Research Note 82-16

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INTEGRATION OF MPT SUPPLY AND DEMAND AND THE SYSTEM ACQUISITION PROCESS

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This effort was conducted to identify behavioral science research activities to assist in the assessment and integration of manpower, personnel, and training (MPT) requirements in the acquisition process. A structure is presented to describe the interactions between MPT demand (requirements) and MPT supply. This structure is used to develop recommended research efforts.

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1.0 INTRODUCTION

This report summarizes a brief (approximately ten person-day) effort conducted to identify and describe potential research activities that could be initiated by ARI to assist in the assessment and integration of manpower, personnel, and training (MPT) requirements in the acquisition process. The effort was conducted by General William E. DePuy (USA, Ret.) and Dr. Seth Bonder.

Section 2.0 provides background information regarding the problem area. A dynamic process deemed necessary to manage the interactions between MPT demand (requirements) and MPT supply is described in section 3.0. Recommendations for key research efforts to initiate and eventually fully develop this process are listed in section 4.0. An appendix contains notes and ideas regarding the content of recommended process-oriented research efforts. Key abbreviations used in the report are defined in a glossary.

2.0 BACKGROUND

The Army is in the process of developing and deploying a very large number of new systems and equipment (approximately 600 items) across every functional area. The total impact of this high rate of change on manning and training the force is not fully understood, but certain features are painfully clear. The new systems, more often than not, involve high technology in an effort to achieve high performance -- performance which provides an advantage over the postulated enemy threat and adversary battlefield systems.

With very few exceptions personnel requirements derived from the new systems require higher aptitudes and more training for operators and especially for maintainers. Often the number of maintainers also increases. A slow but steady "skill creep"[1] is very much in evidence. In its Personnel Supportability Study Assessment (Heavy Division 86 Transition),[2] the Army summarizes the impact of force modernization on enlisted requirements in extenso. The magnitude of the problem is suggested by the following statistics:

- 29 MOS now operating at 90% operational strength have increased manning objectives of 20%.
- 11 MOS with increased manning requirements have course attrition rates in excess of 40%.
- 34% of the MOS with increased manning objectives are potentially not supportable.

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[1] Definition of this term is given in the glossary.

[2] US Army Soldier Support Center, Personnel Supportability Assessment (Heavy Division 86 Transition), Volume I, 1981.

- M-1 Tank
  - MOS 31E, Field Radio Repairer

    Prerequisite: electronics score, 110

    Course attrition: 42%
  - MOS 45G, Fire Control System Repairer

    Course length, 26 weeks (awarded L8 ASI)

    High attrition rate
- DIVAD
  - MOS 24W DIVAD System Mechanic (new MOS)

    Course length, 39 weeks

    (VULCAN System Repairer course length is 23 weeks.)
- Intel/EW
  - MOS 33S EW/INTCEP System Repairer

    Course length, 34 weeks

    Course attrition, 30%

    (High civilian demand)

This "skill creep" is occurring on top of a shortage in the very functional areas which must be expanded to support the new systems -- electronic maintainers (all categories), computer operators and maintainers, mechanical maintainers, fire control specialists, etc.

The personnel management and training communities are scrambling to assess the scope and nature of these system-driven requirements in order to provide the manpower and the skilled personnel required. The supply side of the problem, although difficult, is more immediately tractable than the demand side. Personnel managers can turn to recruiters and ask for the accession of higher quality personnel. They can turn to the trainers and ask for increased skill performance through improved or longer training. Although both actions are necessary, neither is apt to suffice in the long run. In the long run it will probably be necessary to reduce skill demand by intervention in the weapons system acquisition process. At this time there are no commonly accepted methodologies or the resources to do so.

Although program managers (PM) and TRADOC System Managers (TSM) working within the systems acquisition process are charged with responsibility for insuring that MPT and logistic considerations are integrated from the beginning of development, the process does not work very well. What does work is largely reactive in nature. The system is designed and then the MPT implications (how many soldiers must be procured, trained and assigned to the operation and maintenance of the system) are gleaned from (usually subjective) analysis of functions and tasks to be performed by personnel (rather than machines). There is very little effective effort to match skill requirements with skill availability.

There are many reasons for this, but one of the most important stems from the incentive structure as it affects system design. Most system contractors:

- are not given personnel constraints on design in language and detail they can understand and use;
- do not believe that they can afford to trade-off performance to meet vague personnel skill limitations;
- consequently, design to win the performance competition and simply go on to describe the skills required to operate/repair their system;
- note that the values assigned to ILS (including MPT) in the selection process are low compared to the weight and values placed on performance;

- are doubtful that testing is sophisticated enough to isolate MPT aspects of system performance; and
- are reluctant to risk money on elements with low value in the testing and evaluation.

In the face of these perceived realities, design engineers are forced to take the lead, extrapolating ILS considerations from past experience with similar technology on antecedent systems. They sometimes do a superb job with the design as, for example, at the TOW weapons/gunner interface. This accolade conspicuously excludes the TOW trainer. However, the **laissez faire** approach more often produces higher skill requirements than the Army can meet somewhere along the operator/maintainer spectrum. The very real difficulties associated with concurrent development of ILS components, leads to a sequential approach -- an approach easy to understand, relatively simple to follow, and inherently of least risk and cost to the contractor -- and a cumulative disaster to the Army. The approach is summarized below:

- first design the hardware;
- design the maintenance system including requirements for BITE, FIT, other ATE and work echelonment;
- include boilerplate on ILS (all the right words), skimp on the program and thus on the costs;
- build the advanced engineering model;
- perform task/skill analysis and limited man-machine trade-off (keep the operator tasks under control -- they count in testing), let the maintenance tasks compensate as necessary;
- start the tech manuals;
- address the training aspects:

- minimum preparation for DT/OT II training;
- start on the SPAS slowly (there will be many engineering changes [ECPs]);
- start on the simulators slowly (there will be many engineering changes [ECPs]); and

- finesse MPT as much as possible in DT/OT II on the basis that the ILS systems have not yet been refined (or even produced). Anyhow, their relative value in the selection process is low and the tests imprecise.

This is not the way the process should work. There are some noteworthy exceptions in which a few individual program managers and contractors have combined to affect preliminary design from the MPT standpoint. But techniques and standards do not exist. It is, therefore, a haphazard system at best. There is wide and growing recognition of the problem and a high determination to attack it on a broad front. But it is not an easy problem to solve for at least three powerful reasons:

- Acquisition management is driven toward other priorities.
- The MPT community has been reactive and non-specific.
- The MPT tools to operate effectively at the very front end generally do not exist.

When event-oriented development (acquisition) procedures (test/evaluate/decide -- e.g., ASARC/DSARCS) are thrown out of synchronization with a calendar-oriented program and budget, the PM usually runs out of time and money. In close collaboration with the contractors, he drops off the least visible, hardest to do, and safest to ignore part of his program -- ILS/MPT. Senior acquisition managers concur or look the other way. As in the case of the M-1 tank, ILS/MPT considerations are deferred; and when the system hits the field, there is a scramble to repair the damage from **laissez faire** ILS/MPT. A period of several years ensues in which availability is low -- troop performance (proficiency) is marginal. The field forces absorb the readiness problems while the logisticians order more repair parts. By this time design has been frozen, and skill requirements are no longer negotiable.

In the meantime, the undisciplined front end of the process (design without personnel constraints) applied to system after system creates a rapidly cumulating demand for additional manpower and skilled personnel -- a demand beyond the cumulative capability of the Army to satisfy. BITE fails to live up to expectations. Performance then falls short of the technical capabilities so expensively built into the system. Furthermore, and consequently, the length of specialist courses (mostly maintenance) must be increased (eating up unprogrammed manpower) in an attempt to close the soldier/machine interface gap. Faced with these mounting problems, the managers of manpower, personnel, training, and logistics have quite necessarily gone into a damage limiting posture -- reactive in nature. This reactive mode is a <u>supply-side</u> approach and consists primarily of efforts to forecast requirements for MPT so that the recruiting and training machinery can be focused on meeting the higher skill requirements. Certainly it is important to continue to work the reactive fixes to the extent feasible. The new systems are being procured and fielded. Their cumulative impact, although not yet wholly quantified, aggregated, and stratified for recruiters and trainers, apparently is in excess of personnel capacity and skill levels.

From the viewpoint of <u>supply-side</u> management, the technical approach involves the aggregation of skill requirements across all new systems or functions as they arrive in the force and then setting management goals and programs for recruiting, training, controlled migration, controlled retention, and promotion, which in combination hopefully will meet the demand. From the standpoint of demand management there are three ways to reduce MPT requirements:

- engineer complexity away from the soldier/machine interface and thus reduce and/or simplify the operator and maintainer tasks which must be performed by soldiers.
- reduce the number of high demand systems within the force. That is, change the internal composition of the force.
- reduce the size of the force structure and carry the demand downward across all systems.

It is not a trivial or simple matter to engineer down complexity at the soldier-machine interface. The design engineer is probably faced with a zero sum game. He can trade off complexity at the operator/maintainer interfaces for some combination of the following:

- reduced system effectiveness;
- more cost and less complexity;
- lower operational availability;
- higher skill requirements, cost, and time, further back in the support structure.

The personnel manager should be quite certain that he cannot meet the higher skill demands inherent in the higher performance systems through recruitment, reclassification, migrations, retention, or training before he induces one or more of the unattractive trade-offs available to the engineer. Of course the Army can meet the demands of any one system, but the problem is to meet the aggregate demand of all systems.

The magnitude of the problem and its imminent nature have induced a high level of research and study activity in this area. A sample of the MPT-related study and research efforts is listed below:

Study/Activity	Agency	Status
• Personnel Supportability Analysis to "ensure" (determine if?) Army 90 organizational changes are supportable from an MPT standpoint	SSC-NCR Pers. Resource Directorate	Submitted to DA 12 Mar 81
• Sensitivity of Manning Functions and Supply to Army Policies and Environmental Variables	ARI Manpower & Pers. Research Laboratory Military Academy Major Tom Fagan	In process
• National Manpower Inventory - Tri Service	ARI Pers. Policy Research Group	In Process
• Integration of human factors into development of C^3 systems	ARI Human Factors Technical Area	In Process
• The Functional Review (projects personnel changes in each functional area over time -- as new systems and associated units come on line -- expressed in MOS and grade by fiscal year)	SSC-NCR Pers. Resources Directorate	In Process
• Early Training Estimation System (ETES) to determine training requirements early in the acquisition process	ARI Fort Bliss Field Unit	In Process
• The Soldier Analysis to provide "soldier" factors, e.g., task performance times, training times, crew/team size, etc., to the MAA/MENS process -- predicts soldier performance and capabilities	SSC-FBH	In Process

• Soldier 90 -- an effort to display to the MPT community the available (projected?) supply of critical specialties by CMF	SSC-FBH	In Process
• MIST -- a management system to control and coordinate the acquisition and flow of MPT information (and associated data bases) on a system-by-system basis	ARI Systems Manning Technical Area	In Process
• Personnel Long Range Planning System: exploratory research on system and long range personnel plans to specify supply-side flows (accession, migration, retention) by CMF, demographics, etc. to meet specified future personnel requirements	ARI Manpower & Pers. Research Laboratory	In Process

Although important analyses of supply and demand issues are underway, the application of the hard CMF/MOS/skill-level data in dynamic MPT planning analysis which takes both supply and demand into account over time is just now in the beginning stages. The efforts underway by ARI, the SSC, and others are intrinsically valuable. Nonetheless, integration of these efforts (individually and collectively) to affect the overall MPT management problem will be difficult. "Skill creep" is the chief cause of the latter problem. A system for closing the loop between the MPT planning and analysis process and the system design process (the design engineers) must be formulated and formalized.

3.0 INTERFACING MPT DEMAND AND SUPPLY

As noted in the previous section, the Army develops new systems through an intricate event-phased materiel acquisition process. Historically, concern in this development process has been with hardware performance, costs, and schedule. There does not now exist an organized process to determine on a continual basis if personnel with appropriate skills can, in fact, be provided to operate and maintain all of the Army's future systems to their design performance. This section of the report presents a schematic representation of a process that we believe can and should be developed to assist in managing the MPT demand during system development and the interface between MPT demand and supply.

Exhibits 1 and 2 are schematic representations of the interface between MPT demand and supply. Exhibit 1 represents the aggregated interface across all Army systems and exhibit 2 the system-specific interface. (Exhibit 2 is an exploded representation of the MAN/MACHINE ANALYSIS element in exhibit 1.) The left side of exhibit 1 summarizes the demand process, the right side the supply process, and the center their interface. A general description of the demand and supply processes is given in the next two paragraphs, and the interface between them, including the man/machine analysis element (exhibit 2), is detailed in the remainder of this section of the report.

MPT demand is generated by the characteristics of new systems and by the number of those systems which find their way into the force structure of the Army. The SYSTEM ACQUISITION PROCESS employs various studies (MAA, TD, TOA, BTA, etc.) and documents (MENS, LOA, etc.) to move new systems (A, B, ...N) through the development phases (Concept Formulation,

EXHIBIT 1: SCHEMATIC OF MPT DEMAND/SUPPLY INTERFACE PROCESS

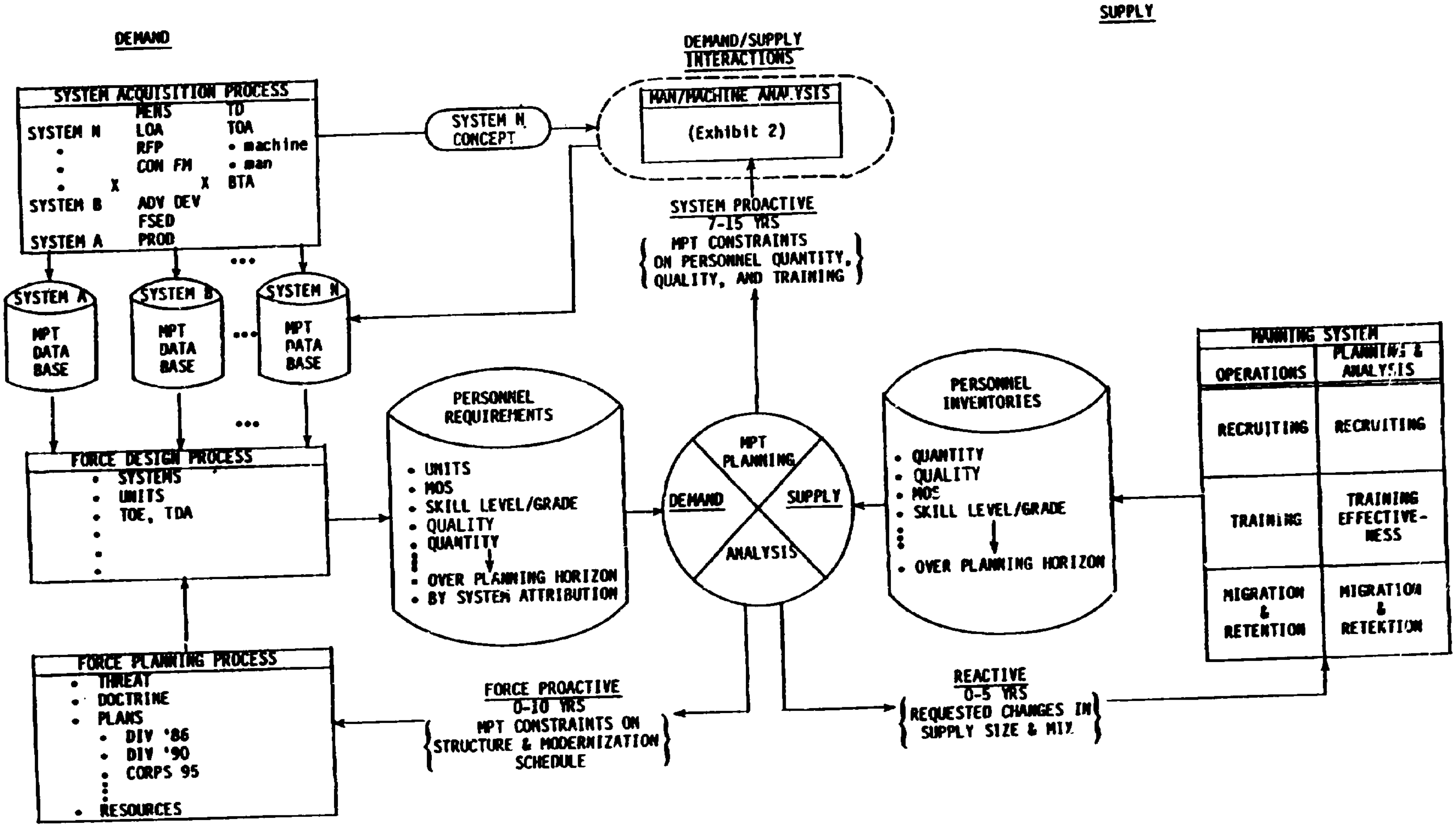
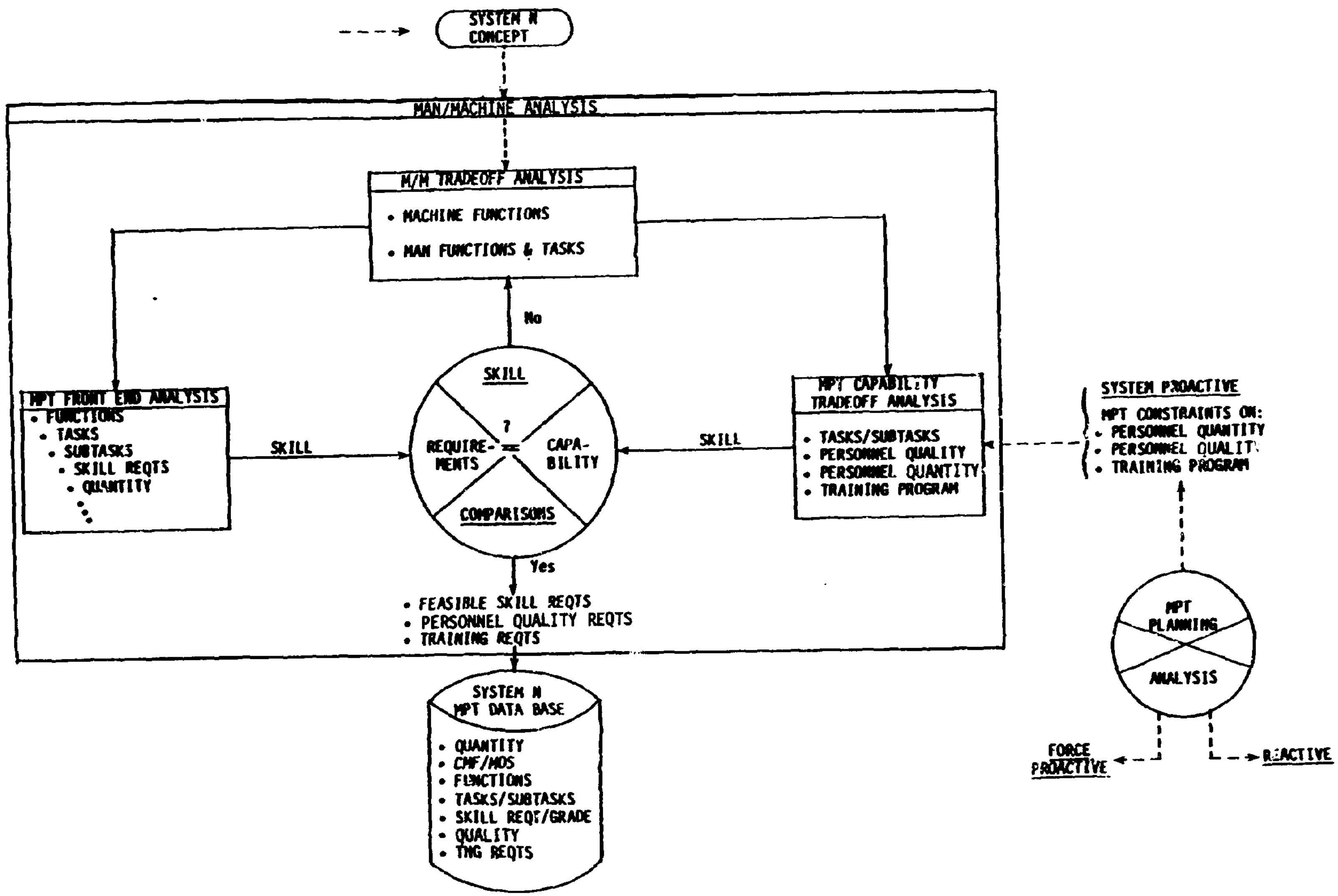


EXHIBIT 2: SCHEMATIC OF MAN/MACHINE ANALYSIS PROCESS



Advanced Development, etc.) to send a stream of systems to the FORCE DESIGN PROCESS where they are melded into the force. The design characteristics for the new systems determine the allocation of functions and tasks between the machine and the operators and maintainers and, thus, the MOS and the nature and level of skills required for the system. The size of the force and its functional configuration (maneuver, fire support, air defense, etc.) derive from the FORCE PLANNING PROCESS which relates strength and structure to the threat, evolving doctrine (DIV 86, Corps 95, etc.) and available resources. The size and composition of the force determine the number of each MOS required. The product of the force design process is a troop list by unit type and number (changing over time) and a table of organization and equipment (TO&E) for each unit within which the systems, their operators, maintainers, and supervisors are integrated. From the MPT standpoint this demand process is finally expressed in a PERSONNEL REQUIREMENTS data base which is described later in discussions of the demand/supply interfaces.

The number and kinds (MOS, grade, skill level) of soldiers required are determined by the demand process. On the supply side, the MANNING SYSTEM involves recruiting, training, reclassification, migration, and retention of soldiers. But the number and kinds by various demographic characteristics, MOS, grade, skill level, etc., of soldiers available are functions of recruiting, reclassification, migration, and retention incentives; the effectiveness of the training system; and demographic characteristics (AFQT category, education, etc.) of the individuals to whom that training is applied. The product of the manning system is a time-phased inventory of trained personnel available for assignment to meet the demand. Supply-side functions (recruitment, reclassification, migration and retention, and training) are the focus of continuing analyses, some of which were noted earlier in this paper.

The aggregated interface between MPT demand and supply is accomplished by MPT PLANNING ANALYSIS which continually identifies time-phased personnel shortages by personnel descriptor class[1] over the Army's planning horizon (0-20 years). These analyses require simultaneous access to the PERSONNEL INVENTORIES data base and a PERSONNEL REQUIREMENTS data base.

Operation of the manning system affects the flows of personnel into the Army (accession), among various personnel descriptor classes (migration), and out of the Army (separation). These flows generate time-phased personnel inventories (available supplies) which (usually) change in both size and mix by personnel descriptor class. Various procedures, such as COMPLIP or VRI's Personnel Planning System, exist to forecast these inventories, which should then be stored in the PERSONNEL INVENTORY data base. The dimensions of this data base must be at a level of detail sufficient for comparison with time-phased overall personnel requirements.

As depicted in exhibit 1, MPT information generated by the SYSTEMS ACQUISITION PROCESS and the MAN/MACHINE ANALYSIS[2] for a <u>single system</u> is stored and continually updated in a SYSTEM MPT DATA BASE. Each will contain current system-specific MPT requirements information such as quantity of personnel; CMF/MOS; functions, tasks, and subtasks to be

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[1]A personnel descriptor class includes MOS, grade, skill level, years of service, and demographic information such as education, sex, AFQT category, and ASVAB aptitude scores.

[2]Details of this are discussed later in this section of the report.

performed by personnel; skill level requirements; training requirements, etc. similar to that contained in a QQPRI. Such a data base would be used to access current MPT requirements as the system advances through the development process and would, through the FORCE DESIGN PROCESS, provide information to develop aggregated demand data.

The PERSONNEL REQUIREMENTS data base is an integrated one which contains total, time-phased MPT requirements for the Army. The requirements information such as units, quantity of personnel, CMF/MOS, skill level, etc. is obtained from the individual SYSTEM MPT Data Bases and represents the overall "demand for Army personnel." This data base serves two principal purposes in the MPT process. It provides the demand data for use in comparisons with time-phased personnel supplies to identify shortages. Secondly, it provides information to identify DCSPER proactive actions required to alleviate some of the shortages. For this purpose it is important that the data base be structured so that the MPT requirements can be linked back to the specific systems that generated them (through the force design process).

Using information contained in the PERSONNEL REQUIREMENTS and PERSONNEL INVENTORIES data bases, the MPT PLANNING ANALYSIS is a time-phased comparison of personnel requirements and inventories both by total quantity and by mix of personnel with appropriate descriptors such as CMF/MOS, skill level, etc. Although not sufficiently detailed, the kinds of information envisioned are shown in exhibit 3 which displays shortages by CMF for FY87, FY91, and FY2001.[1] Thus, for example, the analysis suggests there will be shortages of 23,160 mechanical maintenance

[1]This exhibit was generated by VRI's Personnel Planning System developed for ARI to identify important policy-related personnel research activities.

EXHIBIT 3: EXAMPLE OUTPUT FROM MPT PLANNING ANALYSIS

	FY87				FY91				FY01			
CMF	SUPPLY	DEMAND	DIFF	PERCENT	SUPPLY	DEMAND	DIFF	PERCENT	SUPPLY	DEMAND	DIFF	PERCENT
11	76.1	86.3	-10.2	-11.9	80.1	91.0	-10.9	-12.0	87.0	100.4	-13.4	-13.4
12	23.6	20.7	3.0	14.4	25.1	22.2	2.9	13.0	26.4	24.5	1.9	7.8
13	48.4	47.7	0.7	1.6	52.8	51.5	1.3	2.5	59.5	56.9	2.6	4.6
16	15.2	17.8	-2.6	-14.5	14.9	18.3	-3.4	-18.7	15.0	20.2	-5.2	-25.7
19	35.8	33.8	2.0	5.8	38.5	35.8	2.7	7.4	43.6	39.5	4.0	10.2
23	5.7	4.9	0.8	15.6	6.1	5.1	1.0	19.9	6.7	5.6	1.1	19.6
27	6.4	4.2	2.2	52.0	7.0	4.5	2.5	56.6	8.0	4.9	3.1	62.5
28	4.5	2.4	2.1	89.4	5.1	2.5	2.6	103.4	6.5	2.8	3.7	131.2
29	15.9	14.7	1.2	8.2	17.4	15.6	1.8	11.7	20.0	17.2	2.8	16.3
31	61.4	62.0	-0.7	-1.1	66.0	66.2	-0.2	-0.3	73.5	73.0	0.4	0.6
33	1.7	1.6	0.1	9.4	2.0	1.7	0.3	18.7	2.3	1.9	0.5	25.8
51	16.2	17.0	-0.8	-4.9	17.4	17.9	-0.5	-2.6	19.8	19.8	0.1	0.4
54	6.2	8.2	-2.0	-24.9	7.1	8.9	-1.8	-20.5	7.8	9.8	-2.0	-20.4
55	6.9	6.3	0.6	9.4	8.0	6.8	1.2	18.1	9.5	7.5	2.0	27.3
63	48.8	71.9	-23.1	-32.1	49.4	77.3	-27.8	-36.0	52.6	85.3	-32.7	-38.4
64	36.9	33.0	3.9	11.7	40.0	37.1	2.9	7.8	44.9	41.0	4.0	9.7
67	26.3	20.5	5.9	28.6	27.4	22.6	4.8	21.2	30.0	24.9	5.1	20.3
71	53.8	55.5	-1.7	-3.0	56.9	59.3	-2.4	-4.0	62.5	65.5	-3.0	-4.6
74	4.3	4.7	-0.4	-8.6	4.5	5.1	-0.6	-12.3	4.9	5.6	-0.7	-13.0
76	53.2	49.5	3.6	7.3	56.3	53.8	2.5	4.6	58.6	59.4	-0.7	-1.2
79	13.9	8.6	5.3	61.4	17.0	9.1	7.9	87.2	21.4	10.0	11.4	113.5
81	5.2	1.6	3.7	235.4	5.7	1.6	4.1	247.7	6.6	1.8	4.7	261.7
84	6.0	3.4	2.6	78.3	7.3	3.6	3.7	104.1	9.6	4.0	5.7	143.1
91	45.1	43.9	1.2	2.8	48.4	47.2	1.2	2.6	55.8	52.1	3.7	7.2
92	12.2	6.1	6.0	98.4	15.7	6.9	8.8	127.4	19.2	7.6	11.6	152.8
94	21.2	24.2	-3.0	-12.4	21.6	26.2	-4.6	-17.6	22.9	28.9	-6.0	-20.6
95	28.7	27.6	1.2	4.2	30.8	29.0	1.8	6.2	33.7	32.0	1.7	5.3
96	7.6	7.1	0.5	6.7	8.5	7.6	0.9	11.4	9.6	8.4	1.2	14.1
97	2.3	2.9	-0.5	-18.7	2.6	3.1	-0.4	-13.6	3.1	3.4	-0.2	-7.4
98	11.0	13.2	-2.1	-16.1	12.2	13.9	-1.8	-12.8	13.8	15.4	-1.6	-10.2
TOTAL	700.2	701.0	-0.8	-0.1	751.6	751.3	0.2	0.0	834.8	829.2	5.6	0.7

personnel (CMF 63) in FY87, which is 32.1 percent under the requirement for such personnel skills.

Given a set of shortages (and overages) identified by relevant descriptors (MOS, grade, skill level, etc.), personnel managers could attempt to alleviate the problems in a REACTIVE manner. This would involve time-phased changes in the manning system; recruiting, reclassification, migration, and retention flows and/or training programs to alter the size and/or mix of future personnel inventories. These are short term supply-side fixes (zero to five years) to correct imbalances, if feasible. Alternatively or concurrently, personnel managers could initiate PRO-ACTIVE changes. Thus, for example, if the comparison between requirements and inventories indicates a significant, time-phased, and increasing shortage of mechanical maintenance personnel, then the requirements data base could be queried to identify which systems were utilizing these skills, the timephasing of these requirements for each system, and the system development status (i.e., concept, validation, ..., fielded). For mature systems that are in production or in the latter phases of the system acquisition process (e.g., systems A,B), FORCE PROACTIVE actions such as changes in IOC/FOC dates (i.e., stretch out) for specific systems might be pursued to "smooth out" the shortages. In extreme cases, the number of systems in the force might need to be reduced, with impact on force design. These are midterm (zero to ten years) MPT constraints on force structure size and composition and modernization schedules. For systems in the front end of the development cycle, SYSTEM PROACTIVE actions such as constraining the number and/or skill levels that can be designed into a system might be pursued to alleviate the shortage in the future. These are long term (seven to fifteen years) MPT constraints on system design and derivative skill requirements which are used as input to the MAN/MACHINE ANALYSIS described in the remainder of this section.

In addition to the aggregated interface between demand and supply for all Army systems, integration of MPT into the systems acquisition process requires that demand and supply be interfaced at the system level early in its conceptual design. This interface should occur in the MAN/MACHINE ANALYSIS, components of which are schematically represented in exhibit 2.

Using a concept of what functions the system is intended to perform, a first iteration of a MAN/MACHINE TRADE-OFF ANALYSIS (M/MTA) should be performed to allocate various functions and tasks between the human (operator, maintainer, supervisor, etc.) and machine components, thus formulating an initial conceptual design. This analysis should give consideration to various criteria such as desired system performance, costs, reliability of available component options, etc. This initial conceptual design should then be subjected to both an MPT FRONT END ANALYSIS (MPT FEA) and an MPT CAPABILITY TRADE-OFF ANALYSIS (MPT CTA) as described below.

The purpose of the MPT FEA is to determine specific personnel requirements deemed necessary to accomplish (at an appropriate performance level) the functions and tasks allocated to the human in the man/machine trade-off analysis. The MPT FEA hierarchically decomposes the functions into supporting tasks, subtasks, and skill levels required to achieve the desired performance of the system. Thus, for example, the MPT FEA might produce the following hierarchical structure for a main tank gunner:

- function: fire the gun at a moving target;
- task: aim the gun;
- subtask: track the target; and
- skill level: track with a .60 mil error or less.

The skill level requirement derives from the system performance requirement that the single shot hit probability be .75 or higher.

The purpose of the MPT CTA is to determine the level of <u>personnel capability that can be provided</u> to man the system. For each task/subtask to be performed by the human component in the system, the MPT CTA determines achievable skill levels by examining trade-offs between the number of personnel assigned the task/subtask, quality of personnel (measured by AFQT category, ASVAB scores, etc.), and the training program (type, duration, etc.), within the MPT constraints derived from the central multi-system supply/demand planning analysis.

The SKILL COMPARISON analysis depicted in exhibit 2 compares outputs of the MPT FEA (demand) and MPT CTA (supply) -- by task, subtask, and skill levels -- to determine if the skills required can be provided. Continuing the gunner example, if the MPT CTA indicates that the minimum tracking error that can be achieved (within the personnel quality and training constraints) is 1.5 mils, then the conceptual design process must be iterated. Some options then available include:

(1) reallocate more tasks/subtasks to the machine component (e.g., employ a homing projectile to eliminate the human tracking subtask), resulting in a possible cost increase;

(2) reduce the skill requirement to a feasible level (e.g., accept a tracking error of 1.5 mils), resulting in a degradation in overall system performance; and

(3) loosen the personnel quality requirements and/or training constraints to improve available skill capability (probably causing increased MPT constraints on other systems because the personnel inventory is limited).

This conceptual MPT design process involving the M/MTA, MPT FEA, and MPT CTA, subject to proactive MPT constraints, should be iterated early in the acquisition process until the system's personnel requirements are consistent with forecasts of achievable personnel capabilities. Output of this dynamic interface between system MPT demand and supply is a feasible set of

- skill requirements from the system design (FEA);
- personnel quality requirements (from the CTA); and
- training requirements (from the CTA).

All information generated by this man/machine analysis process -- skill requirements, personnel quality requirements, quantity requirements, CMF/MOS, function allocations, supporting tasks/subtasks, training requirements, etc. -- should be stored, maintained, and periodically updated in a SYSTEM MPT DATA BASE for use by PM and TSM. Additionally, as shown in exhibit 1, information contained in the system MPT data bases should be used to create and continually update the PERSONNEL REQUIREMENTS data base.

4.0 RECOMMENDATIONS

In section 2.0 we summarized the "skill creep" problem and indicated the need to integrate MPT supply and demand and the system acquisition process. Section 3.0 described a conceptual process to interface MPT supply and demand -- both at the macro multi-system level and the micro system-specific level -- within the context of the acquisition process. Although MPT-related documents are now generated,[1] and MPT-related data bases exist,[2] many of the component parts (methods, data bases, etc.) of the structure are not now available, and the MPT process is not organized for use by the ODCSPER.

This section of the report contains a list of activities we believe ARI should pursue to effect development and implementation of the process. The recommended efforts are partitioned into two groups:

(a) long term research efforts focused on the process, and component methods required to develop and implement it; and

(b) shorter-term exploratory projects to bring the users into the development effort at the outset.

The recommended efforts are not an exhaustive list of research and study efforts but, rather, key ones deemed important to develop a momentum for integrating MPT supplies and demand. They are not listed in priority order -- all are deemed integral to the overall program. An appendix describes ideas regarding the recommended process-oriented research. These descriptions generally focus on "what" effort is needed, not "how" to do it.

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[1]Such as QQPRI.

[2]Such as PERSACS and COMPLIP inventories.

4.1 RECOMMENDED PROCESS RESEARCH EFFORTS

This section presents a list of recommended efforts related to development of the process and component parts represented in exhibits 1 and 2. Although we have not conducted an exhaustive review of the many ongoing and recently completed MPT research projects, we are aware that some directly related research efforts are underway. In such cases, their inclusion below is intended to substantiate the requirement for them rather than be a recommendation for a new research program.

OVERALL STRUCTURE:

We believe the structure described in section 3.0 for interfacing MPT supply and demand is conceptually appropriate in that it contains all the necessary components, linkages, and information flows. Development and implementation of this process should be a continuing activity in support of the TRADOC and other operating agencies of the MPT community. Further details should emerge as research on components provides more specifics on the information flows. The specific information flows should then be used to develop the procedural process which details documentation requirements, timing within the MPT management and system acquisition process, component proponents, and overall responsibility for the integration analyses. Particular effort should focus on the MAN/MACHINE ANALYSIS process -- when to conduct an analysis, who conducts it, how to interact with contractors at various phases in the acquisition process, how to interact with PM and TSM, how to interface with development and operational tests; etc.

COMPONENTS:

The main components of the overall structure require detailed research and development. Some could be developed by the operating MPT community proper, while others would be the necessary focus of ARI. They are listed below with an indication of which ones should receive priority in ARI.

(1) MPT Planning Analysis (in process):
Methods that allow for time-phased comparison of overall, multi-system MPT inventories (supplies) and requirements (demand).

(2) Planning in the Manning System (in process):
Methods to forecast future personnel inventories, given time-phased personnel flows, and procedures to search for "good" flow targets that will improve personnel inventories **vis-à-vis** personnel requirements.

(3) Personnel Inventory Data Base (in process):
Data base to store and make available current and projected (ten to fifteen years) personnel inventories by appropriate personnel descripters (e.g., demographics, career fields, etc.)

(4) Personnel Requirements Data Base (ARI):
Data base to store and make available time-phased personnel requirements by appropriate descripters for comparison with personnel inventories. Must have link to individual systems and force designs for requirements attributions.

(5) System MPT Data Base (ARI):
An individual system data base (and DBMS) containing functions allocated to human component of system; supporting tasks and subtasks; personnel quantity, quality, training, and skill requirements; CMF/MOS requirements, etc.

(6) Hierarchy of System Functions and Supporting Tasks (ARI):
A hierarchical structure of operational functions, tasks and subtasks that are performed by soldiers and machines for various generic system types.

(7) Man-Machine Trade-off Procedures and System Front-end Analysis Methodology (ARI):

Methods to allocate a system's functions, tasks, subtasks, etc. between man and machine components (M/MTA), and procedures to determine personnel skill requirements to perform its allocated tasks and subtasks.

(8) MPT Capability Trade-off Analysis Methodology (ARI):

Procedures to determine capabilities (skill levels) that can be attained by Army personnel as a function of their quality, quantity, and training.

(9) Personnel Performance Data Base (ARI):

Data base containing historical information on skill levels achieved by Army personnel, their training, and quality.

(10) Skill Comparison Procedures (ARI):

Procedures for iterative comparison of personnel skill requirements (from the MPT FEA) and personnel skill capability (from the MPT CTA).

(11) MPT Aspects of RFP and Proposals (DARCOM/ARI):

Procedures for expressing MPT requirements in RFPs and evaluating MPT aspects of proposals.

(12) Procedures for DT/OT Evaluation of MPT (OTEA/ARI):

Feasibility and utility of using software and hardware techniques to simulate performance of personnel tasks/subtasks so that MPT testing at DT/OT I can be performed with breadboard and paper designs.

(13) MPT Educational Material (ARI):

Development of educational vehicles such as courses, manuals, etc. on the MPT integration process for PM, TSM, other MPT managers, and contractors.

A brief description of the general scope of the development effort we have in mind for each component is provided in the appendix to this report.

4.2 RECOMMENDED EXPLORATORY EFFORTS

In order to prime the pump -- to involve the operators in process development, to focus and support the requirement research, and to provide visibility and momentum to the effort -- we recommend the following exploratory, near-term efforts.

(1) STINGER Project

- Conduct an **ex post facto** man/machine analysis for the GUNNER-COACH STINGER weapon system with emphasis on the M/MTA and FEA aspects.
- Examine retroactively the front-end of the acquisition process (system design-man/machine function allocation and task distribution) in the light of gunner-coach performance data now available.
- Determine whether performance information of the kind now available could have/should have been used to influence system design. This determination could establish a base line for the structure and data sources required for the PERSONNEL PERFORMANCE DATA BASE. We have in mind performance of such tasks and functions as: detection, recognition, identification, range estimation, target acquisition, tracking, super elevating, and firing.
- Determine how the skill comparison process should work in the procedural loop illustrated in exhibit 2. Identify missing data, tools, etc.
- For the purpose of this exploration, the training program could be held constant. (The training variable will be considered in the second exploratory effort recommended below.)

- ARI should design, preside over, and participate in the project. A small team is recommended for this exploratory analysis. An MPT specialist should represent the supply side. A weapons system acquisition specialist could represent the demand (design) side but should be STINGER-system-qualified. A representative of the SSC would add balance. The DCSPER and DCSRDA should co-sponsor. DARCOM, MILPERCEN, and TRADOC would support.
- The project should be completed by the end of calendar year 1982.

(2) M1 ATE Project

- Conduct an **ex post facto** man/machine analysis for the M-1 ATE (BITE, etc.) with emphasis on the CTA and focus on the training variables. The personnel quality constraint would be considered fixed at the level of the personnel who have been actually assigned to M-1 operations/maintenance.
- Based on actual performance data with M-1 ATE through DT/OT and subsequent testing, determine whether CTA could have/should have affected changes in system design and/or changes in training program.
- Determine how the skill comparison process should work in the procedural loop illustrated in exhibit 2. Identify missing data, tools, etc.
- Consider whether ATE-related functions (fire control system, automotive system, etc.) would be a basis for generic treatment of man/machine trade-off analyses; that is, whether performance with one system fire control BITE is transferrable to other systems for M/MTA (i.e., hierarchical functions/tasks structure).
- ARI should design the approach, preside, and participate in the analysis. As in the case of the STINGER project, a small team would

seem adequate, assuming DARCOM, TRADOC, and MILPERCEN support the effort. The supply side member should be training-oriented; the demand side representative, M-1-ATE-qualified.

- The project should be initiated following the STINGER project.

(3) **ASAS Project**

- ASAS is a forthcoming development. Some performance data on intelligence analysts and ADP terminal operators has been acquired via the BETA project and the TCAC demonstration. Some requirements data has been developed in the functional system design study and its workstation analysis.
- The Army (DCSPER, DCSRDA, DARCOM, and TRADOC) should conduct a comprehensive management exercise (MGX) in 1983 to exercise the entire MPT demand/supply interface process (exhibit 1). An MGX would be an austere CPX-like workshop involving representation from each agency involved in the process. Each step in the MPT process should be performed.
- Where data, formats, or procedures do not exist, they should be assumed, simulated, or breadboarded as necessary. These would provide some of the valuable output of the exercise. Manual procedures should be used in all cases where automated procedures do not exist. More than one exercise cycle would be re ired. The MGX should be regarded as an MPT demand/supply wargame.
- The objectives of the MGX would be:
  - to validate/refine the conceptual MPT demand/supply interface process;

- to introduce the proponents to the concept and illustrate their interrelationships;
- to define/refine components;
- to provide a basis for detailed functional system design for ASAS;
- to provide a basis for focusing and scheduling supporting research and system design; and
- to raise the visibility of MPT in the acquisition community.

- ARI should structure the MGX under the supervision of DCSPER. DCSPER would be the executive agent for the Army staff.

(4) Critical Functions CTA Project (Supporting Research)

The Army's "skill creep" problem is being manifested in the operation and maintenance functions of many Army systems scheduled for fielding in the period 1982-1988. Using whatever data can be collected or generated (even subjectively), ARI should perform quick-response CTA on one or more of the following jobs:

- electronic maintainer;
- computer maintainer;
- computer operator;
- fire control specialist;
- mechanical maintainer; and
- console operator.

The intent of this project is to generate personnel quantity, quality, and training trade-off information to attain different skill levels for the tasks/subtasks involved in performing the functions of each of the above jobs.

APPENDIX: SYNOPSIS OF COMPONENT PROCESS RESEARCH EFFORTS

Section 4.1 listed 13 research efforts related to the development of component parts of the overall MPT demand/supply interface process. This appendix contains brief descriptions of the general scope of the development effort we have in mind for each component.

(1) MPT PLANNING ANALYSIS

Design of methods that allow time-phased comparison of overall (multi-system) MPT supplies (inventories) and demand (requirements). We believe these will require computerized algorithms to:

- facilitate comparison of all relevant MPT dimensions including at a minimum: quantity of personnel, quality of personnel (probably by education, AFQT category and/or ASVAB aptitude scores), CMF/MOS, and training resources/levels;[1]
- examine "optimal" time-phased allocation of MPT supplies against demands;
- identify critical deficiencies in personnel quantity, quality, CMF/MOS, and training resources/levels; and
- identify and evaluate potential proactive remedial actions through appropriate queries of the PERSONNEL REQUIREMENTS data base.

It is important to note that "skill level" was not included in the deficiency dimensions. We believe that macro MPT management should concern itself with quality and training resource dimensions and specify "system proactive" constraints using these dimensions. Transformation of quality

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[1]Some efforts in this direction include FORECAST and VRI's Exploratory Personnel Planning System.

and training resource/level into skill level constraints (availability) should be accomplished using the MPT CTA within the micro MPT management process entitled MAN/MACHINE ANALYSIS (exhibits 1 and 2 in the main text of this report).

(2) PLANNING IN THE MANNING SYSTEM

The MANNING SYSTEM involves both operations and planning. Planning methods are needed to (a) forecast future personnel inventories given time-phased personnel flows (accession, reclassification, migration, and retention), and (b) using "reactive" feedback, search for planning flow targets that will provide improved personnel inventories **vis-à-vis** the personnel requirements.[1] Time-phased personnel supplies generated by these methods are stored in the PERSONNEL INVENTORIES data base and used in the MPT PLANNING ANALYSIS and, accordingly, must include at least the MPT dimensions considered in such analyses.

(3) PERSONNEL INVENTORY DATA BASE

Closely related to the MPT planning methods noted in (2), and probably part of them, is a data base to store and make available estimates of current and projected personnel inventories. The MPT content and structure of this data base must be designed along with a data base management system (DBMS) to insure ease and flexibility to modify and enrich the data base. This data base must be readily accessible to MPT macro management.

[1]Projects to develop such methods are currently underway (e.g., FORECAST and VRI Personnel Planning System) as well as ARI programs to develop related longitudinal data bases and policy relationships (e.g., feasible accession levels as a function of military pay scales, macro economic environment, etc.).

(4) PERSONNEL REQUIREMENTS DATA BASE

The specific MPT contents and structure of this data base must be designed. The data flows must include at least the dimensions used by the MPT Planning Analysis for comparison with personnel inventories. Procedures must be developed to facilitate input from both the FORCE DESIGN PROCESS and each SYSTEM MPT DATA BASE and access by MPT macro management. Information in this data base must have a link to individual systems and force designs so that the level of a particular time-phased demand (e.g., quantity, quality, CMF) can be attributed to specific systems, buy levels, buy schedule, etc. to identify potential proactive MPT management actions. Clearly, the possible enhancement of PERSACS should be explored for this purpose.

(5) SYSTEM MPT DATA BASE

An individual system MPT data base content and structure must be designed, as well as a DBMS to facilitate modification and enrichment of the data base.[1] Provisions should be made to structure information on alternative systems (concepts) simultaneously. As noted in section 3 of the report, this data base is fed by both the SYSTEM ACQUISITION PROCESS and the MAN/MACHINE ANALYSIS. The latter provides data regarding functions allocated to the human component of the system; personnel quantity, quality, training, and skill requirements; CMF/MOS requirements, etc. The data base must be readily accessible by PM and TSM. Although the

[1]This effort is currently in process as part of ARI's MIST program.

data may be inaccurate,[1] QQPRI provide a source of information to test the data base structure and its utility.

(6) HIERARCHY OF SYSTEM FUNCTIONS AND TASKS

The MAN/MACHINE ANALYSIS process of exhibit 2 in the main text relies heavily on the ability to decompose a system into the various activities and tasks that must be performed for it to operate. The purpose of this effort is to develop, perhaps by generic system type, a hierarchy of operational functions, tasks, subtasks, etc. that are performed by either man or machine.[2] This hierarchy is necessary for the conduct of both the M/MTA and the FEA. Example hierarchies are shown in exhibits A-1 and A-2. We believe this sort of functional description of requisite activities is reasonably well known for physical functions such as "shoot" and "drive" but less so on cognitive and perceptual activities (e.g., computer and electronic maintenance, intelligence activities, command functions, etc.). Research related to this effort is being performed for C^3/I systems under ARI's HF/C^3I program and in the MIST program.

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[1]BOIP/QQPRI Task Force, memorandum from Richard D. Lawrence, Major General, GS; Chief, Army Force Modernization Coordination Office, 7 January 1980.

[2]We recognize that many techniques such as work measurement, industrial skill analysis, task analysis and others exist to perform this study. (See, for example, "The Study of Real Skills Volume 2," Compliance and Excellence, Chapter 1, W.T. Singleton (ed.), University Park Press, Baltimore, 1979, pp. 10-44.) The recommended effort is to utilize these techniques to establish a hierarchy of functions, tasks, subtasks, etc. applicable across the spectrum of military systems.

EXHIBIT A-1: FUNCTION, TASK HIERARCHY FOR COMBAT VEHICLE SYSTEM

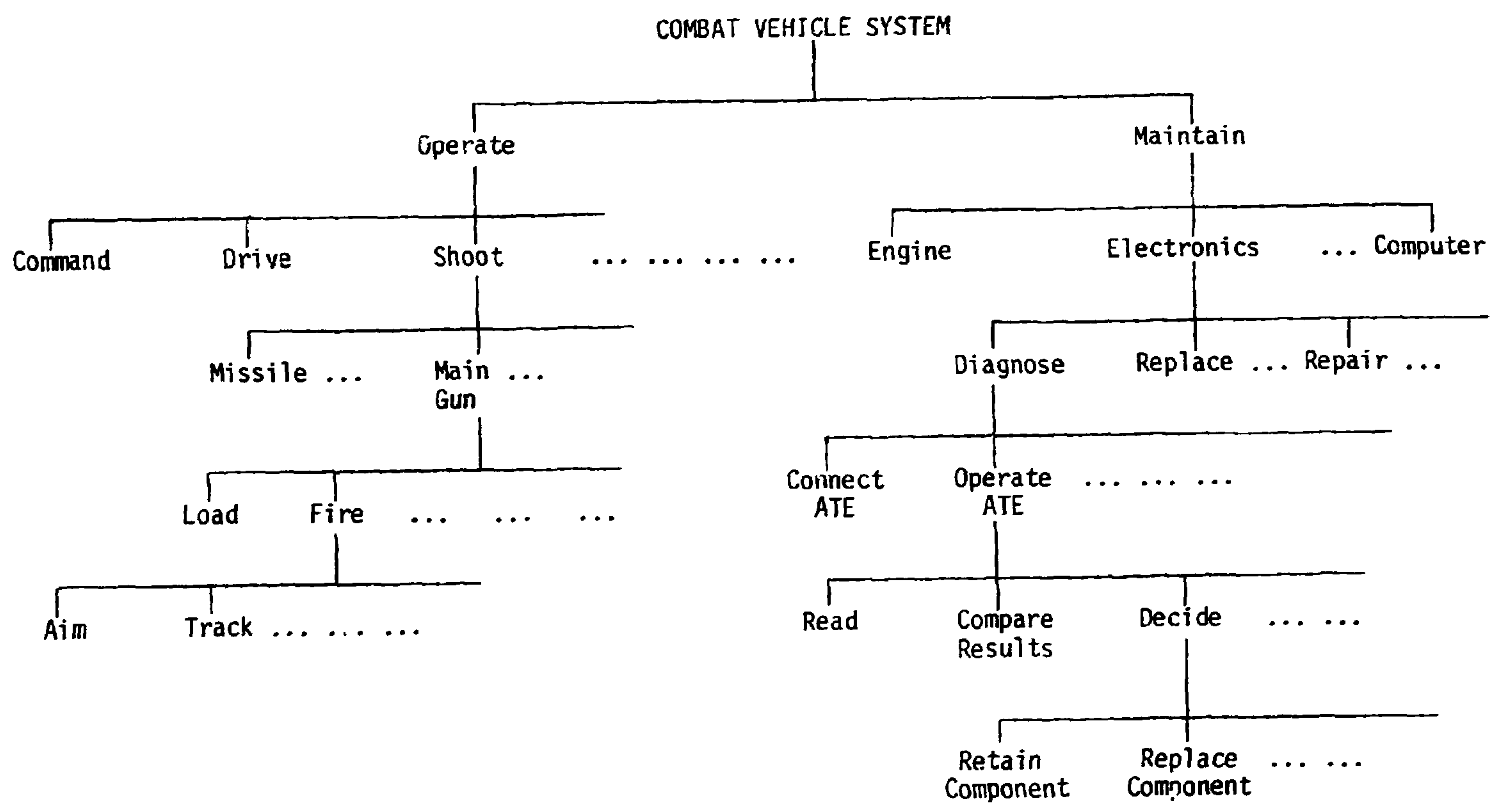
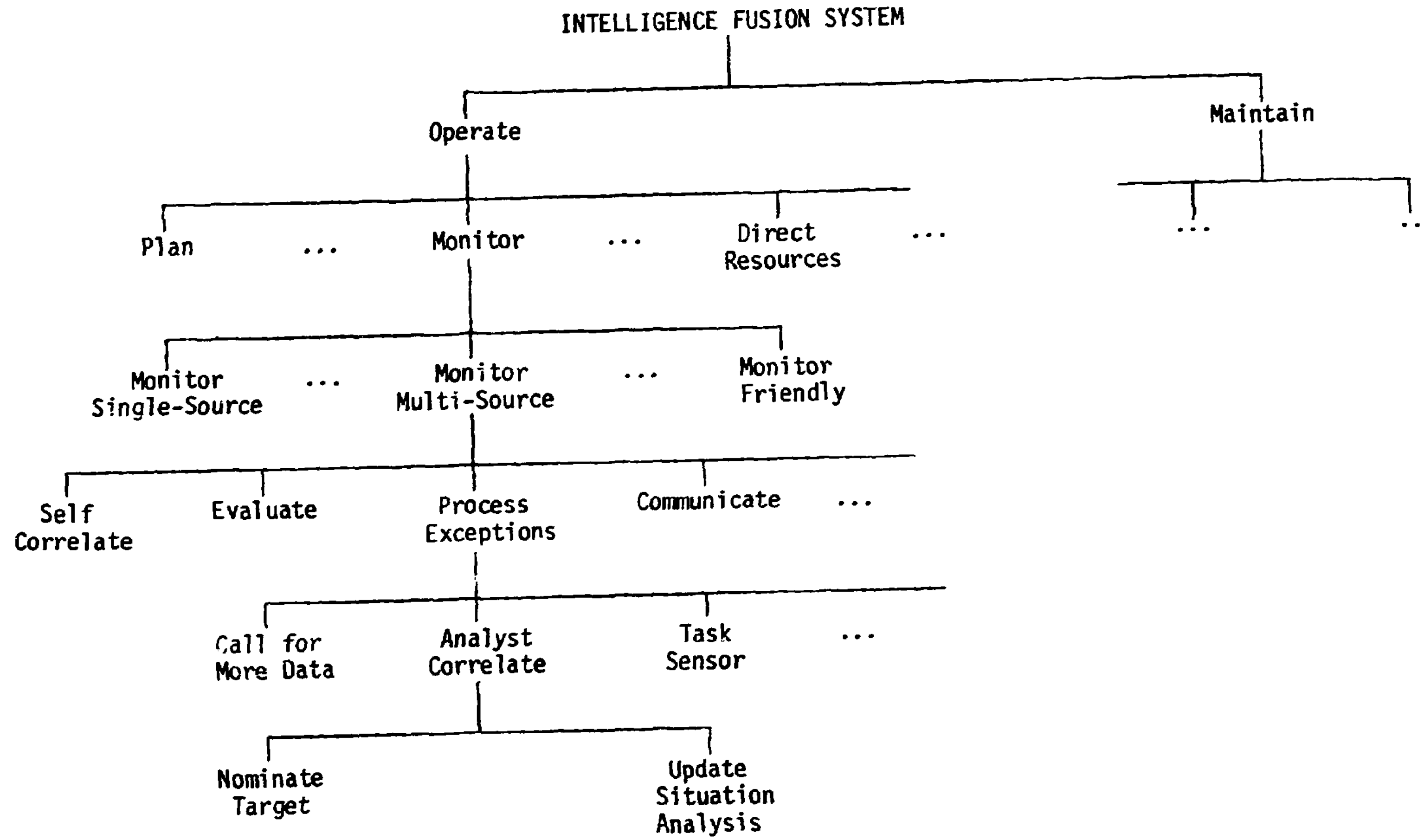


EXHIBIT A-2: FUNCTION, TASK HIERARCHY FOR INTELLIGENCE FUSION SYSTEM



(7) M/MTA AND FEA METHODOLOGY

Discussions in section 3.0 of the main text indicated that the M/MTA and the FEA served two distinct roles in the MAN/MACHINE ANALYSIS process. In the M/MTA various design options are considered to allocate a system's functions, tasks, etc. between man and machine components. It is not unreasonable to expect that this analysis will be conducted by developer contractors considering aggregate system (or function) performance implications and government-provided information regarding personnel constraints. The FEA is intended to determine personnel skills required, where skill level requirements are measured by the performance level to which tasks, subtasks, etc. assigned to the human component must be performed.[1] It is anticipated that this analysis will require more government involvement (than the M/MTA), and will consider the implications that different skill levels have on performance of the function or its related tasks. However, the procedures required to conduct M/MTA and FEA will be very similar. differing more in degree than kind. Depending on the phase of development and amount of previous man/machine analyses conducted, both will involve:

- procedures to accomplish consistent decomposition of a system's operation activities into its functions, tasks, subtasks, etc. (within the structures developed under (6) above);
- aggregate procedures to make the man/machine trade-offs based on numbers of personnel and gross performance parameters; and

[1]Although quantitative scale skill level requirements should be a target for the research (e.g., track with .60 mil error), an ordinal scaling (e.g., high, medium, low tracking requirement) could be used for initial implementation.

- detailed procedures to determine personnel skill level requirements to achieve desired task performance.

Since the M/MTA and significant parts of the FEA should be conducted by contractors, it would appear that they should develop the requisite procedures. However, experience suggests that they do not, as evidenced by the many non-existent QQPRI in 1980,[1] and the prevalent belief that information in existing QQPRI are highly suspect. Although government research effort will be required, we believe the important ramifications of inadequate M/MTA and FEA warrant this government effort. Hopefully, it will provide consistent procedures for potential use by contractors and a mechanism that the government can use to evaluate the credibility of contractor data.

Clearly, it is impossible to develop procedures for all prospective systems or even system types. Accordingly, it might be more productive to consider partitioning the research by function or task performance, e.g., maintenance functions, operations (drive, shoot, etc.) functions. The research might be organized by aggregating functions and supporting tasks by "behavioral components" -- physical, psychomotor, perception, cognitive, etc.

Regardless of how the research is organized, neither the M/MTA nor the FEA should explicitly consider "quality of personnel" or training issues on programs. The procedures should provide as output personnel quantity and skill level requirements by task/subtask for comparison with output of the MPT CTA.

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[1] BOIP/QQPRI Task Force, op. cit.

(8) MPT CTA METHODOLOGY

The purpose of the CTA is to provide information regarding capabilities that can be attained by Army personnel. Since it is intended that output of the CTA be compared with output of the FEA, personnel capabilities should be measured as skill level that can be achieved on a task/subtask basis. The procedures should facilitate examination of the trade-offs among quantity of personnel, quality of personnel, and training level to achieve task/subtask skill levels, within constraints imposed on the quantity, quality, training dimensions by the multi-system supply and demand planning analysis. A conceptual view of the kinds of information envisioned is depicted in exhibit A-3. The "quality" dimension should be reflected by existing measures such as AFQT category, ASVAB aptitude scores, and (possibly) grade. As will be noted below in (10), the CTA is a critical component in determining MPT requirements and in providing usable MPT guidance to design engineers.

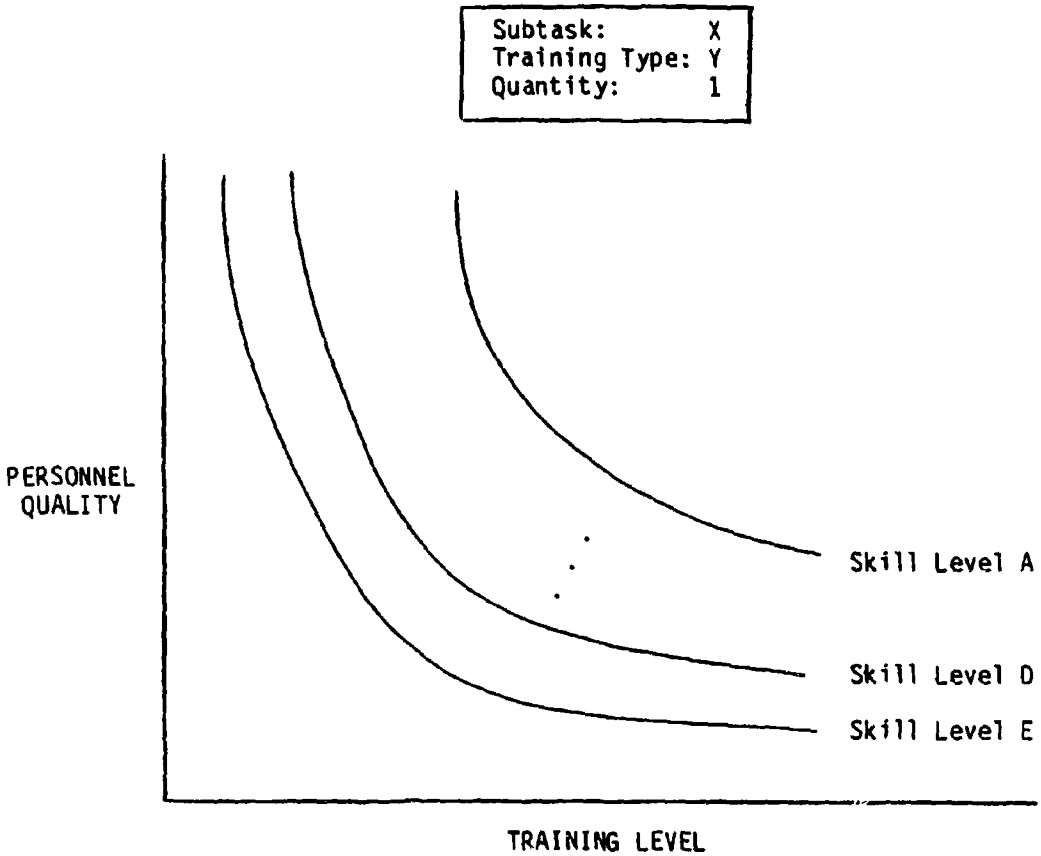
(9) PERSONNEL PERFORMANCE DATA BASE

We believe that a large amount of data exists regarding skill levels achieved by Army personnel (measured by SQT), training received, and their "quality" (as measured by AFQT category and ASVAB aptitude scores). An effort to assemble such historical data, and to design a data base and a DBMS for its storage, analysis, and enrichment as new data becomes available, would provide valuable information for development of the CTA methodology.

(10) SKILL COMPARISON PROCEDURES

These procedures are intended as the means of comparing skill level requirements from the FEA with skill level capability from the CTA;

EXHIBIT A-3: ACHIEVABLE SKILL LEVELS FOR SUBTASK X AS A FUNCTION OF PERSONNEL QUALITY AND TRAINING LEVEL



providing guidance/constraints to designers; and iterating the process until feasible skill, quantity, quality, and training requirements are determined. As such the procedures are more administrative than technical. If, for example, skill requirements (e.g., .60 mils tracking error) exceeds skill capability (e.g., 1.5 mils tracking error), the procedures should feed back the following information:

> "On the tracking subtask using the GLLD, the skill level requirement of .60 mils error is less than half of that achievable by personnel who will be available for assignment as gunners on your system. For this reason the MPT requirements are not acceptable."

The procedures should facilitate (1) iteration of the MAN/MACHINE ANALYSIS process (as depicted in exhibit 2 of the main text) until closure between FEA skill requirements and CTA skill capability is achieved; and (2) recovery of CTA data regarding personnel quantity, personnel quality, and training program to achieve skill level requirements for each task and subtask for entry into the system MPT data base.

(11) MPT ASPECTS OF RFP AND PROPOSALS

As noted in section 2.0 of the main text, contractors and PM treat MPT requirements in a **pro forma** manner. Part of the problem is communications -- the Army has not adequately specified MPT requirements nor evaluated contractor responses. Using some of the concepts in this paper and results of programs recommended above, ARI should develop (1) SOP for expressing MPT requirements in RFP; and (2) procedures for evaluating MPT aspects of proposals.

(12) DT/OT EVALUATION OF MPT

The acquisition process requires various DT/OT be performed as systems advance from one phase to another. At DT/OT II, production prototypes are available for testing, but, as noted in section 2.0 in the main text, most MPT requirements are locked in concrete at this stage. At DT/OT I, testing must be accomplished with a "brassboard" prototype, and at times a "breadboard" or a "paper design". Under this recommended effort, ARI should study the feasibility and utility of using software and hardware techniques to simulate tasks/subtasks so that MPT testing at DT/OT I can be performed with breadboard and paper designs. If deemed feasible, an MPT simulation facility could also be used to provide basic data for development and enrichment of FEA and CTA methodologies.

(13) MPT EDUCATION MATERIAL

Developing MPT knowledge, methods, procedures, data bases, etc. as recommended above is necessary for integration of MPT supply and demand but, clearly, not sufficient. ARI must develop MPT educational vehicles such as courses, manuals, etc. for PM, TSM, other MPT managers, and contractors, to insure that the integration is implemented effectively. These materials should be used to communicate and train individuals in

- the overall MPT supply/demand interface process and MPT planning;
- man/machine analysis methodology (M/MTA, FEA, CTA) and procedures;
- system MPT data bases;
- procedures for expressing MPT requirements in RFP;
- procedures for MPT evaluation in proposals; and
- MPT testing in the acquisition process.

GLOSSARY

ATE:	Automatic Test Equipment
BITE:	Built In Test Equipment
ILS:	Integrated Logistics Support
M/MTA:	Man/Machine Trade-off Analysis
MPT:	Manpower, Personnel, and Training
MPT CTA:	MPT Capability Trade-off Analysis
MPT FEA:	MPT Front End Analysis
Man/Machine Analysis:	Iterative MPT analysis for a single system, including M/MTA, MPT FEA, MPT CTA, and Skill Comparison Analysis
Skill Creep:	The phenomenon of increasing skill requirements for soldiers to maintain and operate new Army systems