Training (ET): Volume 9 of 10. Logistics Implications.
AD A207 240	RP 88-35	Implementing Embedded Training (ET): Volume 10 of 10. Integrating ET into Acquisition Documentation.
AD A195 484	RN 88-14	Review of Eight Army Systems: Characteristics and Implications for for Embedded Training.
AD A203 195	RN 88-94	Tri-Service Review of Existing System Embedded Training (ET) Components.
AD B098 062	RN 85-57	FOG-M System Task and Training Requirements Analysis for Embedded Training.
AD A207 291	RP 89-03	FOG-M System Embedded Training (ET) Demonstration Courseware Outlines.

AD A207 083	RP 89-04	Draft Functional Specifications and Data Item Descriptions for FOG-M Embedded Training Subsystem.
	RP 89-05	Embedded Training Software Specifications for the FOG-M System Demonstration.
AD A207 551	RP 88-36	MCS2 Database Embedded Training (ET): Procedural Findings for Command and Control Systems.
	RR 1512	Embedded Training (ET) and Training Devices for the Howitzer Improvement Program (HIP): Design Concept Recommendations. Volume 1.
AD B132 228	RN 88-111	Embedded Training (ET) and Training Devices for the Howitzer Improvement Program (HIP): Design Concept Recommendations. Volume 2. Appendices.
AD A199 469	RN 88-87	Lessons Learned from ET Design Process for ASAS/ENSCE.
AD A202 392	RN 88-95	Market Survey and Analysis in Support of ASAS Computer-based Training System Design.
AD A206 381	RP 88-21	Training Systems Concept for the Armored Family of Vehicles with Consideration of the Roles of Embedded Training and Stand-alone Training Devices.

Manned Systems Group Working Paper 88-03

A Procedure for Developing Embedded Training Requirements

J. T. Roth

1988

Systems Research Laboratory

United States Army Research Institute
for the Behavioral and Social Sciences

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EXECUTIVE SUMMARY

Requirement

An essential element of developing an effective Embedded Training (ET) capability for Army systems is the comprehensive identification of the training requirements that the ET component is to support. This effort is an initial step toward providing a comprehensive method, integrated with other required training analyses, to identify ET Requirements (ETRs). The procedures presented in this report will later be integrated with guidelines for identifying when ET is needed or desirable for a specific system and providing guidelines for effective ET implementation, and with detailed procedures for the design of ET packages. The combined guidelines will subsequently be presented to an Army-wide audience for review and critique. Later, these guidelines and procedures will routinely be used to develop ET components for systems.

Approach

Experience accumulated in the analyses to design or evaluate several ET components was synthesized and combined with standard Instructional Systems Development (ISD) analyses and techniques. Specific considerations for nominating tasks and behavioral performance objectives for ET were identified and a method of applying those considerations was developed. Factors and methods for initially identifying the potential of implementing tasks and objectives nominated for ET was developed and integrated with other procedures.

Findings

A procedure for developing ETRs was developed. The procedure consists of four phases. The first two phases are directly analogous to task identification and task analysis as normally performed in ISD Front-End Analysis (FEA) to define characteristics of training systems. The third phase nominates identified tasks and behavioral performance objectives for ET, based on their properties of criticality to successful mission accomplishment and perishability without periodic reinforced practice. Then, the nominated tasks and objectives are assessed for implementation feasibility and approaches which may later be adopted in an ET component designed to meet the identified ETRs. The fourth phase consists of preparing documentation of the identified ETRs. Techniques for computer database management to support the analysis process, and other tools for analysis assistance, were developed and provided.

Utilization of Findings

The procedures presented are one part of a totally integrated set of ET definition and implementation guidelines and procedures. These procedures will ultimately be used to define the ETRs for emerging or mature systems for which an ET capability is being contemplated.

LIST OF ACRONYMS AND ABBREVIATIONS

AMC	U.S. Army Materiel Command
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ARTEP, ARTEPs	Army Training and Evaluation Plan(s)/Program
ASA	Applied Science Associates, Inc.
C3I	Command, Control, Communications, and Intelligence
DBMS, DBMSs	Database Management System(s)
DTD	Directorate of Training Development(s)
ECA	Early Comparability Analysis
ET	Embedded Training
ETR, ETRs	Embedded Training Requirement(s)
FEA	Front-End Analysis
FM, FMs	Field Manual(s)
FOG-M	Fiber-Optic Guided Missile
HARDMAN	HARDware versus MANpower analyses
ISD	Instructional Systems Development
JMSNS	Justification for Major System New Start
LCSMM	Life Cycle Systems Management Model
MAA	Mission Area Analysis
MANPRINT	MANPower Requirements INTegration analyses/process
MOS	Military Occupational Specialty(ies)
OJT	On-the-Job Training
O&O	Organizational and Operational

PM TRADE	U.S. Army Project Manager for Training Devices
POI	Plan of Instruction
ROC	Required Operational Capability
SM, SMs	Soldier's Manual(s)
SME, SMEs	Subject Matter Expert(s)
SSG	Special Study Group
STF	Special Task Force
TM, TMs	Technical Manual(s)
TRADOC	U.S. Army Training and Doctrine Command
TSM, TSMs	TRADOC System Manager(s)

FOREWORD

Embedded Training (ET) is a component of the training system supporting a weapon or support system. ET is conducted using the system equipment as the training medium, by integrating training delivery capabilities into the prime system. As a minimum, an ET component provides stimuli to enable personnel to perform specific tasks on which training is required. ET should also provide the capability to measure, score, and report trainee performance, in order to provide effective feedback and close the "training loop." ET capabilities may either be wholly designed into the prime system (integrated ET) or be provided by adjunct equipment which interfaces with the prime system (strap-on ET). ET will seldom, if ever, be the sole training approach for a system, but will commonly provide some portion of sustainment, cross, and transition training for the system. Other training within the training system as a whole will be provided by resident skills training (with or without the use of training devices), and by other types of On-the-Job Training (OJT) in addition to ET.

ET is inherently more than simply practice in using the tactical system equipment to perform various tasks or functions; a capability which is already available in most cases. Rather, ET is a <u>designed</u> approach to providing effective, structured training through guided exercises, assessment of trainees' behavioral performance, and provision of corrective feedback to improve or remediate performance. In this respect, ET is no different than training utilizing sophisticated training devices which are separate from the prime system--ET provides comprehensive, relevant, structured training. With ET, hands-on training is brought to the soldier <u>in the unit</u>, through utilization of in-unit systems for training.

ET offers the potential to provide effective, efficient, adaptable, and flexible training, and may increase training system effectiveness and improve the quality of training. In order that these potentials be realized, the conceptualization, development, and implementation of ET capabilities must be performed with care and insight. The overall focus of the present effort is to provide guidelines, principles, and practical tools to support effective ET development for present and future tactical systems.

<u>The ET System Design Concepts Effort</u>

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) and the Army's Project Manager for Training Devices (PM

TRADE) are joint sponsors of the effort to develop system design concepts to support ET. A team of contractor organizations, led by Applied Science Associates, Inc. (ASA), is providing principal support to ARI and PM TRADE in this effort, under contract MDA903-85-C-0078. Under the general objective mentioned above, this work has several major objectives. These are:

1. Identify critical Human Factors, technology, and training issues in developing and providing ET, and conduct focused research to establish guidelines and principles to support effective, comprehensive ET decisions, design, development and implementation.

2. Develop methods, techniques, and approaches for deciding whether ET is appropriate for consideration as a component of the total training system for a combat or support system, and characterize the scope of potential ET implementations.

3. Develop a methodology for identifying and specifying the ET Requirements (ETRs) for particular systems where the inclusion of ET has been deemed appropriate (the particular focus of this report).

4. Develop approaches and methodologies for defining the content, structure, and implementation requirements of ET, given a comprehensive set of ETRs for a system (ET component design procedures).

5. Conceptualize, develop, and test methods and techniques for comprehensively integrating ET considerations into all aspects of the systems acquisition management and execution processes.

Within this context, the procedures presented here are a significant portion of the preliminary products of the overall ET effort. These techniques should be viewed as an approximation to more comprehensive procedures which will ultimately evolve, as the procedures are used and refined by experience. Also, the procedures for identifying ETRs are only one of many processes which are needed to ensure that effective, capable ET is developed and provided for present and future systems.

ET and Training System Decision Contexts

In order to provide effective guidance for the consideration of ET (and other training system components) throughout the system acquisition process, it is necessary to identify the major impact points, or decision contexts, where such guidance should be provided to effectively influence training system and prime system design. Upon examination of the Life Cycle Systems Management Model (LCSMM) and the decision needs that are known, three general contexts in the system acquisition cycle which are important in the development of effective ET for a system were identified. Each of these three decision contexts requires successively more detailed definition of the ET and total training system capability, to support effective decisions. To provide context for the application of the procedures for identifying training system characteristics, and particularly ETRs, the decision contexts are briefly discussed below.

System-Level Training and ET Decisions

The first decision context involves whether an ET capability should be included in the training system for a particular prime system at all. This decision will ideally be made as early in the system life cycle as possible. Initial training system characteristics should be defined by the time the Organizational and Operational (O&O) Plan for the system is prepared, whether or not an ET component is to be included. Deciding at this point whether to include an ET capability allows integrated consideration of ET component and system characteristics in subsequent stages of system development.

The basis for the decision to continue to consider ET at this point interacts somewhat with prime system characteristics and capabilities, as well as with other elements of the training system. There is relatively little historical data available on which to base sound decisions regarding ET this early in the life cycle. Decisions may therefore be somewhat judgmental, based on a loosely structured set of weighting factors. Also, at this point in the life cycle, it will be difficult or impossible to derive a comprehensive set of ETRs to support decisions, since the system is only at the conceptual development stage. Factors which should be considered in the early decision as to whether to include ET as a component of the training system for a particular prime system are presented in a companion report (Strasel, Dyer, and Finley, 1986). Future efforts will be made to refine these decision factors into a structured and comprehensive system-level decision model concerning the role of ET as a training system component.

ET and Other Training Requirements Definition

The second ET decision context deals with defining the ETRs, once a firm decision to incorporate an ET component in a system has been made. Initially, defining the ETRs is most appropriately done, along with definition of other training system characteristics, during the Concept Development and Evaluation Phase of the LCSMM, as soon as possible after tactical system capabilities and characteristics are initially defined. Development of ETRs and other training requirements for a system should be an iterative process, but must be initiated early, so that continued definition and evolution of the requirements can occur along with more detailed definition of the prime system. Early Comparability Analysis (ECA) paralleling HARDMAN analyses may be used for initial determination of ETRs. Training requirements (including ETRs) derived using this approach should be reconsidered (and, perhaps, re-generated entirely) later in the development process, when specific information on the task requirements of the system under development becomes available.

The identification of ETRs, as detailed in this report, is extremely similar to the methods used in the Analysis phase of ISD, with some additions which are relatively unique to ET. Data requirements for ETR development are greater than for the initial system-level ET decision. A comprehensive task identification and analysis is required to identify the critical characteristics of tasks and learning objectives to judge their suitability for ET, as well as other training system requirements. As mentioned above, preliminary approximations to task identification and analysis may be necessary to support concept-level definition of training system characteristics, including ETRs. Once again, however, requirements based on ECA analyses must be reconsidered in later stages of system development.

Detailed ET Package Design

The third ET decision context is the actual design of an ET component for a system. In this context, ETRs are transformed into specific, detailed requirements for implementation via hardware, software, and lessonware. The ET component design process results in detailed specification of the ET component, in terms of training events, approaches, structure, content, performance assessment requirements, feedback, and training management. Specifying these characteristics of the ET component also allows the consideration of hardware and software requirements for ET implementation. The translation of ETRs into a viable ET component design may or may not be constrained by the characteristics of the system. In order to ensure effective integration of the ET components, the development of an initial ET component design should parallel the design of the system.

Ideally, the initial design of an ET component should closely follow the early definition of the ETRs for a system. It is recognized that many degrees of freedom will remain in system design after the initial definition of ETRs, especially if an initial set of ETRs based on ECA is developed as a preliminary picture of ET requirements. However, an initial attempt at ET package design is warranted early in the design of the system for which ET is being developed, in order that tradeoffs and mutual influences of the ET component and the prime hardware/software system be assessed early in the design process. The ET design will be iteratively refined as the system's design evolves, to accommodate changing system and ET requirements which may emerge, and to assure that the ET provided by the ultimate component completely reflects the fielded system. A full discussion of ET design procedures exceeds the scope of this report. A companion report (Fitzpatrick, Sullivan, and Roth, 1986) dealing with ET design procedures is currently in review.

This report, and the two companion reports mentioned in the previous paragraphs, are really three presently discrete parts of a whole. The ultimate "whole," which is a major objective of the overall ET system design concepts effort, will provide comprehensive guidelines, procedures, and techniques for addressing ET and related considerations throughout the system life cycle. Other "parts" of this "whole" are in less mature stages of development and will be integrated into the overall guidance and documentation dealing with ET as they further mature.

Development of the ETR Identification Procedures

During the design of an ET component for the Fiber-Optic Guided Missile (FOG-M), it was apparent that a defensible and logical method of identifying tasks and performance objectives for inclusion for ET was required. Accordingly, the literature on training and media decisions was consulted to identify candidate factors which might be important in the ETR definition decision. Concurrently, several independent logical analyses were performed by personnel among the various contractor organizations and within ARI and PM TRADE who were knowledgeable in training and ISD analyses. The point of departure for the logical analyses was the general body of ISD media decision models known to the analysts, and the decision factors which were included in those models. The results of the independent analyses were combined, to synthesize the factors identified as likely to be important to the ETR decision process. These factors and their application, were subsequently reviewed and modified during evaluation of an ET component for the SGT YORK air defense system and consideration of the role of ET in the training system for the M109E5 Howitzer Improvement Program cannon system. The process here is the result of those revisions and refinements.

The various efforts identified two primary factors which are important for nomination of tasks and behavioral performance objectives as ET candidates, and several other factors which must be considered to determine appropriate potential implementations of the nominated tasks and objectives. The two nomination factors are:

1. Criticality of the task or objective to mission success. This factor is equivalent to the conventional ISD decision factor of consequences of inadequate task performance.

2. Perishability of the component skills of the task or objective when frequent reinforced practice is not provided. This factor is roughly equivalent to skill decay rate, but is more general in nature than simply skill

decay, in that it includes decay of the ability to perform tasks or objectives which are dependent on a skill.

The other factors address the potential for successful implementation in the system design of the task or objective, the ability to implement the task or objective safely, and the likelihood of developing performance measurement and feedback capability for the task or objective in the ET package. The decision factors are structured into a decision sequence for application. These factors are detailed in the presentation of the ETR identification process in Section 4 of this report.

A need for support for making task or objective perishability decisions to facilitate applying the ET nomination decision model was also identified. It was deemed that criticality judgments were best obtained from qualified Subject Matter Experts (SMEs) and that additional criticality decision support was not needed. Accordingly, additional investigation into the attributes of various kinds of objectives which might influence perishability was made. This investigation resulted in an objectives classification model and general rules for model application. The objectives classification model requires the categorization of a particular task or performance objective into one of seven categories, based on the psychological characteristics (primarily retention) of skills which are incorporated in the task or objective. These seven categories, in turn, are classified as being associated with various levels of perishability. The details and application of the objectives classification model are presented in Section 4 of this report.

Caveat

As discussed in the body of this document, procedures for identifying ETRs and designing ET components do not differ materially, except for some ET-specific factors, from the techniques used in other domains of training system and training device design and development. This unity among training system design and development techniques is explicitly acknowledged. However, ET considerations are not yet well integrated with overall training system definition and design procedures. Existing guidelines and procedures both for more general training system characteristics determination and for ET considerations must be comprehensively integrated, to support the objectives of total training systems definition and development.

One specific area which has not yet been fully addressed is the allocation of training requirements across all candidate training approaches and media, including ET, in an integrated fashion. The opportunities provided by a potential ET capability may appear unique from some perspectives, and this apparent uniqueness may have the potential to de-emphasize consideration of other training system components. This must not take place. While the current effort has not yet produced a comprehensive treatment (incorporating ET) for optimizing training media allocations across approaches, an effort is under way to redress this need. It is intended that the development and maturation of the techniques will later lead to a full integration of ET-specific considerations with other training system analysis, design, and definition procedures.

SECTION 1

INTRODUCTION

The incorporation of microprocessors and other computing capability in major Army weapons; Command, Control, Communications, and Intelligence (C3I); and support systems provides a significant opportunity to directly utilize tactical systems to provide training. Such use is known as Embedded Training (ET), since in most cases, the training capability is embedded in the design of the material system. An ET component, integrated into the design of a system, can provide significant value as a part of the total training system for the prime item materiel system.

As with other training system components and approaches, the implementation of ET needs to be a thoughtful, well-reasoned and -justified process. Appropriate, complete, and efficient training must be provided, and the training must be auditable and manageable, to ensure that training needs are actually satisfied. In addition to these traditional challenges, the implementation of ET must be closely coupled to the design of the materiel system, to ensure that both the ET component and the system itself are capable of performing their intended functions, without mutual interference.

One major aspect of the development of an ET component for a particular system is the definition of the ET Requirements (ETRs) for that system. ETRs are a first approximation to the training content and structure for the ET package. The ETRs are the tasks and behavioral performance objectives to be supported by an ET component. Actual design of an ET component to meet the ETRs is a successor activity to ETR development. Development of ETRs is analogous to (and should parallel or be a part of) the Analysis Phase of the Instructional Systems Development (ISD) process. Derivation of ETRs is an extension of the standard Front-End Analysis (FEA) techniques used in ISD.

This report presents the procedures which have been developed for the identification of ETRs.

Overview of the ETR Identification Process

The remaining four sections of this report present the detailed procedures and guidelines for identifying ETRs. The procedures are divided into four phases, each with several component steps. An overview of the phases of the process is shown graphically in Figure 1.

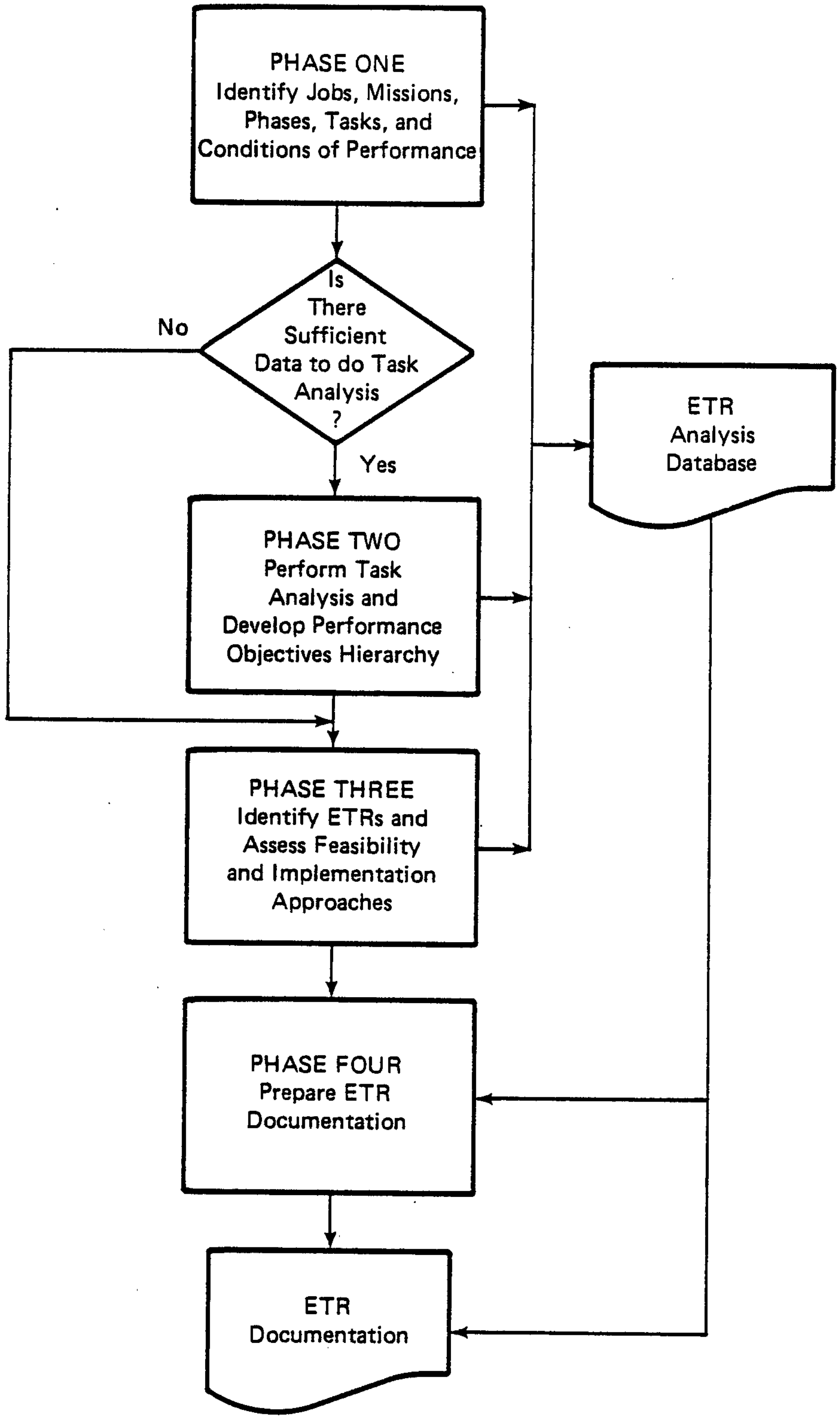


Figure 1. Overview of the ETR Development Procedures

It should be understood that procedures in Phases One and Two are essentially identical to other ISD front-end analysis procedures. In fact, ETR identification should take place as a part of efforts to identify training requirements for a system overall, and to specify other training media and approaches. Duplication of effort should be avoided, and common databases and resources should be used for all training-related front-end analyses. The discussion of procedures here allows the procedures to be applied independently of other training analyses, to suit cases where non-training oriented people must identify ETRs, or where ETRs are defined independent of other analyses in support of total training system definition.

Phase One (discussed in Section 2) is concerned with identifying the higher-level components (tasks) of personnel performance which may be supported by an ET component. The process involved is effectively the same as prescribed in ISD documentation elsewhere. These procedures are presented here to provide a complete-in-itself process for ETR identification without the need to refer to other documents.

Phase Two (described in Section 3) presents procedures for conducting task analysis to identify the behavioral performance objectives which are components of the tasks identified in Phase One. Again, these procedures are exactly analogous to standard ISD task analysis procedures, and are presented here for completeness. Since preliminary identification of ETRs in early stages of the system life cycle may be required, this Phase of the process is shown as optional. This is solely due to the fact that sufficient valid data on which to base a detailed task analysis may not be available at points early in the life cycle, even if HARDMAN or other Early Comparability Analyses (ECA) are performed. If Phase Two is initially skipped, a detailed definition of the ETRs, based on a comprehensive task analysis, must be performed as early as possible, later in the system life cycle, when data becomes available.

Phase Three (discussed in Section 4) is quite specific to ET considerations. Procedures in this Phase are concerned with nominating tasks and objectives as ETRs, based on the perishability and criticality criteria; and assessing the implementation potential of the nominated ETRs, and possible approaches to implementation. Note that these analyses may be performed along with other training system analyses with similar purposes. It is suggested that these analyses be conducted in parallel with, or integrated with, total training system media determination procedures. Combining the analyses will yield opportunities to examine overall training system configuration alternatives and optimize the design of the complete training system.

Phase Four (detailed in Section 5) deals with presenting the identified ETRs. In practice, the database resulting from the three analysis phases tends to become quite large, with many data elements associated with each task and behavioral performance objective. In Phase Four, specific reports are selected and prepared which emphasize various useful facets of the data, and which can be used for different purposes later in the development of an ET component.

The Appendices

In addition to the four sections that make up the rest of the body of this report, three Appendices are included to support and facilitate the ETR identification process, in practice. Appendix A provides a generic mission phases model which is useful in Phase One, where system missions are decomposed into phases as part of the task identification process. Use of this model, adapted to the situation surrounding a particular system, is encouraged, to provide consistency. Appendix B presents an extensive listing and definition of action verbs for use in writing task and objective statements in the analysis process. This verb list is included to provide a standard reference for job and task analysts.

Appendix C presents information concerning the application of computer Database Management Systems (DBMSs) to support the ETR analyses, and documenting the results of the analyses. In practice, it has been found that the use of a DBMS on personal computers is a genuine resource-saver in conducting the ETR analyses and developing reports and documentation both directly involved in and peripheral to identifying ETRs. In Appendix C, a suggested structure for DBMS records is provided, which has been found to accommodate the ETR analyses and documentation effectively. Interim manual and computer-generated recording forms and formats are also presented, and their application in the steps of the ETR analyses is identified. Some suggestions on the use of DBMS capabilities in various parts of the ETR analyses are also provided in this Appendix.

SECTION 2

PROCEDURES FOR PHASE ONE: TASK CHARACTERIZATION

In order to develop valid ETRs, the first requirement is to completely define the activities, or tasks, that system personnel perform on the job. The tasks will be analyzed in more detail and considered for ET in later phases of the ETR development process.

The steps to be performed in Phase One, and the products that are produced, are summarized in Figure 2.

The results of the activities may be entered into a computer database for ease of management. It is strongly suggested that a computer DBMS be used to record and structure analysis results and data, if a DBMS is available. Using the computer database will also make many of the activities in later steps and phases easier, because of the flexible ways that appropriate DBMS software can manipulate and retrieve data. A suggested structure for a computer database for ETR analyses is given in Appendix C of this document. Good results have been had in ETR data management using IBM-PC-compatible computers with hard disks and dBase III data management software. However, any computer with hard-disk storage, and any data management software available, can be used. The goal is to provide consistent data management and to ease the burden of recordkeeping and data retrieval imposed by the large number of steps required to specify ETRs.

The subsections that follow describe each of the steps in Phase One. Each subsection presents the objective of the step, provides rationale for the activities in the step, describes how to perform the step, and specifies the products that should result and how they should be recorded and documented. The steps should be performed in the order they are listed, since the activities in each step make use of products from previous steps.

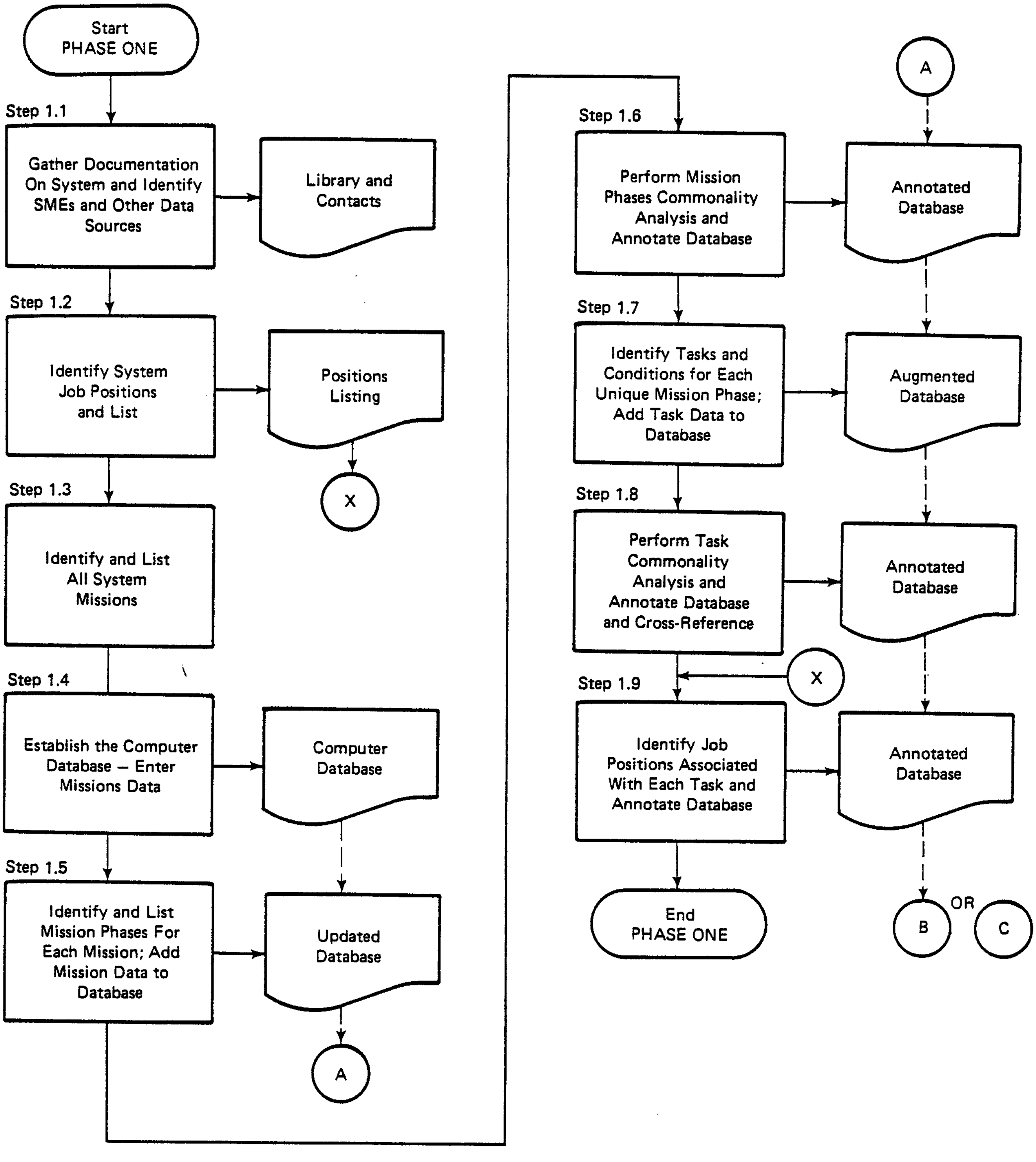
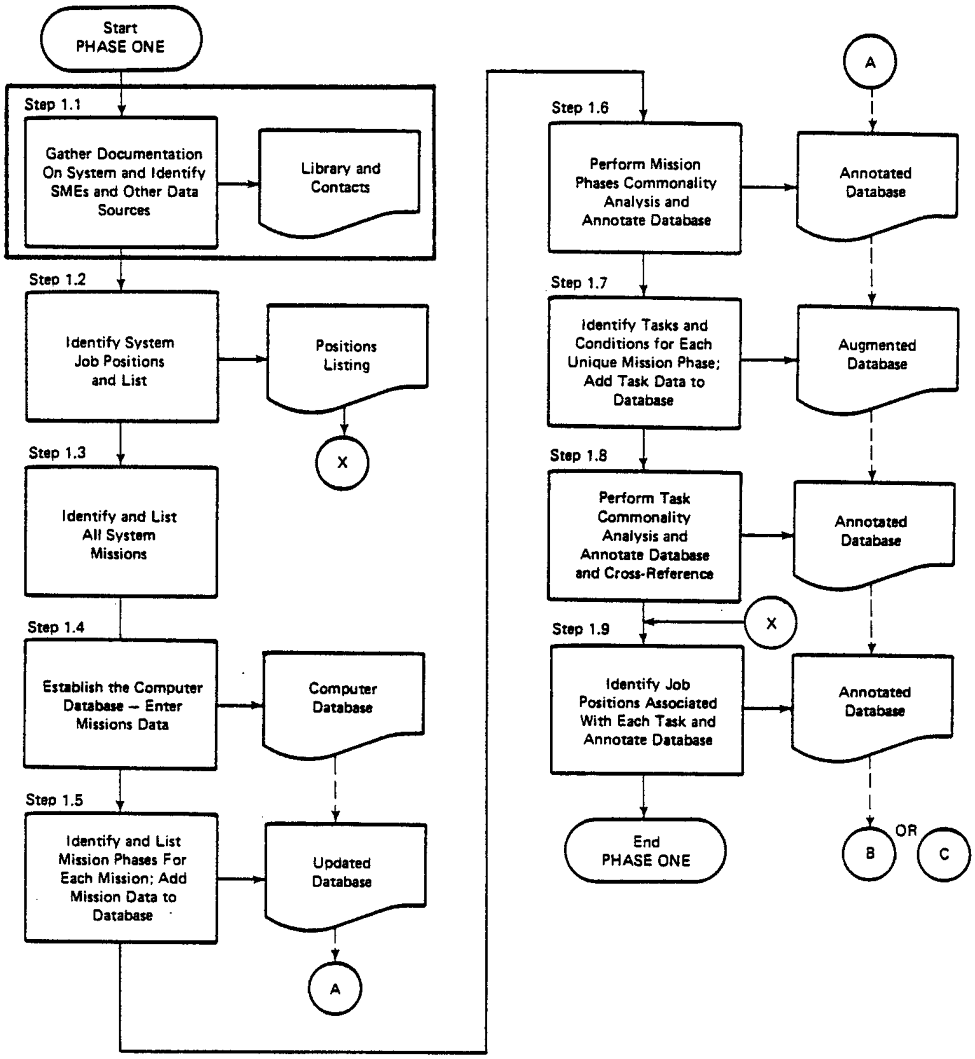


Figure 2. Overview of Phase One Procedures

Step 1.1 -- Gather Documentation and Identify Resources



Step 1.1 -- Gather Documentation and Identify Resources

Objectives: (1) Identify available information sources (people and organizations) about the system for which ETRs are being developed.

(2) Develop a library of reference material (documentation on the system and the activities performed by people who operate the system) to support analysis.

(3) Identify Subject Matter Expert (SME) resources to provide additional information about the tasks that people perform and the important characteristics of those tasks.

Rationale: The analyses to define ETRs depend completely on accurate, comprehensive, detailed information about what people are required to do to make the target system perform effectively. This information provides the basis for developing training objectives and training content, as well as deciding which aspects of job performance should be supported by ET. Both documentation resources and people resources (SMEs) are normally required, to provide the information necessary for the development of a valid set of ETRs for a system.

ETRs may be analyzed either early in the system development process or after the system has been fielded. If the ETRs are analyzed when a system is in the very early stages of its life cycle, before the characteristics of the target system are fully established, specific documentation on the target system and the roles of personnel in operating the system is likely to be absent, inaccurate, or very incomplete. Information sources that are accurate and complete are likely to be hard to come by. When this is the case, the documentation that is available must be used, but it does not support a very detailed level of analysis. Documents which describe the system, its missions and capabilities, and the responsibilities of personnel at this stage of the life cycle will include Mission Area Analysis (MAA) documentation, Required Operational Capability (ROC) statements, and Organizational and Operational (O&O) Plans for the system. Other documentation, including results of HARDMAN analyses and MANPRINT studies, may also be available. If necessary, documentation about other systems that have similar missions or are similar (in design or technology) to the target system may be used. If this is done, however, a later update of the ETR analysis (using accurate, complete information on the actual target system) will be necessary.

If the ETR analysis is prepared after the system has already been fielded (and the possible addition of an ET package is being addressed), large amounts of documentation on the system and the tasks and responsibilities of its personnel are typically available. These information sources are generally complete and accurate, especially if the results of other training analyses on the system can be obtained. Documents that are useful at this stage include Technical Manuals (TMs) dealing with the target system, Field Manuals (FMs) describing how the system is operated and employed, Soldier's Manuals (SMs) that describe the responsibilities and tasks of the crewmembers or system operators of the target system, and Army Training and Evaluation Plans (ARTEPs) that describe system operator tasks and performance standards. Task analysis and training Front-End Analysis information is also useful, as are the results of any ISD analyses that have been done on the target system.

SMEs provide two critical services in an ETR analysis. First, they can validate or revise questionable information, and add details that may not be present in documentation. This is especially important in the case where information is sparse or incomplete. Second, SME input is required to make judgments on how critical specific aspects of job performance are to mission accomplishment, in identifying tasks or performance objectives to be included in the ETRs.

<u>Procedure</u>: The first activity in this step is to identify agencies capable of providing the necessary documentation and the personnel who can serve as SMEs. While details will differ from system to system, sources include: Program Manager's staff, Special Study Group (SSG) staff and reports, Special Task Force (STF) staff and reports, Army Materiel Command (AMC) personnel associated with the system, Training and Doctrine Command (TRADOC) Training System Managers (TSMs), personnel in the Directorate of Training Development (DTD) at the proponent school for the system, and personnel associated with the system at various laboratories and commodity commands (e.g., Army Missile Command, etc.).

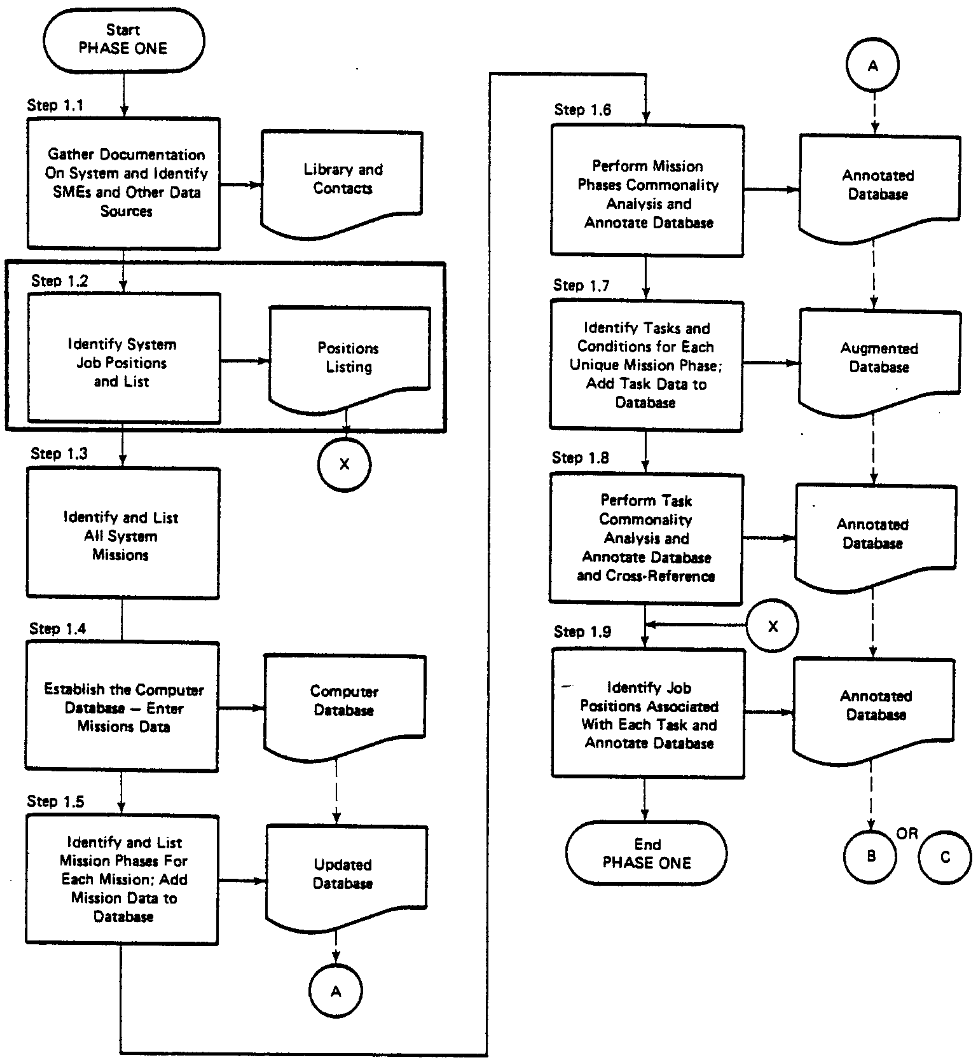
After sources have been identified, they should be contacted, and the documentation available from each source should be requested. In most cases, it is recommended that all available documentation be identified and obtained. If more information than is useful is obtained at this point, it is better than if insufficient information is available later.

Once documentation has been received, it should be catalogued, and a project library should be established for ease of reference. If the volume of documentation is large, it may be helpful to develop a computer database for cataloguing or indexing the information sources for ease of reference in later steps. This can also be helpful when developing an audit trail (i.e., where the information used in the analysis came from) in the analysis database in later steps, since source-identification data can be easily transferred from one database to another.

SMEs are frequently more difficult to come by than is documentation. The ideal SMEs to support an ETR analysis are relatively senior enlisted personnel (Skill Level 3 or higher in Military Occupational Specialty [MOS]) who have a minimum of one year's recent experience on the target system or on very similar systems. It is highly desirable to have two or more SMEs available, especially at critical points in the effort, so that different perspectives on decisions are available. Continuous SME involvement is not absolutely required over the entire period of the ETR analysis, but is desirable, if this is possible. If SMEs cannot be made available on a continuous basis, their involvement at specific points in the analysis process is critical. The steps where SME assistance and input are essential are indicated later in this document, as they are described. In any case, it is highly desirable to have the <u>same</u> SMEs involved over the project period, in order to minimize the amount of re-familiarization required, and its associated delays.

<u>Products:</u> The products of this step are the project library, the lists of personnel or offices in various agencies which may be contacted for additional information, and the identification and assignment of specific SME personnel to support the project.

Step 1.2 -- Identify and List Job Positions for the Target System



Step 1.2 -- Identify and List Job Positions for the Target System

Objective: Identify each job position involved in operation of the target system, including (if possible) MOS, grade, and other specific descriptors.

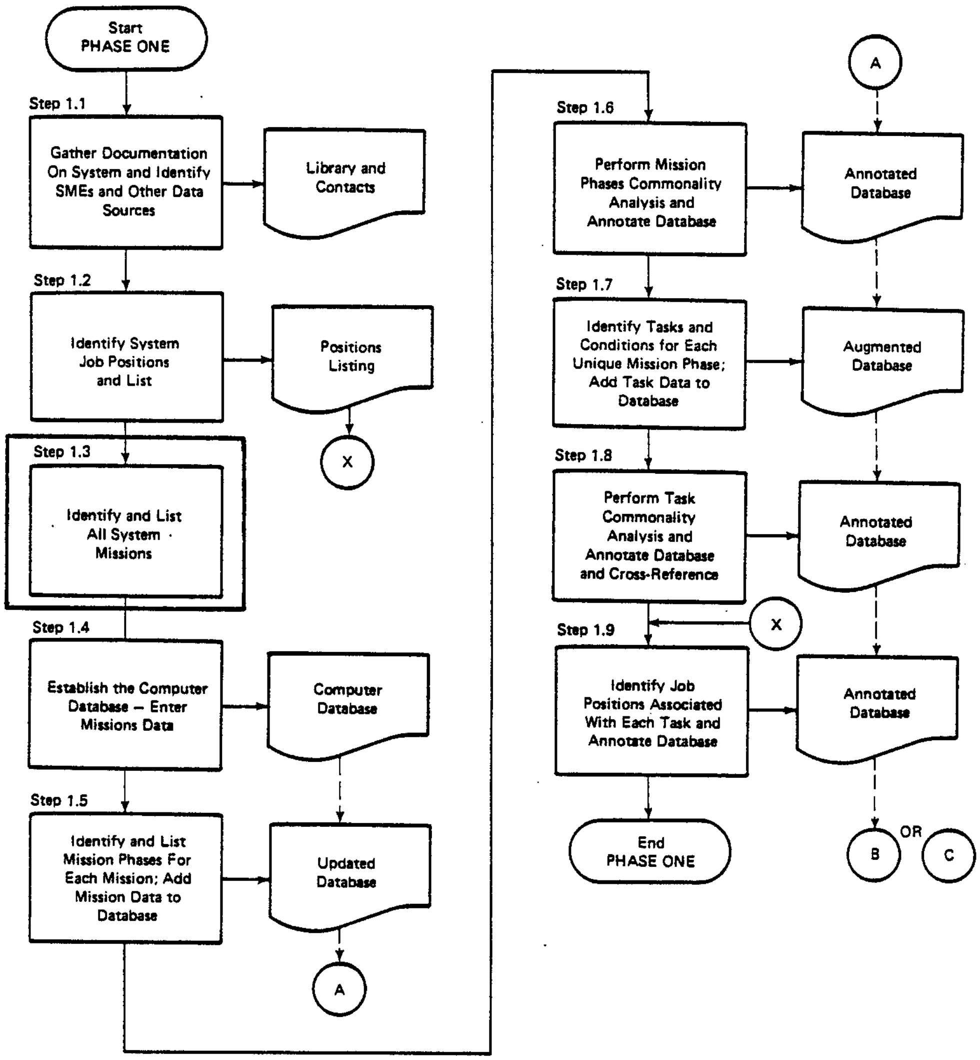
Rationale: The first two phases of the ETR analysis are a top-down analysis of the responsibilities, tasks, and performance of personnel who operate the system. It is necessary to be able to identify which people do what on the system, and under what circumstances, in order to identify valid ETRs. Also, when an ET component is developed for the system, it is necessary to identify which personnel will interact with the ET component, and in what ways.

Procedure: Examine the available documentation and determine the titles of job positions involved in system operation. Job position titles should be descriptive of the general duties performed by each person involved in system operation. For example, an M109 howitzer crew is normally composed of five persons: a Chief of Section, a Gunner, an Assistant Gunner, a Driver/Cannoneer, and a Cannoneer.

After the job position titles have been identified and listed, additional descriptive information about each position should be determined. As a minimum, the MOS and grade for each position should be identified. Other information, such as special qualifications and prerequisites for each position, should be listed if it is conveniently available.

Product: The job position listing. Later, this listing will be used to identify which positions are involved in performing tasks and task-component activities on the system.

Step 1.3 -- Identify System Missions



The use of Form 1 (see Appendix C) for interim data recording is suggested for this step

Step 1.3 -- Identify System Missions

Objective: Identify and list all of the named missions which are to be performed by the target system.

Rationale: Since the identification of tasks and personnel responsibilities is a top-down process, a point of departure is needed. Since all systems are designed to fulfill specific missions, beginning the analysis at the mission level provides a consistent starting place for the ETR analysis. Also, reviewing the missions provides a relatively complete picture of how a system is to be used, which helps to make the analyses complete by providing for the various unique uses of the system.

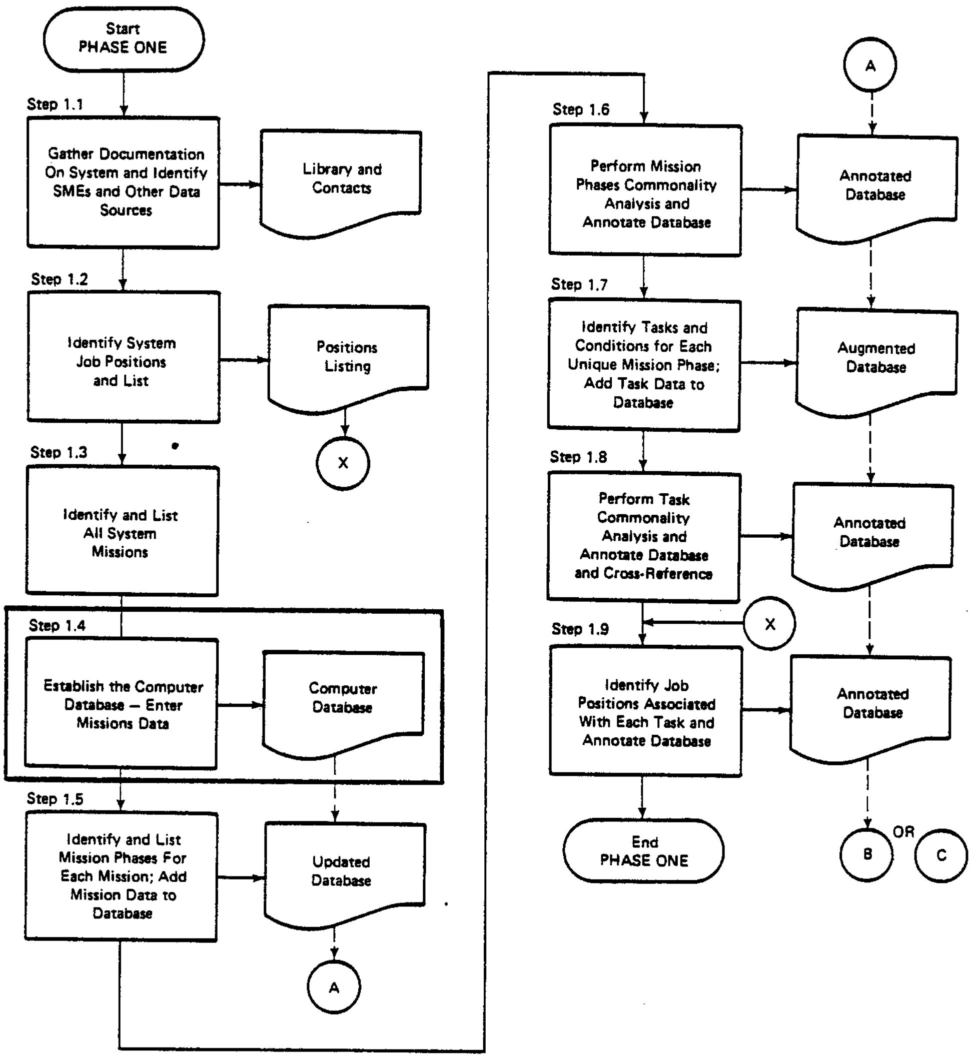
Procedure: Using documentation and SMEs (if available), list each mission performed by the target system. An excellent resource for mission listings data is the O&O concept for the system. This document normally lists all missions and mission variants contemplated for the system. An additional advantage of the O&O concept as a resource is that it is normally prepared very early in the system life cycle. More stable data for systems which are in later parts of the life cycle are typically found in FMs and TMs.

When considering missions, guidelines useful for discriminating missions are the following: (1) a mission is a related set of activities normally performed by a crew or other system of individuals, (2) a mission has clearly definable beginning and ending points, and (3) missions are often related to specific end goals of coordinated crew activities.

It should be recognized that not all systems will have more than one mission. For example, tanks may have many missions, but an antitank weapon may have only one. Tanks can have both direct and indirect fire missions, and can be employed in counter-armor, counter-asset, offensive, and defensive roles. These could all be considered distinct missions. On the other hand, antitank weapons are used to kill tanks, and for very little else, except in very unusual circumstances. In general, the more flexible the overall capabilities of a given system, the more missions it may have, other factors being equal.

Product: The listing of unique missions for the system.

Step 1.4 -- Establish the Computer Database and Enter Missions Data



The use of Form 1 (see Appendix C) for interim data recording is suggested for this step

Step 1.4 -- Establish Computer Database and Enter Missions Data

Objective: Develop and implement a complete and comprehensive database structure to support documentation and analysis in subsequent steps of the ETR identification process.

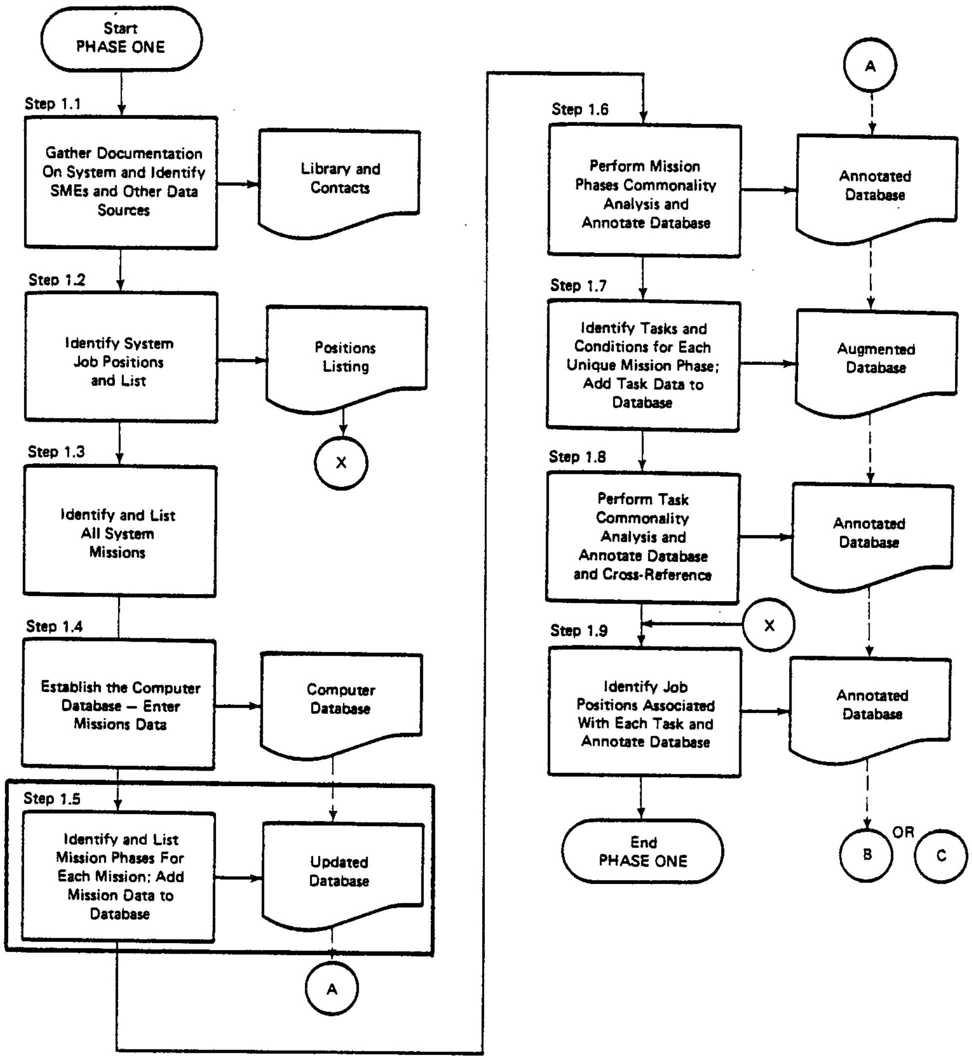
Rationale: Using a computer database management system to support the ETR analyses saves time in the documentation of most steps, and makes the retrieval, modification, and analysis of data much easier. Database management software also facilitates preparation of reports for the intermediate and final steps of the ETR development process, and provides for a consistent and comprehensive level of detail in the data.

Procedure: Using available database management software, establish a database structure similar to that presented in Appendix C of this report. All of the data fields described in Appendix C should be defined in the database structure that is implemented.

After the database is implemented, enter the discrete missions identified in Step 1.3 as individual records in the database, with appropriate codes and descriptions. If only one mission was identified in Step 1.3, there is no need to enter mission records. Also, enter the data sources that were used to identify each mission.

Products: The implemented database structure and mission descriptor records (if applicable).

Step 1.5 -- Identify Mission Phases for Each Mission



The use of Form 1 (see Appendix C) for interim data recording is suggested for this step

Step 1.5 -- Identify Mission Phases for Each Mission

Objective: Identify all discrete mission phases for each system mission and add the mission phase data to the database.

Rationale: Decomposing missions into phases is the next step in the top-down analysis to develop the complete database for identifying ETRs.

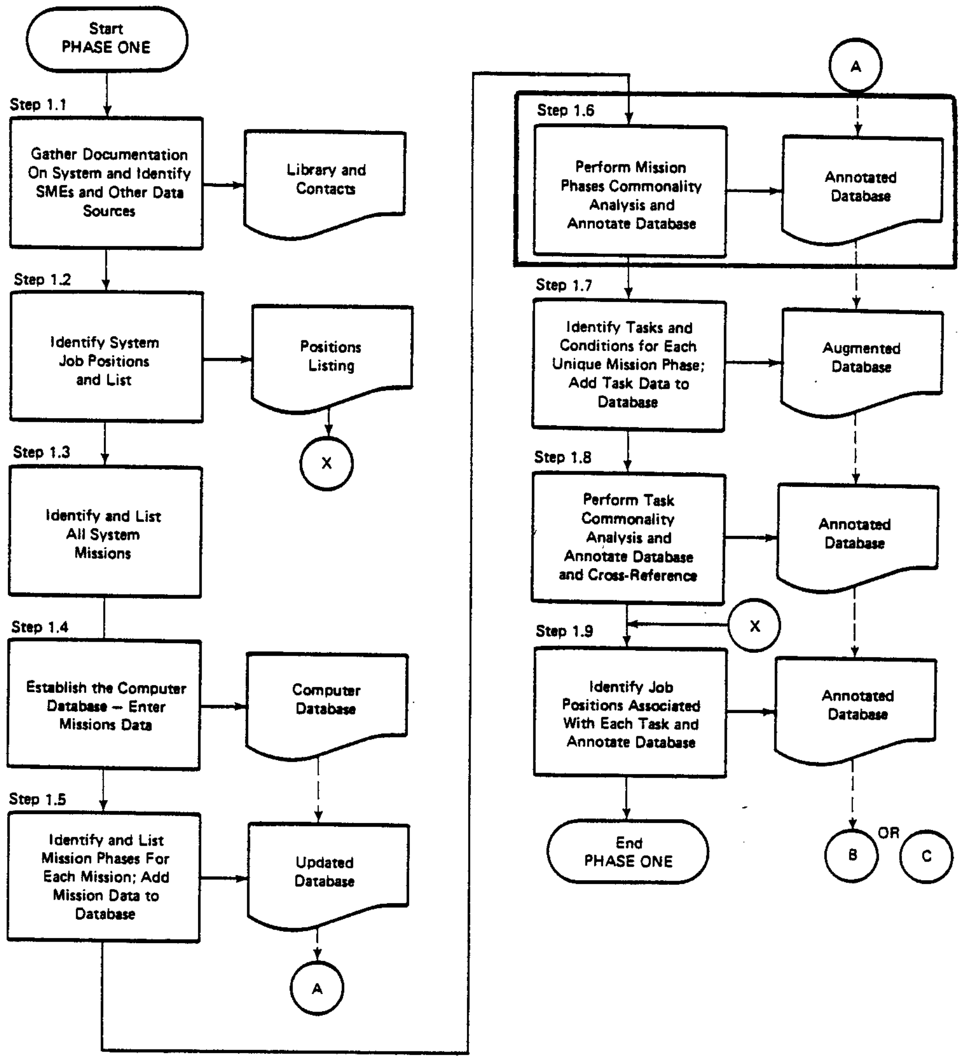
Procedure: For each of the missions identified in Step 1.3, use documentation and SME resources to identify the phases of the missions. Mission phases have the following characteristics: (1) each mission phase can be given a meaningful name, (2) each mission phase has a logical beginning and ending point, (3) each mission phase occupies a unique time slice within the mission, and (4) all phases taken together describe an entire mission.

Good sources for mission phase description data are SMs, TMs for the system or for very similar systems (if available), and SMEs. When SMEs are used to identify mission phases, they should be briefed on the four characteristics listed in the previous paragraph, and provided documentation for reference. If desired, the generic mission phases model presented in Appendix A can be used as a starting point for mission phase identification. It will probably be necessary to adapt this generic model to the specific system that is being considered. Also note that the generic mission phases model is based on typical ground systems missions. Aircraft systems and non-weapons systems may have very different mission phase breakdowns. Some non-weapons systems may not have mission phase structure at all. However, such systems usually have functional groupings of tasks that are analogous to mission phases. Such task groupings can be used to organize the remainder of the analysis process, instead of mission phases.

As mission phases for each mission are identified, they should be listed, by mission. Also, the documents or other sources used to derive the mission phases should be recorded, to provide an audit trail for the analyses. After identifying phases for all missions, enter the mission phases for each mission as records in the database. Codes used for the mission-phase records should be one level subordinate to the codes used for mission records. Also, the codes assigned to phases of each mission should reflect the sequence of the phases in the mission.

Product: Mission phase listings for each mission, entered as mission phase records in the computer database.

Step 1.6 -- Mission Phases Commonality Analysis



The generation and use of Form 2 (see Appendix C) for interim data recording is suggested for this step

Step 1.6 -- Mission Phases Commonality Analysis

Objective: Identify and annotate the unique mission phases among the various missions. (NOTE: This step may be omitted when there is only one mission or functional task area defined for a system.)

Rationale: Later steps in the analysis process may consume large amounts of time and resources. If several missions have identical phases, it makes no sense to duplicate effort in analyzing the tasks and operator behaviors contained in such phases more than once. This step identifies the phases that are unique among all the missions identified. Only the unique mission phases will be considered in later steps.

Procedure: Obtain a listing of mission phases (sorted or indexed by mission) from the database. Use this listing to identify the phases in different missions that have similar or identical titles. Using SMEs as a primary source, review all of the mission phases that have similar or identical titles in different missions, and judge which of these phases are unique. An appropriate approach is to consider all possible pairs of mission phases with similar titles. Questions to ask when trying to determine if phases with similar titles are, in fact, identical are:

(1) Are there different goals or objectives among mission phases with similar titles? If yes, the phases may be unique.

(2) Is the system or its subsystems used in different ways in mission phases with similar titles? If yes, the phases are probably unique.

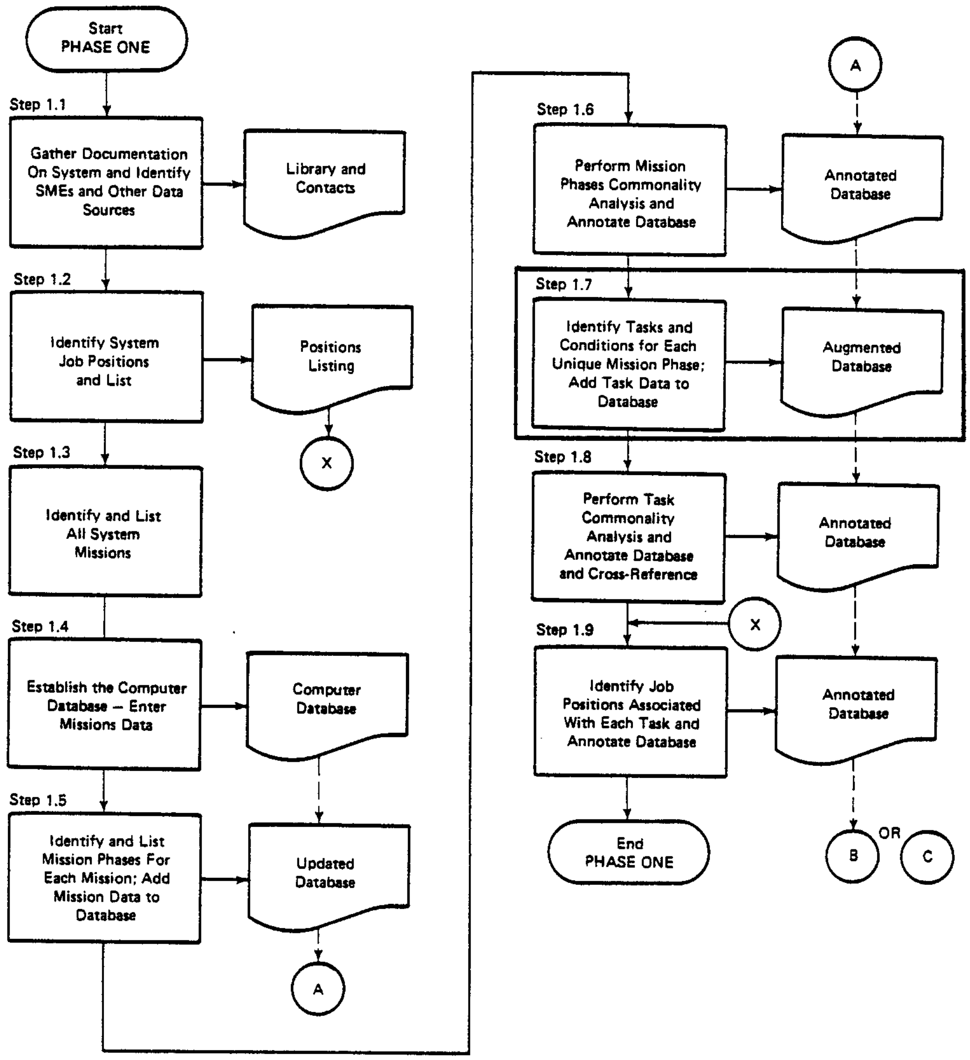
(3) Are there differences in the responsibilities allocated among operators or crewmembers across phases with similar titles? If yes, it is likely that the phases are unique.

As the phases are evaluated, identify the first occurrence of identical phases. Then identify each phase that is identical to these first ones. Generally, the "first occurrence" phases should be those with lower numbered mission codes in the database.

After all phases have been evaluated, annotate the mission-phase database records. Two kinds of annotation will be needed. The first is to identify the unique phases and the "identical" phases that are the same as the unique ones. Using a logical database field, code the unique phases as "True" and the "identical" phases as "False." The second kind of annotation is a cross-reference of the phases that are identical. It is suggested that the database codes of all "identical" mission phases be listed in the appropriate field of the unique "first occurrence" phase to which they are identical.

Product: Database annotations indicating unique and "identical" mission phases, and cross-reference fields in the unique mission-phase records.

Step 1.7 -- Identify Tasks and Conditions



The use of Form 1 (see Appendix C) for interim data recording is suggested for this step

Step 1.7 -- Identify Tasks and Conditions

Objective: Identify all tasks performed by operators or crewmembers while performing each unique mission phase, and the conditions under which each task is performed.

Rationale: Decomposing mission phases into tasks is the next step in the top-down analysis to develop the complete database for identifying ETRs.

Procedure: The following procedures are performed for each unique mission phase. The primary information sources are documentation (SMs and ARTEP documents are good sources) and SMEs. If only documentation is used for initial identification of tasks, the task listings should be validated by two or more knowledgeable SMEs and should later be updated, as appropriate, based on their comments.

(1) Go through each unique mission phase in sequence, identifying and listing all tasks. In identifying tasks, look for names of products produced by personnel while doing their duties, or names of processes they use to accomplish goals. Also, consider the following characteristics when identifying tasks:

(a) Tasks are significant operator activities that can be named;

(b) Each task has an observable beginning and ending point, or results in a consistently identifiable product;

(c) Most tasks include a consistent sequence of specific behaviors (these will be dealt with in Phase Two).

Task names should consist of an action verb, a noun that specifies the object of the action verb, and an appropriate modifier (or qualifier) phrase that briefly describes how the action is carried out. Modifier phrases should be neither too detailed (getting into specifics) nor too general. For example, the task statement for manual laying of a howitzer might be "Lay howitzer, using manual method." A list of generic action verbs for use in developing task statements is provided in Appendix B. Note that some special action verbs, such as to "lay" a howitzer, may be absent from this list, although they are common in traditional military usage. These should be used when necessary for clarity.

Provide sufficient detail to enable the listing to be validated by someone else using the same resources. If enough detail is not provided, important tasks may be omitted from consideration or be analyzed wrongly in later steps of the ETR identification process. Generally, an appropriate level of detail in listing tasks is considered to be: (a) the point below which task components would be described, rather than tasks and (b) the lowest level at which performance might be evaluated independently from other contiguous tasks. An example of a task statement that is not sufficiently specific is "Lay howitzer," since there are several methods for laying the howitzer. An example of a task statement that is too specific is "Select the manual alignment mode on the inertial navigation system," this is a behavioral component of a task.

As tasks are identified, they should be given numeric codes that reflect their level in the database hierarchy. Task codes are one level below mission codes. For example, a code for the ninth task in Mission 1, Phase 6 would be 01.06.09. These codes will reflect the position and level of subordination of the task in the overall operator performance hierarchy.

(2) After all tasks in a mission phase have been identified, organize the tasks so that all the tasks at each level in the task hierarchy are independent. Review each task, and ask the question, "Can this task be subsumed under any other task listed at this level for this mission phase?" If it can, then the task should be moved to a lower level in the hierarchy. Task statements at each level in the task hierarchy should be completely independent of each other--neither subordinate nor superordinate.

(3) Continue identifying tasks in each unique mission phase until all of the mission phases have been analyzed. After completing the task identification for a mission phase, add the task data (task statements and hierarchy numeric codes) to the database as separate task records. Also, include the information source(s) you used to identify each task.

(4) Identify the conditions of performance for each mission, phase, and task. Conditions are the "givens" of a performance. They describe the circumstances under which a task is performed. Conditions may include (but are not limited to) the following:

(a) environmental factors (such as space, light, noise or quiet, temperature, wind, weather, or system conditions);

(b) relationships to other personnel (alone, working as part of a team or crew, under supervision, etc.);

(c) equipment factors (what job aids, tools, equipment, etc. are available or provided);

(d) information (what job-relevant information is available at the workplace; checklists, operator manual, charts, etc.);

(e) problem definition (what stimuli are present to signal that a task is to be initiated; system characteristics that provide cues and "feel," etc.);

(f) time (duration, pacing, etc.);

(g) concurrent tasks.

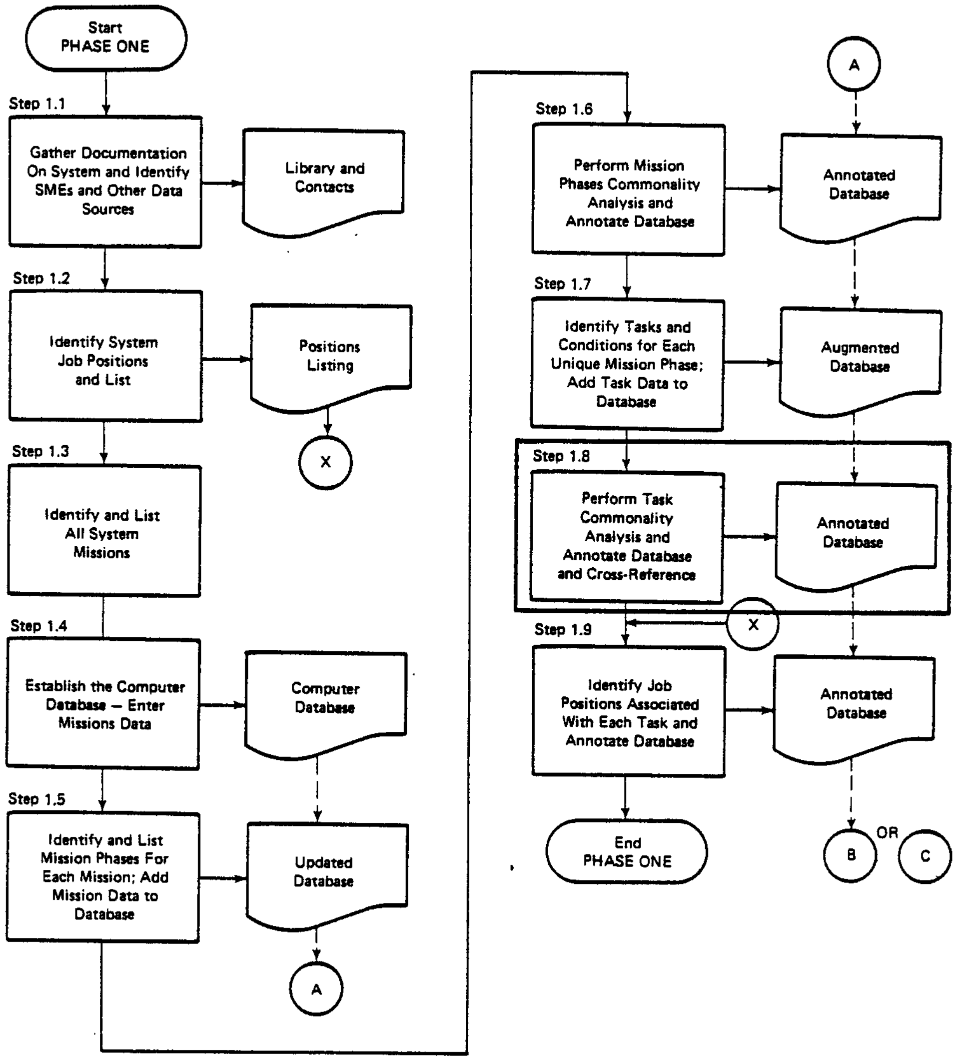
Add the conditions information to each mission, unique mission phase, and task record in the database.

(5) List all additional tasks required in each mission phase for performance under extraordinary conditions. Extraordinary conditions include malfunctions, emergencies, and abnormal system conditions (such as operating at half power because one of two engines has failed). This is best accomplished by asking, for each mission, phase, and task, "Are there any conditions under which this is performed that require deviations from normal procedures?" Note that SME input is extremely valuable at this step; documentation often deals only with normal system operation or operating under nominal conditions. The existence of extraordinary conditions requires the identification of tasks previously overlooked in developing the task listings. New tasks created by identifying extraordinary circumstances are added to the task database and are subsequently treated the same as any other task.

(6) Re-examine and validate the task listing. Review the task listing against the available documentation, and with one or more SMEs who were not involved in the original development of the task listing (if possible), to identify possible omissions and errors. Add to the database any tasks that were overlooked, and correct any errors that were discovered during the validation process.

Product: The validated task data, added to the project database.

Step 1.8 -- Perform Task Commonality Analysis



The generation and use of Form 2 (see Appendix C) for interim data recording is suggested for this step

Step 1.8 -- Perform Task Commonality Analysis

Objective: Identify and annotate the unique tasks among the various mission phases.

Rationale: Later steps in the analysis process may consume large amounts of time and resources. If there are identical tasks in several mission phases, it makes no sense to duplicate effort by analyzing these tasks (to identify their operator behaviors) more than once. This step identifies the tasks that are unique among all the tasks identified. Only the unique tasks will be considered in later steps.

Procedure: Obtain from the database a listing of tasks sorted or indexed by task statement. Use this listing to identify those tasks (in the same or different mission phases) that have similar or identical task statements. Using two or more SMEs as primary sources, review all of the tasks having similar or identical statements, and judge which of the tasks are unique. An appropriate approach is to consider all possible pairs of tasks with similar or identical titles. Questions to ask when trying to determine whether tasks with similar statements are, in fact, identical are:

(1) Are there different goals or objectives among tasks with similar titles? If yes, the tasks may be unique.

(2) Is the system or its subsystems used in different ways in tasks with similar statements? If yes, the tasks probably are unique.

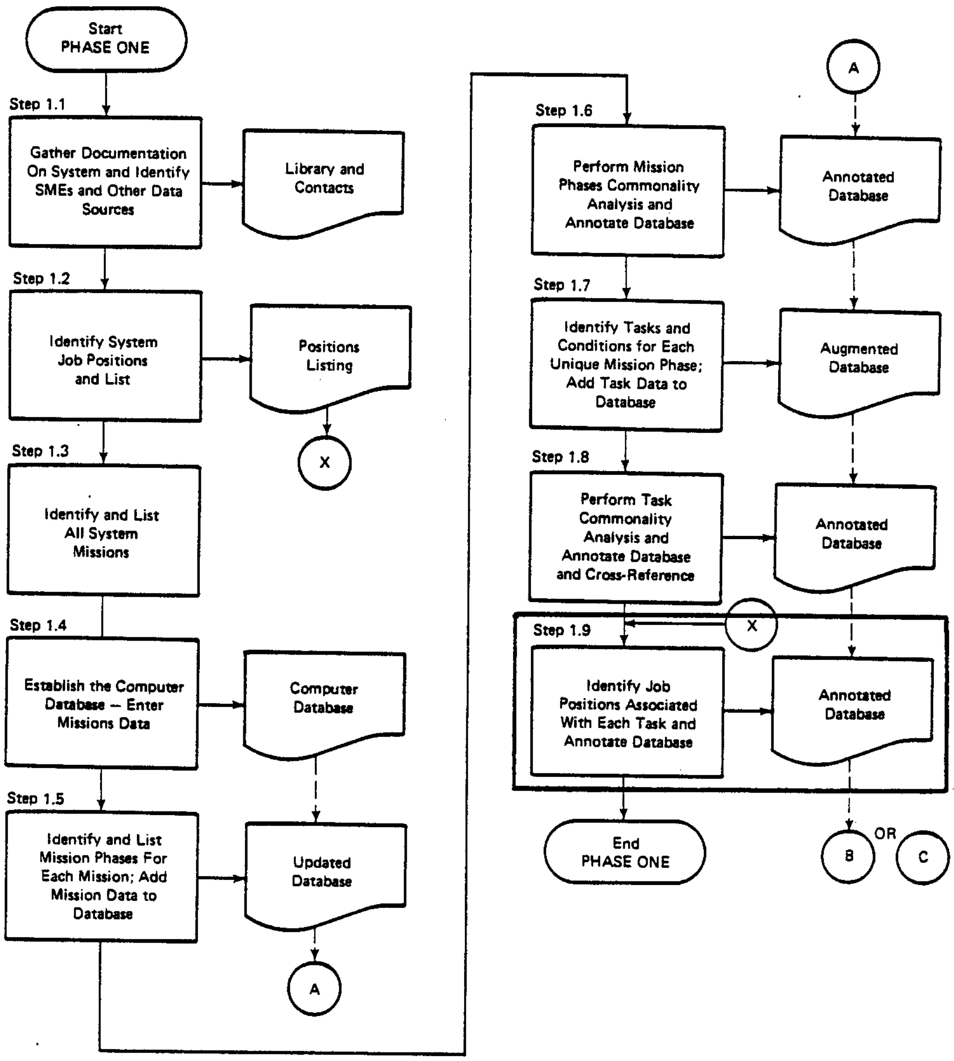
(3) Are there differences in the responsibilities allocated among operators or crewmembers across tasks with similar statements? If yes, it is likely that the tasks are unique.

As the tasks are evaluated, identify those tasks that are the first occurrences of identical tasks. Also, identify each task that is identical to these "first occurrence" tasks. Generally, the "first occurrence" tasks should be those with lower numbered codes in the database.

After all tasks have been evaluated as described above, annotate the task database records. Two kinds of annotation will be needed. The first is to identify the unique tasks and the "identical" tasks that are the same as the unique ones. Using a logical database field, code the unique tasks as "True" and the "identical" tasks as "False." The second kind of annotation is a cross-reference of the tasks that are identical. It is suggested that the database codes of all "identical" tasks be listed in the appropriate field of the unique "first occurrence" tasks to which they are identical.

Product: Database annotations indicating unique and "identical" tasks, and cross-reference codes placed in the unique task records.

Step 1.9 -- Identify Job Positions for Each Task



Step 1.9 -- Identify Job Positions for Each Task

Objective: Identify the personnel involved in performing each system operation task.

Rationale: Knowing which operators or crewmembers are involved in performing each system task is critical to later design of an effective ET package for the system. Identifying the personnel involved, at this point in the analysis, also provides data for later use in judging whether particular activities are appropriate for inclusion in an ET package.

Procedure: Develop unique one-letter codes for each system operator or crewmember position (e.g., C for chief-of-section, L for loader, D for driver, etc.). Obtain a listing of all the unique tasks identified in Step 1.8. Using documentation and SMEs (if needed), examine each task statement, and identify the system operator or crew personnel involved in performing each task. List the appropriate codes to reflect the crewmembers involved in each task. Add these codes to the unique task database records.

Product: Annotations to unique task database records reflecting which personnel are involved in performing each unique task.

SECTION 3

PROCEDURES FOR PHASE TWO: PERFORM DETAILED TASK ANALYSIS

Normally, the procedures presented in Phase Two are not segregated from Phase One procedures. In most ISD analyses, these activities are performed in sequence. In considering ETRs, however, there are two possible cases. The first is the normal case where ET analyses and other analyses to define training system characteristics are carried out together. In this situation, task analysis will always be done, immediately following validation of the task listings.

The second case is when it is necessary to define preliminary ETRs early in the system life cycle--before specific data on the system being assessed is available. Since ET will commonly interact to a certain extent with prime item system design characteristics, such an analysis may be necessary to evaluate the extent that the system will have to be designed with hardware and software features unique to the ET capability. Also, early analyses in support of ET and other training system development may provide insights into effective design of the soldier-machine interface, since task data and the relationships of tasks and soldier functions are considered. The front-end analysis procedures for identifying ETRs have been divided into two separate Phases to accommodate this second case.

If the analysis is being carried out under the second case, Phase Two can be skipped, and preliminary ETRs can be defined at the task level. If this is done, a more detailed analysis (with task analysis) to further define ETRs must be carried out concurrent with other training front-end analyses later in system development. It is difficult to specify exact sources for task data upon which to exercise the task analysis procedures very early in the system acquisition cycle (e.g., the concept development stage). If system baselines have been selected or synthesized as part of Early Comparability Analyses (ECA) such as HARDMAN, information on operator tasks for the baseline system(s) used for those analyses <u>may</u> be appropriate. Caution is suggested if such an approach is used, however. Current ECA analyses concentrate on maintenance implications of potential system designs. The soldier-machine interface and task allocations between soldiers and hardware/software components of new systems may differ markedly from those of the system(s) used as ECA baselines.

If Human Factors Engineering (HFE) function allocations have been performed in support of the system under consideration, it may be possible to construct an operator baseline composite system based on the function allocations and assumptions from existing systems' capabilities to be used for initial ET requirements and training system requirements determination analyses. The same caution as above for using data from baseline systems applies to this case. Also, great care must be taken not to accept working baseline composites as drivers of the characteristics of operator tasks in later stages of the system acquisition process. Later re-definition of the training system and ET requirements must be made based on accurate data from the target system.

An overview of the steps performed in Phase Two is provided graphically in Figure 3. The following subsections present the procedures for task analysis and definition of performance objectives.

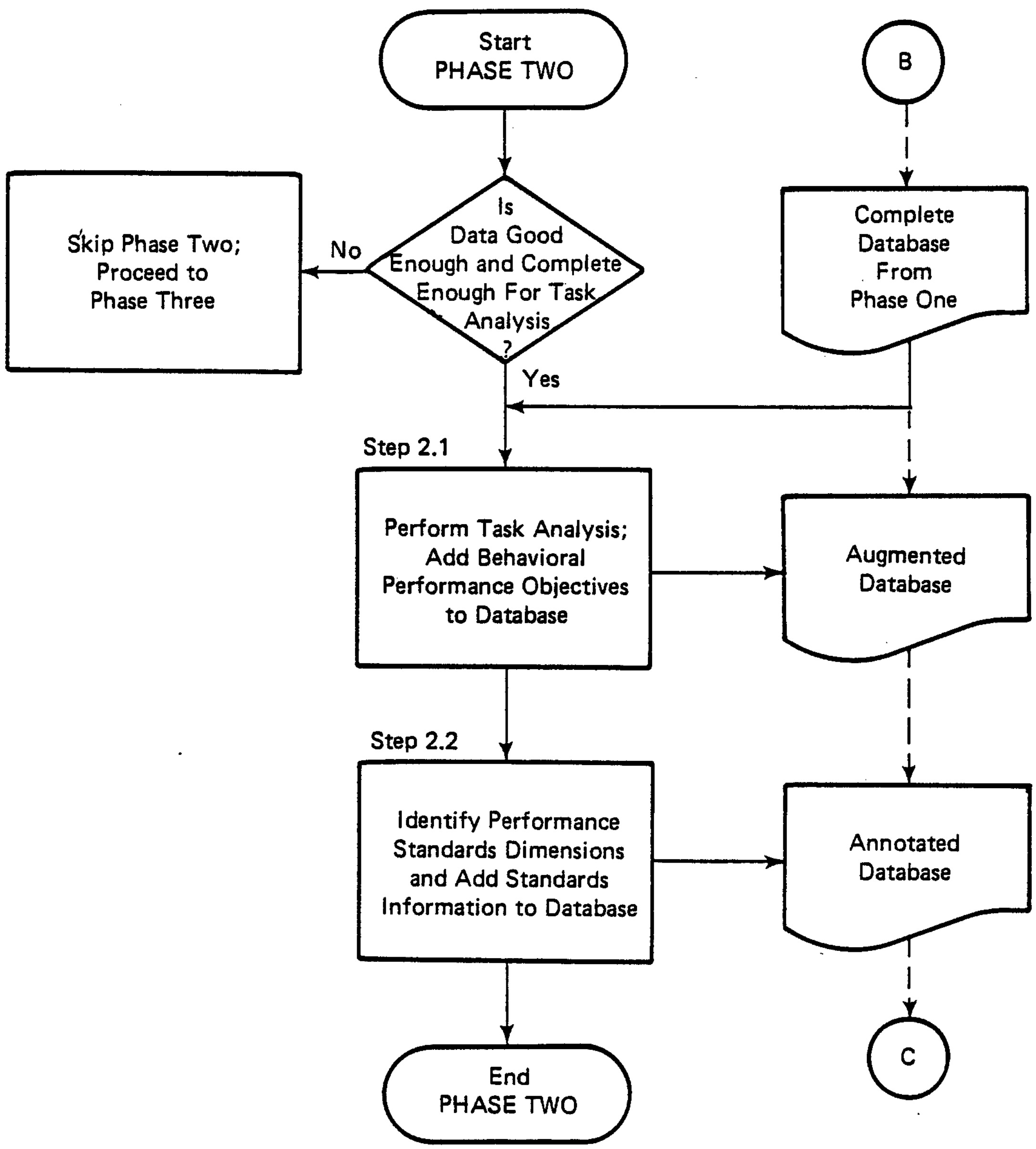
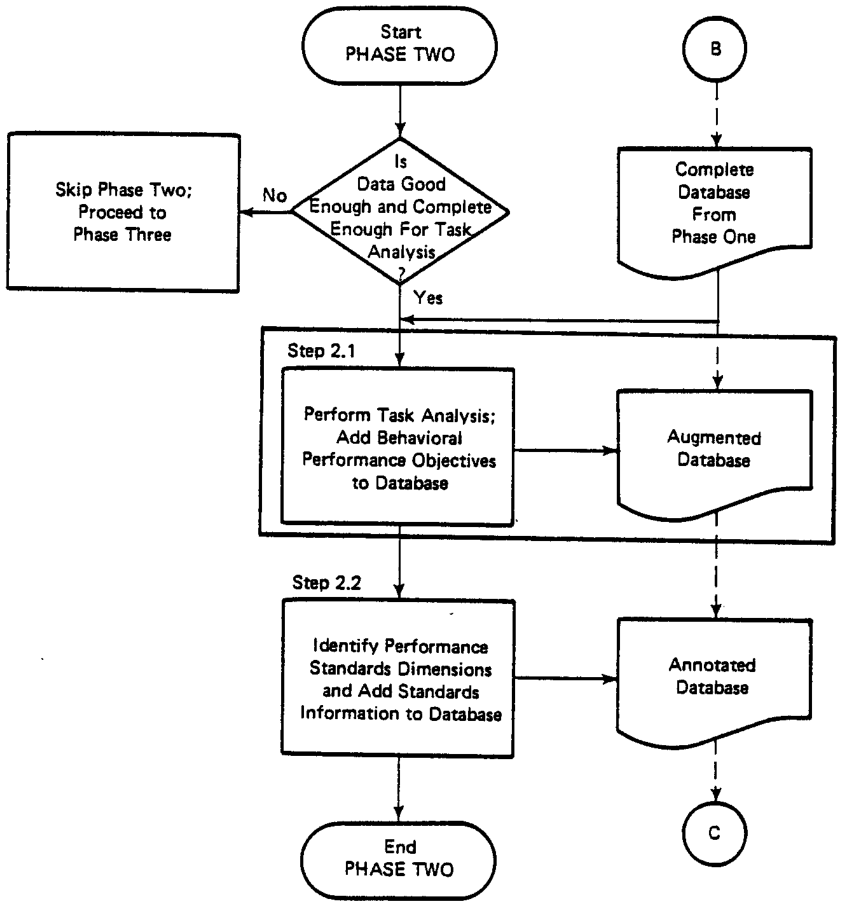


Figure 3. Overview of Phase Two Procedures

Step 2.1 -- Perform Task Analysis



The use of Form 1 (see Appendix C) for interim data recording is suggested for this step

Step 2.1 -- Perform Task Analysis

Objective: Analyze each unique operator task to identify the behavioral performance objectives included in the task.

Rationale: In order to design effective task training, it is necessary to know exactly how personnel perform each task for which they are responsible. Specifically for purposes of developing ET or standalone training devices, it is also necessary to understand specifically how the equipment system and the operator interact. Decisions about the appropriateness and feasibility of providing ET for particular tasks depend partly on the stimuli provided by the equipment system and the environment, and partly on the actions that personnel must perform to respond to or control those stimuli. Thus, each task must be broken down into its behavioral performance components. This analysis performs that breakdown.

Procedure: In conjunction with knowledgeable SMEs and documentation, perform the steps described below for each unique task in the database.

(1) Divide the task into its component subtasks. This is normally done by identifying each behavioral action performed by the operator in accomplishing the task. Both overt, observable acts and decisions or judgments should be considered to be subtasks or elements of a task. Each performance component identified should be listed, with a hierarchial database code that reflects its position under the task being analyzed. It is suggested that the components for each task be entered into the database as analysis of that task is completed. Source data should also be included in the objective database records.

(2) Determine whether all of the necessary decisions in performing the task have been identified as performance components. Clues as to when a decision is required include: (a) when personnel must decide when to perform a procedure, (b) when personnel must determine which of several alternate rules or procedures to use, (c) when personnel must evaluate the adequacy of a procedure or a product, and (d) when personnel must decide when a procedure should be stopped. When a new decision is identified in this evaluation, add it to the components list for that task. The description of the decision must spell out exactly what decisions that personnel must make to perform the task in all situations.

(3) Determine whether memorization is a significant element of the task. This will be true if it is judged that average personnel would be unable to perform the task as a whole if they could not remember which task components must be performed or the order in which they should be performed. This will also be true if a person must remember large amounts of reference information to use in the task (for example, communications codes). If job aids, computer prompts, or other memory aids for performing the task are likely to be available, then memorization should not be identified as a significant element of the task. If it is determined that memorization is a significant component, then memorization must be added to the list of components for a task. The memorization objective should be at the same level of importance as other task components.

(4) Determine if too many subtasks or performance components have been identified. This is done by examining the components which have been identified collectively. There are too many components when:

   (a) a component is a lower-level element of any other component listed; or

   (b) any component repeats any other component listed; or

   (c) any component is not necessary to accomplishment of the task; or

   (d) any component is trivial.

   If there are too many components, perform Step 5; otherwise skip Step 5 and go to Step 6.

(5) Narrow the list of components to the minimum required to perform the task. This can be done in one or more of the following ways:

   (a) eliminate components that overlap;

   (b) eliminate any component that is part of another component;

   (c) eliminate unnecessary components (that are not essential to task performance); or

   (d) group trivial components into major logical categories, and designate each category as a single component.

(6) Determine whether there are too few components. If, after having mastered all of the performance components listed under a task at this point in the analysis, a person would be unable to perform the overall task after receiving a few simple instructions and a minimal amount of practice, then one or more components have been omitted. If this is true, the task must be re-examined, and the missing critical components must be added to the list of task elements. Add components as required, so that the following statement is true:

Criterion-Level Performance of All Components	+	Some Minimal Instructions & Practice	=	Criterion-Level Performance of the Entire Task.

(7) Determine if there are training-related components for the task. Training-related components are behaviors that must be performed in the training environment only, as distinguished from mission-oriented components. This type of component is included to facilitate the learning of mission-related components (for example, touch-and-go landings and stall recovery procedures in flight training). If a need for training-related components is found, add those components to the component list for the task. Training-related components should be identified by a unique code so that they are distinct from mission-related components.

(8) Identify conditions of performance for each component. These conditions are of the same sort that were developed for tasks in Phase One, Step 1.7. Use the same procedures and criteria to identify conditions for performance components.

(9) Ensure that the performance components under the task are coded to reflect their hierarchial relationship to the task.

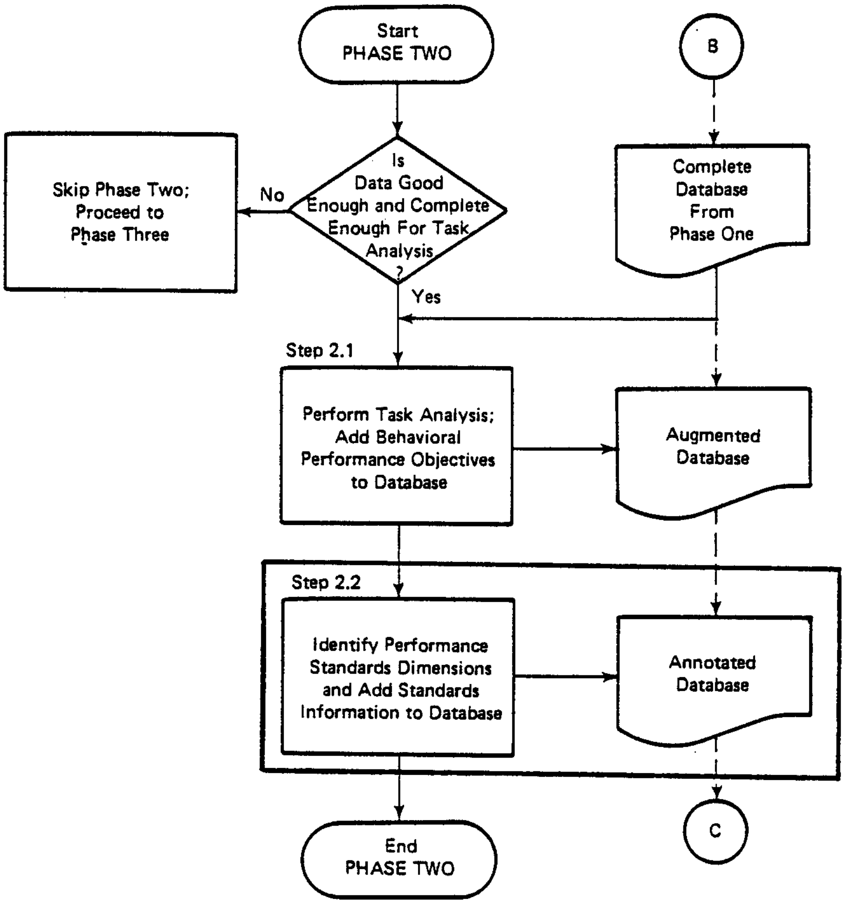
(10) Determine whether each performance component is a basic-level behavior (not trivial, but a required element of performance). If all performance components identified under a task are basic-level behaviors (e.g., individual procedural steps, specific decisions, or judgments), then analysis of that task is complete. If there are components which are higher than basic-level behaviors, then those components must be analyzed, in turn, until basic-level behaviors have been identified for all aspects of task performance.

Multiple levels of components under a task should be assigned hierarchy codes which reflect their subordination to higher-level components and superordination over lower-level components.

(11) Validate the performance objectives database. If, as suggested above, the components of each task are added to the database on completion of the analysis of the task, a final review of the database should be made before moving to the next step. This consists of obtaining an indexed listing of the entire database, and validating that all mission, phase, task, and behavioral performance objective data have been entered correctly, and that the numeric codes of all elements of the database accurately reflect the hierarchial relationships among the elements.

<u>Product:</u> Complete task analysis information, added to the project database.

Step 2.2 -- Identify Performance Standards Dimensions



The generation and use of Form 4 (see Appendix C) for interim data recording is suggested for this step

Step 2.2 -- Identify Performance Standards Dimensions

Objective: Identify the dimensions upon which performance of each task and performance objective will be assessed.

Rationale: One of the major distinguishing advantages that ET affords is its superior ability to measure and assess trainee performance. In order that appropriate performance measurement be provided by an ET package, the dimensions of correct performance must be identified. The ability to obtain performance measures on a task or behavioral performance objective is one of the factors considered in deciding whether or not to include a task or objective as an ET requirement.

Procedure: For each task and behavioral performance objective in the database, identify the dimension(s) upon which the correct performance of the element can be evaluated. At this point, specific criteria such as numeric values of a performance measure are not important. What is needed is to identify the measurement variables for the task or objective. Standards dimensions include (but are not limited to):

(a) Time or speed of performance (e.g., completes procedure within $\underline{x}$ seconds);

(b) Accuracy or error rate (e.g., speed, heading deviation, mechanical tolerance, etc.);

(c) Safety considerations;

(d) Process measures (e.g., sequence of steps in a procedure, correct selection from alternatives, etc.);

(e) Product specifications.

Note that particular tasks and objectives can have more than one dimension of correct performance. For example, some procedures may be measured both by the sequence of behaviors (process) and the time to complete the procedure.

As dimensions of performance are identified, add descriptions of the dimensions to the database records of the tasks and objectives.

Product: Dimensions of correct performance for all tasks and objectives identified and added to the database.

SECTION 4

PROCEDURES FOR PHASE THREE: IDENTIFY ETRS AND ASSESS FEASIBILITY AND IMPLEMENTATION APPROACHES

An overview of the steps performed in Phase Three is presented graphically in Figure 4. This Phase of the ETR identification process consists of two major subphases. The first subphase is concerned with nominating tasks and behavioral performance objectives as ETRs, using two characteristics of objectives: criticality and perishability. Criticality refers to the effect on the outcome of a system's mission if an objective is not performed, or is performed incorrectly. Perishability refers to the extent to which a soldier's ability to perform an objective correctly decays without periodic reinforced practice of the objective. An intermediate step of assigning each task and behavioral performance objective to one of seven categories, based on its psychological properties with respect to retention, is used in assessing objective perishability. The first four procedural steps in Phase Three make up this subphase.

The second subphase is concerned with assessing, in general terms, the ability to implement the nominated ETRs, and identifying candidate approaches to implementing each task and objective identified as suitable for inclusion in an ET package. The final two procedural steps make up this subphase.

NOTE: In evaluating the feasibility of implementing the ETRs, there are a number of decisions which are made which have potential impact on the need to include features or capabilities in the prime system design to effectively implement ET. These needs can sometimes have a significant effect on the design of the prime item system. It is critical that material developers be made aware of such needs very early in the system design process, so that these needs can be satisfied by the system design. Also, material developers can often provide information about evolving system characteristics and capabilities which influence decisions about the feasibility of implementing tasks and objectives in the ET component. It is critical that early and frequent interaction between the ET requirements developer and material developers take place to insure that such information is exchanged. It is strongly recommended that an ongoing dialogue with responsible personnel in material development for the system (commonly the Project Manager's staff) be established at the beginning of this phase, and that this dialogue be continued throughout the remainder of the ETR development process.

The subsections which follow present procedures for performing the analyses and steps to identify the behavioral performance objectives which are ETRs for a system.

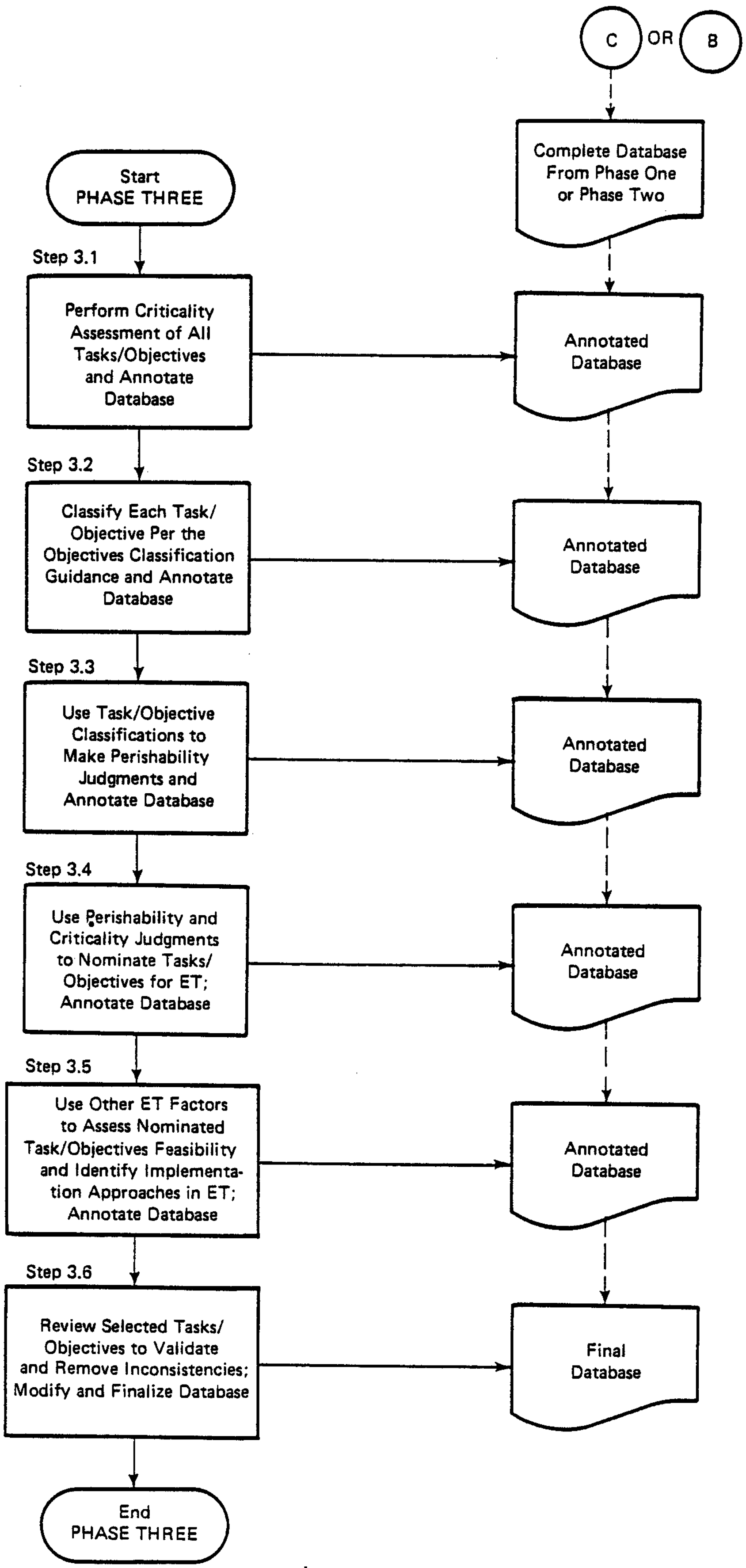
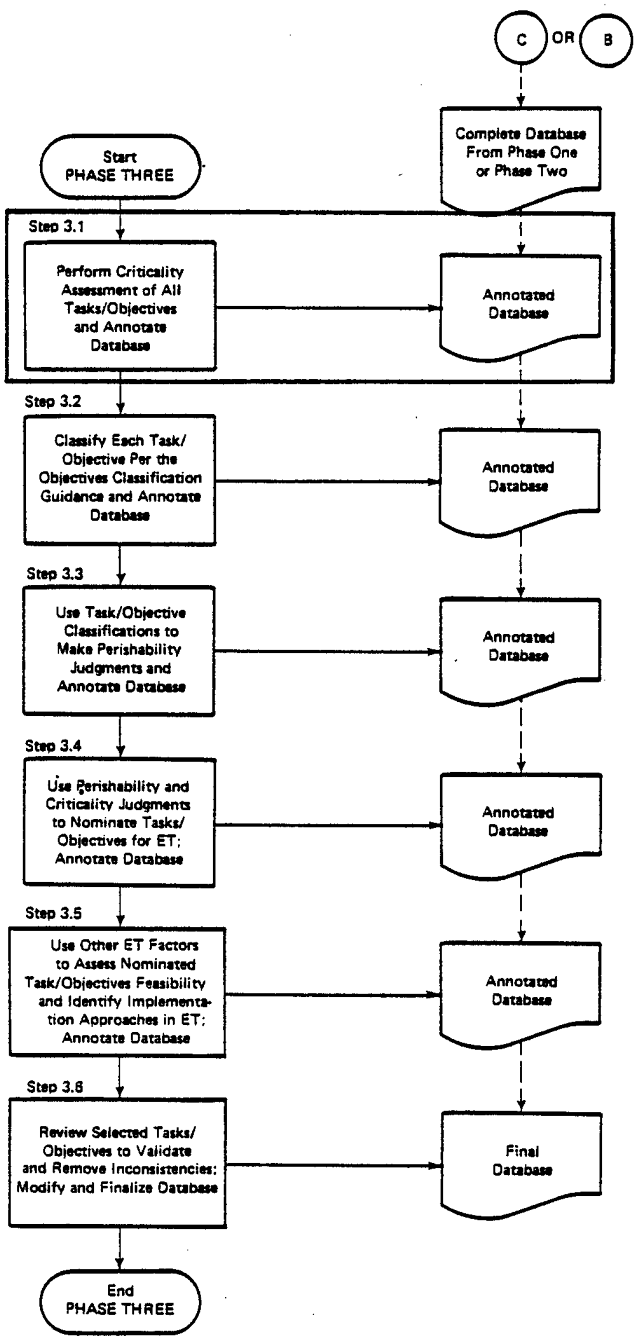


Figure 4. Overview of Phase Three Procedures

Step 3.1 -- Perform Criticality Assessment



The generation and use of Form 3 (see Appendix C) for interim data recording is suggested for this step

Step 3.1 -- Perform Criticality Assessment

Objective: Classify each behavioral performance objective in the database as to its level of criticality to successful mission accomplishment.

Rationale: Since a principal role of ET will be to provide sustainment training, the objectives that are most important to effective soldier performance must be included in the ETRs. This step identifies the general level of criticality of each behavioral performance objective to mission accomplishment.

Procedure: Obtain a listing of all the unique tasks and objectives in the project database. For each task and objective, evaluate the importance of the task or objective to effective mission accomplishment, according to the guidance provided below. It is critical that SME judgments support the criticality classifications in this step; documentation generally cannot be relied on to provide the context needed to assess criticality. A panel of two or more SMEs should be used for developing criticality judgments, to ensure that individuals' unique perspectives do not bias the results. In classifying the criticality of the tasks and objectives, use the following categories and decision guidance:

HIGH criticality - there is more than a 50 percent chance that mission failure will occur, equipment will be seriously damaged, or personnel will be injured or killed, if the task or objective is not performed correctly.

MODERATE criticality - there is between a 25 percent and a 50 percent chance that mission failure will occur, equipment will be damaged, or personnel will be injured, if the task or objective is not performed correctly.

LOW criticality - there is less than a 25 percent chance that mission failure will occur, equipment will be damaged, or personnel will be injured, if the task or objective is not performed correctly.

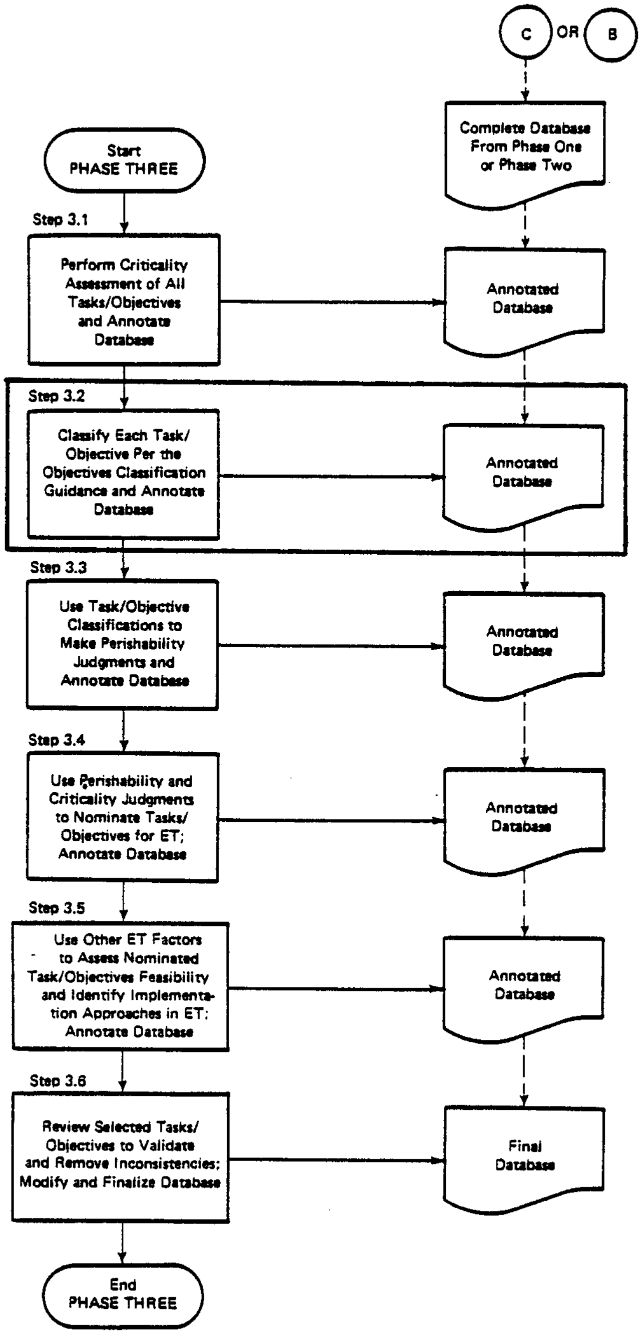
Assign each task or objective to one of the three criticality categories. If there is doubt about which of the categories a task or objective should be assigned to, assign it to the highest criticality category being considered.

As the criticality ratings are made, add a code indicating the level of criticality assigned to each task or objective to the appropriate database records. Use of the first letters of the three categories (H, M, L) is suggested.

If possible, an independent review of the criticality ratings by SMEs not involved in the original ratings development is desirable. This provides independent verification of the criticality assessments, which feed directly into the decision to include tasks and objectives as ETRs. If no independent SME review is possible, the personnel who originally made the criticality judgments should review the criticality data for each task and objective after it has been entered into the database, as verification.

Product: Criticality judgments of each task and objective assigned, and appropriately coded in the project database.

Step 3.2 -- Categorize Tasks and Objectives



The generation and use of Form 3 (see Appendix C) for interim data recording is suggested for this step

Step 3.2 -- Categorize Tasks and Objectives

Objective: Categorize each task and objective according to its general learning and retention characteristics, to support assessment of the perishability of each task and objective.

Rationale: Different kinds of skills, knowledge, and abilities decay at different rates when not practiced under conditions where feedback is provided. Seven categories have been defined which have different performance and retention characteristics that impact on their overall level of perishability. Each task and objective can be classified into one of the seven categories. In addition to helping in the identification of perishability, these classifications also provide information which is useful in the later design and structuring of an ET package for a system. The classifications are performed at this point to support both uses of the data.

NOTE: If desired, this step may be performed at the same time as Step 3.1. The steps are separated because of the necessity of using SME input for Step 3.1. SME input is not required for this step, but may be useful in clarifying the category into which a particular task or objective should be placed, if there is doubt about the classification.

Procedure: Obtain a listing of all tasks and objectives in the database. Using the objectives classification guidance shown in Table 1, classify each task and objective into one of the seven categories. Assign the appropriate numeric code shown in the classification guidance table to each task and objective as it is classified. Enter the classification codes into the database.

NOTE: In some cases, the classification of a task or objective may appear ambiguous, with the possibility that the task or objective may fit into more than one classification. In cases like this, assign the task or objective to the classification with the highest number code being considered. This will avoid "underclassifying" tasks and objectives as to their level of perishability, in the next step.

Product: Classification codes assigned to all tasks and objectives, and entered in the project database.

Table 1

OBJECTIVES CLASSIFICATION GUIDANCE

Class. Code	Task or Objective Type	Description	Examples
6	Integrated Multiple Skills Performance	Coordinated task performance, using multiple complex skills in a manner governed by rules; requires flexible adaptation to changing mission conditions and threats. Normally highly perishable.	Perform air-to-ground weapons delivery; Plan tactical disposition of units; Lay howitzer using manual methods; Coordinate concentration of fire from multiple sources; Direct air strike
5	Variable or Contingency Procedures	Performance of procedures requiring flexible response to a wide variety of contingencies; normally associated with a single task or skill area. Moderately to highly perishable.	Start turbine engine, compensating for abnormal conditions; Assess and correct weapon stoppage; Troubleshoot failed jammer subsystem
4	Rule or Concept Utilization	Simple or complex classification or decision tasks or skills based on applying concepts or rules to available information or situations. Moderately perishable.	Identify ground vehicle type from seeker video; Determine aspect of airborne target; Compute meteorological effects on artillery fires; Select munitions type based on target characteristics
3	Invariant Procedures	Specific procedures directed toward completing one major task or activity; seldom with contingencies. May be composed of many steps, but performance is essentially linear. Low to moderate perishability.	Perform preflight inspection of aircraft; Strip, clean, and reassemble M16A2; Compose tactical message in JINTACCS AG format; Load and fire howitzer; Prepare mortar round for firing

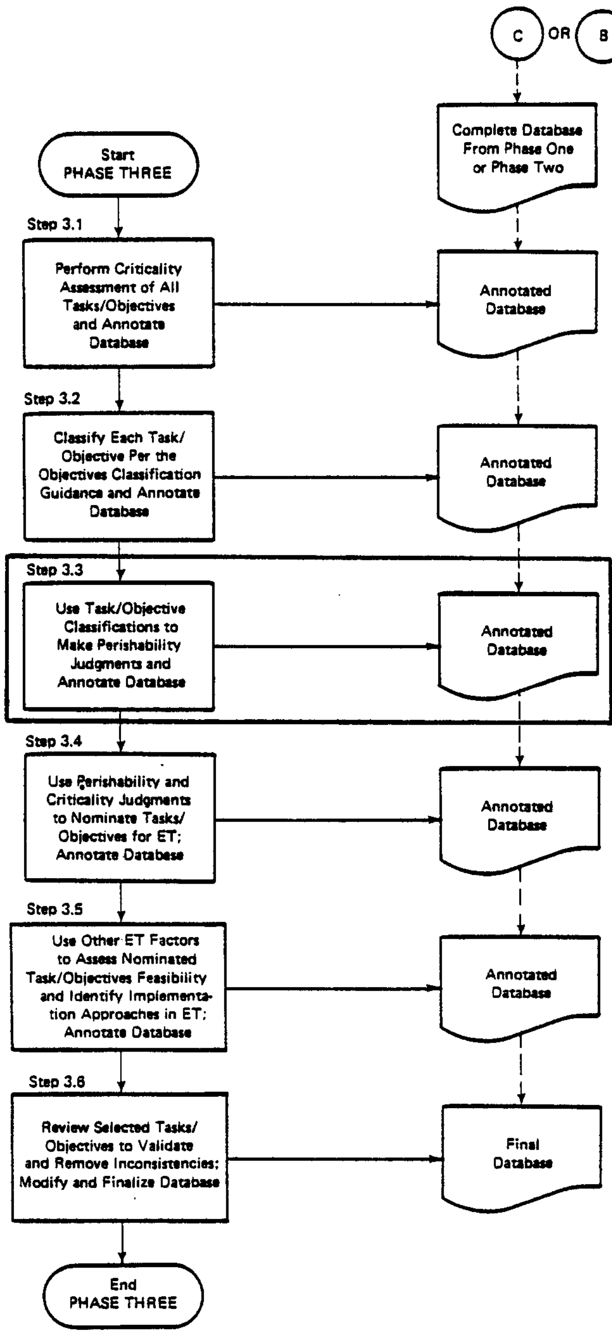
Table 1

OBJECTIVES CLASSIFICATION GUIDANCE
(Concluded)

Class. Code	Task or Objective Type	Description	Examples
2	Basic Manipulative Skills	Manual skills which are concerned with basic aspects of equipment operation or employment; typically prerequisites or components of advanced skills. Low perishability.	Maintain altitude, heading, and airspeed; Load M16A2 rifle; Drive self-propelled howitzer; Set up mine detector; Track target using seeker video and joystick
1	Knowledges	Facts, either about system structure, characteristics, and operation or about specific aspects of mission performance. Low perishability.	State the operational range of the AH-64; Locate the turret traverse switch; Recall the maximum allowable service hydraulic pressure; Recall the location of OPFOR elements; State location of the single-point refueling receptacle
0	Basic Level Behaviors	Behavioral components at a lower level than subtasks or procedures (not knowledges) which are performance components of subtasks or procedures, but which will not be evaluated independently from the subtasks or procedures of which they are components; behavioral skill performance components. Low perishability.	Set MODE switch to DIAGNOSTICS (component of a checkout procedure); Verify LANDING GEAR POSITION INDICATOR shows gear down and locked (component of procedure to lower landing gear); Pull DC BUS B Circuit Breaker (component of an emergency procedure)

NOTE: Basic Level Behaviors are coded to discriminate them from tasks, subtasks, and procedures which are used in determining ETRs. Basic Level Behaviors are identified in task analysis because they make up important content items of the training that will ultimately be developed, but are not of themselves critical for making ETR decisions. In some cases, examining the basic level behaviors which make up tasks, subtasks, or procedures can support decisions about the higher-level performance components in the ETR development process. Basic Level Behaviors should be retained in the database throughout the ETR analyses (and afterwards, as well), but need not be considered individually in making ETR nomination and feasibility decisions in Phase Three.

Step 3.3 -- Develop Perishability Judgments



Step 3.3 -- Develop Perishability Judgments

Objective: Identify the level of perishability of each task and objective, to support identifying which tasks and objectives are nominated as ETRs.

Rationale: Criticality (identified in Step 3.1) and perishability are the two factors used to nominate tasks and objectives for inclusion in an ET package.

Procedure: Using the capabilities of the database management software in use, or manually if necessary, examine the task and objectives classifications made in Step 3.2 (field in the database records for tasks and objectives). Classify the perishability of each task and objective, and annotate the database, according to the following rules:

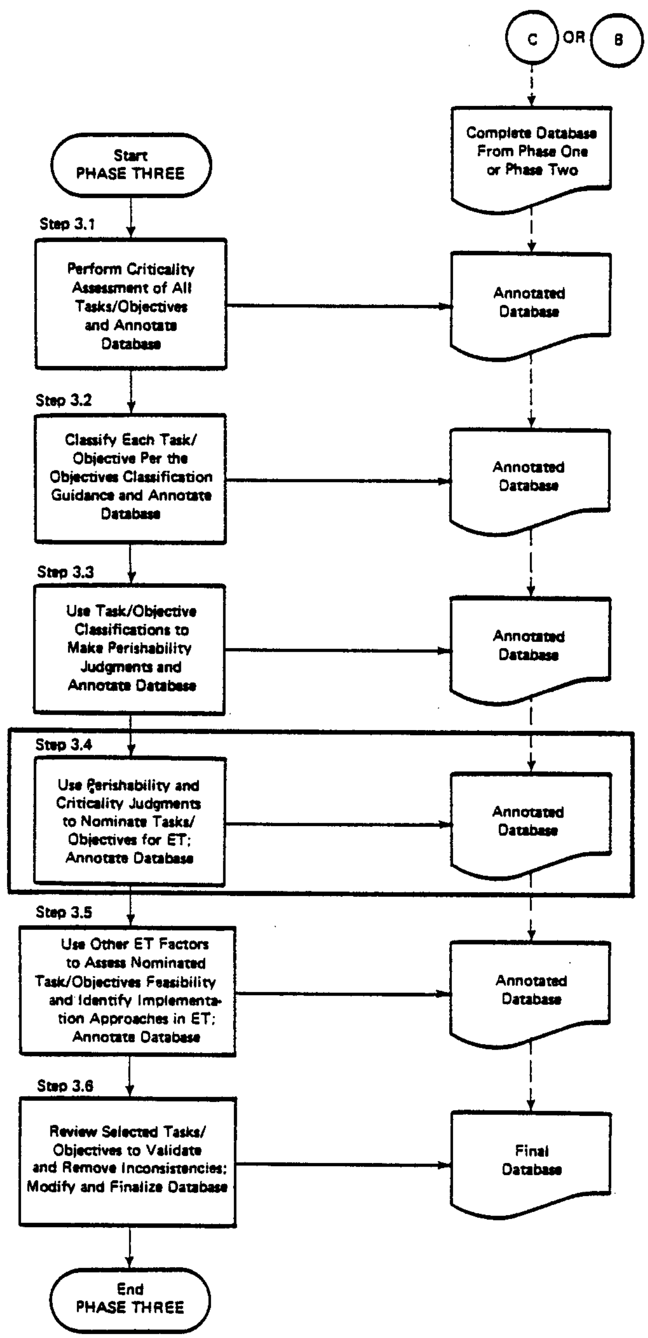
A task or objective is HIGH perishability if it is classified as an Integrated Multiple Skills Performance, classification code 6. Insert the code H in the database record field corresponding to objective perishability classification.

A task or objective is MODERATE perishability if it is classified as a Variable or Contingency Procedure (classification code 5) or a Rule or Concept Utilization (classification code 4). Insert the code M in the database record field corresponding to objective perishability classification.

A task or objective is LOW perishability if it is classified as an Invariant Procedure (classification code 3), a Basic Manipulative Skill (classification code 2), a Knowledge (classification code 1), or a Basic Level Behavior (classification code 0). Insert the code L in the database record field corresponding to objective perishability classification.

Product: Perishability levels identified for each task and objective, and appropriate codes added to the project database.

Step 3.4 -- Perform ETR Nominations



Step 3.4 -- Perform ETR Nominations

Objective: Identify the tasks and objectives in the database which have either High or Moderate criticality or High or Moderate perishability, and designate those tasks and objectives as nominated for inclusion in the ETRs.

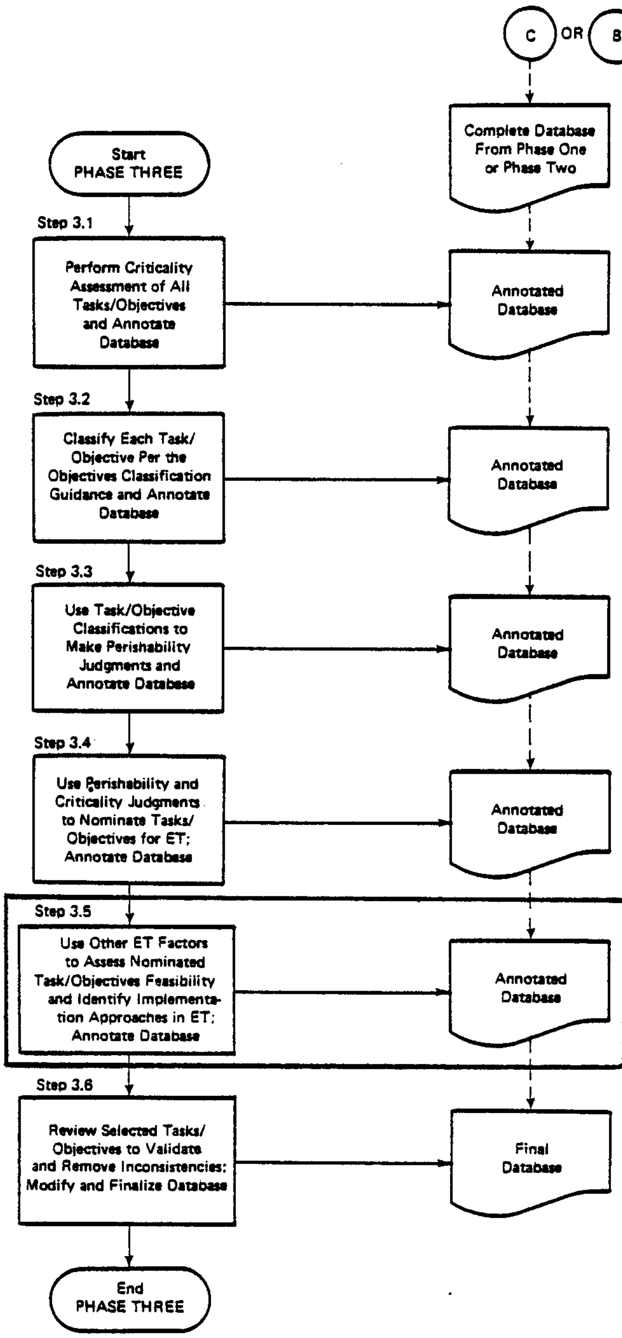
Rationale: High or Moderately critical tasks and objectives and High or Moderate perishability objectives are the best candidates for including in the ETRs. This is due to the fact that many ET components will be used for sustainment training in the unit environment, after initial skills have been acquired elsewhere. To maximize personnel readiness to perform combat missions, critical and perishable skills must be maintained at high levels by sustainment training.

Procedure: Using the capabilities of the database management software in use, (or manually, if necessary) examine the perishability and criticality classifications for each task and objective. Using the following rule, annotate the database record for each task and objective as to whether the task or objective is selected as nominated as an ETR, or not.

If the criticality classification code is H(igh) or M(oderate) or if the perishability classification code is H(igh) or M(oderate), identify the task or objective as selected as an ETR by placing a Y(es) code in the database record field used for that purpose (normally a "Selected for ET" field). If both the criticality and perishability codes are L(ow), identify the task or objective as not selected as an ETR by placing a N(o) code in the database record field.

Product: Identification of each task and objective as nominated for ET (or not) and appropriate annotation of the records of the project database.

Step 3.5 -- Identify Implementation Feasibility and Approaches



The generation and use of Form 5 (see Appendix C) for interim data recording is suggested for this step

Step 3.5 -- Identify Implementation Feasibility and Approaches

Objective: Perform an initial assessment of the feasibility of implementing each task and objective nominated as an ETR, and identify potentially suitable approaches to implementation of the ETRs.

Rationale: The ETR nomination performed in Step 3.4 considers only perishability and criticality, and does not deal with possible requirements for implementing the nominated ETRs. This step provides an initial assessment of each of the ETR-nominated tasks and objectives, from the viewpoint of potential requirements to include the task or objective in an ET package. The analysis here is done on a gross level in an attempt to exclude obviously unsuitable tasks and objectives, and to obtain an initial estimate of the proportion of ETR-nominated tasks and objectives that will be straightforward to implement, and those that will require large amounts of resources or be difficult to implement.

These analyses assume that general characteristics of the soldier-machine interface(s) of the target system can be at least estimated. That is, a concept of how the soldier interacts with the target system and with the environment in which the target system will operate should be available. For example, if most input is provided to a soldier through a video display, or if the soldier sees direct-view or optically relayed images of the visual environment outside the system, these are important characteristics of the way task stimuli are presented by the system. The ways the operator controls the system are also important characteristics that should be considered, especially when thinking about implementing performance measurement requirements for ET. If discrete actions (like moving a joystick or pressing keys) performed by a soldier can be sensed by the ET software, it is likely that performance measurement can be relatively straightforward. On the other hand, if the result of an operator task is a decision or spoken language, it may be impossible for the ET software to sense the outcome (and, thus, to measure performance).

If it is possible to have at least a gross concept of the ways the soldier interacts with the system, this step should be accomplished. If (as is sometimes the case very early in the system life cycle) a concept of the soldier-machine interface is not available, then this step may be bypassed. If this step is bypassed, explicit note of doing so should be made in reporting the ET requirements identified by this process. Assessment of the feasibility of implementing the various ETRs will have to be made during preliminary design of the ET package, if it is not done here.

Procedures: Obtain a listing from the database of each task and objective nominated as an ETR in Step 3.4. This listing must include the complete task or objective statement, and the conditions and standards of performance for each task and objective, as identified in Phase Two. This information will be required to make some of the judgments in the substeps that follow. An overview of the implementation and feasibility decision algorithm that will be used to address the tasks and objectives is found in Figure 5. Study the algorithm until you are comfortable that you understand its structure and the decisions that must be made to go through the algorithm. After you are familiar with the algorithm, follow the procedures below.

NOTE: It is often useful to deal with these decisions on a global basis before performing the detailed analyses at the task or objectives level. In some cases, it may not be necessary to apply all of the decision questions, if you decide that the characteristics of the target system or the tasks under consideration support a global decision about some implementation factors.

For example, if you are dealing with a target system where personnel only interact with a computer terminal or a console, it is probably not necessary to consider whether providing visual or auditory simulation of the non-equipment environment is needed for effective training. In such a case, the questions dealing with visual and auditory environment simulation requirements could be omitted.

If you are able to make this kind of global decision, you can shorten the analysis process so that all questions do not have to be asked for all tasks or objectives which are nominated as possible ETRs. Before you "tailor" these procedures by omitting decision questions, however, review the nominated ETRs and the characteristics of the target system to ensure that questions that you consider omitting are not relevant to providing effective training.

If you are able to "tailor" the decision algorithm, you will be able to omit some of the steps below. However, you should study all of the steps before omitting them so that you will ask the correct questions in your "tailored" procedures. If you do not "tailor" the decision algorithm, follow the exact sequence of questions and decisions as shown below, for each task/objective nominated as a possible ETR.

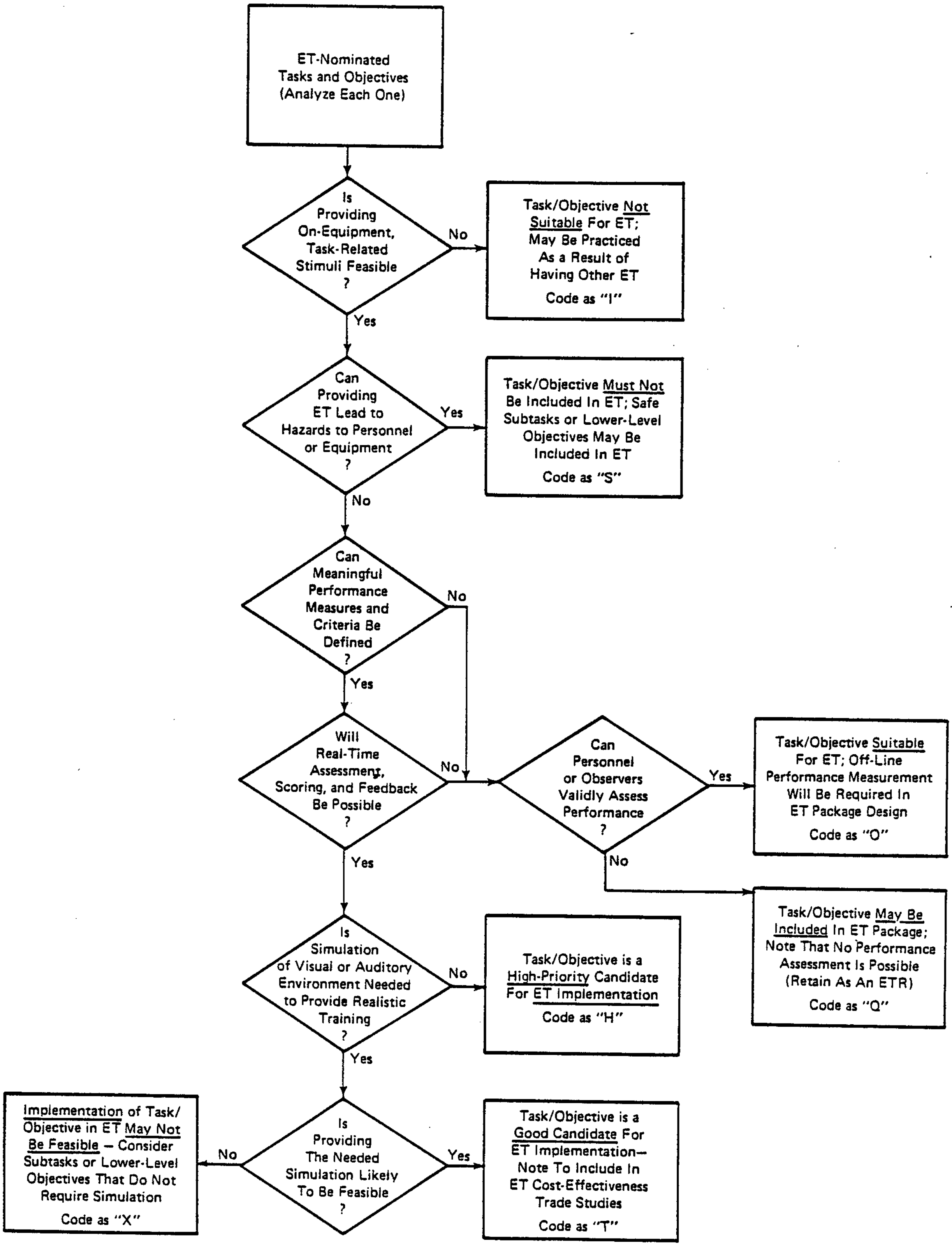


Figure 5. Overview of the Algorithm for Evaluating Implementation Approaches for ETRs

Substep A - Decide whether providing the stimuli needed to perform the task or objective on the target system equipment is feasible. At this point, do not consider stimuli that a soldier may get from other sources than the system equipment. This will be considered at a later step in the algorithm. For example, if most information is presented to soldiers by means of visual display units (VDUs), implementing a task or objective will probably be fairly easy. On the other hand, if most information comes from "round dial" displays, the task or objective may be somewhat be harder to implement. A general guideline to use is that anything that is presented or controlled by a computer or microprocessor in terms of system displays can probably be implemented fairly easily. This includes such things as lighted pushbuttons or function switches, in addition to VDU displays, etc. Note also that, if this analysis is being done in early phases of system development (e.g., concept formulation), it may be possible to provide additional capabilities to implement an ET component. Do not assume that stimuli for a task or objective cannot be implemented without some positive evidence that this is true. It is recommended that material developers be consulted throughout the process of determining whether it is feasible to implement aspects of an ET component on the system.

If you judge that it is feasible to present the stimuli needed to perform the task or objective, then go on to Substep B below.

If you decide that it is not feasible to present the equipment stimuli, you have decided that the task or objective is not feasible to include in ET. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "I." This indicates that the objective is judged Infeasible for implementation.

Substep B - Decide whether providing the task or objective as part of he ET package could result in a situation where there would be hazards to personnel or the possibility of damaging the system or other equipment.

To make this judgment, you will need to imagine or form a concept about how the system might be used in unit training, and how including a task or objective in ET could be hazardous to personnel or equipment. Consider the conditions under which the task or objective is performed in developing this concept. For example, if you are considering an aviation system, and providing visual stimuli on a heads-up display to train a task or objective in-flight would be required, consider whether the stimuli could obscure a crewmember's ability to see safety-related cues in the outside world. A general guideline that can be used is: if the system is in motion during a task or objective, or the task or objective causes gross physical movement of the equipment or its parts, there could be reason to believe that a possible hazard could be created if the objective were included in ET. Another useful guideline is: if a task or objective requires live fire of weapons or handling of live ordnance, there could be a safety compromise if the objective is included in ET. Consultation with material developers may also assist in developing concepts about implementation safety.

The guidelines above should not be thought of as ruling out simulation of damage to the system as part of an embedded training exercise. For example, it may be a useful form of feedback to provide simulated indications that erroneous operator actions have caused the system to be damaged, or in an abnormal state, in response to such actions. Actual damage to the system would, of course, not take place. Also, simulated malfunction indications might be used to provide stimuli for maintenance fault isolation tasks.

If you judge that the possibility of safety compromise does not exist for a task or objective, or that safety compromise is unlikely, then go on to Substep C below.

If you judge that safety compromise is a significant possibility if a task or objective is included in ET, then you have decided that the task or objective must not be included in ET. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "S." This indicates that the objective has been excluded from further consideration for ET because of the likelihood of safety compromise.

Substep C - Decide whether meaningful performance measures and criteria can be defined for the task or objective. In this case, meaningful refers to the ability to identify the way a soldier performs a task or objective, by sensing the soldier's actions or identifying specific outcomes of the soldier's behavior which reflect how well the soldier has performed. When making this decision, you should consider more than just gross-scale "tactical" measures of performance such as the number of targets killed versus the number presented. A useful guideline in this decision is: if it is possible to sense the actions the soldier takes in performing a task or objective, and relate those actions to the outcome of the soldier's performance, as reflected by the performance standards identified in Phase Two, then there is a good chance that meaningful performance measures can be derived. You should consider that any action performed by a soldier which causes a physical change in the controls the soldier interacts with (e.g., changing the position of a switch, moving a joystick, typing in a command on a keyboard) could be sensed by an ET package. As in the safety compromise judgment in Substep B, it may be useful to develop a "scenario" of how a soldier would perform the task or objective, what behaviors the soldier would perform, and what equipment would be involved.

If you judge that meaningful performance measures can be derived by sensing and interpreting operators' actions, then proceed on to Substep D.

If you decide that meaningful performance measures cannot be derived by sensing and interpreting operators' actions, then proceed to Substep E.

Substep D - Decide whether it is feasible to perform assessment, scoring, and real-time feedback of performance related to the task or objective. Performance assessment and feedback to improve performance are critical features of an ET package, so this decision can be crucial. Although the decision is crucial, the information needed to make the decision is often not available.

The actual determination as to whether it will be feasible to provide capabilities for assessment, scoring, and feedback of trainee performance will rest with overall system capabilities. In case of doubt as to whether such capabilities will be made available, it is strongly suggested that discussions with the system material developers be held. If there is a potential need to make special provision for these training support capabilities, requirements for the system can sometimes be augmented to provide the needed capabilities. However, it is extremely important to make such inputs to material developers early in the system acquisition process, so that expensive design changes later in the development cycle can be avoided.

Although this is a tentative judgment, it appears that the limiting factor on this decision is the amount of computer processing capability and storage available through the system or via the ET package. It is perhaps wise to make this decision on a global basis. The question to ask is: will there be processing and storage capacity available to support assessment, scoring, and feedback in general? Frequently, even such a high-level decision will be impossible. If it is not possible to make a decision at this point at either a task/objective level or a global level, skip this decision, and assume that all desirable assessment, performance scoring, and feedback capabilities are possible. However, if this decision is made, do not neglect to perform Substep E for tasks and objectives for which developing performance measures and criteria is not possible.

If you judge that performance assessment, scoring, and feedback are possible for specific tasks or objectives, proceed to Substep F.

If you have made a general judgment that performance assessment, scoring, and feedback are possible through the equipment or the ET package at large, also proceed to Substep F.

If you judge that performance assessment, scoring, and feedback are NOT possible for specific tasks or objectives, proceed to Substep E.

Substep E - For tasks and objectives where either: (a) meaningful performance measures and criteria cannot be derived by measuring soldiers' actions or (b) performance assessment, scoring, and feedback are not possible through the ET package for a particular task or objective, decide whether the soldiers performing the task or objective, or an over-the-shoulder observer or instructor, can provide effective performance assessment and feedback.

Since ET will commonly be used for sustainment training, it is possible that soldiers may be proficient enough to evaluate their own performance and diagnose their own errors, in some cases. Also, if the ET package cannot provide performance assessment, scoring, and feedback, it may be possible to provide an instructor or observer to do so.

Two guidelines are useful in making this decision. In the case where you are considering whether the soldiers themselves can assess their own performance, decide whether: (a) in a crew situation, some crewmembers are likely to be more proficient or senior than others; or (b) in any situation, the overall level of proficiency and expertise of task performers is likely to be high. If either of these considerations is true, self-assessment potential is high, and it is probably feasible to allow crewmembers or individual soldiers to assess their own performance in an ET environment.

In the case where you are considering the possibility of over-the-shoulder evaluation, consider whether it is possible for an evaluator to observe exactly what situations and stimuli are presented to the trainee, and what the trainee's actions and behaviors are. If this is judged to be the case, then the probability of successful over-the-shoulder evaluation is high. Whether it is feasible to provide over-the-shoulder evaluation from other standpoints (such as personnel requirements or cost) should not be considered at this time.

If you judge that self-assessment or over-the-shoulder evaluation is reasonably feasible, you have identified the task or objective as suitable for ET with off-line performance measurement. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "O." This indicates that the objective has been judged feasible for ET implementation with Off-line performance measurement.

If you judge that self-assessment or over-the-shoulder evaluation are not possible for a given task or objective, the value of including the task or objective in an ET package is questionable. If this decision is reached, the task or objective will be retained in the ETRs for the time being, but will be coded specifically to reflect that performance measurement is not possible. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "Q." This indicates that the objective is Questionable from the viewpoint of performance measurement.

Substep F - Decide whether the task or objective requires simulation of any aspects of the visual or auditory environment external to the equipment in order to provide all needed stimuli to accomplish the task or objective. This includes such stimuli as out-the-window views of the environment, images from remote or indirect sources such as cameras or infrared sensors, weapons firing sounds or visual impact signatures, or any other completely external stimuli. In general, such stimuli are difficult and costly to provide, so the need for them must be carefully considered. However, if static images are required, it is more feasible to provide them than if dynamic images are required.

In making this judgment, knowledge of the stimuli which are present in the actual task performance situation will be critical. Use the conditions of performance data provided for each task and objective to support this decision. "Scenarios" of how the task or objective is performed, and how the soldier interacts with the equipment and the performance environment may be useful in making this decision. In general, if a soldier receives stimuli from a source outside the equipment itself which are critical to task or objective performance, then it will probably be necessary to simulate those stimuli in the ET package.

If you judge it is necessary to provide visual or auditory environment stimuli in order to present the task or objective to the trainee, proceed on to Substep G.

If it is not necessary to provide visual or auditory environment stimuli, then you have finished with the decisions for this task or objective. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "H." This indicates that the task or objective is a High-priority candidate for implementation in the ET package, and is retained as an ETR.

Substep G - Decide whether providing the needed visual or auditory stimuli is likely to be feasible. There are two aspects of the stimuli and the task/objective situation to consider in making this decision. The first is whether a static representation of the visual environment can be used, or whether a dynamic representation is required. (Auditory stimuli cannot be static.) If visual motion of any portion of the external environment has to be simulated, then a dynamic representation is required. If a completely static representation of the "outside visual world" will do, then it is probably feasible to provide that presentation.

As with assessment, scoring, and feedback capabilities, the implementation of visual and auditory simulation requirements will interact strongly with system characteristics. If visual and auditory stimulation requirements are identified as necessary for implementing ET, it is strongly suggested that these requirements be made known to material developers as early as possible. If early identification of these requirements is made, it may be feasible to augment system capabilities to make presentation of such stimuli possible, or to provide for these capabilities in the system design. The decision to implement these capabilities must be coordinated with the material developers, however. Providing simulation capabilities to support ET may have significant impacts on system design, and knowledge of possible requirements for these capabilities is essential in the design trade-off process for the system. Decisions about including these capabilities should be made jointly with material developers.

If a dynamic representation of either auditory or visual aspects of the external environment is required, then the required level of fidelity of presentation must be considered in judging feasibility. If a soldier will have to use the representation to make fine judgments about the characteristics or dynamic nature of what is presented, then a high-fidelity presentation will be required. Examples include discriminating subtle visual characteristics to classify targets by their visual signatures, and judging by sound how many rounds have been fired from an automatic weapon.

If the soldier will only be required to make gross judgments about the presence or absence of major features of the environment representation, then a lower level of fidelity will be required. Examples include judging whether artillery aiming stakes are lined up in a sight reticle, and discriminating the presence of an auditory warning tone from background noise.

Visual and auditory fidelity decisions can be difficult, and the examples above are extremes; there are many points between them on the fidelity continuum. In general, consider the fineness of judgment about the external environment that the soldier will have to make, given what is presented. The finer the judgment, in general, the higher the fidelity required in the stimulus presentation, and the lower the feasibility of providing the needed stimuli will be (other things being equal).

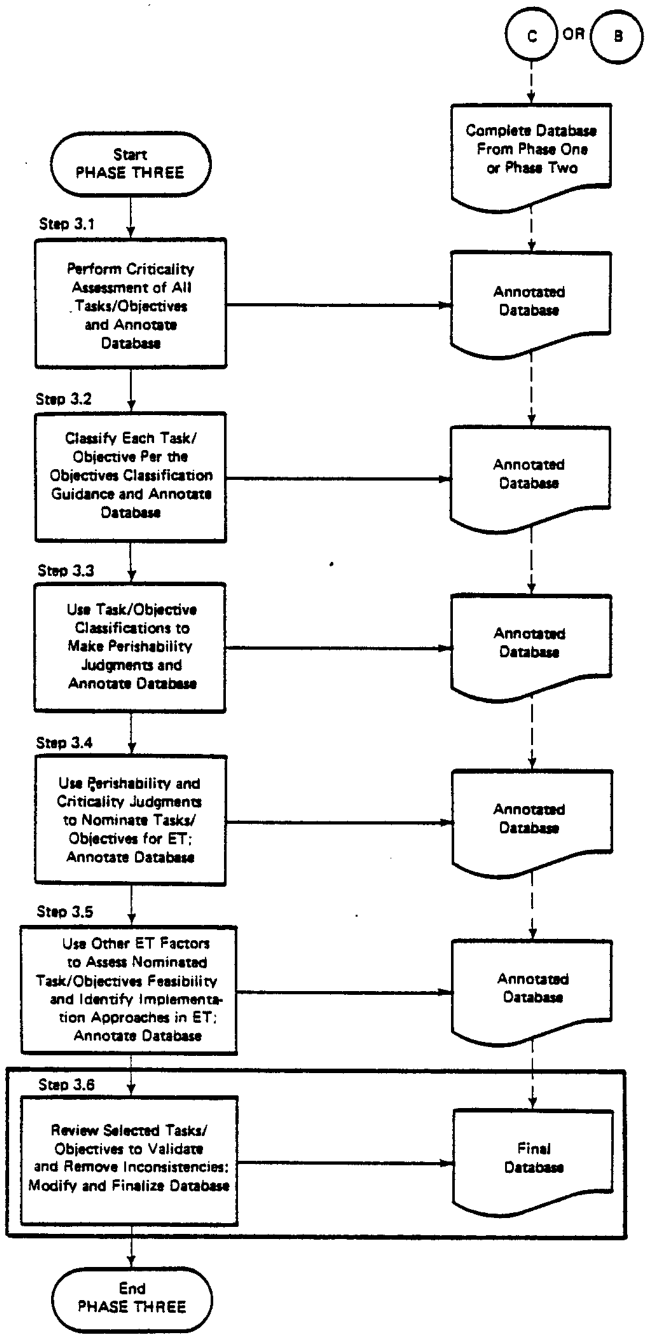
If you decide that it is <u>at least marginally feasible</u> to consider including the needed level of fidelity in simulating the external environment, then you have classified the task or objective being considered as a good candidate for ET. It will be retained in the ETR. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "T." This indicates that the objective will require simulation of exTernal auditory or visual stimuli, but that providing that simulation is considered feasible.

If you decide that <u>it is probably not feasible to include the needed level of simulation fidelity</u>, then you have <u>contingently excluded</u> the task or objective being considered <u>from the ETRs</u>. Some subtasks or lower-level objectives that are subordinate to a task or objective may still be good candidates for inclusion, however, and should be carefully considered, in turn. When you make this decision, annotate the task or objective "ET Feasibility Judgment" field in the appropriate database record with the code "X." This indicates that the objective has been eXcluded from further consideration for ET because providing the needed external environment stimuli is probably not feasible.

At this point, all decisions in this step about the task or objective under consideration are complete. Proceed to analyze the next task or objective on the listing.

<u>Product</u>: ET feasibility and implementation approach judgments, coded and added to the project database.

Step 3.6 -- Review ETRs and Correct Inconsistencies



The generation and use of Form 6 (see Appendix C) is recommended

Step 3.6 -- Review ETRs and Correct Inconsistencies

Objective: Identify ETR selection anomalies among the tasks and objectives, correct the anomalies, and validate the project database.

Rationale: In some cases, the strict nomination criteria for ETRs (perishability and criticality) will not nominate all of the tasks or objectives which are above a nominated lower-level task or objective. This is a mistake: if a lower-level task or objective is nominated as an ETR, then all of the tasks/objectives superior to it in the hierarchy should be nominated, as well. A lower-level component being validly nominated as an ETR should result in all of the components above it in the hierarchy being nominated.

The reverse case, where a higher-level task or objective is nominated, but lower-level tasks or objectives are not nominated, is not a cause for concern. A perishable or critical aspect of performance can have some non-perishable or non-critical components.

This step will identify cases where low-level tasks or objectives are nominated, but elements superior to them in the hierarchy are not. Then, the hierarchy will be examined to identify the source of the problem and it will be corrected.

Procedure: Obtain a listing of the entire database, indexed by hierarchy codes. As a minimum, codes, task and objective statements, criticality judgments, objectives classifications, perishability judgments, ET nomination codes, and feasibility codes should be included in this listing. Then, examine the task and performance objectives hierarchy in detail, and identify all cases where lower-level tasks or objectives are nominated as ETRs and higher-level elements above them in the hierarchy are not nominated.

For each case where this occurs, examine the criticality and perishability judgments and the objectives classification for the lower-level task or objective first. Determine if a mistake has been made in assigning codes for any of these data items. Also, determine if wrong judgments may have led to the assignment of the erroneous codes.

If it turns out that the only error is in coding or judgment of one or more factors for the lower-level task or objective, simply correct the appropriate items in the database. This is the most likely case, if the preceding steps have been done conscientiously.

Otherwise, it will be necessary to examine each of the tasks and objectives superior to the lower-level task or objective, determine where erroneous judgments have been made or wrong database codes have been inserted, and correct all problems that are found.

As the database is examined, also look for minor errors such as misspellings and missing information. Correct any such errors, where possible. The database will be used to support the design of the ET package. Thus, it should be comprehensive, accurate, and complete at the end of this step.

Product: The final analysis database, reflecting the task and performance objectives hierarchy, all judgments made in the ETR definition process, the nominated ETRs, and the implementation judgments.

SECTION 5

PHASE 4: FINAL DOCUMENTATION

Objectives

The ETRs feed three subsequent processes. First, the output from the ETR analyses is used in the ET design process, where the form and content of ET are structured. Second, the ETRs have strong implications for early hardware and software decisions that are part of the design process for the prime equipment in which training is to be embedded. Third, after the decision has been made to develop ET, courseware and training development processes will use the database developed in identifying ETRs. The purpose of this section is to structure the outputs from the ETR process so that they are maximally useful to support these processes. While this section does not prescribe exact procedures for generating outputs, a general structure is provided. This structure is reflected in Figure 6.

Rationale

The final documentation and database resulting from the ETR analyses contains a large amount of data; in the next subsection 17 different data elements are listed. These data elements are either descriptions or multiple logical entries. The most useful way to present most of this information is on a task-by-task basis. If one were to create a listing that has several columns, the information about each task might be seen side-by-side. The sheer amount and number of different data items pertinent to a task or performance objective make the concurrent presentation of all of the data items impossible. It is necessary to break this information down into coherent smaller reports so that each user sees relevant information quickly, and can perform rapid analyses of the data to facilitate decision making.

The purpose of this section is to specify formats for a set of data reports that present this information to different users, in a usable way. Some of the information is presented more than once, because different processes require both common information and unique information.

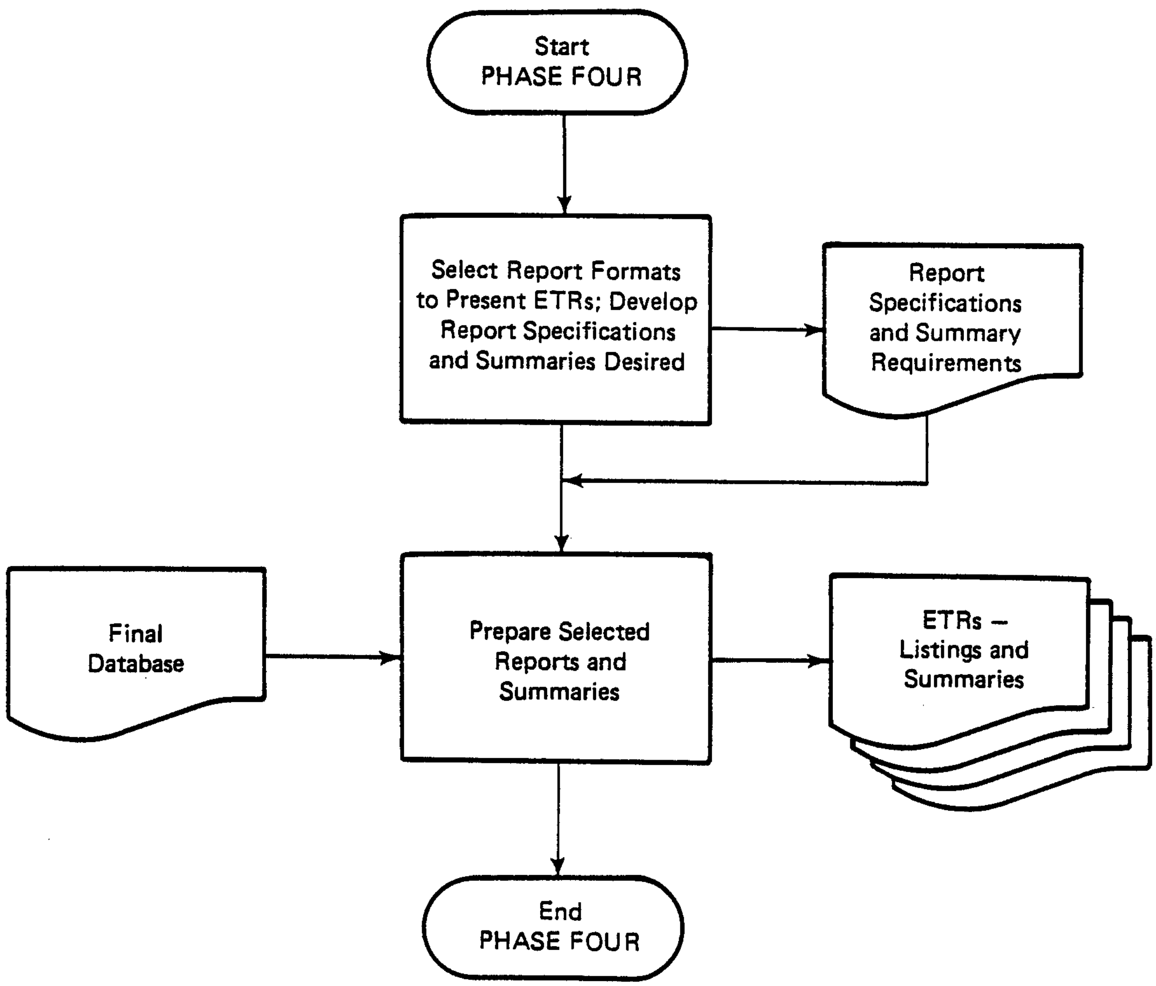


Figure 6. Overview of Procedures to Prepare ETR Documentation

Procedure

Data items in each task or objective record come from the analyses performed in Phases One through Three. The data to be formatted and organized are in 3 categories: (1) task analysis data, (2) ET development data, and (3) audit trail data.

Data Elements to be Reported

Task/objective analysis data are:

1. Task/objective number generated during analysis (also mission and phase numbers).

2. Task/objective title/statement (also mission and phase titles).

3. Conditions of performance.

4. Standards of performance.

5. Common phase and task/objective numbers.

6. Crew positions involved in the performance of the task.

ET development data are:

1. Objectives classification.

2. Task/objective perishability rating.

3. Task/objective criticality rating.

4. ET nomination.

5. Implementation approach for task/objective within ET.

Audit trail data are:

1. Source of task/objective description information.

2. Page reference within the information source.

Content of Data Elements

The above data elements are explained here. Justification of the content and examples of the data elements are included as appropriate.

Task/Objective Number. This is assigned to the task/objective by the analysis team. The numbering system is hierarchical; longer numbers represent lower-order tasks/objectives that enable the performance of higher-order task/objectives. A convenient approach is to use two digit numbers to represent mission phases (e.g., 02, Mission Preparation phase), two additional digits separated from the phase digits by periods to represent tasks (e.g., 02.06, Load Ammunition), two more digits to represent subtasks/subobjectives, and so forth for finer subdivisions, with each two digits separated from the previous pair by a period. Each lower-order subtask/subobjective is required for the proper performance of the higher order phase/task/objective.

Title/Description. This is a title or description of the task/objective. The wording of the task/objective descriptions should be chosen carefully. Each description of a task/objective, subtask/subobjective, etc. should be able to stand alone. That is, if the description were to be written outside the context of the task/objective elements above and below it, the reader should understand it. For example.

Incorrect

02.06.01	Perform a receipt inspection on the projectile.
02.06.01.01	Unpackage.
02.06.01.02	Inspect.

Correct

02.06.01	Perform a receipt inspection on the projectile.
02.06.01.01	Unpackage the projectile.
02.06.01.02	Inspect the projectile.

Conditions of Performance. These are the circumstances under which the task is performed as identified in Phases One and Two.

Standards of Performance. This is how well an action must be performed. For the ETR, this statement only specifies the measure or dimension of performance measurement (e.g., speed of trigger pull, distance from target), and not the actual values.

Common Task/Objective Numbers. Some activities are called for more than once in a task/objectives hierarchy. For instance, "Prepare for firing" might appear under both manual and automatic firing tasks/objectives. All the numbers that refer to the same activity are common task/objective numbers.

Crew Position. These are the crew positions that are involved in the performance of the particular task/subtask, and are the targets of training. A task/objective that has lower-level subtasks/subobjective includes the crew positions that are involved in the subtasks/subobjective.

Objectives Classification. This is the classification of the objective into one of seven types, performed during Phase 3. This information is used in the rating of perishability, and is described in Section 4.

Perishability Rating. Perishability is defined as the likelihood that task performance will suffer if the task is not practiced. This rating can take values of low, medium, or high. Task perishability is inferred from the objective classification, which is performed in Phase 3. A procedure to generate task perishability ratings is found in Section 4.

Criticality Rating. Criticality is defined as the likelihood that a given task may result in mission failure, personal injury, and/or damage to equipment. This rating can take values of low, medium, or high. Criticality ratings are performed in Phase 3, and the classification scheme is presented in Section 4.

ET Nomination. This nomination is a product of the ET decision model that is applied in Phase 3. There will be a nomination of the suitability for ET for each task/objective.

Implementation Judgment. This is the code assigned during assessment of the implementation potential of each ET-nominated task and objective, in Phase Three. Codes which will appear in this data field are described in Section 4.

Source of Information. This is a statement of where the information for the task/objective description or other data were obtained. As the task/objective analysis is developed to the appropriate level of detail it sometimes becomes unclear where the information about a task/objective or subtask/subobjective came from. Sources of data include original task/objective listings, Plan of Instructions (POIs), training manuals, engineering data, system development briefings, SME inputs, and so forth. A training feature may be developed to serve a particular training need, and questions may arise about the substance of this task. The source of information pinpoints the exact wording of original task/objective information and also helps in evaluating the currency of the information source. Document numbers should be included. This field should be initially used when source information is first identified and used in task identification. The field should be expanded and/or updated if new information is gathered or discovered.

Page/Reference Number. Information about where in the source the information was found speeds checking of the original source documentation.

Military Service Task/Objective Number. If the original source of information for this task/objective was a military task/objective listing, then there is a task/objective number already assigned to the task. This number should be included in the audit trail data, even if subsequent editing results in minor word changes. Note that this is only the administratively-accepted task number which corresponds to an identified task. The "working" task number (see Phase Two and Appendix C) is used for analysis. The number in this field is included to provide a cross-reference to official documentation which may have been used as source material.

Products

Reports are relatively easy to generate if the data collection has made use of a computer-based DBMS, because these systems usually have built-in report generators that can structure the data output to fit the formats described.

The above data elements could be reported in one large printout, but this would require that they be listed sequentially for each task/subtask or objective/subobjective. This approach is not amenable to rapid overview and quick consultation for analytic and decision making purposes.

An approach that is better suited to further analysis is to present the data in matrix form, with each task/objective or subtask/subobjective occupying a row in the matrix, and with the proper data elements in columns. Using this approach, there is too much information for either dimension, rows or columns, to fit on a page. The solution is to generate separate reports that include the data required for the purposes of each report. This approach is taken for all but the first report, which is a task/objective analysis reference document.

There are two data elements that are common to all reports: task/objective number and task/objective statement. It is difficult to make sense out of a report without the description, and the number provides a unique reference. Reports are designed so that they can easily be printed and published. All but the first report are of a size that can be printed across wide paper (130 columns), which can be bound sideways in a report; the first is standard width (75 columns).

Report 1--Task/Objective Analysis Overview. This report contains the basic task/objective analysis information. Its data elements are: task/objective number, task/objective description, crew positions, conditions of performance, standards of performance, and common task/objective numbers. Each data element is listed sequentially as a separate row, unlike the other reports. This report is sorted or indexed by task/objective number. This information is useful during efforts aimed at producing courseware or generating a final task/objective analysis.

Report 2--ET Nominations. This report is printed in 130 columns and contains: task/objective number, task/objective description, crew positions, objectives classification, perishability rating, criticality rating, ET nomination, and implementation approach. The purpose of this report is to be able to look at all tasks and see which ones are nominees for ET along with the data supporting this nomination. This report is sorted or indexed by task/objective number.

Report 3--ET Nominations and Implementation Judgments. This report is printed in 130 columns and contains: task/objective number, task/objective description, ET nomination, and implementation approach. It is useful to present this report indexed by task/objective number.

Report 3A--Crew Position Breakdown. This is a series of ET nomination and implementation judgment reports, one for each crew position. Only the data pertaining to the individual crew position should be included in each report. This report is of use when revising prior training and training guidance material already organized by crew position. These reports also provide a clear picture of how many ET-nominated objectives and tasks pertain to each crew position.

Report 3B--ET Task/Objective Listing. This is an optional report that presents the data of Report 3, but only for those tasks for which ET is nominated. The ET nomination column is deleted. If the full task/objective listing is quite large, then this listing is useful in reviewing ET and determining requirements for implementation.

Report 4--Audit Trail. This report is printed in 130 columns and contains: task/objective number, task/objective description, source of information for the task/objective description, page reference within the information source, and military service task/objective number (if applicable).

Report 5--Common Task/Objective Numbers. This report is printed in 130 columns and contains: task/objective number, task/objective description, and common task/objective numbers. The common task/objective numbers are often quite long, and this mode of presentation simplifies looking them up when creating courseware.

REFERENCES

Fitzpatrick, J. A., Sullivan, G. K., and Roth, J. T. Procedures for Embedded Training (ET) Package Design. (Draft Working Paper). Valencia, PA: Applied Science Associates, Inc., 1986 (Prepared for the U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Virginia under Contract No. MDA903-85-C-0078).

Strasel, H. C., Dyer, F. M., and Finley, D. L. Implementing Embedded Training (ET) in Army Systems: Preliminary Guidance and Remaining Issues. (Draft Working Paper). Columbus, GA: Hi-tech Systems, Inc., 1986.

APPENDIX A

Weapon System Operational Mission Model

This Appendix presents a generic mission model that can be applied to a weapon system during the task/objective analysis. The model aids analysts in structuring the tasks/objectives into a hierarchical form. This model is suitable only for weapon systems and their operational missions. The model uses the following phases to describe the operational mission:

1. Planning
2. Preparation
3. Movement
4. Deployment
5. Operation
6. Replenishment/Resupply
7. Post-Mission

The first two phases normally occur once during a mission. Phases three, four, five, and six can occur numerous times and in different order during a mission. The final phase normally occurs once, at the end of the mission. Figure A-1 presents these phases in hierarchical form.

Planning Phase. Crews perform some planning tasks/objectives which are normally covered by doctrine in the form of Standard Operating Procedures (SOP). These tasks/objectives are often performed at a briefing site and result in a briefing to disseminate mission information.

Preparation Phase. Tasks/objectives associated with weapon system initialization, preventive maintenance checks and services (PMCS), communications checks, and operator maintenance.

Movement Phase. Transporting and navigating the weapon system. It includes movement to, within, and from the deployment site. Contingencies such as navigational system failure are important during this phase.

Deployment Phase. Emplacement, camouflage, and defense posture of the weapon system. It may include initialization procedures for weapon subsystems secured during movement.

Operation Phase. Operating the weapon system and engaging the enemy. In sensor driven weapon systems, this phase is divided into search, detect, track, acquire, identify/classify, engage, and assess engagement. Other aspects of this phase may include: operating communications equipment; performing unusual operations, such as fire-fighting or NBC warfare; and contingencies, such as response to weapon system equipment failures and response to tactical changes.

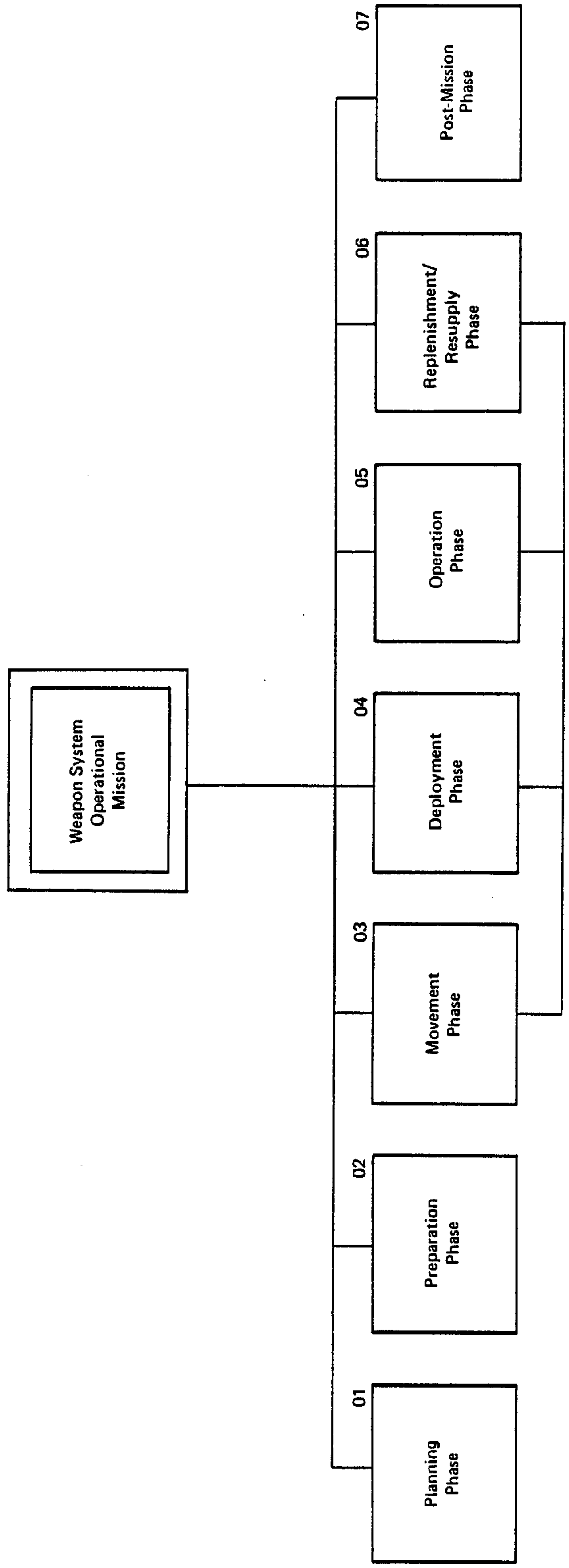


Figure A-1. Weapon System Operational Mission Model

Replenishment/Resupply Phase. Resupplying ammunition, fuel, and other commodities needed by the weapon system. This phase may include requesting a resupply mission and coordinating a rendezvous with a resupply vehicle.

Post-Mission Phase. Weapon system shutdown, clean-up, and post-mission preventive maintenance checks and services, and mission debrief. Most of the tasks/objectives in this phase are procedures.

APPENDIX B

TASK/OBJECTIVE ACTION VERBS AND THEIR DEFINITIONS

INTRODUCTION

This Appendix lists action verbs that may be used in a task or objective title and its definition. Some specialized verbs, not listed here, may be needed for particular weapon systems. For example, "lay" is commonly used in task or objective titles for cannon-type weapon systems, but is not applicable to all weapon systems. Verbs for operator maintenance tasks/objectives are included in this listing. Many of the verbs presented here are synonymous. The analysts should select the one verb which appears to be best and use it consistently throughout the analysis.

Accomplish	To do, carry out, or bring about; to reach an objective.
Achieve	To carry out successfully.
Acknowledge	To make known the receipt or existence of.
Actuate	To put into mechanical motion or action; to move to action.
Adjust	1. To bring to a specified position or state.
	2. To bring to a more satisfactory state; to manipulate controls, levers, linkages, etc.; to return equipment from an out-of-tolerance condition to an in-tolerance condition.
Administer	To manage or supervise the execution, use, or conduct of.
Advance	To move forward; to move ahead.
Advise	To give information or notice to.
Alert	To warn; to call to a state of readiness or watchfulness; to notify (a Person) of an impending action.
Align	To bring into line; to line up; to bring into precise adjustment, correct relative position; or coincidence.
Allocate	To apportion for a specific purpose or to particular persons or things.
Allow	1. To permit; to give opportunity to.
	2. To allot or provide for.
Analyze	To examine and interpret information.
Announce	To make known.
Apply	1. To lay or spread on.
	2. To energize.
Arrange	To group according to quality, value, or other characteristics; to put in proper order.
Assemble	To fit and secure together the several parts of; to make or form by combining parts.

Assess	To determine the importance, size, or value of; to evaluate.
Assign	To apportion to for a specific purpose or to particular persons or things; to appoint to a duty.
Assist	To give support or help; to aid.
Attach	To join or fasten to.
Authenticate	To prove or serve to prove the authenticity of.
Balance	To equalize in weight, height, number, or proportion.
Brief	To give final precise instructions; to coach thoroughly in advance; to give essential information to.
Calculate	To determine by arithmetic processes.
Calibrate	To determine accuracy, deviation, or variation by special measurement or by comparison with a standard.
Camouflage	To conceal or disguise by camouflage.
Categorize	To put into categories or general classes.
Center	1. To adjust so that axes coincide. 2. To place in the middle of.
Change	1. To replace with another comparable item. 2. To adjust.
Check	1. To confirm or establish that a proper condition exists; to ascertain that a given operation produces a specified result; to examine for satisfactory accuracy, safety, or performance; to confirm or determine measurements by use of visual or mechanical means. 2. To perform a critical visual observation or check for specific conditions; to test the condition of.
Chock	To place a blocking device adjacent to, in front of, and behind a wheel to keep from moving.
Choke	To enrich the fuel mixture of a motor by partially shutting off the air intake of the carburetor.
Choose	To select after consideration.

Classify	To put into categories or general classes.
Clean	To wash, scrub, or apply solvents to; remove dirt, corrosion, or grease.
Clear	1. To move people and/or objects away from. 2. To open the throttle of an idling engine to free it from carbon.
Close	1. To block against entry or passage; to turn, push, or pull in the direction in which flow is impeded. 2. To set a circuit breaker into the position allowing current to flow through.
Collect	To bring together into one body or place; to accumulate.
Command	To direct authoritatively.
Communicate	1. To exchange information. 2. To make known.
Compare	To examine the character or qualities of two or more items; to discover resemblances or differences.
Complete	To bring to an end.
Comply	To conform with directions or rules; to accept as authority; to obey.
Compute	To determine by arithmetic processes.
Condense	To make denser or more compact.
Connect	1. To bring or fit together so as to form a unit, to couple keyed or matched equipment items. 2. To attach or mate (an electrical device) to a service outlet.
Construct	To make or form by combining parts; to fit and secure together the several parts of.
Control	To exercise restraining or directing influence over; to fix or adjust the time, amount, or rate of.
Coordinate	To bring into a common action, movement, or condition.

Correct	To make or set right, to alter or adjust so as to bring to some standard or required condition.
Correlate	To establish a mutual or reciprocal relation between.
Cover	To protect or shelter by placing something over or around.
Decide	To arrive at a solution.
Deenergize	To take energy from.
Define	1. To determine or identify the essential qualities or meaning. 2. To fix or mark the limits of.
Deflate	To release air or gas from.
Deliver	1. To hand over. 2. To send to an intended target or destination.
Demonstrate	To show clearly.
Depart	To go away; to leave.
Depressurize	To release gas or fluid pressure from.
Derive	To infer or deduce.
Describe	To represent or give an account of in words.
Destroy	To ruin, demolish, or put out of existence; to make unfit for further use.
Detect	To discover or determine the existence, presence, or fact of.
Determine	1. To obtain definite and first-hand knowledge of, to confirm, or establish that a proper condition exists. 2. To investigate and decide to discover by study or experiment.
Develop	To set forth or make clear by degrees or in detail.
Diagnose	To recognize and identify the cause or nature of a condition, situation, or problem by examination or analysis.
Disassemble	To take to pieces; to take apart to the level of the next smaller unit or down to all removable parts.

Disconnect	1. To sever the connection between; to separate keyed or matched equipment parts. 2. To detach or separate (an electrical device) from a service outlet.
Discriminate	To distinguish or differentiate by discerning or exposing differences.
Disengage	To release or detach interlocking parts; to unfasten; to set free from an inactive or fixed position.
Dispose of	To get rid of.
Distinguish	To perceive a difference in.
Distribute	1. To apportion for a specific purpose or to particular persons or things. 2. To divide among several or many; to divide or separate, especially into kinds.
Drain	To draw off (liquid) gradually or completely.
Draw	To produce a likeness or representation of.
Drive	To direct the course and motions of a vehicle.
Egress	To go out.
Elevate	To lift up; to raise.
Eliminate	To expel; to ignore or set aside as unimportant.
Emplace	To put into position.
Employ	To put into action or service; to carry out a purpose or action by means of; to avail oneself of.
Energize	To impart energy to.
Enforce	To compel or constrain.
Engage	1. To cause to interlock or mesh. 2. To enter into conflict.
Enter	1. To go or come in. 2. To put on record. 3. To put in information or data.
Erect	To put up by the fitting together.

Establish	To set on a firm basis.
Estimate	To judge or determine roughly the size, extent, or nature of.
Evaluate	To determine the importance, size, or nature of; to appraise; to give a value or appraisal to on the basis of collected data.
Exchange	To part with or substitute.
Execute	To carry out fully.
Explain	To make something plain and understandable.
Express	To represent in words; to state.
Extract	To draw forth; to pull out forcibly.
Fill out	To enter information on a form.
Find	1. To discover or determine by search; to indicate the place, site, or limits of.
	2. To discover by study or experiment; to investigate and decide.
Fire	To launch a missile or shoot a gun.
Hold	To have or keep in the grasp.
Identify	1. To establish the identity of.
	2. To determine the classification of.
Illustrate	To make clear or clarify.
Indicate	To point out.
Inform	To make known to; to give notice or report the occurrence of.
Initialize	To set to a starting position or value.
Insert	To put or thrust in, into, or through.
Inspect	To perform a critical visual observation or check for specific conditions; to test the condition of.
Install	1. To perform operations necessary to properly fit an equipment unit into the next larger assembly or system.
	2. To place and attach.

Instruct	To provide with authoritative information or advice.
Intercept	To stop or interrupt the progress or course of.
Interpret	1. To conceive in the light of individual belief, judgment, or circumstance. 2. To explain the meaning of.
Investigate	To observe or study by close examination and systematic inquiry.
Isolate	To use test equipment to identify or select a source of trouble.
Issue	To put forth or distribute.
Lift	To move or cause to be moved from a lower to a higher position; to elevate.
List	To enumerate; to place a group of items together.
Listen	To hear something with thoughtful attention.
Load	To place in or on; to place cargo or aircraft components on an airplane or other vehicle.
Locate	1. To find, determine, or indicate the place, site, or limits of. 2. To set or establish in a particular spot; to station.
Lubricate	To put lubricant on specified locations.
Maintain	1. To hold or keep in any particular state or condition, especially in a state of efficiency or validity. 2. To sustain or keep up.
Manage	To handle or direct with a degree of skill.
Maneuver	To make a series of changes in direction and position for a specified purpose.
Manipulate	To operate with the hands.
Measure	To determine the dimensions, capacity, or amount by use of standard instruments or utensils.
Modify	To alter or change somewhat the form or qualities of.

Monitor	1. To visually take note of or to pay attention to in order to check on action or change.
	2. To continually or periodically attend to displays to determine equipment condition or operating status.
Mount	To attach to a support.
Move	To change the location or position of.
Name	To identify by name.
Navigate	To operate and control course of.
Neutralize	To destroy the effectiveness of; to nullify.
Notify	To make known to; to give notice or report the occurrence of.
Observe	1. To conform one's actions or practice to.
	2. To visually take note of; to pay attention to.
Obtain	1. To get or find out by observation or special procedures.
	2. To gain or attain.
Open	1. To move from closed position; to make available for passage by turning in an appropriate direction.
	2. To make available for entry or passage by turning back, removing, or clearing away.
	3. To disengage or pull out a circuit breaker.
Operate	To control equipment in order to accomplish a specific purpose.
Organize	To arrange elements into a whole of interdependent parts; to form into a coherent unity; to integrate.
Orient	1. To acquaint with the existing situation or environment.
	2. To set or arrange in any determinate position.

Originate	To give rise to, to set going, to begin.
Park	To bring a vehicle to a stop and leave it standing for a time in a specified area.
Perform	To do, carry out, or bring about; to reach an objective.
Place	To put or set in a desired location or position.
Plan	To devise or project the achievement of.
Plot	To mark or note on or as if on a map or chart; to locate by means of coordinates.
Position	To put or set in a given place.
Post	To station at a given place.
Prepare	To make ready; to arrange things in readiness.
Prescribe	To lay down as a guide, direction, or rule of action; to specify with authority.
Press	To act upon through thrusting force exerted in contact.
Pressurize	To apply pressure within by filling with gas or liquid.
Prevent	To keep from happening or existing.
Prioritize	To arrange or list in order of priority or importance.
Process	To submit to a series of actions or operations leading to a particular end.
Program	To work out a plan or procedure or a sequence of operations to be performed.
Provide	To supply what is needed, to equip.
Pull	To exert force upon an object so as to cause motion toward the force.
Pump	1. Raise or lower by operating a device which raises, transfers, or compresses fluids by suction, pressure or both. 2. To move up and down or in and out as if with a pump handle.

Push	1.	To press against with force so as to cause motion away from the force.
	2.	To move away or ahead by steady pressure.
Qualify		To declare competent or adequate.
Raise		To move or cause to be moved from a lower to a higher position; to elevate.
Receive		To come into possession of; to get.
Recognize		To perceive to be something previously known or designated.
Record		To set down in writing.
Recover		To get back; to regain.
Refuel		To put fuel into the tanks of a vehicle again.
Release	1.	To set free from an inactive or fixed position; to unfasten or detach interlocking parts.
	2.	To let go of.
	3.	To set free from restraint or confinement.
Remove	1.	To perform operations necessary to take an equipment unit out of the next larger assembly or system.
	2.	To take off or eliminate.
	3.	To take or move away.
	4.	To take off devices for closing off the end of a tube.
Repair		To restore damaged, wornout, or malfunctioning equipment to a serviceable, usable, or operable condition.
Repeat		To make, do, or perform again.
Replace	1.	To restore to a former place of position.
	2.	To substitute serviceable equipment for malfunctioning, wornout, or damaged equipment.
Report	1.	To describe as being in a specified state.
	2.	To make known to; to give notice or report the occurrence of.

Request	To ask for.
Reset	To put back into a desired position, adjustment, or condition.
Respond	To react.
Review	To examine again; to go over or examine critically or deliberately.
Rotate	To cause to revolve about an axis or center.
Route	To send by a selected course of travel; to divert in a specified direction.
Scan	To make a wide, sweeping search of; to look through or over hastily.
Schedule	To appoint, assign, or designate for a fixed future time; to make a timetable of.
Secure	To make fast or safe.
Select	To take by preference or fitness from a number or group; to pick out; to choose.
Send	To dispatch by means of communication.
Service	To perform such operations as cleanup, lubrication, and replenishment to prepare for use.
Set	1. To put a switch, pointer, or knob into a given position; to put equipment into a given adjustment, condition a mode. 2. To put or place in a desired orientation or location.
Set up	To prepare or make ready for use.
Show	To point out or explain.
Shut down	To perform operations necessary to cause equipment to cease or suspend operation.
Sight	1. To look at through or as if through a sight. 2. To aim by means of sights.

Signal	To notify or communicate by signals (i.e., a prearranged sign, notice or symbol conveying a command, warning, direction or other message).
Solve	To find a solution for.
Specify	To name or state explicitly or in detail.
Squeeze	To force or thrust together by compression.
Start	To perform actions necessary to set into operation; to set going; to begin.
State	To express the particulars of in words.
Stay	To remain; to continue in a place.
Steer	To direct the course of.
Stop	To perform actions necessary to cause equipment to cease or suspend operation.
Stow	To deposit or leave in a specified place for future use.
Strike	To deliver or aim a blow or thrust; to hit.
Submit	To make available; to offer.
Summarize	To tell in or reduce to a summary.
Supervise	To oversee; to have or exercise the charge of.
Synthesize	To combine or produce by synthesis.
Take	1. To get into or carry in one's hands or one's possession. 2. To get or find out by observation or special procedures.
Tap	To strike lightly.
Tell	To express in words.
Test	To perform specified operations to verify operational readiness of a component, subcomponent, system, or subsystem.

Tighten	1. To perform necessary operations to fix more firmly in place.
	2. To apply a specified amount of force to produce a rotation or twisting motion to fix more firmly in place.
Trace	To follow or study out in detail or step by step.
Transmit	1. To convey or cause to pass from one place to another.
	2. To send out a signal by radio waves or wire.
Transport	1. To convey or cause to pass from one place to another.
	2. To carry by hand or in a vehicle or hoist, or in a container, etc.
Traverse	To move from side to side.
Troubleshoot	To localize and isolate the source of a malfunction or break down.
Turn	To cause to revolve about an axis or center.
Unload	To take off.
Use	To put into action or service; to avail oneself of; to carry out a purpose or action by means of.
Utilize	To put into action or service; to avail oneself of; to carry out a purpose or action by means of.
Verify	1. To confirm or establish that a proper condition exists.
	2. To establish the truth or accuracy of.
Wait	To suspend activity in a sequence of activities until a given condition occurs or a given time has elapsed.
Write	To inscribe words on a surface.
Zero	To bring to a desired level or null position.

APPENDIX C

DATABASE MANAGEMENT SYSTEM (DBMS) USE AND SUGGESTED TECHNIQUES FOR ET REQUIREMENTS ANALYSIS

Introduction

This Appendix discusses how to use a database management system (DBMS) for ET requirements analysis. Techniques presented are suggestions, not rules. Use of these guidelines depends on the DBMS and the purpose of the analysis. The information is presented in three parts. First is the suggested structure of the database for an ET requirements analysis, and second are techniques and commands which can aid the analyst using a DBMS. Following the discussion on database structure and DBMS use, a set of forms for use in interim recording of analysis products (before they reach the database) is described, and their use in the steps of the analysis process is discussed. It is necessary to have a basic knowledge of computer operation to use the information in this Appendix.

Database Structure

The database structure is presented in four categories: task/objective characteristics, audit trail information, analysis information, and additional data elements for future analyses. Each category contains a list of suggested data elements to include in the database, type of data element or field it represents, and, when applicable, the size of the element.

Task/Objective Characteristics

Title/Description. This is a short but accurate description, beginning with an action verb, followed by a proper noun and modifiers. There is a title/description for each task or objective. In the DBMS, this is a character/text type data element of at least 120 character length.

Number. This is the task or objective number which is unique for each task or objective. The numbering system can be a sequential numbering system for listings or, in the case of a hierarchy, a numbering system indicating the level of the task/objective. The numbering system suggested is double digits separated by periods. For example, "01.02.03" indicates the task/objective is the third subtask, in the second task, of the first phase. The example below shows how the numbering system indicates the task/objective relationship with other tasks/objectives in the hierarchy.

01	Planning Phase.
01.01	Collect weather information.
01.01.01	Communicate with weather center.
01.01.02	Record relevant weather information.
01.02	Determine route to combat area.
01.02.01	Examine maps of ops area.

There is a unique number for each task/objective. If the numbering system is sequential, the data element is a character/text type of at least five characters. For task/objective hierarchies, the data element is character/text of at least 23 characters. This is equal to eight hierarchical levels (i.e., 01.02.03.04.05.06.07.08).

Conditions of Performance. There can be numerous conditions for each task/objective. Conditions are enumerated in a prioritized order within this data element. In the DBMS, the data element is a character/text type large enough to accommodate text descriptions of conditions.

Standards of Performance. There can be numerous standards for each objective. Standards are enumerated in a prioritized order within this data element. In the DBMS, the data element is a character/text type large enough to accommodate text descriptions of standards.

Crew Positions. With multi-crew member weapon systems it is important to keep track of which crew members perform the task/objective. The analyst should include one logical (boolean) data element for each crew position to indicate whether the task/objective is performed by that crew member. A logical type data element is simply a Yes/No or True/False indicator. It may be desirable to include a character/text data element for recording the actual crew position name. The character/text type data element is better for printouts than the logical type, while the logical type is better for database manipulations such as counts and restricted printouts.

Common Numbers. This is a list of the other task/objective numbers in the hierarchy which are equivalent to the current task/objective description. A particular task or objective may occur numerous times in the hierarchy. To keep track of this, a character/text type data element of a large size contains the list of numbers in order of appearance in the hierarchy. This data element is only used for hierarchies and not for sequential listings.

First Appearance Indicator. This is a logical type data element which indicates whether this is the first occurrence of the task/objective in the hierarchy. This is only used for hierarchies and not sequential listings.

Audit Trail Information

Source of Information. This data element is a record of the document or other source from which the task/objective was derived. It may be useful to note the agency responsible for developing the task/objective. The data element of the DBMS is a character/text type of at least 60 characters.

Page/Reference Number. When the task/objective is derived from a specific document, the page number or other relevant reference number is recorded in this data element. The data element in the DBMS is a character/text type of at least 15 characters.

Task/Objective Developer. This data element denotes the analyst or subject matter expert (SME) who developed a new task/objective. This data element is a character/text type of at least 10 characters. Separate initials can be separated by commas or slashes.

Military Service Task/Objective Number. This data element is used when a task/objective in the developing hierarchy is equivalent to a task/objective currently in the military service. The military task number is often found in a POI, training guide, or soldier's manual. The data element is a character/text type of at least 25 character length.

Analysis Information

Criticality Rating. This is a character/text type data element of one character. The codes are H(igh), M(edium), and L(ow). There is a criticality rating for each task/objective.

Perishability Rating. This is a character/text type data element of one character. The codes are H(igh), M(edium), and L(ow). There is a perishability rating for each task/objective.

ET Nomination. This is a logical type data element which indicates whether ET is suitable to train the task/objective. There is one data element for each crew position in the weapon system for each task/objective.

Objectives Classification. This data element is used when the analysis is performed on an objectives hierarchy. Each objective can be classified as one of seven types of objectives: integrated multiple skills, rule/concept utilization, variable/contingency procedures, knowledges, invariant procedures, basic manipulative skills, and basic level behaviors. This classification is described in Section 4.

Several techniques can be used to handle this data element in the DBMS. First, a one character code representing the objectives category can be placed in a character/text type data element. The code is a number or a letter. Second, the full category name can be entered in a character/text type data element of at least 25 characters. The other alternative is to use a logical type data element for each possible category. One category would be marked true for each task/objective. This should be in addition to one of the first two methods because it is useful for DBMS functions, but not as clear for printouts.

ET Implementation. This data element is the ET implementation and feasibility judgment code assigned in Step 3.5 of the analysis. This is a character/text data element one character long.

Additional Data Element for Future Analyses

Training Media. This data element contains the media appropriate for training the task/objective. The media can be selected using a media selection model. The data element in the DBMS is a character/text type large enough to accommodate the media names.

ET Comments. This data element describes the method of training the task/objective by ET envisioned by the analyst who nominates this task for ET. For instance, if "Operate the radar" is the task, "Simulated radar targets and use of actual radar controls" would be the ET comment. This data element is a character/text type of at least 120 characters.

DBMS Analysis Techniques, and Commands

Indexing and Sorting the Database

A database can be indexed or sorted on any data element. The difference between index and sort is that the index is a logical arrangement of the database, whereas the sort is a physical reordering of the database records. Indexing is faster and does not require additional storage space. A sort normally requires three times the space of the database and if there is not enough room on the storage device for a sort, loss of data can occur.

Another application of an index is to organize the database by title/description. This is useful when identifying and standardizing common tasks/objectives and finding the initial occurrence of the task/objective. This is used during the commonality analyses (Steps 1.6 and 1.8).

Character/Text Types and Logical Types

The advantage to using a character/text type data element in a database is that it is descriptive and useful for printouts. The logical type data elements are, however, better for DBMS features. For example, it is easier to print out tasks/objectives for a particular weapon system operator, by searching for a yes/no indicator for that operator. On the other hand, for the printout, operator names may be clearer than a Y or N in a column for that operator.

Find/Locate Commands

Most DBMSs have a find or locate feature. This allows the person entering information or changing data to access a specific record. For instance, if the DBMS contains descriptions and numbers the next action may be to enter other information for certain tasks/objectives. It is quicker to call the task/objective of interest than it is to scroll through the database manually.

Count Commands

Some DBMSs have built-in counting features. This is useful during analysis to assess the number of times something occurs. For example, if the analyst wants to know how many ET nominated tasks/objectives there are, the DBMS can count faster than a person with a printout. Logical type data elements are useful for counting.

Replace Commands

Some DBMSs have a replace feature. This allows the user to enter information automatically in a data element for a specified condition. For instance, if all of the newest entries are from the same document, the data entry person can enter one letter, (e.g., "X"). After entering all the data, the user can replace all occurrences of "X" with the actual source document name.

Structure to Facilitate Data Entry

Generally, a task/objectives hierarchy is developed in stages. First, the title/description is entered and then numbers are assigned. The remainder of the information is added after these steps. To facilitate data entry, the data elements should be ordered as they will appear on the data entry forms or in the order they will be entered. Some DBMSs allow the user to modify the format of the data entry presentation, which simplifies data entry. This allows the user to present a screen for data entry which looks like the data entry form.

Deleting Records

A task/objective should not be permanently deleted from the database until it is certain that the task/objective is not needed. Some DBMSs can designate records as logically deleted rather than physically erasing them from the database. By using this capability, tasks/objectives can be screened out, without losing the data. Even when it is determined that a task/objective is not needed, the task/objective should be placed in a separate file of deleted tasks/objectives as a safety measure.

Report Generation

Most DBMSs have an automatic report generator. Experience has shown that it is usually faster to use the automatic feature rather than program a customized report generating program. In the case when an customized report is desired, it is sometimes possible to use the automatic report generator to create a text file and then use a word processor to customize it.

Programming with the DBMS

Most DBMSs have all of the needed functions and capabilities built into the command language. It is suggested that the casual DBMS user not spend time writing programs using the DBMS programming capabilities. Most DBMSs do not have a full programming capability. Even though it may appear to be similar to a known programming language, it may have its own stumbling blocks.

Database Entry, Interim Recording Forms, and Data Printouts for ETR Analysis

ETR analysis data are entered in various stages during analysis. A data entry form and five printout formats, used during specific steps of the ETR analysis, are presented to assist the DBMS user. Table C-1 shows the data elements generated in the analyses and discussed in this Appendix and the form each is associated with.

The forms are discussed in detailed below. The printout formats follow the assumption that the printer used by the DBMS is capable of printing on wide paper, either 11 inches for 8.5 x 11 inch paper or, preferably, 11 X 14 inch paper. The paper can be sheet fed or tractor fed (preferable). It is important to note that all data elements are under continuous refinement, even though they may not appear on a form. The printouts can be used while the DBMS is on line with the analyst entering new data elements directly into the database, or the analyst can make entries on the printout and have clerical personnel enter the information into the database later.

Form 1 is used for Steps 1.3, 1.4, 1.5, 1.7, and 2.1 of the ETR analysis. This is a data entry form which has places to record the task/objective number, title/description, conditions of performance, crew positions performing each task/objective, and audit trail information. This form is used for mission, mission phase, task/objective, and subtask/subobjective identification. Once the data is entered on the form, clerical personnel (or the unlucky analyst) can enter the data into the DBMS.

Table C-1

DATA ELEMENT VS. DATA-ENTRY/PRINTOUT FORM

INPUT/OUTPUT FORMS FOR ETR ANALYSIS

Data Element	Entry Form 1	Printout Form 2	Printout Form 3	Printout Form 4	Printout Form 5	Printout Form 6
Number	I	O	O	O	O	O
Title/Description	I	O	O	O	O	O
Conditions	I			O	O	
Standards				I	O	
Crew Positions	I		O	O	O	O
Common Numbers		I				
First Appearance		I				
Source	I					
Page No.	I					
Developer	I		O/I			
Mil. Task No.	I					
Criticality			I		O	O
Objective Class.			I		O	O
Perishability			A		O	O
ET Nomination			A		O	O
Implementing ET					I	O

I - Initial entry of this data element.
O - Output data element to assist entry of other data element.
A - Automatically computed and entered by the DBMS program.

Form 2 is used for Steps 1.6 and 1.8 of the ETR analysis. This is a printout of information contained in the DBMS database with blank columns for data elements generated in these steps, which are to be entered into the database. The printout is indexed on the mission phase or task title/description to assist identifying common mission phases, tasks/objectives, and subtasks/subobjectives. The printout contains the number and title/description, which are used to identify the commonalities; a blank column for recording the numbers of the common mission phases, tasks/objectives, and subtasks/subobjectives.

Form 3 is used for Steps 3.1 and 3.2 of the ETR analysis. This form is a printout of information contained in the DBMS database, with blank columns for data elements generated in these steps, which are to be entered into the database. The printout is indexed on the number data element, to present a hierarchial list. The printout should be limited to the initial occurrence of each element to prevent analyzing common mission phases, tasks/objectives, subtasks/subobjectives repeatedly. The printout contains the number, title/description, crew positions, and the initials of the developer of the task/objective. If the current analyst is different from the original developer, the analyst's initials can be recorded in the developer column, separated from the original developer's initials by a comma or slash. Blank columns for criticality codes (H, M, L) and objective classification codes (1, 2, 3, 4, 5, 6) are used to record the codes for each task/objective based on the determinations of the analyst.

Form 4 is used for Step 2.2 of the ETR analysis. This form is a printout of information contained in the DBMS database, with blank columns for data elements generated in this step, which are to be entered into the database. The printout is indexed on the number data element to present a hierarchial list. The printout should be limited to the initial occurrence of each element to prevent analyzing common mission phases, tasks/objectives, subtasks/subobjectives repeatedly. The printout contains the number, title/description, crew positions, and conditions of performance. A blank column for standards of performance is used to record the standards determined by the analyst for each mission phase, task/objective, and subtask/subobjective.

Form 5 is used for Step 3.5 of the ETR analysis. This is a printout of information contained in the database, with blank columns for data elements generated in this step, which are to be entered into the database. The printout is indexed on the number data element to present a hierarchial list. The printout should be limited to the initial occurrence of each element to prevent analyzing common mission phases, tasks/objective, and subtasks/subobjectives repeatedly. The printout contains the number, title/description, crew positions, conditions of performance, standards of performance, criticality codes, perishability results, and ET nomination results. A blank column for ET implementation codes (i.e., I, S, O ,Q, H, T, and X) is used to record the codes determined by the analyst for each mission phase, task/objective, subtask/subobjective.

Form 6 is used for Step 3.6 of the ETR analysis. This is a printout of information contained in the database. This printout is used to validate the database contents. The printout is indexed on the number data element to present a hierarchial list. The printout should be limited to the initial occurrence of each element to prevent validing common mission phases, tasks/objectives, and subtasks/subobjective repeatedly. The printout contains the number, title/description, crew positions, criticality codes, objective classification codes, perishability results, ET nomination results, and ET feasibility codes.

No forms are possible for Steps 1.1, 1.2, 1.9, 3.3, or 3.4, since these steps are either to be done by the DBMS software or are off-line tasks. The exception to this is Step 1.9 because it is envisioned that direct input into the database should be feasible.

Page No.: ____________

DATA ENTRY FORM 1

NUMBER	TITLE/DESCRIPTION	CONDITIONS	POSITION	AUDIT TRAIL INFORMATION
				Source:
				Page No.:
				Developer:
				Mil. Task No.:
				Source:
				Page No.:
				Developer:
				Mil. Task No.:
				Source:
				Page No.:
				Developer:
				Mil. Task No.:
				Source:
				Page No.:
				Developer:
				Mil. Task No.:
				Source:
				Page No.:
				Developer:
				Mil. Task No.:
				Source:
				Page No.:
				Developer:
				Mil. Task No.:

Page No.: __________

PRINTOUT FORM 2

NUMBER	DESCRIPTION	FIRST	COMMON NUMBERS
(SIZE OF NUMBER DATA ELEMENT)	(50 CHARACTERS WIDE, MINIMUM; INDEX ON THIS DATA ELEMENT)	(INPUT TRUE/ FALSE)	(INPUT LIST FOR EACH TASK/ OBJECTIVE)

Page No.: ________

PRINTOUT FORM 3

NUMBER	TITLE/DESCRIPTION	POSITION(s)	DEVELOPER	CR	OBJ CAT
(SIZE OF NUMBER DATA ELEMENT; INDEX ON THIS DATA ELEMENT)	(50 CHARACTERS WIDE, MINIMUM)	(PRINTOUT LIST OF EACH POSITION PERFORMING EACH TASK; SIZE AS NEEDED)	(PRINTOUT INITIALS ENTERED FROM FORM NO. 1; SIZE AS NEEDED; ENTER NEW INITIALS AS NEEDED)	INPUT CODE	INPUT CODE

Page No.: ____________

PRINTOUT FORM 4

NUMBER	TITLE/DESCRIPTION	POSITION(s)	CONDITIONS	STANDARDS
(SIZE OF NUMBER DATA ELEMENT; INDEX ON THIS DATA ELEMENT)	(50 CHARACTERS WIDE, MINIMUM)	(PRINTOUT EACH POSITION PERFORMING EACH TASK; SIZE AS NEEDED)	(PRINTOUT LIST OF CONDITIONS FOR EACH TASK/ OBJECTIVE; SIZE AS NEEDED)	(INPUT STANDARDS FOR EACH TASK/ OBJECTIVE)

Page No.: ________

PRINTOUT FORM 5

NUMBER	TITLE/DESCRIPTION	POSITION(s)	CONDITIONS	STANDARDS	CR	PR	ET NOM	ET IMP
(SIZE OF NUMBER DATA ELEMENT; INDEX ON THIS DATA ELEMENT)	(50 CHARACTERS WIDE, MINIMUM)	(PRINTOUT LIST OF EACH POSITION PERFORMING EACH TASK; SIZE AS NEEDED)	(PRINTOUT LIST OF CONDITIONS FOR EACH TASK/ OBJECTIVE; SIZE AS NEEDED)	(PRINTOUT STANDARDS FOR EACH TASK/ OBJECTIVE)	PRINTOUT CODE	PRINTOUT RESULT	PRINTOUT RESULT	INPUT CODE

Page No.: ___________

PRINTOUT FORM 6

NUMBER	TITLE/DESCRIPTION	POSITION(s)	CR	OBJ CAT	PR	IMPL	ET
(SIZE OF NUMBER DATA ELEMENT; INDEX ON THIS DATA ELEMENT)	(50 CHARACTERS WIDE, MINIMUM)	(PRINTOUT EACH POSITION PERFORMING EACH TASK; SIZE AS NEEDED)	PRINTOUT CODE	PRINTOUT CODE	PRINTOUT RESULT	PRINTOUT CODE	PRINTOUT RESULT

Working Paper

WP MSG 90-09

ADL: AN EXTENSION OF THE McCRACKEN-ALDRICH WORKLOAD ANALYSIS TECHNIQUE

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June 1990

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ADL: AN EXTENSION OF THE McCRACKEN-ALDRICH WORKLOAD ANALYSIS TECHNIQUE

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ADL: AN EXTENSION OF THE McCRACKEN-ALDRICH WORKLOAD ANALYSIS TECHNIQUE

INTRODUCTION AND OVERVIEW

Purpose

The purpose of this report is to describe a new method for assessing and predicting the mental workload of weapon system crews while they are engaged in combat operations. The method is an extension of the technique originated by J. McCracken and T. Aldrich (McCracken & Aldrich, 1984). The extention is based on the concept of attentional demand level (ADL) as the primary measure of operator work.

The McCracken-Aldrich Approach

In 1984 J. McCracken and T. Aldrich developed a Task Analysis/Workload methodology in order to analyze the workload of crews flying the LHX helicopter (McCracken & Aldrich, 1984). The objective of the Task Analysis/Workload methodology is to produce a model for predicting the mental workload of weapons system crews as they operate the system. The method involves two basic processes, (1) a comprehensive task analysis of the combat mission of the weapon system and (2) a detailed moment by moment analysis of the mental workload of each crew member during each operational segment. Two design goals of McCracken and Aldrich in devising this technique were to provide a procedure that; (1) would enable rapid completion of workload prediction models and (2) would be applicable to systems in the concept stage as well as fielded systems.

The McCracken-Aldrich method involves performing mission and task analyses that generate a timeline of operator tasks. The tasks are further broken down into task elements which are then used to generate estimates of workload in five categories, viz., cognitive, visual, auditory, psychomotor, and kinesthetic.

Estimates of workload are obtained from subject matter experts (SMEs) who rate the tasks on a seven point scale. The SMEs are provided with verbal descriptions which serve as anchor points for each of the seven levels of workload. For example, the anchor points for the Visual Scale range from "monitoring" (scale value = 1) to "decipher text" (scale value = 7). Since the verbal anchor for the scale value 7 represents the highest possible workload for each of the five components, workload values greater than 7 imposed on any one channel creates an overload condition. Workload values are computed separately for each channel or component.

The McCracken-Aldrich process centers around a detailed "timeline" analysis of a crew member's activities during a tactical operation. The tasks required to accomplish a mission are identified along with data regarding their frequency, duration, and sequencing. Decision rules programmed in a digital computer (Bierbaum & Hamilton, 1989) are applied to these data to obtain an estimate of the mental workload of each crew member at each one-half second interval during the tactical operation.

Application of the McCracken-Aldrich methodology produces three outputs; (1) identification of overload conditions, (1) periods when one or more operator overloads has occurred, (2) overload density, i.e., the percentage of time that an overload has occurred within a mission segment, and (3) subsystem overloads, i.e., the number of times that a subsystem is associated with an operator overload.

The McCracken-Aldrich Task Analysis/Workload process proceeds in three stages. In the first Stage, Task Analysis, the analyst's first job is to perform a top-down decomposition of the use of the system (see Figure 1). At the top level of analysis, each unique type of tactical operation is termed a "mission". After the mission is specified, the top-down analysis continues with the separation of the mission into divisions called "phases". The mission phases are further analyzed and divided into subparts called "segments". The segment level is the highest level directly simulated by the software.

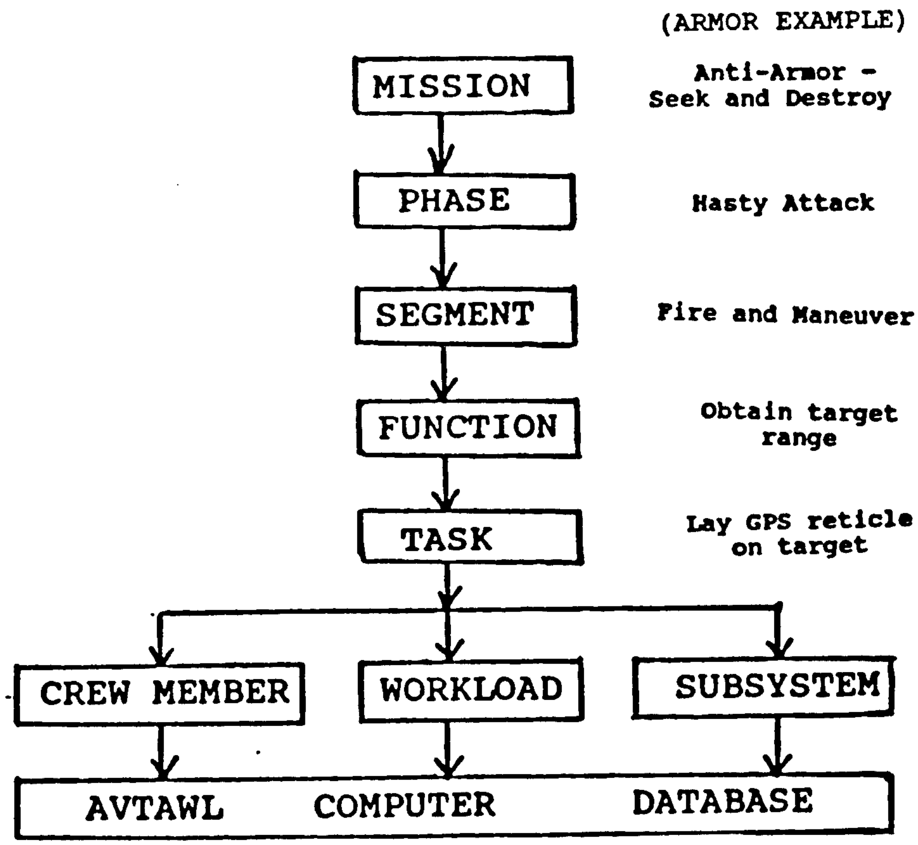

Figure 1. McCracken-Aldrich Top-Down Task Analysis Process

The next step in the top-down decomposition process of Stage 1 is to identify all of the subparts of the segments called "functions". Functions represent all crewmembers' actions necessary to carry out a single logical activity. The lowest level of mission decomposition is the "task". Tasks are defined as the non-interruptible crew activities that are essential to the successful completion of the function. Each task is described by a verb and and object. The verb describes the crewmember's action and the object describes the recipient of the action.

In order to identify the subsystems most associated with high workload, the subsystem associated with each task is also entered into the computer database. This allows each overload condition to be associated with a particular subsystem during the workload simulation.

In the second stage of the McCracken-Aldrich procedure, Development of Decision Rules, the decision rules which specify how the tasks are dynamically combined to form functions and segments are developed. First, function decision rules are developed for combining the tasks into functions. Segment decision rules are then developed to combine the functions into segments. The function and segment decision rules reconstruct the mission to simulate the behavior of each crewmember at each point on the mission timeline.

Stage 3, Computer Simulation, involves execution of the decision rules and simulation of the crewmembers' actions during the operation of the system. This procedure produces estimates of each crewmember's workload by summing the component workload for each task that the crewmember is currently performing. Thus, the effect on operator workload of various system changes can be investigated by developing two models, one for the existing system and one with system modifications, and comparing the workload predictions.

The ADL Approach

In the ADL approach, mental work is defined as the mental effort exerted by a person in coping with the demands imposed by the external environment. The ADL workload rating scales are based on the degree of mental concentration required to perform various goal oriented actions or tasks. The degree of mental concentration, i.e., the mental effort exerted by a person, is a function of the attentional demand level of the task. Estimates of the mental concentration (and corresponding degrees of attentional demand levels of tasks) are obtained by ratings assigned by subject matter experts (SMEs).

The ADL approach was developed to provide a MANPRINT database for use in the material acquisition process of combat weapon systems. The specific focus is on MANPRINT considerations in the design and operation of armored vehicles, particularly those involved in the Armored Systems Modernization (ASM) program. However, the ADL approach is applicable to workload analysis of any individual or crew served weapon system.

Operator Workload and MANPRINT

MANPRINT is an initiative recently undertaken by the Army to insure that soldier-related factors are fully considered in the design of weapon systems. The basic thrust of MANPRINT is to assure a positive answer to the question - Can this soldier, with this training, perform these tasks to these standards under these conditions? Guidance for implementing MANPRINT is contained in Army Regulation (AR) 602.2, Manpower and Personnel Integration (MANPRINT) in the Material Acquisition Process (Dept. Army, 1987). AR 602.2 requires consideration of data regarding crew member characteristics and performance in six distinct but interrelated domains, viz., manpower, personnel, training, human factors engineering, safety and health hazards.

The issue of operator workload is relevant to design trade-offs in all six MANPRINT domains. For example, reducing the size of a crew from 4 to 3 saves manpower but has an obvious impact on the workload of the smaller crew. New electronic sensors may increase the range, sensitivity, or precision of target acquisition data but may also increase the mental demands on the operator. This would require combat developers and system designers to consider the cost-benefit values of various trade-offs between soldier quality (as reflected in ASVAB scores, for example) and the full utilization of hardware capabilities. Specialized training is often a feasible method to reduce the effects of mental overload but the cost of the specialized training devices and sustainment training may outweigh the probable effects of momentary overload on the accomplishment of the tactical mission.

A requirement to consider operator workload issues during all stages of the material acquisition process has been established by AR 602-1, Human Factors Engineering Program (Dept. Army, 1983). This regulation specifies that a Human Factors Engineering (HFE) program shall be initiated for each weapon system in accordance with MIL-H-46855B, Military Specification: Human Engineering Requirements for Military Systems, Equipment and Facilities (Dept. Army, 1979). Section 3.2.1.3.3 of MIL-H-46855B requires that individual and crew workload analyses shall be performed and compared with performance data. However, no guidance is provided to system developers as to how such a workload should be performed. (Bulger, Hill & Christ, 1989).

Prior Research

The lack of a comprehensive and systematic data base to serve as guidance for individual and crew workload analyses prompted the Army Research Institute (ARI) to sponsor an exhaustive search of the scientific and technical literature dealing with this topic. The result was a report (Lysaght et al., 1989) providing a comprehensive review of currently available methodologies and techniques that have been developed and used in the assessment of operator workload.

In this report, more than 1500 documents were reviewed and almost 500 research reports are cited. This review provides a critique of the methods and techniques that have been used to examine workload. It contains descriptions of the methodologies and techniques as well as discussions concerning the available information regarding their validity, reliability, sensitivity, intrusiveness, and practicality. The concluding paragraph of the report reads:

> "The importance of understanding the level of operator workload is clear: High workload may result in unexpected and undesirable performance changes. The operator may shed tasks, be unable to perform them, or in some way fail to perform them acceptably. In one form or another, rightly or wrongly, the operator will adapt. Without such considerations, the incorporation of MANPRINT concerns into the design of systems will continue to be problematical." (p 197)

ADL is basically an analytic workload analysis technique. That is, it can be used to predict performance and estimate workload without the necessity of having an operator physically exercise the system. As such, it has many characteristics in common with the existing analytic techniques described in the previously cited ARI report (Lysaght et al., 1989); particularly those categorized as task analysis techniques. The existing techniques include Timeline Task Analysis (Stone, Gulick and Gabriel (1987); Workload Assessment Model (WAM), (Edwards, Curnow, & Ostrand, 1977); Computerized Rapid Analysis of Workload (CRAWL), (Bateman and Thompson, 1986); Workload Index (W/INDEX), (North, 1986); and, of course, the McCracken-Aldrich technique. The interested reader is referred to Chapter 3 of the ARI report (Lysaght et al., 1989) for a more detailed discussion of these techniques.

Simulation Modeling in Workload Analysis

The application of computerized simulation models is another technique useful in workload assessment and prediction. Such models, e.g., TAWL (Bierbaum & Harper, 1989) incorporate characteristics of the operator, the system hardware, and the operational environment along with software rules governing the interaction of these three elements. The computer model can be run repeatedly using a statistical representation of the operator to yield measures of effectiveness (MOE) of the performance of the total soldier-machine system.

In a recent development, Laughery et al. (1986) utilized the McCracken-Aldrich approach to provide workload estimations using Micro SAINT, a task network simulation language. Micro SAINT uses a menu-driven interface that provides a framework for assigning the workload requirements for operator actions. Laughery et al. tracked workload levels at 2-second intervals through a simulated helicopter mission scenario. The results demonstrated that the procedure is sensitive to variations in system hardware and that specific types of overload can be identified. The application of task network simulation to the process of mental workload analysis is a major objective in development of the ADL technique.

ADL and Micro SAINT

The ADL method is congruent with the networking approach used in Micro SAINT software. It thus allows the use of Micro SAINT to manipulate situational variables and to conduct computer simulations of realistic tactical scenarios. The expected MANPRINT-related benefits of Micro SAINT simulations of the ADL technique include:

(1) Overload prediction, i.e., obtaining probability distributions of the likelihood that serious (mission threatening) overloads will occur under various battlefield conditions.

(2) Improved training devices and procedures, i.e., identifying the incidents that produce serious operator overload conditions and have a high probability of occurrence. This is a necessary first step leading to the development, where feasible, of special training devices or procedures that enable the soldier to increase skill levels to a point where the overload condition is eliminated.

(3) System design evaluation, i.e., evaluating alternative in-house or vendor proposed weapon system designs to determine which design minimizes the likelihood of serious mental work overloads during critical, highly stressful combat operations.

(4) Human factors assessments, i.e., assessing which displays, controls, or processes contribute to operator overload and are thus candidates for redesign or automated assistance.

Need For Multitask Workload Analysis

As evidenced in the Lysaght et al. (1989) report, prior research has provided many valuable insights into the relationship between workload and performance. However, most of the research has dealt with the analysis of single or dual task performance. As a result, the methodologies and techniques developed to date are not well suited to the analysis of the complex environment of combat operations. A general conclusion from this report is that:

> "a full understanding of operator workload will begin to emerge only when sufficient workload investigations have emphasized multiple tasks and multiple situations." (p 193)

The application of improved knowledge about performance in multitask situations will benefit the system designer and impact not only workload evaluation but also a variety of MANPRINT issues. As the above report notes;

> "The designer will benefit by being able to improve designs and optimize task allocation. The trainer will benefit by having a better understanding of performance rules and which components need more emphasis. The trainer will also benefit by being able to teach time-sharing skills." (p 193)

The report further concludes

> "As more realistic multitask multisituations are investigated, the performance and workload trade-offs and how they can be handled will become .... more pressing. New metrics are needed to facilitate more precise predictions about the trade-offs." (p 194)

The purpose of the present report is to describe a new approach to the development of the needed metrics.

Organization of the Paper

This Working Paper is divided into three sections. Section I provides details of the features and processes involved in the ADL technique. Section II contains descriptors and examples of the operations that comprise operator workload. In Section III, a conceptual model of the control system for the management of attention in humans is described. The model was developed as an aid in visualizing the nature and interactions of the mechanisms and processes associated with operator workload. This model is described in Section III. The model is based on the processes utilized by electric power companies to manage their power distribution networks. By analogy, the human attention control and distribution system is the hypothetical mechanism by which a person manages the operation of an attentional (mental work) distribution network.

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SECTION I: THE ADL APPROACH TO WORKLOAD ANALYSIS

Overview

Basic Metric

The new approach proposed here is based on the concept of attentional demand level (ADL) as the basic metric for the analysis of operator workload. The ADL methodology is an attempt to express the impact of operator workload in terms of the performance of the entire soldier-machine system, not just the performance of the soldier himself. Although there are numerous sub-criteria for denoting the impact of operator overload, the final product of the ADL method is an estimate of the impact that a particular mental overload will have on mission accomplishment.

The combat environment of crew served weapon systems is extremely complex. For this reason, a large number of rating scales (more than a dozen) have been devised in the ADL approach to assist in assessing operator workload. However, the basic measure, the ADL Rating, is a simple seven point rating scale of the momentary level of overall attentional demand imposed by the tactical situation.

Additional Rating Scales

Most of the other rating scales can be invoked selectively to aid SMEs in articulating the causal factor(s) responsible for a given ADL rating. This additional information aids in pinpointing the specific aspect(s) of the tactical situation creating the attentional demand, e.g., time pressure, information complexity, personal danger, etc. This approach was devised in order to maximize the information transfer from SMEs while minimizing their administrative burden in providing their ratings.

Although the ADL approach involves a large number of rating scales for assessing various aspects of operator workload, the ultimate criterion is the impact of such workload on the manned weapon system* performance. Table 1 shows a summary ADL data matrix. This matrix provides estimates of the probability of performance degradation at various system levels. The ADL approach recognizes that soldiers and systems do function, and missions are accomplished, even though operator overload does occur. Furthermore, system performance is affected not only by the occurrence of an overload but also by the severity and duration of the overload, the operational significance of the overload, the characteristics of the soldier-machine performance envelope, and the particular tactical scenario in which the overload occurs.

* The term system refers to soldier-machine combinations (e.g., a tank and crew) assembled to accomplish a tactical mission. The term sub-system applies to a soldier and his MOS-related equipment.

Manned System Performance Envelopes

The various scales developed for use in the ADL methodology contribute inputs to a matrix whose scores indicate the impact of identified operator overload at various levels of system analysis, e.g., task, function, mission). Each of these levels constitutes a distinct performance envelope within which operator performance can be assessed. The ADL method is designed to produce data that can be used to evaluate the impact of operator workload on all aspects of the design of crew served weapons systems; from hardware components to battlefield doctrine.

The final product of the ADL technique is a Mission Impact Score. This is a cumulative score for each occurrence of an overload based on the probability of degraded system performance at the various levels of system analysis shown in Table 1. The Mission Impact Score provides a MANPRINT-based means for prioritizing actions to be taken to reduce operator overload through changes in doctrine, tactics, personnel, training, soldier-machine interface design, or operating procedures.

Table 1. Probability of Degraded Performance Matrix

System Level Impacted	Probability of Degraded Performance (%)	
	Typical Scenario	High Density Scenario
1 = SUB-TASK. Minor system impact. Noticeably degraded task or sub-task performance; function disruption possible, mission accomplishment likely.		
2 = TASK. Moderate system impact. Seriously degraded task or sub-task performance; function disruption likely; mission disruption unlikely but possible.		
3 = SUB-FUNCTION. Substantial impact. Function disruption; mission disruption a concern.		
4 = FUNCTION. Serious system impact. Degraded function performance; mission accomplishment possible but jeopardized.		
5 = PHASE. Very serious system impact. Function abort; mission accomplishment unlikely.		
6 = MISSION. Extremely serious impact. Mission abort.		
7 = SYSTEM INTEGRITY. Catastrophic impact. Loss of vehicle or life.		

Details of the ADL Approach

Definition of Operator Workload

The ADL methodology is concerned with the analysis of "operator" workload. This term refers to work performed while interacting with a dynamically changing external environment. It is thus distinguished from the mental work performed while interacting with a static environment; for example, a maintainer repairing an engine.

Mental work is defined in the ADL approach as the effort exerted by a person in coping with demands imposed by the external environment. Two types of effort are involved;

(1) Processing, i.e., obtaining and utilizing information about the external environment.

(2) Controlling, i.e., managing the operation of various somatic and cognitive processes through which the operator interacts with the external environment.

Components of Operator Workload

As in the McCracken-Aldrich approach, the components of operator workload consist of activities in the five distinct channels through which the operator interacts with the environment, viz., the visual, auditory, cognitive, psychomotor, and kinesthetic channels. The visual components include such actions as scanning, searching, reading, and tracking. The auditory components include such actions as detecting, discriminating, and understanding. The cognitive components include such operations as planning, calculating, deciding, and remembering. The psychomotor components (hereafter referred to as "muscular" components) include such actions as pushing, pulling, rotating, and speaking. The kinesthetic (or "feel") components include such operations as detecting or judging pressure, resistance, orientation, and movement.

ADL Workload Rating Scale

Attentional demands imposed on each channel by an action, sub-task, or task are rated by subject matter experts (SMEs) on a seven point scale as a function of the degree of mental concentration (attentional capacity) required. The scale is shown in Table 2.

Table 2. ADL Workload Rating Scale.

0 = Casual	
1 = Routine	(See Section II for
2 = Directed	explanation and examples
3 = Moderate	of the Workload Rating
4 = High	Scale).
5 = Intense	
6 = Extreme	
7 = Total	

Workload "Drivers"

The scale shown in Table 2 is a summary scale. It is essentially a reflection of the interaction of various situational factors that can impact on the operator's perceived workload. In the ADL approach, the momentary attentional demand level of a task or action is considered to be a function of these situational factors or workload "drivers".

Two types of "drivers" are distinguished; (a) those related to the tactical scenario (Type S) and (b) those inherent in the task itself (Type T). The Type S drivers consist of Time Pressure, Criticality, and Interruptibility. The Type T drivers, Task Complexity, Ease of Information Extraction, and Precision Required can be considered to be components of a more general workload driver labeled Task Difficulty. The latter category (Task Difficulty) is provided for those cases where an SME might have difficulty in unraveling the interaction of its three component drivers in a given task.

Workload Driver Scales

In order to pinpoint the factors that contribute to the attentional demand level of a task at a particular moment in time, subsidiary scales have been devised for each of the seven drivers. These subsidiary scales enable subject matter experts (SMEs) to articulate more fully the significant factors contributing to the momentary workload.

Task Complexity Scale

The scale for rating Complexity of a task is shown Table 3.

Table 3. Task Complexity Rating Scale

1 =	VERY LOW, e.g., status of a single variable.
2 =	LOW, e.g., simple interaction of two variables; status of a complex variable.
3 =	MODERATE, e.g., simple interaction of three or more variables; complex interaction of 2 variables.
4 =	HIGH, e.g., complex interaction of two changing variables; complex interaction of three variables.
5 =	VERY HIGH, e.g., rapid, complex interaction of 2 changing variables; rapid, complex interaction of 3 variables.
6 =	EXTREMELY HIGH, e.g., rapid and complex interaction of three changing variables; interaction of 4 variables.
7 =	MAXIMUM, e.g., complex interaction of multiple, rapidly changing variables.

Ease of Information Extraction Scale

The ease of information extraction scale is shown in Table 4.

Table 4. Ease of Information Extraction Rating Scale

1 = EASY, i.e., directly accessible without effort from a single source.

2 = SLIGHT EFFORT, i.e., requires momentary fixation on a single source.

3 = DEFINITE EFFORT, i.e., requires concentrated effort for determination or discrimination of status; imposes a burden on short term memory.

4 = MARGINAL, i.e., requires interpolation or extrapolation; imposes a significant burden on short term memory; poor signal-to-noise ratio; poor discriminability.

5 = HARD, i.e., complex interpolation or extrapolation; considerable burden on short term memory; very poor signal-to-noise ratio approaching limit of resolution capability of sensor (eye, ear, etc.).

6 = VERY HARD, i.e., very close to limit of sensor resolution capability; severe burden on short term memory; extremely poor signal-to-noise ratio.

7 = EXTREMELY HARD, i.e., at the very limits of sensor resolution capability, very complex interpolation or extreme burden on short term memory.

Precision Required Scale

The precision required of an action is shown in Table 5.

Table 5. Degree of Precision Required Rating Scale.

1 = VERY LOW, e.g., flick switch

2 = LOW

3 = MODERATE

4 = HIGH

5 = VERY HIGH

6 = EXTREMELY HIGH

7 = ABSOLUTE, e.g., hit a two meter target (tank turret at a distance of 5000 meters).

Task Difficulty Scale

In those cases where a SME would find it difficult to articulate the specific factors contributing to the perceived difficulty of a given task, a composite Task Difficulty scale is provided. In this scale, difficulty level is assessed on a 7 point scale as a function of the interaction of the three subfactors;

(1) complexity of the action or task.
(2) ease of information extraction.
(3) precision required of the action.

The level of difficultly of an action or task is rated on a seven point scale as shown in Table 6.

Table 6. Task Difficulty Scale

1 = Trivial
2 = Easy
3 = Routine
4 = Moderate
5 = High
6 = Very High
7 = Extreme

Time Pressure (TA:TE Ratio) Scale

The TA:TE Ratio is the ratio of time available (TA) to the operator versus the minimum time needed to execute (TE) the action or task with no loss of effectiveness. ADL recognizes the fact that even when overloaded (e.g., due to time pressure) people can make responses of varying degrees of effectiveness.

The TA:TE Ratio is expressed in the seven point scale shown in Table 7.

Table 7. The TA:TE Ratio Scale

1 = >1.2:1 = no problem
2 = 1.1:1 = limit of comfortable performance.
3 = 1:1: = limit of effective performance.
4 = (.8 -.9):1 = somewhat degraded performance.
5 = (.6 -.7:)1 = significantly degraded performance.
6 = .5:1 = marginal performance.
7 = <.5:1 = inadequate performance.

A TA:TE ratio of less the 1:1 can occur in two ways:

(1) The task must be completed faster than the operator can physically respond.

(2) The operator must simultaneously perform one or more conflicting tasks.

Other factors contributing to time pressure include;

(1) Sampling rate between and within channels.

(2) Duty cycle required.

(3) A refractory period associated with a return to an interrupted, higher-demand level (= > 4) task.

Task Criticality

The degree of attention given to an action, sub-task or task is affected by its criticality, as rated by SMEs, with repect to such factors as additional workload, mission accomplishment, personal danger, and other factors.

SME assumptions regarding perceived criticality are rated on the seven point scale shown in Table 8.

Table 8. Task Criticality Rating Scale

1 = Minor, e.g., poor performance will require some extra work, no real danger, mission unaffected.

2 = Moderate, e.g., poor performance will require lots of extra work, possible danger, mission may be affected.

3 = Substantial, e.g., poor performance may cause function disruption, some danger, mission may be affected.

4 = Serious, e.g., function abort, definite danger, mission disruption possible.

5 = Very Serious, e.g., high danger, mission disruption probable.

6 = Extremely Serious, e.g., very high danger, mission abort.

7 = Catastophic, i.e., loss of vehicle or life.

Task Interruptibility

The extent to which an action, sub-task, or task can be interrupted is rated on the seven point scale shown in Table 9.

Table 9. Task Interruptibility Rating Scale

1 = can be interrupted; no performance degradation.

2 = can be interrupted; minor performance degradation.

3 = short interruption tolerable; minor performance degradation but causes extra work later.

4 = short interruption tolerable but a noticeable degradation of performance

5 = cannot be interrupted without a significant degradation of performance.

6 = cannot be interrupted without a severe degradation of performance.

7 = cannot be interrupted without a total loss of effectiveness.

Weighted Driver Matrix

In order to elicit information about the "drivers" that are contributing to the operator workload at a particular moment, some additional data may be collected on selected task elements. This additional information is in the form of "weights" assigned in accordance with the coding schema shown in Table 10. The purpose of these weights is to enable the SME to indicate the situational factors (workload drivers) that led to the ADL Workload Rating assigned to the task at a particular moment.

Table 10. ADL Workload Driver Matrix.

Workload Driver	Code	Weight Assigned + Comments
Task Complexity	TC	
Info Extraction	TX	
Precision Required	TP	
Task Difficulty	TD	
TA:TE Ratio	ST	
Criticality	SC	
Interruptibility	SI	

In cases where this additional information is to be collected the SME would assign weights to one or more of the drivers. To illustrate, consider the case where a task that might ordinarily be given an ADL rating of 3 is actually assigned a rating of 7 because of the extreme time pressure (ST) and criticality (SC). For example, the task of a tank gunner in aiming the main gun at a truck might be assessed an ADL value of 3 (Moderate). However, performing the same task against an enemy tank preparing to fire on his tank a second time would probably be rated 7 (Total) due to the added Criticality (+2 ADL levels) and the added time pressure (+2 ADL Level). The data recorded by SME in this instance would read "ADL=7 (+2 SC, +2 ST)".

It should be noted that such driver weights would not be assessed for each segment (e.g., 1\2 sec interval) of the timeline analysis. Rather, such assessments would only be recorded in those instances where (a) an ADL mental workload rating of 5 or more was assessed during a timeline segment or (b) where (as will be discussed later) a within channel or between channel mental workload "overload" occurs during a particular timeline segment.

Aggregation of Overload Effects

Cumulative Effects of Overload

Degradation of an operator's performance can result from an overload that is transient but severe (the need to do two essential things at once) or from an overload condition that is non-disabling per se but, if continued, induces fatigue, stress, memory lapse, or other performance degrading states in the operator. The comment section of the Workload Driver Matrix can be used to indicate the point along the mission timeline where the cumulative effects of a moderate overload requires that a greater weight be assigned to the overload condition.

Within Channel Aggregation of Overloads

As a working hypothesis, ADL values within a channel are assumed to aggregate as a function of the sum of the ADL values imposed by the various concurrent tasks within the channel.

Attentional Demand Level (ADL) values of 8 points or more imposed on any one channel create a task-disrupting overload condition. Minimum combinations of ADL values WITHIN a given channel that will cause a task disrupting overload condition are shown in Table 11.

Table 11.
Within Channel ADL Overload Combinations

7+1	4+4
6+2	4+3+1
6+1+1	4+2+2
5+3	4+2+1+1
5+2+1	3+3+2
5+1+1+1	2+2+2+2

ADL values greater than 8 points can occur, e.g., three simultaneous visual tasks each with a 4 point ADL value. Such situations create a higher level mental workload demand involving prioritization of data sampling and responses.

Between Channel Aggregation of ADL

As a working hypothesis, ADL values between various channels aggregate as a function of the square root of the sum of the squares of the momentary ADL values of each of the channels involved in the ongoing actions, sub-tasks, or tasks currently underway.

ADL values in excess of 49 (7 squared) in any combination of channels will always create a task disrupting overload condition. These include all tasks with aggregate ADL values equal or exceeding the values shown in Table 12.

Aggregate ADL values below 45 (e.g., 3+3+3+3+3) will not create a task disrupting condition. In other words, people can maintain a moderate level of attention in all five channels for an extended period of time without overload.

Aggregate ADL values between 45 and 49 might cause a task disrupting overload depending on the tactical situation.

Table 12.
Between Channel ADL Overload Combinations

Channel Level	Sum of Squares
7+1	50
6+4	52
6+3+3	54
6+3+2+1	50
5+4+3	50
5+4+2+2+1	50
4+4+4+2	52
4+4+3+3	50

Effects of Overload on Manned System Performance

Operator Actions to Reduce Overload

When faced with an overload, the operater may elect to:

(1) Emit a gross, partially effective response.

(2) Delay action until conditions improve (danger is that the item will be forgotten).

(3) Omit a response, e.g., ignore a warning buzzer (and hope for the best).

Impact of Operator Overload

The impact of the operator actions in response to an overload can be:

(1) none
(2) a minor amount of extra work later on.
(3) a significant amount of extra work later on.
(4) a substantial amount of extra work later on, creating a mission disrupting increase in workload.
(5) noticeably degraded mission performance.
(6) seriously degraded mission performance.
(7) mission failure.

Types of Impacts of Overload

The effects of an overload condition can be manifest in one or both of two ways, viz.,

(1) performance effects, i.e., effects which are immediately observable with respect to their impact on the successful execution of the tasks and functions associated with a tactical mission.

(2) personnel effects, i.e., effects which are not immediately apparent but which may reduce the capability of the operator to respond effectively at some future time.

Performance effects are differentiated into two types in terms of the locus of their major impact, viz.,

(1) operator performance.
(2) system performance.

Personnel effects are likewise differentiated into two types in terms of the locus of their major impact, viz.,

(1) operator status.
(2) system status.

Effect of Overload on Operator Status

The consequences of frequent or continuous ADL overload with regard to the operator may be manifest as:

(1) fatigue
(2) slow rate of sampling of situational status data.
(3) inefficient rate of sampling.
(4) poor prioritization of sampling.
(5) job dissatisfaction.
    (a) sub-par performance.
    (b) low re-enlistment rate.

Levels of System Affected by Operator Overload

The failure of an operator to perform effectively can have an impact on system performance at one of more of the levels shown in Table 13.

Table 13. System Performance Levels

(1) sub-task
(2) task
(3) sub-function
(4) function
(5) phase
(6) mission
(7) crew or vehicle

Probability of Performance Degradation Scale

The likelihood of performance degradation resulting from an overload is estimated using the scale shown in Table 14.

Table 14. Probability of Performance Degradation Scale

1 = possible but unlikely (p = <10%)
2 = definitely possible (p = 10-20%)
3 = substantial chance (p = 20-40%)
4 = probable (p = 40-60%)
5 = highly probable (p = 60-80%)
6 = almost definite (p = 80-95%)
7 = definite (p = >95%)

Probability of Degraded Performance Matrix

The probability of degraded performance at various system levels likely to result from an overload is shown in Table 15.

Table 15. Probability of Degraded Performance Matrix

System Level	Probability Level							Scenario Type	
	1 <10	2 10-20	3 20-40	4 40-60	5 60-80	6 80-95	7 >95	Typical	High Density
1. Sub-task									
2. Task									
3. Sub-Func.									
4. Function									
5. Phase									
6. Mission									
7. Crew									

Impact of Overload on Overall System Performance

The consequences of an ADL overload with regard to performance effects may be manifest at one of seven levels shown in Table 16.

Table 16. Level of Impact of Operator Overload

(1). Noticeably degraded task or sub-task performance; function disruption possible; mission accomplishment likely.

(2). Seriously degraded task or sub-task performance; function disruption likely; mission disruption unlikely but possible.

(3). Function disruption; mission disruption a concern.

(4). Degraded function performance; mission accomplishment possible but jeopardized.

(5). Function abort; mission accomplishment unlikely.

(6). Mission abort.

(7). Catastrophe, i.e., loss of vehicle or life.

The data from Tables 15 and 16 can be combined to provide an overall score reflecting the impact of a given overload condition on overall mission success as shown in Table 17.

Table 17. Impact of Overload on Mission Performance

System Level Impacted	Probability of Degraded Performance (%)					
	Typical Scenario			Hi Density Scenario		
	P	M	SPS	P	M	SPS
1 = SUB-TASK. Minor mission impact. Noticeably degraded task or sub-task performance; function disruption possible, mission accomplishment likely.		1			1	
2 = TASK. Moderate mission impact. Seriously degraded task or sub-task performance; function disruption likely; mission disruption unlikely but possible.		4			4	
3 = SUB-FUNCTION. Substantial impact. Function disruption; mission disruption a concern.		9			9	
4 = FUNCTION. Serious system impact. Degraded function performance; mission accomplishment possible but jeopardized.		16			16	
5 = PHASE. Very serious system impact. Function abort; mission accomplishment unlikely.		25			25	
6 = MISSION. Extremely serious impact. Mission abort		36			36	
7 = SYSTEM INTEGRITY. Catastrophic impact. Loss of vehicle or life.		49			49	
Mission Impact Score (MIS)						

System Performance Score

A System Performance Score (SPS) is derived by multiplying the probability of performance degradation (P) by a multiplier (M) which reflects the relative importance of the various levels of granularity of system structure. For illustration purposes, the M values consist of the square of the ordinal value of the seven levels of system analysis listed in Table 16, i.e., 1 =1, 2 = 4, 3 = 9, 4 = 16, 5 = 25, 6 = 36, and 7 = 49.

Mission Impact Score

The SPS values at each of the seven system levels are summed to produce a Mission Impact Score (MIS). The MIS is the final product of the ADL methodology. It provides a composite and cumulative score that reflects the relative impact that a given overload condition will have upon performance of the entire soldier-machine system. As such, it provides a means to prioritize remedial actions taken to reduce operator overload through changes in doctrine, tactics, training, personnel, soldier-machine interface design, or operating procedures.

SECTION II. DESCRIPTION AND EXAMPLES OF MENTAL WORKLOAD OPERATIONS

Visual Operations Descriptors

List of Visual operations

A. Scan (i.e. observe known indicators).

1. inside vehicle

    a. entire work station
    b. functional area (e.g., instrument panel for out-of-normal conditions).

2. outside vehicle

    a. entire field of view
    b. significant area

B. Search (i.e., for known class of indicators)

1. objects, e.g.,

    a. targets in air space
    b. targets on electronic display
        (1) uncluttered
        (2) somewhat cluttered
        (3) highly cluttered

2. feature, e.g.,

    a. terrain
    b. man-made

3. pattern

C. Detect

1. presence of signal on display
2. movement
3. change

D. Locate

1. specific object (usually exterior)

E. Observe

1. presence of safety light
2. position of pointer

F. Discriminate

1. differences in
    a. color
    b. shape
    c. position
    d. angle
    e. etc.

G. Read

1. alphanumeric
    a. letter or numeral
    b. words
    c. phrases/legends
    d. sentences

2. icons and other conventionalized symbols

3. arbitrary symbols

H. Align

1. cross hairs
2. cursor with target
3. vehicle with desired path
    a. aircraft with runway
    b. tank with narrow bridge

I. Track

1. moving target with gunsight
2. moving vehicle, etc. to determine
    a. rate of movement
    b. direction of movement
    c. pattern of movement

J. Relate

1. analyze relationship(s) between objects

K. Discriminate

1. figure from ground

L. Compare

<u>Types of Observed Features</u>

A. Single object or element

B. Multiple objects or elements

C. Pattern

D. Single feature

E. Cluster of features

F. Relationships

Location of Observed Features

A. Interior

1. entire work station
2. sector (e.g., engine status indicator panel).

B. Exterior

1. entire
2. significant area

Examples of ADLs of Various Visual "Jobs"

The examples given in the following sections merely provide a starting point for discussions with SMEs. The next step would be to have the SMEs provide examples in each of the 8 categories to serve as a frame of reference (anchor points) to other SMEs or users of the scale.

Civilian Examples

A. Level 0 (Casual attending)

1. Driving on an Interstate highway, clear day.

B. Level 1 (Routine attention)

1. Checking fuel, speed, and other instruments.

2. Observing scene in rear view mirror.

C. Level 2 (Directed attention)

1. Negotiating a curve marked 35 mph while driving at 45 mph.

2. Observing directional traffic signs at a major junction to determine proper lane.

3. Passing a truck doing 55 mph on an Interstate highway.

4. Checking to see if car radio is tuned to AM or FM.

5. Searching for a telephone number in the white pages in a well lit room.

D. Level 3 (Moderate concentration)

1. Preparing to and passing a car that is going 50 mph on a two lane highway located in gently rolling countryside.

2. Reading suburban street signs in a strange town (day).

3. Searching for a telephone number in the white pages in a dimly lit room.

4. Negotiating a curve marked 35 mph while traveling at 55 mph.

E. Level 4 (High concentration)

1. Preparing to and passing a car that is going 50 mph on a heavily traveled two lane highway in an urban area.

2. Reading street signs while traveling on a heavily trafficked city street in a heavy rain.

3. Finding a telephone number in the white pages in a room so dark that the numbers are barely visible.

F. Level 5 (Intense concentration)

1. Reading street signs while traveling on a heavily trafficked city street in a heavy rain at night.

2. Negotiating a series of three "S" curves marked 35 mph while traveling 55 mph (daylight).

G. Level 6 (Extreme concentration)

1. Negotiating a series of three "S" curves marked 35 mph while traveling 65 mph.

2. Avoiding on-coming car 200 yards distant passing at 60 mph in your lane of a two lane highway; your speed = 50 mph.

H. Level 7 (Total concentration)

1. Negotiating a series of descending hairpin curves on a rainy, foggy night; brakes have almost given out.

2. Avoiding on-coming car 100 yards distant passing at 60 mph in your lane of a two lane highway; your speed = 50 mph.

Tank Examples

A. Level 1. Checking speedometer, check fuel gauge, etc

B. Level 2. Observing bearing and distance of PL's tank.

C. Level 3. Fording a stream containing large boulders.

D. Level 4. Following a "cleared" path through a minefield.

E. Level 5. Detecting an enemy Red tank reported at 5000 m.

F. Level 6. Detecting an enemy ATGM gunner at 2000 m.

G. Level 7. Identifying an enemy tank at 3000m in the dark (night goggles)

Cognitive Operations Descriptors

List of Cognitive Operations.

calculate	compare	estimate	solve
plan	convert	filter	decide
predict	judge	calibrate	resolve
determine	anticipate	remember	translate
interpret	analyze	select	choose

Examples of ADLs of Various Cognitive "Jobs"

A. Level 0 (casual attention)

1. Normal wakefullness, e.g., freewheeling thoughts, casual conversation, etc.

B. Level 1 (Routine attending)

1. Cognitive activity focused on a single variable or a simple interaction of two variables; e.g., add digits; assess indicator status (fuel, speed, etc.).

C. Level 2 (Directed attention)

1. Cognitive activity focused on the simple interaction of several static variables; e.g., assess adequacy of fuel supply, plan route of march where no enemy is expected; select route to avoid terrain obstacles.

D. Level 3 (Moderate concentration)

1. Simple interaction of several dynamic variables, moderate time pressure; e.g., calculate path crossing pattern of intersecting aircraft and estimate likelihood of collision.

E. Level 4 (High concentration)

1. Complex interaction of several dynamic variables, severe time pressure; e.g., maneuver tank to avoid visible anti-tank obstacles and traps while approaching suspected enemy position.

F. Level 5 (Intense concentration)

1. Very complex interaction of several dynamic variables, severe time pressure, high danger level; e.g., maneuver tank to avoid visible anti-tank obstacles and traps while conducting a hasty attack (driver); devise best response to the sudden appearance of an equal sized force of enemy tanks (commander).

G. Level 6 (Extreme concentration)

1. Very complex interaction of multiple dynamic variables, very severe time pressure, severe danger level; e.g., sudden fire from concealed enemy tanks; collision of own helicopter with an obstacle appears imminent within 20 seconds.

H. Level 7 (Total concentration)

1. Very complex interaction of multiple dynamic variables, extreme time pressure, extreme danger level; e.g., sudden simultaneous attack by red helicopters and tanks.

Auditory Operations Descriptors

List of Auditory Operations

detect	compare	discriminate	interpret
track	estimate	verify	understand
filter	scan	listen	discern

Characteristics of Auditory Signals

A. frequency

B. intensity

C. rhythm

D. pattern

E. speech

1. identify (speaker)
2. understand
   a. precisely
   b. generally

Types of Auditory Operations

A. Communication
1. internal
2. external
3. standard format
4. random format

B. Determination of status

1. own vehicle
2. external source
    a. location
    b. direction
    c. size
    d. type
    e. number

<u>Ambient Noise Characteristics</u>

A. Type
1. voices
2. static
3. tones

B. Intensity
1. high
2. low
3. varying

C. Signal-to-noise ratio.

<u>Examples of ADL Levels of Various Auditory "Jobs"</u>

A. Level 1 (routine attention)

1. Listening for onset of sound e.g., expected communication; engine noise signalled by fault light, etc.

2. maneuver control conversation

B. Level 2 (directed attention)

1. Discerning expected words and phrases under normal ambient noise conditions, e.g., receipt of frag order in low ambient noise.

C. Level 3 (moderate concentration)

1. Discerning expected words and phrases under adverse conditions, e.g., receipt of frag order in high ambient noise.

D. Level 4 (High concentration)

1. Discerning complicated speech via radio, e.g., directions for landing an aircraft in the dark; alternate route because of washed out bridge ahead, some danger present.

E. Level 5 (intense concentration)

1. Discerning complicated speech as in Level 4 but in presence of severe static.

F. Level 6 (extreme concentration

1. Discerning complicated speech or sound patterns that portend a highly dangerous situation, e.g., is that a faint scraping sound in the rotor assembly which might signal imminent rotor failure unless engine speed is reduced?

G. Level 7 (total concentration)

1. Discerning faint, broken, complex sound patterns (e.g., complex speech) under extremely degraded conditions (high ambient noise, severe static, jamming, etc.) in a highly dangerous situation, e.g., scout report seems to indicate rapid advance of a nearby large enemy force, very faint signal with considerable static and distortion.

Muscular (Psychomotor) Operations Descriptors

List of Muscular Operations.

push	pull	twist	turn
flick	turn	slide	move
rotate	hold	speak	look

Granularity Level of Muscular Operations

A. precise

B. fine

C. gross

Complexity Level of Muscular Operations

A. Pre-established (routine) movements
   1. simple discrete action
   2. simple action pattern
   3. complex action pattern

B. Non-programmed movements
   1. simple action pattern
   2. complex action pattern

Examples of Muscular Channel "Jobs" at Various ADL Levels

A. Level 1 (routine)

1. Gross, simple movement to maintain status, e.g., auto steering wheel movements while travelling on a paved road.

B. Level 2 (directed attention).

1. Fine, simple movement to maintain status, e.g., as above while negotiating a sharp curve.

C. Level 3 (moderate concentration)

1. Complex, gross movement pattern, e.g., making a runway approach in a fixed wing aircraft.

D. Level 4 (high concentration)

1. Complex, fine movement pattern, e.g., touchdown in a fixed wing aircraft.

E. Level 5 (intense concentration)

1. Execution of a complex pattern.

F. Level 6 (extreme concentration)

1. Precise execution of a complex pattern, e.g., a tank gunner tracking a moving target while traversing rough terrain.

G. Level 7 (total concentration)

1. Precise execution of an extremely complex movement pattern, e.g. high speed NOE flight in a heavily forested area at night.

Kinesthetic Operations Descriptors

Kinesthetic Functions

A. Detection

B. Discrimination

C. Comparison

D. Judgment

Sensory Aspects

A. Resistance

B. Orientation

C. Pressure

D. Movement

Examples of kinesthetic operations

A. Reach for and locate a switch without looking at it.

B. Judge the position of a control by feel.

C. Making a fine adjustment to a control by feel.

D. Operating an auto gearshift by feel.

E. Judging rate of turn.

F. Discerning a change in direction of motion.

Types of Kinesthetic Inputs

A. Discrete input

1. occurrence
2. level
3. pattern
4. location
    a. finger
    b. hand
    c. foot
    d. leg
    e. head
    f. body

B. Continous steady input

1. occurrence
2. level
3. pattern
4. rate

C. Continuous changing input

1. occurrence of change
2. rate of change
    a. slow
    b. rapid
    c. instantaneous
3. pattern of change
    a. simple
    b. complex
    c. repetitive

Sensitivity Level of Input

A. precise

B. fine

C. gross

Sources of Input

A. External
1. force exerted by controls
2. force exerted by seat
3. force exerted by tilt of vehicle

B. Internal (own muscles)

Kinesthesis ADL Matrix

The format for collecting data regarding kinesthetic operations is shown in Table 18.

Table 18. Kinesthetic ADL Matrix

Operation	Body Part	Precision	Sensitivity	Channel ADL	Scenario ADL	Total ADL

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SECTION III. A CONCEPTUAL MODEL OF THE HUMAN ATTENTION CONTROL SYSTEM

General Model Characteristics

An ADL Attention Control Model (ADLAC) has been developed as an aid in visualizing the nature and interactions of the mechanisms and processes associated with mental workload. The ADLAC model for the human attentional distribution network is based on the processes utilized by electric power companies to manage their power distribution networks. By analogy, the human attention control and distribution system is the hypothetical mechanism by which a person manages the operation of an attentional (mental work) distribution network.

A complete attentional circuit includes various combinations of the components shown in Table 19.

Table 19. ADLAC Model Analogs to Electrical Components

Electric Component	ADL Network Model Analog
Electric Power Generator	Attentional Current Generator. The brain (cerebrum) acting as a power source.
Appliance	Device. A metaphor for the various sensors and effectors that enable a human operator to meet the demands imposed by external conditions. These demands are in the form of "jobs" that require the operator to perform a series of coordinated actions, sub-tasks, or tasks in order to accomplish a mission.
Conductor	Conduit. Nerve fibers that distribute attentional current from the generator to all of the devices involved in accomplishing a job.
Step Potentiomenter	Circuit Gate. A hypothetical mechanism that operates in the manner of a variable resistor and acts as a variable sized gate in allocating current (attentional capacity) to successive conduits.
Condensor	Capacitor. A hypothetical mechanism that stores current (attentional capacity).
Wheatstone Bridge	Current Demand Comparator. A hypothetical mechanism that indicates the relationship between the amount of current available and the amount demanded by a device.

ADLAC Model Component Description

The components and processes associated with a typical electric power distribution system provides a framework for characterizing the structure and operation of the mechanism by which the distribution of human attentional capacity is controlled.

Power Generator Description

The brain provides attentional current, i.e., the energy that provides the capacity for a sensor (e.g., an eye) or effector (e.g., a muscle) to interact with the external world in meeting demands imposed by the external environment in accomplishing a mission.

Attentional capacity is produced in five separate, quasi-independent current generators corresponding to functional areas of the cerebral cortex, viz.,

- C (cognitive),
- V (visual),
- A (auditory),
- M (muscular, aka psychomotor),
- K (kinesthetic).

The cognitive channel is unique in that it controls and distributes attentional current for two quasi-independent mechanisms, viz.,

A. The Cognitive Processor (CP); a hypothetical mechanism that controls the distribution of attentional current required to perform various cognitive operations (e.g., calculate, compare) in order to satisfy the demands of the various devices used to accomplish the "jobs" (actions, sub-tasks, or tasks) involved in meeting mission objectives.

B. The Cognitive Controller (CC); a hypothetical mechanism that manages the switching of attentional current among the various conduits. The CC operates in three modes:

1. autonomous
2. semi-autonomous
3. responsive

Device Description

To accomplish a combat mission, a soldier (operator) must perform certain actions, sub-tasks, and tasks associated with his MOS. The actions, sub-tasks, and tasks can be viewed as "jobs" imposed by the external environment. The operator has available various sensors and effectors (i.e., devices that enable him to execute these "jobs"). When external conditions impose a job on the operator, the Cognitive Controller meets the demand by energizing the devices appropriate to the situation.

Each device involved in performing an action, sub-task, or task imposes a certain level of attentional demand (current load) which varies as a function of the external situation.

The amount of current (attention) demanded by a device varies as a function of the interaction of the difficulty of the job and the importance of the job, i.e., the priority assigned by the Cognitive Controller to satisfy the current situation.

Conduit Description

Attentional capacity is distributed via various sized conduits. The conduit through which each of the five generators distributes its current is termed a channel.

Channels are subdivided successively into branches, cable, and wires.

The conduits are divided into sub-conduits which serve:

(1) physical capacities, e.g., arm, fovea, hand, etc. or
(2) functional capacities, e.g., scanning, tracking, etc.

Circuit Gate Description

Circuit gates operate in the manner of a seven step variable resistor.

Gates operate at various levels (i.e., provide variable rates of current flow) as a function of the attentional demand level of their associated devices.

The rate of flow through a gate is determined by the cognitive controller based on the ratio of amount of current supplied (CS) versus the amount of current demanded (CD) by the device. If the ratio of CS to CD is less than 1:1, more current is supplied to the device - if it is available.

Demand Comparator Description

The Cognitive Controller contains a Demand Comparator mechanism that periodically samples each activated gate to assess the CS:CD ratio at that gate.

The rate at which the Demand Comparator samples a given gate is a function of the both the CS:CD ratio and the absolute value of the current demand (CD).

When a device imposes a demand on a circuit, the gates of conduits to lower priority applicances are closed for a period determined by the Cognitive Controller.

If the priority of a device with a closed gate increases to a level equal to or higher than a previously higher device the gate will open to allow current flow to that device.

As demand level increases in a given conduit, the threshold value necessary for a lower priority device is raised with regard to the rate of sampling by the Demand Comparator.

The rate of switching among activated conduits by the Demand Comparator is controlled by two factors:

A. Autonomous control, i.e., occasioned by a command from the Cognitive Processor.

B. External events, e.g., the appearance of a target.

<u>Capacitor Description</u>

Each successive conduit in a circuit is equipped with a capacitor that stores current at a "standard" level.

Each capacitor holds a charge sufficient to provide the current flow needed to carry out normal (Routine level) activities for a period of time without reducing the current available to its associated devices to a point below the "standard" level.

An attentional demand level that drains a capacitor charge below the "standard" level will produce an "operator overload" condition in the affected conduit.

Tasks can be deferred as long as the amount of current remaining in the capacitor is above the "standard" level. That is, a device can be activated and be drawing current without ill effect so long as the capacitor is above the "standard" charge. Below this standard charge, continued demand will cause overheating; resulting in fatigue, stress, or other performance degrading conditions in the operator.

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WP MSG 88-11

Working Paper

SENSITIVITY ANALYSIS OF MAINTENANCE MANPOWER REQUIREMENTS

FOR THE AQUILA REMOTELY PILOTED VEHICLE

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June 1988

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INTRODUCTION

Overview

The following sensitivity analysis was performed in order to provide the Army with updated information about maintenance requirements for the Aquila remotely piloted vehicle. HARDMAN Hardware vs. Manpower) analyses on the system were published in 1983 and 1985, but lower than expected automatic fault isolation rates obtained during Development Testing II in 1986 and Operational Testing II in 1987 indicated that maintenance manpower requirements should be readdressed. This report accomplishes that task.

Background

Original autonomous concept. The Lockheed Aquila remotely piloted vehicle was originally to be fielded in five sections,in which each section was autonomous. Each autonomous RPV section was to consist of a Ground Control Section (GCS), a Remote Ground Terminal (RGT), a Launch Subsystem (LS), a Recovery Subsystem (RS), an Air Vehicle Handler (AVH), a Maintenance Shelter (MS) and five Air Vehicles (AVs). Under the Autonomous Operational and Organizational (O&O) Plan, a section would be fully capable of conducting RPV missions, and would provide full organizational maintenance services to the AV and the associated ground assets. HARDMAN analysis, a methodology for estimating manpower, personnel and training (MPT) requirements for an emerging system, was performed on Aquila by Dynamics Research Corporation in 1983. The original analysis assumed that the system would be fielded in the form of the original autonomous concept. This was later superseded by a different organization which imparted more centralization and control to the Aquila battery. As a consequence, a re-analysis of the orginial HARDMAN was required to incorporate these changes, discussed in more detail below.

CLRS (Centralized Launch and Recovery Section) O&O Plan. The autonomous concept was dropped in favor of the CLRS. The CLRS plan also consists of five sections, but none of these has the ability to provide full operational and maintenance support to the whole battery organization. Three of the GCSs are redesignated Forward Control Sections (FCSs) which have no LS, RS, AVH, or MS facilities to support the AV. Two GCSs are situated to the rear of the FCSs, and though both have LS, RS, and AVH equipment, only one, located as part of the primary CLRS, provides organizational maintenance for the AV. The MS and its four man crew is colocated with the primary CLRS, or CLRS 1. Each CLRS is composed of a GCS, RGT, LS, RS, and AVH.

It is the responsibility of the two CLRS to conduct launch and recovery operations for the entire battery. The MS and its crew of four must provide organizational level maintenance for a total of 13 AVs (five at each CLRS plus three spares at the MS). The Battery Operations Center (BOC) is at the Primary CLRS, and is responsible for coordinating battery activities as well as the timing of launches and recoveries. BOC also responds to orders from Division level for various AV missions, as well as to requests from the FCSs for specific missions.

Another difference between the CLRS and autonomous O&O concepts is the fact that the former will assume a 24 hour a day operational scenario, because of the recent addition of a miniaturized forward-looking infrared (FLIR) mission payload. This change from a 12 hour mission should require additional maintainer spaces on top of increased annual maintenance manhours.

It should become obvious at this point that the reorganization of RPV assets into the CLRS configuration can result in severe logistical problems. The Lockheed O&O Tradeoff Study(1986) gives as an example of a worst case scenario the situation in which the LS or RS at the Primary CLRS are inoperative, so that the Secondary CLRS, with no MS, is required to launch and recover five AVs. Also, even when both CLRS are operational, the MS must provide maintenance services to the five AVs at the Secondary CLRS or CLRS 2.

The draft Human Factors Engineering Analysis (HFEA; 1987) states that two of the MS crew, both E-4s, have the responsibility of traveling to the remote CLRS and retrieving the AVs in need of maintenance. Newly-repaired AVs should flow from the Primary to the Secondary CLRS, with AVs in need of repair flowing in the opposite direction. Originally, it was intended that there be two MSs, one at each CLRS. This requirement was later cut to one MS. Moreover, in the opinion of the subject matter experts (SME)s, Warrant Officers in the Target Acquisition Department of The Field Artillery School, this, coupled with the 24 hour scenario may result in greater logistical delay and travel time costs than anticipated, with the consequence of increased maintenance manpower demands. It also seems questionable that two maintainers are being effectively utilized if much of their time is spent retrieving and returning AVs.

ATE (Automatic Test Equipment) Performance Criteria

The Required Operational Capabilities (ROC) document called for a successful fault-isolation rate of 90%. It was assumed that for the remaining 10% of faults that could not be isolated, intermediate direct support (IDS) maintainers would be able to come forward and manually trouble-shoot the systems. This would result in 90% of all repairs that required electronic diagnosis being performed at organizational level, thus relieving intermediate maintainers of a significant maintenance burden.

While in principle, ATE technology sounds like an effective means of moving the maintenance burden forward, and reducing the skills required among those who perform the repairs, such advantages have not been realized in most existing electronic aids to maintenance (EAMs). In brief, it would seem that EAM performance has been poor (see Nauta, 1985). During Development Test II (DT II; see Cozby, 1986), the Aquila ATE system only isolated 35% of all faults. During Operational Test II,(OT II; Operational Test & Evaluation Agency, 1987) this rate was slightly less than 20%. Thus it would seem reasonable to suppose that organizational (unit) level maintenance personnel would have to learn to trouble-shoot manually many of the faults (those with a Mean Time to Repair (MTTR) of 90 minutes). IDS contact teams would only be called upon for the more demanding non-ATE repairs (those with an MTTR of 120 minutes).

The Air Vehicle Fault Isolator (AVFI) is the ATE system mounted inside the MS. This means that for most diagnoses of faults to be carried out, the AV must be partially disassembled, defueled, and then moved inside the shelter. The LS has some fault-detection capability, but cannot isolate faults. It indicates that there is something wrong with the AV and shuts it down. Thus in order for ATE technology to be used at all (and organizational level maintenance is dependent on ATE for 90% of all repairs), not only must the MS be present, but the AV must be inside it. It can be seen quite clearly that the crew at the secondary CLRS is at a distinct disadvantage when it comes to maintenance support. Although one MOS 13T p9 is located there, he is without the tools needed to diagnose systems faults when they occur. Instead he must wait for MS crews to retrieve the defective AV and take it back to the primary CLRS for repairs.

Documentation

There is currently no fielded system highly similar to Aquila. Therefore no consistent trail of comparable maintenance data exists from which failure rates and repair times can be extrapolated. There are, however, a good number of requirements documents which set standards for reliability, availability and maintainability (RAM) for Aquila and which specify mission profiles. There have also been some studies performed which look at Aquila usage rates under the wartime operational scenario, attempting to derive maintenance manpower estimates from these parameters. Among these are a HARDMAN analysis, (1983; revised 1985), and a CLRS O&O Plan Trade-Off study performed by Lockheed (1986). Likewise there are maintenance manpower standards set forth in TRADOC-AMC Pamphlet 70-11.

METHOD

Analytical Approach

The approach employed in the present analysis was based primarily on a large number of assumptions which in turn were predicated upon performance standards set forth in requirements documents. In addition, test data were available from DT II and OT II which provided information on maintenance ratios, the number of repair actions at organizational and intermediate levels, and operational availability estimates from these tests. From these sources and from the HARDMAN analyses, it was possible to derive estimates of the Mean Time to Repair for each AV, the Final Maintenance Ratio to be expected, and the number of Annual Maintenance Manhours (AMMH) and Manyears (MMY) projected for a 365 day year, worst-case (wartime) operational scenario. Travel times could also be estimated from the HARDMAN documentation.

AMMH figures were compared to those obtained for the HARDMAN analysis and were found to correspond rather closely. Extrapolating to the revised O&O Plan and the new 24 hour operational scenario, total AMMH from the HARDMAN were 7722 hours versus 7961 for the present analysis (assuming two maintenance shelters).

Assumptions

Repair times. Recall that, because of the lack of a similar fielded predecessor, assumptions from various secondary sources had to be used. Mean Time to Repair (MTTR) times using ATE from the revised O&O Plan are wrench-turning times only. This document assumed that all non-ATE repairs would either be done at IDS or that contact teams from intermediate would do them. However, this assumption was predicated on the adequate performance of ATE, and, if ATE makes as poor a showing as it did in OT and DTII, it would seem unreasonable to request maintenance support from intermediate whenever a fault could not be isolated. Consequently it is assumed that maintainers at organizational level will have to learn how to manually diagnose faults if Aquila is to be kept operational. Table 1 gives the projected MTTRs for the system.

Table 1

<u>Organizational Level</u>		(90% of repairs)
ATE	30 min day	45 min night
No ATE	90 min day	135 min night
<u>Intermediate DS</u>		(10% of repairs)
Manual	120 min day	180 min night

It was assumed that half of all repairs would be done by day and half by night; it may be possible to schedule most repairs for daylight hours, but maintenance SMEs at Fort Sill are unsure as to what percentage will be manageable. Considering the disparity in repair times, it may be advisable to attempt to minimize night maintenance as much as possible. If 20% of all repairs were done at night, some manpower savings may be realized which could mean the difference between the successful and unsuccessful completion of a mission. In fact, it would be a reasonble expectation that, if the AVFI fails to live up to requirements, some adjustments in scheduled repair times would be necessary to keep the maintenance workload from becomimng unmanageable. Maintenance SMEs at Fort Sill concurred that every attempt should be made to perform repairs, especially difficult ones that may be time consuming, during the daylight hours.

<u>Operational Scenarios</u>. Total AV operating hours for the 24 hour-25 mission scenario would be 54 hours, based on the 1986 revision of the O&O Plan. Interviews with SMEs suggested that all 13 AVs would be exercised, including the three spares.

<u>Maintenance Ratios</u>. From OT II data it can be inferred from the AV maintenance ratio (MR) that 1.27 maintenance actions per day will be required per air vehicle (AV). The current analysis will focus on the organizational level of maintenance, where the proposed manpower requirements are driven by the successful performance of ATE. The maintenance ratio is .18 for day (from OT II). The estimated night MR is .27. This does not include indirect MMH (35%) or Maintainer Induced Failures (25%). The resultant MR for the 24 hour scenario is .23. Indirect MMH and Maintainer Induced Failures, as well as travel times, are figured into the Final Maintenance Ratio (FMR). One maintenance man year is from 2400-2500 hours or 47 hours per week (TRADOC-AMCPAM 70-11). It is assumed that Intermediate Direct Support (IDS) maintenance will have a constant 10 percent share of the total workload. Any workload increase brought about by ATE degradation must be absorbed at organizational level. SMEs state that it is unrealistic to offload any more of the maintenance burden than this onto IDS. It should also be noted here that many of the

so-called "forward" repairs performed during OT II were done by the contractor; hence, the MTTR data obtained from these tests may not be very reliable. There were very few night repairs performed during OT II.

Effects of travel. For the remote CLRS, there should be 6.35 maintenance actions per day anticipated. It is assumed that two maintainers from the maintenance shelter (MS) will retrieve the AV (see draft HFEA). It is further assumed that they will whenever possible attempt to retrieve at least two AVs at a time. Travel time between CLRS is assumed to be 30 KPH. The launch and recovery crew at the remote CLRS also are responsible for retrieving the AV after the MS crew has completed the repairs.

The MS will make one 50 KM round trip per day to replenish its prescribed load list (PLL). This may be an underestimate, if ATE does not perform better than 40%. Recall that it was originally intended to equip the Aquila battery with two MSs, each mounted on a 5-ton truck. Cutting this number to only one may be a cost-saving measure "up front," but it could very well adversely impact the success of the mission, especially where the AVFI does not isolate as many faults as originally intended. Literature reviews and interviews with SMEs for Aquila as well as for other Army systems that rely on ATE technology and the results of OT II and DT II, have indicated that a 90% successful fault isolation (FI) rate is highly improbable.

SMEs at Fort Sill believe that the FI system can be improved. The ATE system for the Modular Integrated Communications and Navigation System (MICNS) they consider to be well-designed. In their estimation, the best possible FI rate would be 70%, with 60% being considered an unmitigated though unlikely success. Their most realistic expectation for the fielded system is 40 to 50%.

RESULTS AND DISCUSSION

The sensitivity estimates showing AMMH, FMR, Ao, AVs and MMY as joint functions of (a) ATE fault isolation (FI) rate, (b) percentage of repairs performed during daytime hours, and (c) distance between CLRS 1 and 2, are presented in Table 2.

Table 2

AQUILA RPV MAINTENANCE SENSITIVITY ANALYSIS

Distance Between Primary and Secondary CLRS (Km)

	0	4	6	8	10	12	14
ATE FI = 90%							
(50% daytime repairs)							
AMMH	7961	8579	8888	9197	9506	9815	10124
FMR	.40	.44	.45	.47	.48	.50	.51
Ao	.60	.56	.54	.53	.52	.50	.49
AVs	7.75	7.34	7.13	6.93	6.72	6.52	6.32
MMY	3.32	3.57	3.70	3.83	3.96	4.08	4.22
(80% daytime repairs)							
AMMH	5998	6464	6697	6938	7188	7447	7715
FMR	.30	.33	.34	.35	.36	.38	.39
Ao	.70	.66	.66	.65	.64	.62	.61
AVs	9.10	8.58	8.58	8.45	8.28	8.06	7.93
MMY	2.50	2.69	2.69	2.89	2.98	3.10	3.21
ATE FI = 60%							
(50% daytime repairs)							
AMMH	11571	12188	12498	12807	13116	13425	13743
FMR	.59	.62	.63	.65	.67	.68	.70
Ao	.41	.38	.37	.35	.33	.32	.30
AVs	5.36	4.95	4.75	4.55	4.34	4.16	3.94
MMY	4.82	5.07	5.21	5.34	5.47	5.59	5.72
(80% daytime repairs)							
AMMH	8974	9671	10019	10380	10753	11141	11542
FMR	.46	.49	.51	.53	.55	.57	.59
Ao	.54	.51	.49	.47	.45	.43	.41
AVs	7.04	6.63	6.37	6.11	5.85	5.59	5.33
MMY	3.74	4.03	4.17	4.33	4.48	4.64	4.81

Table 2 (Cont.)

ATE FI = 40%
(50% daytime repairs)

	0KM	4KM	6KM	8KM	10KM	12KM	14KM
AMMH	13988	14605	14915	15224	15533	15824	16151
FMR	.71	.74	.76	.77	.79	.80	.82
Ao	.29	.26	.24	.23	.22	.20	.18
AVs	3.77	3.38	3.12	2.99	2.86	2.60	2.34
MMY	5.82	6.08	6.21	6.34	6.47	6.60	6.72

(80% daytime repairs)

	0KM	4KM	6KM	8KM	10KM	12KM	14KM
AMMH	10966	11818	12243	12684	13141	13614	14104
FMR	.56	.60	.62	.64	.67	.69	.72
Ao	.44	.40	.38	.36	.33	.31	.28
AVs	5.72	5.20	4.94	4.68	4.29	4.03	3.64
MMY	4.57	4.92	5.10	5.29	5.48	5.67	5.88

ATE FI = 30%
(50% daytime repairs)

	0KM	4KM	6KM	8KM	10KM	12KM	14KM
AMMH	15191	15809	16118	16427	16735	17045	17354
FMR	.77	.80	.82	.83	.85	.87	.88
Ao	.23	.20	.18	.17	.15	.13	.12
AVs	2.98	2.60	2.34	2.21	1.95	1.69	1.56
MMY	6.33	6.59	6.72	6.84	6.97	7.10	7.23

(80% daytime repairs)

	0KM	4KM	6KM	8KM	10KM	12KM	14KM
AMMH	11976	12936	13309	13708	14119	14543	14979
FMR	.61	.66	.68	.70	.72	.74	.76
Ao	.39	.34	.32	.30	.28	.26	.24
AVs	5.07	4.42	4.16	3.90	3.64	3.38	3.12
MMY	4.99	5.39	5.55	5.71	5.88	6.06	6.24

ATE FI = 20%
(50% daytime repairs)

	0KM	4KM	6KM	8KM	10KM	12KM	14KM
AMMH	16398	17016	17325	17634	17943	18252	18561
FMR	.83	.86	.88	.90	.91	.93	.94
Ao	.17	.14	.12	.10	.09	.07	.06
AVs	2.18	1.82	1.56	1.30	1.17	.91	.78
MMY	6.83	7.09	7.22	7.35	7.48	7.61	7.73

Table 2 (Cont.)

(80% daytime repairs)

AMMH	12963	13969	14993	15201	15534	16093	16672
FMR	.66	.71	.77	.76	.79	.82	.85
Ao	.34	.29	.24	.23	.21	.18	.15
AVs	4.42	3.77	3.38	2.99	2.73	2.34	1.95
MMY	5.40	5.82	6.25	6.33	6.47	6.71	6.95

ATE FI = 10%
(50% daytime repairs)

AMMH	17603	18221	18530	18839	19148	19457	19766
FMR	.89	.92	.94	.96	.97	.99	1.01
Ao	.11	.08	.06	.04	.03	.01	.00
AVs	1.43	1.04	.78	.52	.39	.13	.00
MMY	7.33	7.59	7.72	7.35	7.48	7.61	7.73

(80% daytime repairs)

AMMH	13959	15034	15486	15950	16429	16921	17429
FMR	.71	.76	.79	.81	.83	.86	.88
Ao	.29	.24	.21	.19	.17	.14	.12
AVs	3.77	3.12	2.73	2.47	2.21	1.82	1.56
MMY	5.82	6.26	6.45	6.65	6.85	7.05	7.26

Clarification of dependent variables. The AV row in the table refers to AVs mission ready, without faults (no degradation of performance). This is assuming that there is no Minimal Equipment List for the AV and its mission payload sensor system.

MMY denotes the full time equivalent number of maintenance manyears. On a 24 hour schedule, two shifts would require more spaces than maintenance manhours (or manyears) alone would dictate. (For safety reasons, at least two persons must be employed at the MS at any given time; this would require that the MMY estimates be increased by two MOS 13T p9 spaces to derive the actual number of spaces needed for continuous operations in the worst-case wartime scenario. If the HARDMAN (1985) findings were taken as a baseline for estimating maintainer spaces from MMY, a rough estimate could be obtained by multiplying MMY by a constant of 1.5. Thus, for the maintenance scenario where ATE FI rate is 20%, 80% of all repairs are by day, and there are two MSs, approximately eight maintainers would be required.

Effects of independent variables. Distance between CLRS= 0 means that there are two maintenance shelters. It can be seen that where ATE performs in accordance with specifications (90%), there appears to be no problem in terms of maintenance manpower nor in terms of AVs which are fully mission capable (a maximum of five can be airborne at any one time). Scheduling most repairs during the day confers some advantage, but in no instance does the number of mission ready AVs fall below the maximum number required for a mission.

At 60% it becomes apparent that mission requirements can still be met, although this becomes marginal if the CLRs are over 4 km apart and half the repairs are made during the day.

At 40% ATE FI performance the picture changes. If half repairs are performed during the day, there would be no full mission capability even with two maintenance shelters. If 80% of all repairs took place during the day, the situation would improve somewhat. Here the presence of another maintenance shelter would make a lot of difference. With only one, distances between CLRS of more than 6 km would result in a drop in mission capability below five AVs. With the CLRS 8 km apart, the lack of full mission capability becomes evident.

At 30% ATE performance, an Aquila battery can only hope to have five AVs ready if 80% of repairs are performed in the daytime and if there are two maintenance shelters. Thus at this level the joint effects of repair scheduling and the number of maintenance vehicles in the TOE become apparent. Recall that this is close to the ATE FI rate found in DT II.

When ATE FI rates drop to 20% the greatest number of AVs available for a mission at any given time is four. One should realize that as Operational Availability (Ao) diminishes, the maintenance workload increases. Thus if ATE performed no better than at OT II, not only would an Aquila battery not be able to mount a 5-AV mission under the 24 hour wartime scenario, but would also have to add four maintainers to the TOE to keep up with the workload. The 1987 draft HFEA states that during OT II the MS crew had difficulty keeping up with the workload for only one CLRS for a battery "minus" and doubted that four men could handle a full battery during this kind of operational scenario. The same report expresses doubt as to the adequacy of only four maintainers and only one MS to support the AV maintenance workload in the CLRS organizational structure. These estimates tend to confirm this statement.

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