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Methodology for Conducting Analyses of Army Capabilities

**Michael P. Wagner, Lawrence H. O'Brien,
and Howard Clark**

Dynamics Research Corporation

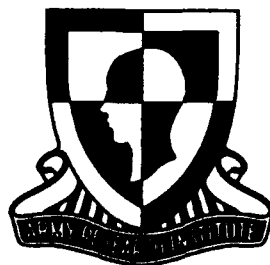
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June 1992



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**United States Army
Research Institute for the Behavioral and Social Sciences**

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13. ABSTRACT (Maximum 200 words) This report describes a methodology for conducting analyses of Army capabilities to support force modernization planning. This methodology parallels the Army's Concept Based Requirements System (CBRS). The methodology can be divided into four phases: (1) the analysis of missions, (2) the assessment of capabilities, (3) the identification and assessment of capability improvements, and (4) tradeoff analysis and development of capability improvement plans. The report also includes a description of a process for incorporating the results of capabilities analysis into requirements specifications for capability improvements (e.g., weapon system enhancements). A number of tools that are an integral part of conducting capabilities analysis were developed in conjunction with the methodology. The first tool is the "operation template," which can be used to analyze missions to determine operational requirements. A comprehensive listing of operation types is included, as well as a discussion of how to develop templates. (Continued)				
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The second tool is the Blueprint of the Battlefield (TRADOC Pamphlet 11-9). The Blueprint is a comprehensive, hierarchical listing of the activities the Army performs in and in support of military operations. It is used to break missions and operations into their essential performance elements.

The third tool is a set of measures of effectiveness (MOE) that can be used to assess performance and a methodology for developing MOE. MOE are essential to the measurement and evaluation of battlefield task performance and its relationship to mission success.

The fourth tool is a taxonomy of conditions that can be used to structure descriptions of the physical and operational environment in which combat is being examined. This taxonomy is particularly important to the measurement of human performance since humans tend to be more sensitive than equipment to many of the conditions inherent in combat.

The methods and tools included in this report provide a horizontally and vertically integrated structure for conducting analyses. The structure integrates horizontally by being functional. That is, it provides opportunities to conduct tradeoffs across branches and proponents, as well as across the five principal domains of capability (doctrine, training, leadership, organizations, materiel). It integrates vertically by being applicable across echelons and the levels of war (tactical, operational, and strategic).

Block 14. SUBJECT TERMS (Continued)

Blueprint of the battlefield

Doctrine

Training

Materiel

Leadership

Organization

Conditions

Weapon system acquisition

Performance

METHODOLOGY FOR CONDUCTING ANALYSES OF ARMY CAPABILITIES

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METHODOLOGY FOR CONDUCTING ANALYSES OF ARMY CAPABILITIES

INTRODUCTION

Background

The mission of the MANPRINT Division of the U.S. Army Research Institute (ARI) involves developing tools and methods for ensuring that soldier characteristics and abilities are properly considered in the design, development, testing, and fielding of Army doctrine, training systems, weapon systems, and units. In order to integrate consideration of the soldier in these domains, one must be quite clear and specific about the Army's battlefield requirements.

A number of analytic processes are employed by the Army in assessing the capabilities of its forces and in proposing and implementing improvements to these forces. This study originated out of a desire to improve the tools and methods for considering the soldier in these analyses. ARI established a Memorandum of Agreement (MOA) with the Deputy Chief of Staff for Combat Developments (DCSCD) at the U.S. Training and Doctrine Command (TRADOC) to develop tools and methods to support the integration of soldier considerations in capabilities analyses conducted by TRADOC. The MOA was based on the premise that (1) insufficient attention was paid to human performance capabilities and resource impacts during the conduct of analyses and that (2) this inattention resulted in negative performance impacts on new weapon systems.

A contract (#MDA903-86-C-0087) was awarded to Dynamics Research Corporation (DRC) by ARI in March 1986 to fulfill the requirements specified in the MOA. This work was focused on capabilities analyses performed in TRADOC as part of the Concept Based Requirements System (CBRS). The CBRS is designed to identify battlefield deficiencies, study and compare alternative solutions, and make integrated force modernization recommendations to Headquarters, Department of the Army (HQDA). A number of tools and methods are required in order to perform integrated analysis that includes appropriate consideration of human performance capabilities. The purpose of this report is to describe various tools and methods developed under this contract, show their application to capabilities analysis, and to show how consideration of human performance abilities/constraints during capabilities analysis can be incorporated into the Army's system acquisition process.

Requirement for Capabilities Analysis

The U.S. Army constantly reviews its ability to support the U.S. National Military Strategy so that it can invest its limited resources to improve those capabilities whose enhancement is most critical to the Army's ability to perform its assigned missions. This task is difficult for four basic reasons. First, the Army is a complex organization both vertically (i.e., by echelon) and horizontally (i.e., by branch and unit type). Second, the missions assigned to the Army are complex, requiring many different capabilities and their synchronization in time and space. Third, there is a great deal of uncertainty as to the specific nature of the threats that the Army might face and under what environmental and operational conditions they might have to face those threats. Fourth, the task of developing performance measures of complex constructs like missions and operations is very difficult.

TRADOC'S Role in Capabilities Analysis

The primary mission of the Army's Training and Doctrine Command (TRADOC) is to prepare the Army for war. To meet its responsibility, TRADOC plays an important role in the analysis process described above. In the 1970s, TRADOC initiated a system to systematically carry out analyses of the Army's capabilities and to recommend improvements to the Army's leadership. This system was called the Concept Based Requirements System (CBRS). CBRS is designed to analyze the warfighting requirements of the Army, identify critical issues, and make force modernization recommendations to Headquarters, Department of the Army (HQDA).

The work described in this report began in 1986. Guidance for the conduct of the CBRS process was recently approved, and is contained in TRADOC Regulation 11-15 (August, 1989). During the time period from 1986 until August of 1989 a number of issues concerning the conduct of the CBRS process were unresolved, including:

- the organization of the analyses by a specified number of mission areas, their titles, their definitions, and the identification of proponents,
- the role of the branches versus the role of the integrating centers and the headquarters in the analysis process,
- the schedule and sequence for conducting studies as part of this process, and
- the names and definitions of the products of the studies (i.e., Mission Area Analyses, Mission Area Development Plans, Battlefield Development Plans, Battlefield Functional Mission Area Modernization Plans, Army Modernization Memorandum, etc.).

The basic requirements for tools and methods to support the conduct of the CBRS were largely unaffected by these issues. However, the steps of the methodology described in this report do not map exactly onto the current CBRS guidance because the details of the guidance were unresolved during most of the period of performance of the contract effort.

Figure 1 shows a diagram from TRADOC Regulation 11-15 that depicts the CBRS methodology. The CBRS process, as represented in Figure 1, is divided into three phases. The first phase, Planning Guidance and Concept Formulation, involves the incorporation of top-down guidance into the development of operational concepts. The second phase, Needs Identification, involves the identification of issues that need to be resolved. The third phase, Solution Prioritization, involves the development of solution alternatives, their grouping into capability packages, and the prioritization of these packages.

The remainder of this report is divided into three sections and a series of appendices. The first section describes a number of factors that make it difficult to successfully execute the CBRS process. The second section of this report describes a series of tools and methods for executing a capabilities analysis process to produce valid performance requirements

**TOP DOWN
PLANNING GUIDANCE**

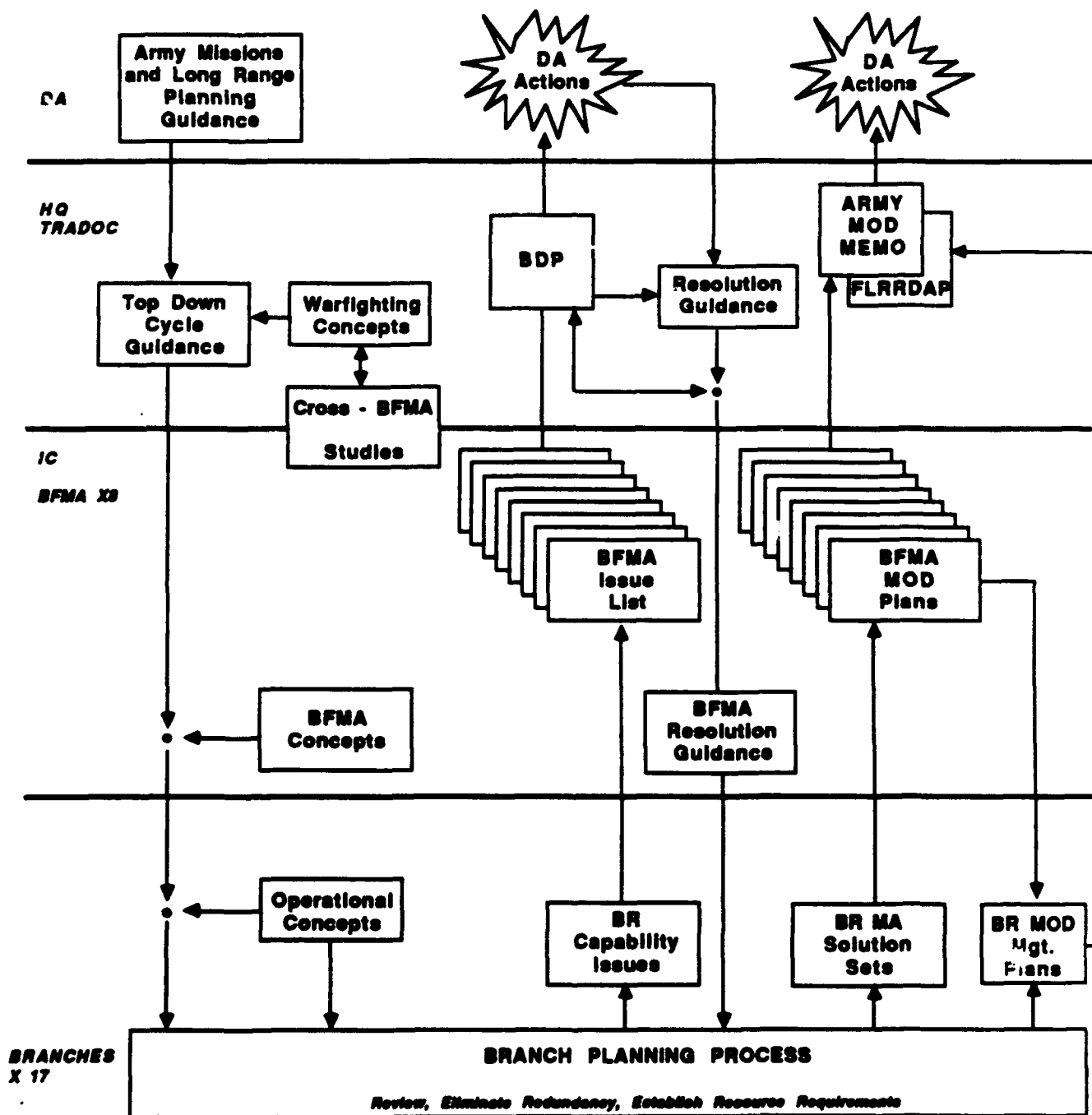


**Figure 1. The CBRs Products and Events
(From TRADOC Reg 11-15, 1 August 1989)**

for capability improvements. The third section describes an approach for incorporating performance requirements generated during the analysis process into the weapon system acquisition process, with particular emphasis on the contribution of soldiers to weapon system performance. The appendices elaborate on specific tools or concepts employed in the methodology described in the report.

UNDERSTANDING THE PROBLEM

In order to appreciate the difficulty of successfully executing a capabilities analysis process, one has to understand the factors that make the analysis so difficult. In this section, we describe the various factors that contribute to the analysis challenge. These factors fit into four general categories.

The first category concerns the complexity of the political and operational environment the Army operates in: the threats, conditions, and missions.

The second category involves the complexity of conducting military operations: combined arms, as well as joint and combined operations. Further, the increased sophistication of weapon systems, rather than simplifying the demands on soldiers, has greatly complicated their role in both leading and conducting combat.

The third category involves the complexity of measuring combat performance and costs: performance of battlefield functions, performance of operations, and the costs required to achieve this performance.

The fourth category concerns the complexity of the Army's organization for performing analyses: branch organization, functional directorates, and vertical layers.

Complexity of the Political and Operational Environment

In conducting analysis of the adequacy of the Army's current or projected capabilities, one must examine the range of situations in which military force may be required. These situations will vary in terms of their likelihood and significance. Thus, while general war in Central Europe seems unlikely, it is critical to our national security interests. On the other hand, our military involvement in third world or minor nations like Grenada or Panama is more likely to occur, but not as critical to our national security interests.

The specific situations which are selected for study will have a major impact on the analysis results. For example, the value of particular capabilities (e.g., air defense) to the Army may vary significantly across the spectrum of conflict. Thus, while an air defense capability might be essential to the conduct of operations in Central Europe, it may have little or no influence on the conduct of operations in Central America.

Assumptions about the operational environment can also have a major impact on the analysis. This includes assumptions about the specific capabilities and intentions of a threat force and the nature of the forces and capabilities available to the friendly force. For example, the level of support from host nations or from allies is critical to the assessment of the adequacy of current or projected military capabilities.

The capability to perform a specific function on the battlefield is directly impacted by the environmental conditions on the battlefield under which the function is performed. Thus, for example, performance of an air defense weapon system can be best described by assuming a particular set of conditions on the battlefield pertaining to visibility, the EW environment, the range of targets, etc.

The optimal capabilities of a military force are those whose performance is least sensitive to the variety of conditions found on the battlefield. Thus, the best anti-tank weapon is one whose lethality is not diminished by various battlefield conditions (e.g., visibility) or threat (e.g., type or thickness of armor) characteristics. The performance of such systems is "robust" with respect to the variety of battlefield conditions under which it might be employed. The analysis of a capability across a range of situations might reveal, for example, that in some situations, the current capability is adequate and in others, inadequate. If the situations where the capability is deficient are important ones, then improvements may be in order. How much improvement will be required? It depends on information concerning the current level of performance and assumptions on characteristics of the threat, the conditions of the battlefield, etc.

Finally, within a scenario or operational plan, it is difficult to estimate the required mix of missions and operations. For example, will engagements be brief, intense, and linear where firepower will be decisive, or will engagements be prolonged and nonlinear because neither side is willing to fully commit its forces? In the latter situation, engagements may be preceded by a period of reconnaissance and counterreconnaissance during which intelligence capabilities will be especially critical. The uncertainty about the answers to these questions adds a degree of uncertainty to any solutions that are generated from a CBRS process.

Increased Complexity of Conducting Military Operations

Technological developments have led to the increased complexity of combat. Weapons are no longer simply an extension of the soldier's physical power (e.g., sword). Sophisticated electronic weapon systems have assumed increasing roles in the performance of battlefield functions. As a result, the performance of any function on the battlefield may be dependent on the combined contributions of soldiers, hardware, and software. This makes it difficult to compute the exact performance potential of a system that relies on contributions from all three sources.

In addition to the increased complexity involved in performing a single function on the battlefield, technological advances have led to a diversification of battlefield functions. For example, the addition of aircraft to the battlefield has led to the development of specialized weapons to defeat them. The use of indirect fire weapons in conjunction with maneuver forces requires control by observers (which requires communication capabilities) as well as close coordination with the movements of maneuver forces. Thus, the differentiation of the technology of combat has dramatically increased the complexity of combat.

This increased complexity has also created interdependencies among the various elements of combat capability, leading to requirements for coordination, interoperability, synchronization, and integration. Even in the operation of a single weapon system, which may perform numerous functions on the battlefield, there is a need to understand the interrelationships among the hardware, software, and soldiers who man and maintain the system. Thus, the performance of a function may be contingent on the execution of other functions by the same weapon system (to include soldiers, software, and hardware) or by other systems. For example, the functions of target acquisition, firing on targets, and loading ammunition are interdependent.

Joint and Combined Operations. It is unlikely that the Army will fight by itself. Rather, it will undoubtedly fight as an element of a Joint and/or Combined force. Thus, the Army's doctrine and equipment must be compatible with and complementary to that of the other Services and with our allies. For example, a key problem in the Grenada operation was the lack of interoperability of the communications equipment and procedures used by each of the Service forces participating in the operation.

The requirement for the Services to complement one another poses very difficult problems as well. From the Army's perspective, a key Navy priority ought to be the development of rapid sealift capabilities and a key Air Force priority ought to be close air support. However, each of these Services has other functions which they consider more important. Thus, the Air Force feels that its air-to-air combat requirements are more important to the Air Force than providing close air support to the Army.

The Navy, in its recent mission to clear the sea lanes to permit the safe passage of oil tankers in the Persian Gulf, did not possess mine sweepers required to do the job. It had to depend on the provision of these ships by our allies. Thus, the Navy could most successfully execute this mission only as a Combined force operation.

A more subtle, yet no less important point concerns the ability of Joint or Combined forces to synchronize their capabilities towards the achievement of assigned missions. This requires either a unified commander with the authority to allocate all military assets as he sees fit or a common understanding among all component forces as to the priorities and sequencing of carrying out the required operations.

It also requires the commander to understand the various capabilities at his disposal and the potential contributions of each element of the force. The commander must then decisively employ these capabilities to seize the initiative, shock the enemy, disrupt and destroy his forces, and quickly destroy his will to fight. In order to be successful, the whole must be greater than the sum of the parts.

Complexity of Measuring Combat Performance and Costs

Measurement of combat "potential" is difficult for a number of reasons. First, the measurement of the Army's combat "potential" for even a single function or task may be difficult because (1) there are multiple measures for that activity, (2) the capability to perform the

activity may be found in different branches or organizations within the Army, and (3) performance results from the combined effects of several elements, including materiel systems, the soldiers who operate and maintain them, the training these soldiers receive, and the doctrine they employ.

Multiple Measures. Most functions or tasks are multidimensional in nature. As a result, more than one measure of effectiveness may be required to fully describe the performance of a function. Most functions require measures on at least two dimensions. One dimension involves time (performance time) or rate (speed) at which an activity is performed. The other dimension involves accuracy (probability of a hit or circular error probabilities) or power (lethality, transmission range) with which an activity is performed. Some measures are hard to classify as being clearly in one or the other of these dimensions. Such measures include the operating range of a weapon system, reliability (error rates), or the acceleration in movement that a system can achieve. Measures on both dimensions are often necessary to fully define effectiveness for a function or task.

Multiple Sources of Capability to Perform. The process of measuring combat "potential" is complicated by the fact that similar capabilities may be found in a variety of Army branches or unit types. For example, the field artillery, intelligence, and aviation branches each have some aerial observation capability for acquiring targets. Measures of performance for these different sources of capability must be the same in order to aggregate across such sources. Similarly, measures used to assess capabilities at different echelons of units should also be the same.

Varying Sources of Performance. In calculating the capability of a specific weapon system or unit to perform any function or task, the Army must consider that its capabilities stem from several sources, including:

- the characteristics of its soldiers (their quality, training, and leadership),
- the particular design of the equipment,
- the organization of its soldiers and systems in units, and
- the doctrine (principles, tactics, techniques, and procedures) the weapon system crew or the unit, employs to perform functions and conduct operations.

Assessing the Soldier's Contribution to Performance. In calculating the ability of a unit to perform some function on the battlefield, the soldier presents a great challenge to measurement for two basic reasons.

First, individual aptitude and skill differences among soldiers (e.g., tank drivers) will result in wide variations in the performance achieved by weapon systems and units (e.g., mobility of tanks) on the battlefield. These individual differences in soldier performance are caused by variations in aptitude, experience levels, and the amount and type of training provided to soldiers.

Secondly, many conditions of the battlefield (see Appendix D) tend to affect the performance of soldiers differently than equipment. For example, continuous operations causes soldiers to become fatigued, resulting in significant degradation over time. However, the degree of degradation is difficult to calculate. A second example concerns the ability to deliver fires on enemy targets when friendly positions are themselves under heavy fire. In this example, enemy fires will tend to suppress friendly fires. However, it is difficult to determine how great the effect will be.

Measures of Operational Performance. Performance measures get increasingly aggregated and complex as the focus of measurement moves from functions to operations. Aggregated performance measures such as attrition rates, force exchange ratios, and movement of the FLOT are often used to judge the success of Army units in conducting operations. However, these are measures of success of an operation and not of specific functions. Such aggregated measures, while useful in determining the outcome of an operation, provide little diagnostic information that could be used to develop force modernization recommendations. Measures of performance for functions are key to successful analysis because they can be used to determine the sensitivity of operations success to specific force modernization improvements. In addition, they can be used to assess the contribution of force modernization improvements across operations and scenarios.

Costs of Performance. What are the costs and resource requirements of achieving a particular level of performance on the battlefield? This includes personnel costs, materiel costs, training costs, etc. Costs are influenced by many factors, including such things as manpower levels (including force sizing and the relative size of active vs. reserve forces), the mix of type units, the amount and quality of equipment, the extent and type of training conducted, and the appropriateness of the Army's doctrine. Making changes in any of these areas has resource and cost implications.

Validity of Predictions about Combat Performance. In conducting analyses to determine capabilities that ought to be enhanced, one must consider the validity of current estimates of combat performance. There are reasons to suspect the validity of each of the most common sources of data for analysis.

Combat models are frequently used to support analysis of capabilities. However, the outputs of combat models may be questionable, either because of the models themselves or because of input data to the models. Because of the difficulty of comprehensively modeling all aspects of warfare, models tend to focus on several important dynamics of warfare. As a result, one model may focus on direct fire effects but ignore indirect fires; or may address both direct and indirect fires but ignore the ability to maneuver to trade space for time. As a result, some analysis outcomes, while addressing weapons effects in great detail, may not provide good indications of mission or operations success.

In addition to questions about the models themselves, there are serious questions about the input data to the models. For example, where does weapon system capability data come from? This data projects weapon system performance (e.g., $p(h)$ and $p(k)$ rates) under varying conditions on the battlefield. If the data comes from engineering design estimates, does it reflect the abilities of soldiers who will man and maintain the system?

If the data comes from operational tests or from training exercises, do the estimates truly reflect the friction of war, which degrades the performance of all tasks which soldiers contribute to? If the data comes from historical analyses of warfare, are the estimates of casualty rates accurate? How about the estimates of conditions on the battlefield? How about the capabilities of the equipment and the level of training and quality of leadership of the soldiers on each side? If the data comes from contractor estimates of equipment performance generated during the early phases of the Army System Acquisition Process, how reliable is it?

How valid are intelligence estimates of the capabilities of weapon systems belonging to a potential adversary? Do we really know the strengths and limitations of the weapon systems and soldiers of a potential adversary? The accurate estimation of unit or weapon system performance is difficult to achieve, whether based on engineering judgment, simulated experience, or real experience.

Complexity of the Army's Organization for Analysis

The organization of the Army also has significant impacts on the Army's ability to conduct capabilities analysis.

Branch Organization of the Army. The Army is organized into a number of branches, as follows:

- Aviation (01)
- Chemical (03)
- Engineers (05)
- Field Artillery (06)
- Infantry (07)
- Ordnance (09)
- Quartermaster (10)
- Signal (11)
- Adjutant General (12)
- Finance (14)
- Chaplain (16)
- Armor (17)
- Military Police (19)
- Military Intelligence (30)
- Special Forces (31)
- Air Defense Artillery (44)
- Transportation (55)

Each branch is responsible for managing resources to include soldiers and equipment. Each branch also develops doctrine and is responsible for training. As a result, each branch has its own perspective of the future battlefield, and these perspectives do not always agree with one another. Finally, while each branch has a different focus requiring unique capabilities, the functions performed by each branch overlap to some extent as well. For example,

a number of branches possess capabilities to destroy enemy armor. However, each branch does not agree as to the relative emphasis that the Army as a whole ought to place on the various means to accomplish the destruction of enemy armor. In addition, the branches have difficulty agreeing on the relative importance of performing different functions on the battlefield. For example, what emphasis should be placed on mines and obstacles to reduce the mobility of the enemy (i.e., countermobility) vs. enhancing the mobility of our own units and systems (e.g., M1 Tank, Bradley Fighting Vehicle)?

Divided Responsibilities for Doctrine, Training, Leadership, Organization, and Materiel (DTLOM). Within TRADOC Schools and Centers, the responsibility for monitoring the status of capabilities stemming from the Army's doctrine, training, leader development, organizations, and materiel is generally divided among doctrine, training, and combat developments directorates. The combat developments directorates are responsible for the development of concepts (ultimately to become doctrine, if implemented), and requirements for materiel and organizations. However, improvements to training originate in training directorates, and actual doctrine development takes place in doctrine directorates. Consequently, the solutions proposed to identified problems typically correspond to responsibilities of the directorate making the proposal. Thus, combat developments directorates tend to develop materiel solutions and training directorates tend to develop training solutions. This situation makes it difficult to develop an integrated perspective on capability issues.

Problems, if they exist, cannot be classified as training problems or doctrinal problems per se; rather, there are only problems in performing some function or task. The solution(s) to one of these problems may be in one or more of the domains of doctrine, training, leadership, organizations, and materiel. Thus, in order for a unit to achieve a desired level of performance in, for example, its ability to destroy enemy tanks, there is no preset allocation of the role of doctrine, training, leadership, organization or materiel factors in achieving the desired level of performance. Rather, the combination of these factors leads to some level of performance and each of these factors may provide some opportunity for changes that result in, for example, improved tank killing performance.

Multiple Participants in Army Capabilities Analysis. A number of organizations within the Army participate in analyses of Army capabilities including DUSA/OR, PA&E, DCSOPS, and CAA for HQDA; TRAC, TEXCOM, and CACDA for TRADOC, etc. The range of studies conducted by the Army to analyze its capabilities and support investment decisions concerning possible improvements includes:

- the conduct of studies of specific capability issues on the battlefield (e.g., armor/antiarmor),
- the development of new concepts and doctrine (e.g., AirLand Battle Future Concept, O&O Plans for units or weapon systems),
- the development of approaches to force modernization (e.g., Heavy Forces Modernization),

- the development and implementation of training programs (e.g., Combat Training Centers, Battle Command Training Program),
- the conduct of studies to produce lists of critical capability issues facing the Army (e.g., Battlefield Development Plan),
- the development of dynamic combat models to simulate combat and the relationship of inputs to outputs (e.g., JANUS)
- the analysis of specific proposed improvements to the force (e.g., as examined in COEAs, TEAs),

Status of Army Analysis Process. Many individuals inside and outside the Army analysis community have expressed dissatisfaction with the results of these processes as they are currently designed. For example, the Congress has asked that the military Services “more clearly define the necessary operational capabilities and concepts of operations as part of the requirements process”. Congress wants military analysts to link proposals for improvements, and the resources necessary to accomplish them, to our military strategy. Through this approach, it might be possible to assess the relative value or “combat worth” of alternative proposals to improve military capabilities.

Several years ago, a TRADOC IG report criticized the parochialism among the branches of the Army analyzing capabilities and establishing requirements. It also criticized the CBRS process for focusing too heavily on materiel improvements and not heavily enough on doctrinal, training, leadership, and organizational opportunities to improve combat performance. This was followed by a TRADOC initiative called “The Architecture for the Future Army (AFA)”. This initiative was designed to get TRADOC to focus itself further forward in time and to integrate its capabilities analysis both horizontally and vertically.

In response to the AFA initiative, TRADOC initiated improvements to the CBRS process. One improvement initiated by TRADOC involved the development of a functional structure identifying the domain of activities performed on the AirLand battlefield. Another improvement involved the increased role of TRADOC’s Integrating Centers in the conduct and management of the analysis process. These changes, and others being developed by TRADOC, are designed to produce more integrated analysis results while ensuring that branches and proponents, who possess a great deal of specialized expertise, participate fully in the analysis process.

In an era of decreasing resources for the military, the Army must ensure that its investment choices yield the greatest payoff. However, the complexity of the Army’s organization and the uncertainty regarding the possible threats to our nation’s national security in the future make this a difficult task.

Summary

The Army is facing a challenge in its ability to conduct capabilities analyses and use the results to guide its resource allocation in preparing for war. This challenge is a difficult one due to the complexity of combat, of the resources required to carry out combat activities, and of the organization of the Army to analyze combat. However, due to the reality of increasingly constrained resources, it is a challenge that the Army must meet. The remainder of this paper contains a description of methods that could be used to meet this challenge.

DESCRIPTION OF ARMY CAPABILITIES ANALYSIS METHODOLOGY

An approach to conducting analyses of Army capabilities is illustrated in Figure 2. It consists of four phases. In each phase, one or more blocks are shaded indicating that they are the focal point(s) for analysis in that phase. Further, each step in the methodology is numbered.

The key to designing an effective capabilities analysis methodology is determining the level of detail of analysis in each phase that will yield the greatest overall payoff. The blocks in Figure 2 are organized into a series of three rows. Each row represents a different perspective and a varying degree of detail. The top of these three rows represents the mission perspective and a limited degree of detail. The second row represents an operations perspective and a moderate degree of detail. The third row represents a functional perspective and a rather high degree of detail. While each phase of the analysis may require all three perspectives, the focus of analysis will vary across the phases along with the degree of detail.

Each phase of the proposed CBRs process also has a clear objective and output as summarized in the following paragraphs.

Phase 1: Analyze Missions. The purpose of this phase is to set the context for analysis by identifying the warfighting concepts, likely combat situations, and missions the Army must prepare for. The analysis must also identify the current or programmed force as well as the doctrine (or approved concepts) for use in the analysis. The output of this phase is a series of operations and their critical functions that have been identified as key to the Army's success.

Phase 2: Assess Capabilities. The purpose of this phase is to examine the ability of the Army to conduct key operations, to identify operations that are at risk given current or programmed capabilities, and to identify the weak points in the conduct of these operations. This analysis should lead to the identification of specific battlefield activities or functions that could make a difference in key high-risk operations, and to the estimation of the degree to which the capability to perform these activities or functions must be enhanced to ensure that the Army possesses an adequate capability. The analysis of functional performance must consider contributions to performance from a number of domains, including doctrine, training, leadership, organizations, and materiel. The output of this phase is the specification of issues or groups of issues (i.e., issue packages) that, if resolved, would provide the Army with the ability to successfully carry out its key missions.

Phase 3: Identify and Assess Capability Improvements. Given the issues identified in the previous phase, the objective in this phase is to explore the possibility of making improvements to various means necessary to resolve key performance issues. The primary domains for improving performance include doctrine (mostly techniques and procedures), training, leadership, organizations, and materiel. In addition, each of these primary domains has secondary impacts as well. For example, improvements in materiel (i.e., weapon systems)

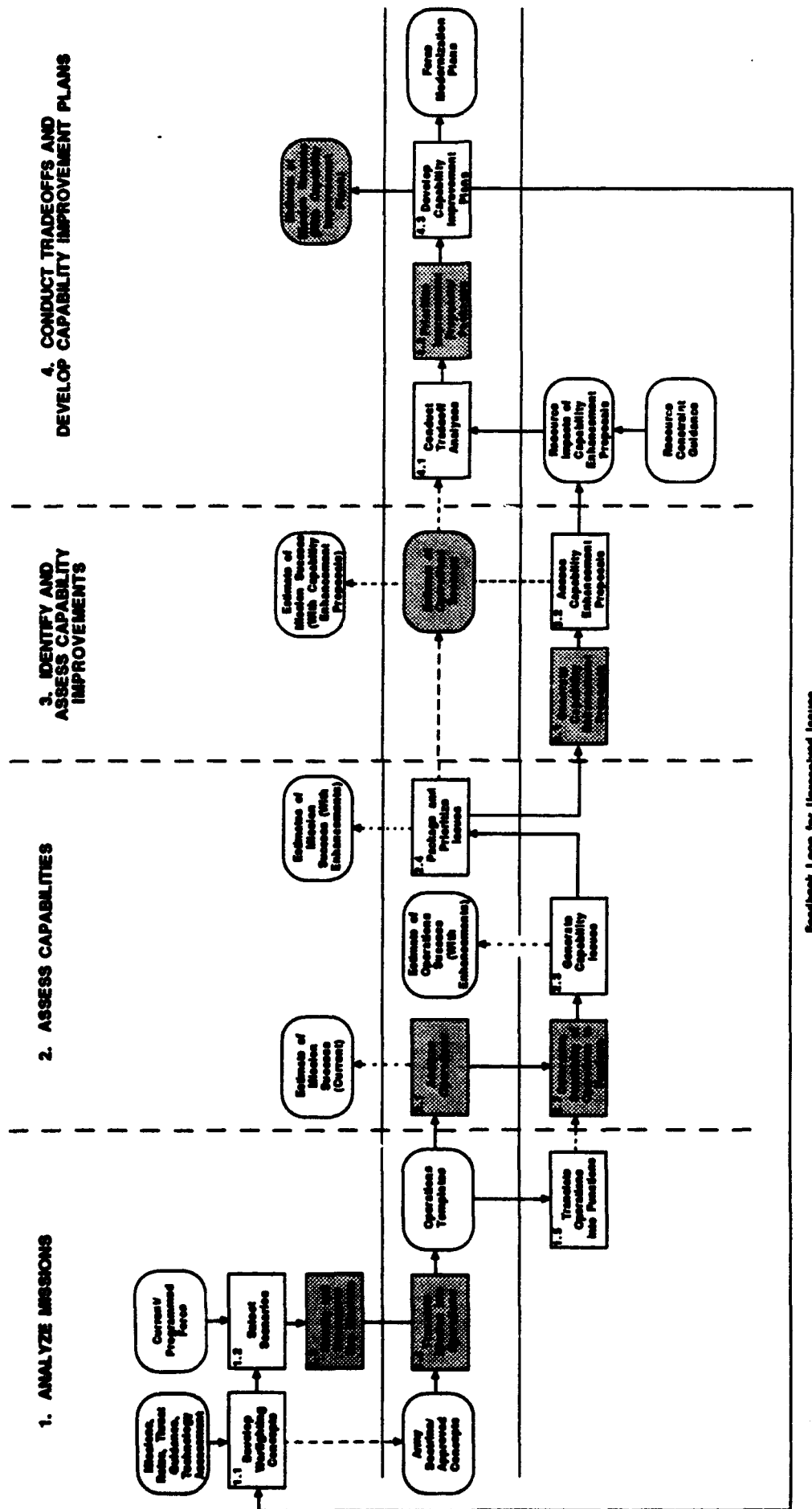


Figure 2. Army Capabilities Analysis Methodology

inevitably require changes in organizations, doctrinal techniques/procedures, and training programs. The product of this phase includes proposed improvements packaged by function and/or operation.

Phase 4: Conduct Tradeoffs and Develop Capability Improvement Plans. The purpose of this phase is to compare capability improvement packages in terms of their ability to address performance problems, their costs of implementation, the timing of their implementation, their ability to fit within current resource constraints (e.g., MANPRINT), and risks (e.g., technological) associated with their potential implementation. The results of the tradeoff analyses are then used to prioritize capability improvement packages and to develop Army-wide plans for implementing the improvements that best meet the overall mission requirements (see Phase 1) of the Army. If any key missions of the Army are unmet as a result of this process, additional studies could be conducted to devise new concepts for conducting such missions in the future (see feedback loop).

Summary. The Army does not conduct a single integrated analysis of its operational requirements, capability issues, and potential solutions. Rather, a large number of studies are initiated for a variety of reasons by a variety of organizations to address a multitude of issues. These issues often concern different areas of the world, threats, and involve different types of forces and various echelons. A wide variety of organizations, within the government and outside the government (i.e., contractor) apply a wide variety of analysis and modeling techniques in performing or supporting these studies. A single methodology cannot be devised that anticipates the full range of activities conducted under the umbrella of capabilities analysis. Nor can a single methodology specify how the results of a large and diverse set of study results can be integrated.

However, an Army capabilities analysis methodology can provide a structure and common language to the analysis community so that results of various studies can be effectively communicated and reported in ways that can be reconciled with one another, and ultimately integrated. Undoubtedly, even if integration were to be accomplished, many gaps in analysis data will exist, and decisions based on the analysis results will require a large degree of subjective judgment on the part of decision makers.

The following sections provide guidance on the conduct of analysis of Army capabilities using this approach. Examples are provided in the text to aid the analyst in planning and conducting required analyses.

1.0 ANALYZE MISSIONS

The objective of this first phase of the analysis is to use national military goals, threat guidance, technology assessments, and existing Army roles and missions to develop warfighting concepts for the Army in the future. Scenarios are then developed that embody this information and describe the missions and operations most critical to the Army.

The product of this phase of the analysis is an articulation of the Army's requirements in qualitative terms — that is, to establish what has to be achieved by the force. Later phases of the capabilities analysis will address the quantitative question of how well functions must be performed (or how much of various capabilities is required) to accomplish military objectives.

A comprehensive capabilities analysis reflects defense planning and programming guidance, Army-wide missions, geopolitical realities, and foreseeable military contingencies in terms of the best possible mix of hypothetical situations for analysis purposes. In order to move from concepts to missions to detailed capabilities assessment, a selection process involving scenarios, missions, combat operations, and battlefield functions must be performed. This process is discussed in the following paragraphs.

1.1 DEVELOP WARFIGHTING CONCEPTS

Warfighting concepts provide a vision of how the Army will fight on the future battlefield (TRADOC Reg. 11-16). Prior to committing itself to large investments in new doctrine, training, leader development, organizations, or materiel, the Army leadership must make the best possible projection of the potential nature of future warfare. Assessments of new technologies, emerging threats and global issues, projected alliances and treaties, and changes to our national military strategy or Service roles and missions all contribute to changing views as to how the US Army will fight in the future. This process is illustrated in Figure 3.

Military Threats. The Army and its Allies face a variety of threats ranging from subversion, terrorism, low-intensity conflict (LIC), through nuclear war. The U.S. Army must continually reassess these threats to determine if enemy intentions or capabilities are changing or are likely to change in the future. Conventional force reduction talks and implementation in Europe, fielding of new armor on Soviet tanks, the use of chemical weapons in regional conflicts, and many other developments around the world need to be monitored in order to judge the adequacy of our current warfighting concepts and/or to identify opportunities to leverage our strengths against weaknesses of our potential adversaries.

Global Trends. The Army must also examine economic and political trends around the world and identify any impacts on U.S. Army warfighting requirements. Trends in the availability of strategic materials (e.g., oil), the political stability of countries in Latin America, progress towards the democratization of Eastern block countries, increasing global

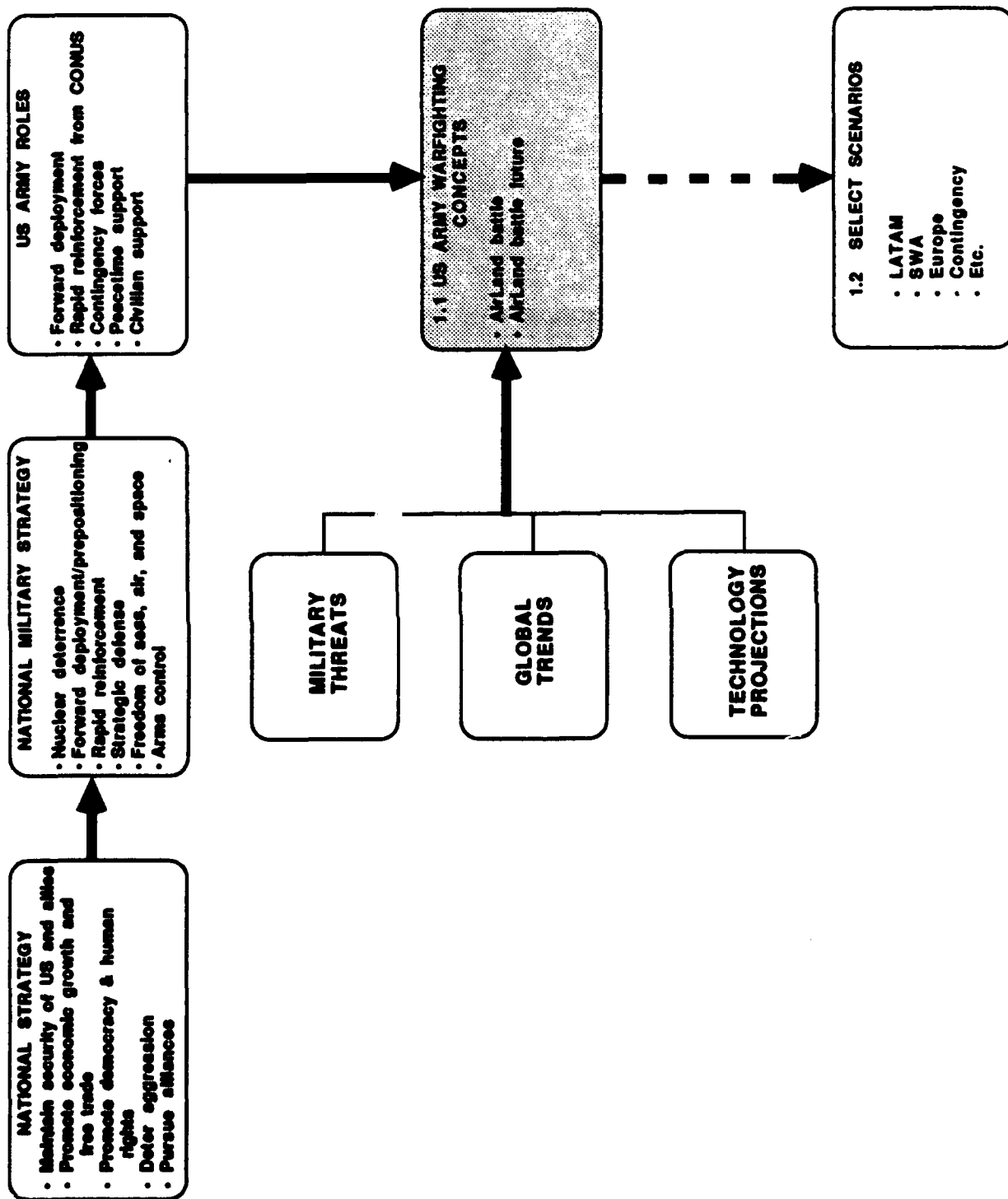


Figure 3. Development of Warfighting Concepts that Drive the Concept Based Requirements System (CBRS)

concerns over environmental issues (e.g., rain forests in Brazil), and developments in many other areas could have significant impacts on our military requirements, and consequently on our approach to meeting them.

Technology Projections. Rapid progress is being made in a number of technologies that could have dramatic impacts on the way that military forces wage war. Technological developments in materials for armor (e.g., ceramics), superconductivity, laser technology, very high speed integrated circuitry (VHSIC), stored energy technology, artificial intelligence, genetic engineering, and many other areas could significantly impact military operations in the future. In addition, technological advances in training simulation and in personnel selection and classification technologies could also have major impacts on how we plan to conduct military operations in the future.

The development of new concepts and their use in capabilities analysis is essential if the Army is to prepare to fight and win in the world as it will be rather than as it is today. The vision that is established should be a realistic one so that the Army can truly be prepared for the next war. An example of a warfighting concept that could have been used for conducting capabilities analysis was the AirLand Battle warfighting concept published in 1981 (TRADOC Pam 525-5). This concept emphasized a new approach to conducting military operations. This concept included the idea of extending the depth of the battlefield through deep attacks designed to "disrupt the enemy timetable, complicate command and control, and frustrate his plans, thus weakening his grasp on the initiative". Concepts such as AirLand Battle affect the ways the Army will execute its roles, missions, and functions as well as the character of the operations performed in the process of executing them. Once approved, the Army must determine its ability to implement these concepts and identify force modernization initiatives required to make them viable.

Relationship of Development of Warfighting Concepts in Phase 1 to Development of Doctrinal Improvements in Phase 3. The concepts developed in this step of the methodology (Step 1.1) are broad in scope, with pervasive implications on how the Army fights. In Phase 3 of the methodology, specific improvement proposals are developed and evaluated in several domains, including doctrine. In Phase 3, doctrinal improvement proposals generally involve narrower doctrinal issues than are typically examined in Phase 1. In most cases, the doctrinal improvements examined in Phase 3 refer to doctrinal tactics, techniques, and procedures. For example, consideration of increased doctrinal emphasis on performing reconnaissance functions in a battalion level deliberate attack operation is an example of how doctrinal improvements may get considered in Phase 3 of the methodology. A second example might involve a proposal for a new, automated command and control system that may have a number of implications for the doctrinal techniques and procedures involved in command and control.

1.2 SELECT SCENARIOS

The choice of scenarios determines the forces and missions for analysis. A scenario is a graphic and narrative description of the area, environment, forces, and events of a hypothetical armed conflict during a predetermined time frame. It reflects approved assumptions, Red and Blue force structures, terrain, operational art, and tactics. A scenario portrays approved doctrine and designated warfighting concepts in selected situations under simulated conditions. The scenarios selected for study connect the larger national military strategy and Army missions to the types of units and conflicts anticipated for the time period in question.

A major analysis may require a number of different scenarios to adequately represent the range of its forces and likely combat situations. Scenario choices may be based on the probability of their actual occurrence, as well as on their importance to national security.

Each scenario being considered for use in capabilities analysis should be judged in terms of its likelihood, criticality, as well as other criteria. Thus, while European scenarios are not very likely, they are critical to our national security interests. Other scenarios may be far more likely, but less critical than the European scenario. The overall "importance" of a scenario can be used later in the analysis process to weight various solutions.

If no scenario is available that meets the needs of the analysis, one might have to be developed. A number of issues have to be considered in developing a scenario. In particular, it is important that the scenario emphasizes those aspects of the threat, missions, conditions, etc., that are most critical and present the highest risk to the friendly force. It must represent both friendly and enemy doctrine for the time frame being examined. The level of resolution of a scenario is also important, since it must have enough resolution to be sensitive to variations in the performance of critical functions, but not so much that the analysis becomes unwieldy.

Scenarios provide a coherent structure to coordinate analysis efforts, and maintain the constraints (forces available, threat characteristics, battlefield conditions) throughout the process.

Forces Available. Scenarios are not built using specific Army units, but are built using the types of units earmarked to operate in certain areas of operations. Scenarios generally provide for examining force effectiveness at various echelons. This is illustrated in Figure 4 in which a scenario portrays a mechanized infantry division in an area defense. Within this division, a mechanized infantry brigade reinforced with armor and attack helicopters is assigned a mission to defend in sector. The brigade may form the object of some analyses, while the division provides the opportunity for another level of analysis.

Threat Characteristics. Scenarios provide a detailed description of the capabilities of threat forces. Much of this threat information is included under battlefield conditions (see following paragraph) because the threat, like the environment, affects the ability of friendly forces to successfully conduct military operations. The description of the threat includes the

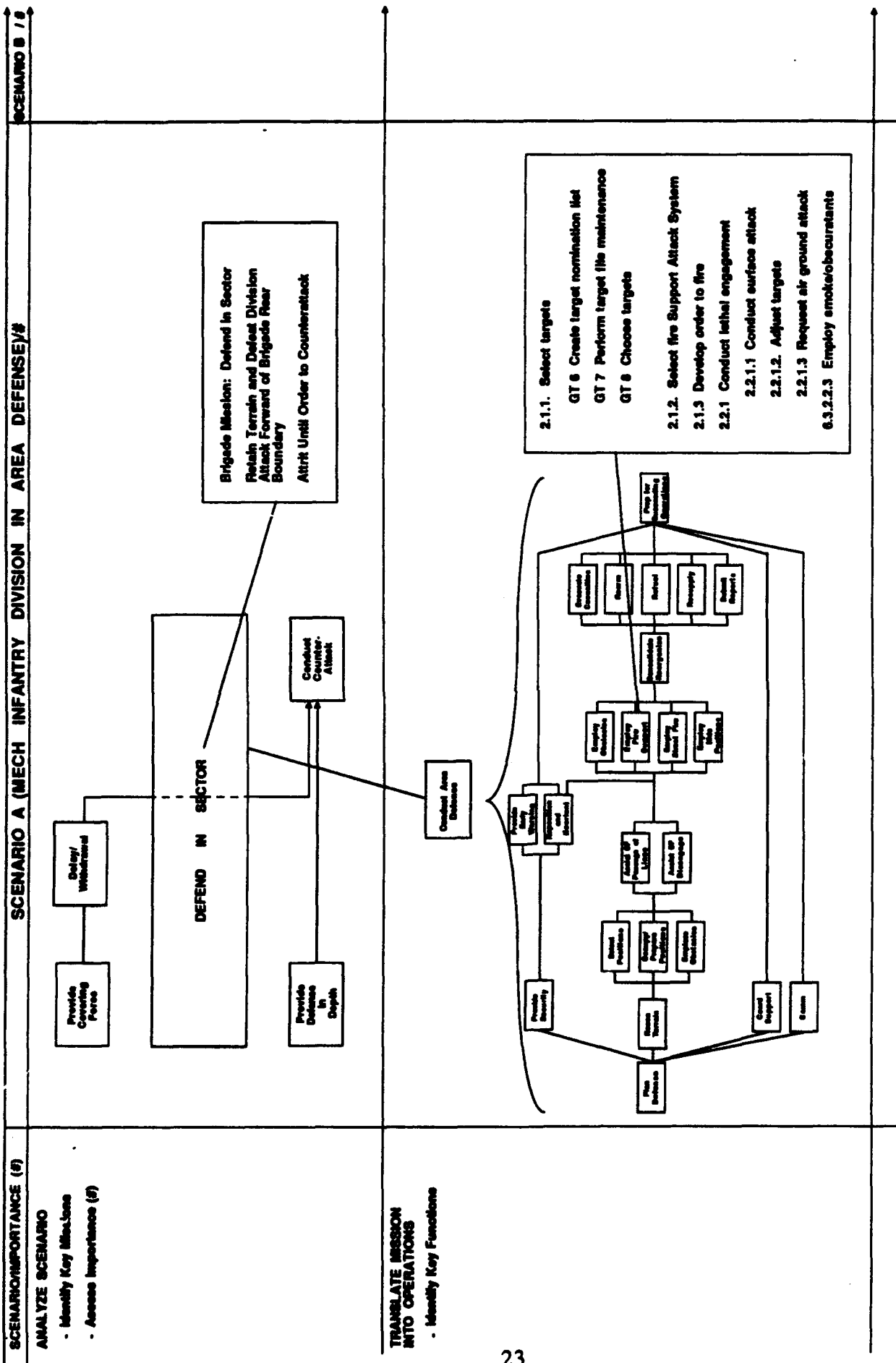


Figure 4. Example: Analyze Missions

disposition, composition, and strength of potential enemy forces. In particular, this involves identifying the mix of enemy forces (i.e., committed, reinforcements), their type (i.e., armor, infantry, artillery, aviation, air defense, intelligence, logistics, etc.), and their specific capabilities (as they are derived from personnel, their hardware, doctrine and training) to perform various activities as part of, or in support of, military operations. Enemy vulnerabilities may also be described based either on their inherent limitations or on their tactical doctrine and practices.

Battlefield Conditions. Scenarios provide details on a set of conditions that affect the ability of friendly forces to execute their assigned missions. These conditions include those related to both the area environment and the operational environment. The area environment consists of those factors that are "natural" insofar as they are unaltered for military purposes or unimproved by civilization as well as those relatively, permanent aspects of the environment created by the military (e.g., airfields) or by civilization (e.g., transportation routes). The operational environment includes those factors of the mission, enemy situation, and friendly situation that may affect how military units, systems, and soldiers are employed and perform. The operational environment represents, therefore, the nature of the threat being confronted. Figure 5 depicts the organization of conditions that are specified in scenarios. A much more detailed breakout of conditions variables is contained in Appendix D along with a discussion of these variables. The conditions specified in a scenario provide an audit trail that should be followed in all analyses involving the scenario.

1.3 IDENTIFY AND DECOMPOSE KEY MISSIONS

Scenarios identify the missions for the major force elements and subordinate commands taking part in the hypothetical conflict. The importance of the combined arms and services orientation in current doctrine requires that the capabilities analysis incorporate as many combat, combat support, and combat service support missions as practical. Choice of missions needs to reflect the capabilities of forces and equipment available in the time period under study, options to achieve results using different capabilities, and the considerable importance of the orchestration and integration of combat assets. For this reason, hypothetical battles should be planned which require a broad sampling of missions associated with the component forces. Analysts use a variety of sources to identify and list the important missions. These sources include TOEs, OPLANS, doctrinal manuals, ARTEPs/AMTPs, and METL.

Mission Sequencing. The missions of various force elements within a scenario can be displayed in sequence diagrams like that shown in Figure 4. These diagrams portray a sequence of interrelated missions occurring over time. Thus, while one element of the force is performing a "defense in depth mission", another element of the force may be "defending in sector". The development and examination of such diagrams may be helpful in identifying those missions that are most critical to the success of the overall military force in achieving its assigned objectives. The most critical missions are the ones that should receive the most analysis attention.

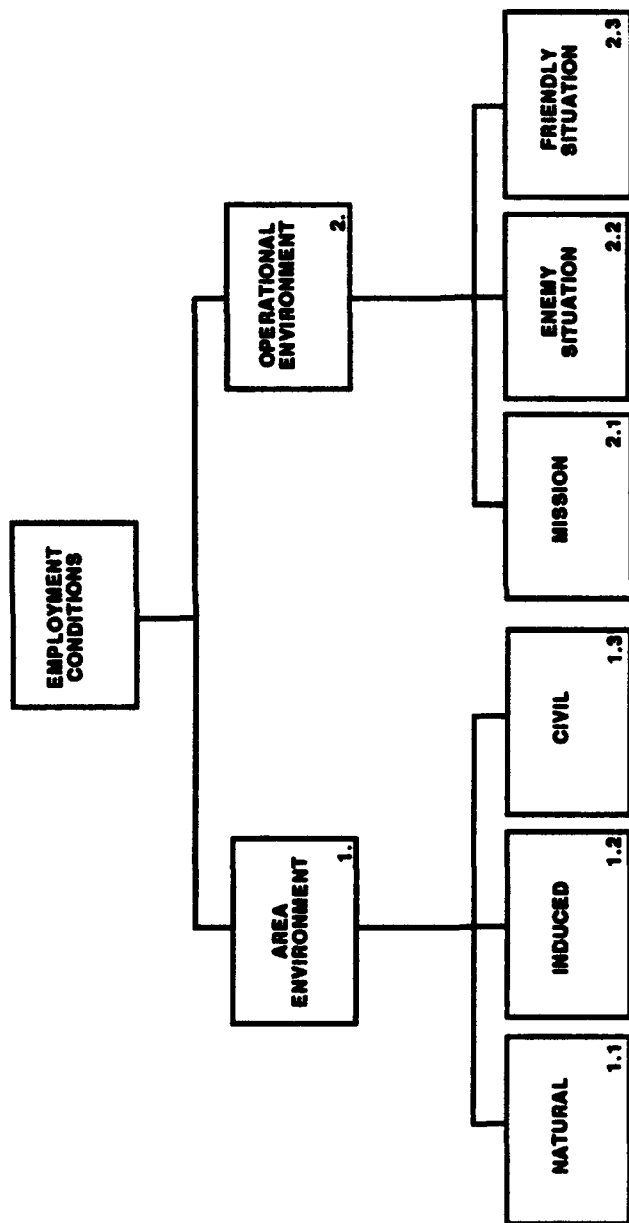


Figure 5. Conditions Affecting Military Operations

Mission Hierarchy. The mission for a force element states the purpose and intended end result of a combat action. Military forces are not homogeneous; rather, they consist of subordinate elements that perform a variety of activities in support of the mission. A commander at one echelon develops a concept for executing his mission by utilizing subordinate elements of the force he commands. He then assigns missions to his subordinate unit commanders that are consistent with his mission and with the mission of his superior commander. Missions of the higher level units are decomposed into missions assigned to lower level units. Figure 6 depicts this relationship between a brigade mission and subordinate battalion missions. This process of decomposing missions illustrates a vertical relationship across echelons.

Selecting Missions for Analyses. In conducting analyses, it would be too time consuming to examine all missions performed by the forces involved. It is therefore important to identify and examine those missions that are crucial to the success of friendly forces. Both techniques described above, sequence diagrams and hierarchical diagrams, can be helpful in identifying those missions most critical to overall success. A particular mission may be critical in several respects. It could be absolutely essential to the continuation of the fight. For example, if a unit fails to secure a key bridge, road, or trail, the operation may have to be halted. Alternatively, a critical mission could be one where there appears to be significant doubts as to the ability of friendly forces to execute it. For example, daylight attack dictates the use of smoke to cover the enveloping force. If smoke generation and projection capabilities are lacking, the entire attack could be seriously jeopardized.

1.4 TRANSLATE MISSIONS INTO OPERATIONS

Units are assigned responsibilities to execute specific missions. The commanders of these units translate mission guidance into operations (to include tactics, techniques, and procedures) for carrying out the assigned missions. Military doctrine describes various types of "operations" for conducting combat. For example, there are several types of offensive operations and several types of defensive operations. The doctrine for each type of operation describes the basic tactics and techniques for conducting that operation. Of course, each instance in which a particular operation is performed is unique and requires some tailoring to the specific situation. However, the various operations types provide a useful way of communicating information about the conduct of military combat at the various echelons of command.

As stated above, operations are doctrinally derived alternatives (i.e., tactics) for executing missions. Operations are therefore somewhat analogous to plays in a football game. Repetitions of the same play will resemble one another, but will vary somewhat in their execution depending on the defensive alignment as well as the particular players on the field.

Examples of military operations include conducting a hasty attack, performing a raid, and conducting a passage of lines. Units conduct these and other operations in combination to accomplish missions. Thus, operations are the building blocks required for the successful execution of missions.

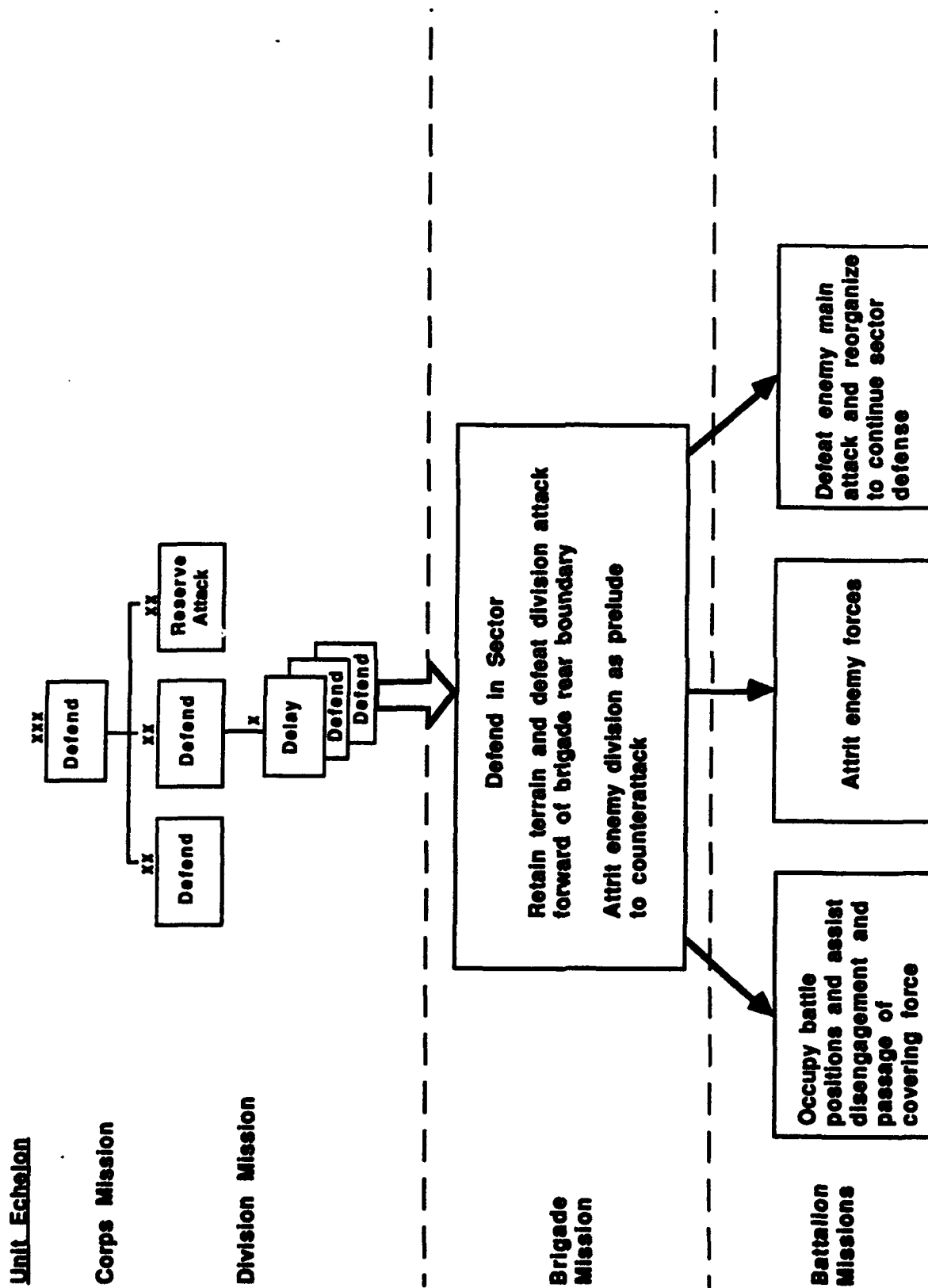


Figure 6. Missions are Successively Derived for Lower Echelon Units

The detailed description of operations enables analysts to relate the capabilities of Army units to the military objectives they are tasked with achieving. Combat operations are described in greater detail in Appendix A. Also, a comprehensive listing of operations types is also provided in Appendix A. A key to successful analysis of Army capabilities lies in the ability to fully and comprehensively describe the operations performed as part of the process of executing missions.

1.5 TRANSLATE OPERATIONS INTO FUNCTIONS

Whereas missions are relatively simple statements of the task and purpose or intent of a military action, operations are complex structures that translate intent into executable action plans. Operations are complex because they are multifunctional — that is, many different types of actions are required to achieve the desired outcome. Moreover, these actions or functions may vary in their level of contribution to the outcome. As important as the actions themselves, relationships of precedence and timing of actions provide additional complexity to the discussion and representation of operations.

Doctrinal literature describes the characteristics and the action sequences of operations. However, two analysis tools are helpful for depicting the component actions of operations and for detailing the functions, tasks, and capabilities associated with these component actions.

One tool is the operation template. An operation template is a sequence diagram that depicts the essential activities of an operation, arrayed to show the temporal sequence of events. An operation template uses doctrinal terms in a straightforward graphical format to summarize the important tactical and procedural components of the operation. Operation templates can be constructed for any type of operation. Templates are derived from descriptions of operations found in doctrinal field manuals and the sequencing of component actions is represented using a standard schematic approach (see Appendix B). An example of an operations template is shown at the bottom of Figure 4. The operation depicted in this figure is that of “conducting an area defense”.

Operation templates can be further detailed by reference to a common structure of battlefield functions and generic tasks, the Blueprint of the Battlefield (TRADOC Pam 11-9, 8 July 1988). The Blueprint is a comprehensive listing of battlefield functions and generic tasks, each of which may be associated with one or more components of the operation template. Linking Blueprint functions with an operations template provides a way of specifying the types of capabilities necessary for the successful conduct of an operation in a way that supports analysis of the operations. For example, in the bottom half of Figure 4, a conduct area defense operation is broken down into various elements and arrayed in a sequence diagram or operations template. One element of the operation, employ fire support, is then systematically linked to functions and generic tasks found in the Blueprint of the Battlefield.

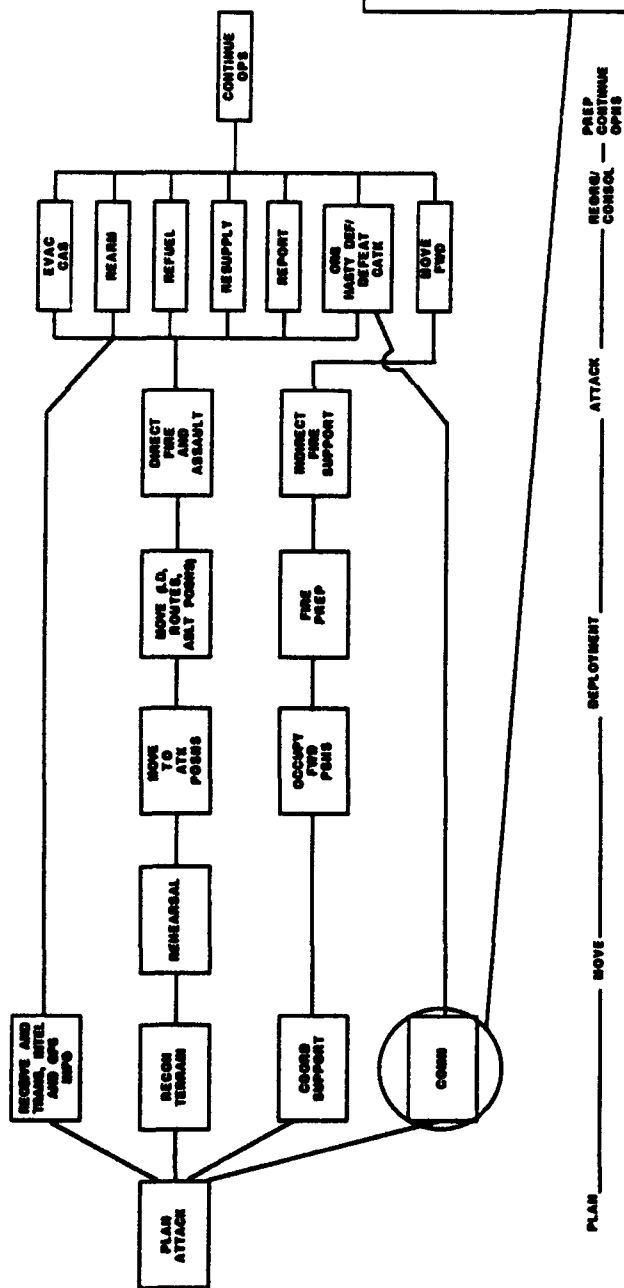
A second example is shown in Figure 7. In this example, an operations template is shown for a deliberate attack operation. One element of the operation, communications, is deemed to be critical to the success of the operation and therefore selected for more detailed analysis. Communications refers to the systems that pass information and reports, requests for and adjustment of fire support, and provides coordination and orders to the ground forces during operations. The "communications" element is then linked to the specific functions and generic tasks that must be performed as part of the operation.

Levels of War. Over the past few years, the Army has been articulating each of the three levels of war (strategic, operational, and tactical) and its role in each. The analysis process described in this report focuses for the most part on the tactical level of war. However, the tools and methods described in this report could be extended to the operational and strategic levels of war. The Blueprint of the Battlefield, a tool developed to support capabilities analysis, was initially designed to address the tactical level of war. However, the Blueprint is currently being extended to cover both the operational and strategic levels of war. Analyses that address these levels of war, will simply have to articulate operational and strategic level missions and operations and then use these Blueprints to identify key functions. The analysis can proceed from that point much the same way as described in this report.

Identification of Key Operations Elements. As stated in Section 1.3, analyses are limited to an examination of the most critical/essential missions and operations performed in a scenario. Similarly, only the most critical elements of operations can be examined in detail. Subject matter experts/analysts judgment, historical experience, or previous studies may indicate which elements of operations are most critical. Those operations elements that are most risky or likely to fail based on what we already know about our capabilities should be selected and then decomposed into battlefield functions to permit quantitative analysis in Phase 2 of the analysis process.

Phase 1 Summary. The product of Phase 1 is a list of operations that are key to the success of the Army on the battlefield and of those operational elements and functions deemed critical to their successful conduct. This product is the result of a top-down analysis of the Army roles and responsibilities and estimates of the types of conflicts the Army will be required to support. The key operations identified are analyzed in terms of doctrinal templates that describe the general sequence of events in conducting an operation. It provides the basis for more detailed analysis of the performance of various functions and tasks during an operation and the interrelationships of these activities.

II
OPERATION
DELIBERATE ATTACK



- 4.1. Acquire and communicate information and maintain status
- 4.1.1.1. Receive/transmit mission
- 4.1.1.2. Receive/transmit enemy info
- 4.1.1.4. Receive/transmit friendly info
- 4.1.2. GT 1 Establish communication nets and facilities
- 4.1.3. Maintain info and force status
- 4.1.3.4. Manage info distribution

Figure 7. Communicate - Functions and Generic Tasks

2.0 ASSESS CAPABILITIES

In this phase, the ability of a unit or military force to meet the requirements of its assigned missions is examined. This process is illustrated in Figure 8. The analysis of capabilities is accomplished through a systematic examination of the functions and generic tasks that comprise the operations being conducted. The nature of the operations being conducted and the conditions under which they are conducted determines, to a large extent, the degree to which various functions must be performed for the operations to be successful.

In addition, the analysis permits the examination of alternative means for performing various functions on the battlefield. For example, the direct fire engagement of enemy armored vehicles may be conducted using man-portable anti-armor systems, attack helicopters, or tanks. Enemy tanks could also be engaged by field artillery systems or mines. In this phase of capabilities analysis, all available means are examined to determine, not so much the adequacy of a single weapon system, but the adequacy of the units or forces available to perform the functions and generic tasks necessary for the successful conduct of military operations on the battlefield.

2.1 ANALYZE OPERATIONS

A variety of approaches are used to determine the relative contribution and importance of the functions comprising specific operations. Military history, doctrinal literature, operational test reports, major exercise results, combat training center after-action reports, and reports of special studies provide insights into what functions are central to operational success. Studies using combat and functional area models provide another source for determining functions important to unit performance. Analysis of threat capabilities offers yet another perspective on the relative importance of functions in potential conflicts.

The aim at this stage is to identify those functions in need of detailed analysis. This is accomplished by annotating or highlighting the components of the operations template that experience or research shows to have special significance. However, once these components are identified, all the functions associated with each component are reviewed to find those functions that have major impacts on the successful completion of that operation. Functions may be singled out as important under the following circumstances:

1. Changes in operational concepts or doctrine that place a particular emphasis on a function or group of functions (e.g., due to technological advances),
2. Changes in the likelihood of various types of conflict that require the performance of operations that emphasize particular functions (e.g., increased likelihood of LIC operations),
3. Changes in estimates of threat capabilities, the value of various political alliances, or environmental conditions that may affect the difficulty of performing various functions, or

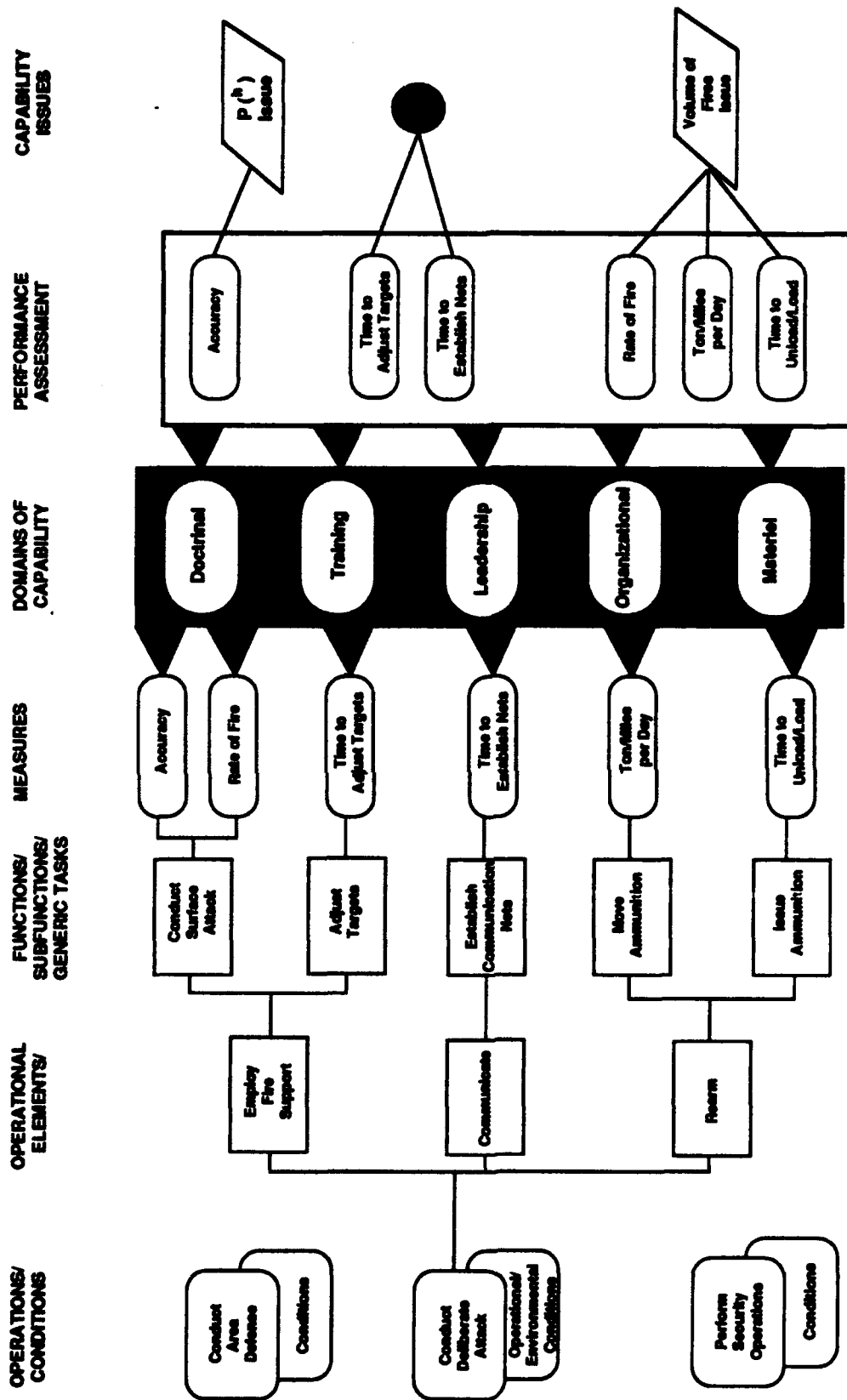


Figure 8. Example: Assess Capabilities

4. **Function(s) that have been an ongoing problem for which no solutions have been implemented to date.**

Each of these situations will occur during the normal process of updating capability analyses to reflect changing political situations, technology, and national security objectives on the part of various countries. In such a dynamic context, the demand for the performance of various functions may change over time as will the contribution value of these functions to mission success. For example, as engagement ranges increase due to technological advances in non-line of sight weapons systems, the importance of, and the demand for direct fire weapons may decrease correspondingly in some operations.

The conduct of an operation typically involves a range of functions and generic tasks. While these activities may vary in their importance to the operation, they are all integral to its conduct. In addition to these functions, there are other functions (herein called "secondary" activities) that may not be performed in the immediate context of the operation, but whose successful performance may also be critical to the success of the operation. Many of these secondary functions may be in the areas of combat support and combat service support. For example, the success of an operation requiring aggressive movement of armored vehicles such as deploying in a meeting engagement, is largely dependent on the degree to which scheduled maintenance was performed on all vehicles prior to initiation of the operation. While these maintenance activities are not part of the conduct of the operation itself, their successful and timely performance nonetheless is critical to the operation. Conversely, a static defense operation is less dependent on maintenance.

Secondary activities or functions permit "what if" excursions to discover the impacts of preceding or successor activities on an operation. These activities often act as constraints on the activities integral in time and space to the operation. Thus, the failure to properly recon the area of operations in advance of the operation or the failure to stockpile enough fuel to carry the forces through the operation could greatly impair the ability of friendly forces to effectively conduct its operations.

The objective of this step in the analysis is to identify the activities that are critical to the execution of the required operations. The activities identified must include both those integral to it as well as so called "secondary" activities that may significantly influence the operation.

The templating approach provides a useful tool for describing operations and the sequencing of component activities. It also provides an opportunity to identify and assess the impacts of secondary activities that may influence or constrain the performance of other, related activities. This approach may reveal unexpected opportunities or vulnerabilities in performing combat operations. The contribution of these functions is explored in the next step of the analysis.

2.2 DETERMINE SENSITIVITY OF OPERATIONS TO FUNCTIONS

The outcome of an operation is sensitive to the performance of many functions. Ideally, a single dynamic simulation that represented the performance parameters of all the functions of an operation, as well as the battlefield conditions under which these functions would be performed, could be used to identify the degree to which various functions contribute to successful conduct of an operation. The enormity of this task for combined arms operations that include many force elements exceeds the capabilities of any current or near-term simulation models. While a single model is not feasible, it may be possible to use the "family of models" approach already initiated by TRADOC. Families of models, if properly coordinated, offer the potential of comprehensive analysis of operations to determine the adequacy of current capabilities for performing the many activities (including secondary ones) key to the success of military operations.

Operations, which are doctrinally derived "action plans", provide the focus for analysis. However, operations templates provide only general descriptions of operations, identifying the key elements and their sequencing. The relative and specific emphasis on each of these elements must be tailored to the specific situation being examined. As a result, each study or capabilities analysis will examine different operations, or as a minimum, different variations of the same operations.

In order to coordinate analyses from different models, studies, or other analyses, a framework must be available to integrate the results. This framework must contain standard elements for the analysis. These elements include three components: standard functions and generic tasks, standard conditions of the battlefield, and standard measures of effectiveness for the activities performed on the battlefield. These will each be discussed briefly, in turn.

Standard Set of Battlefield Functions and Tasks. The Blueprint of the Battlefield (TRADOC Pam 11-9, 8 July 1988) provides a standard set of functions and generic tasks performed during combat. It also provides definitions for these terms. The functions and generic tasks are not linked to specific means, so they can be applied to different types of units performing different types of operations.

Standard Set of Battlefield Conditions. A helpful tool in determining the contribution of the functions to operation outcome is a taxonomy of battlefield conditions (see Appendix D). Because neither the Blueprint of the Battlefield nor operation templates contain references to battlefield conditions, the analyst must integrate the stated or implied conditions from the scenario into the analysis of each function. A condition may not affect performance of a function, as in the case of the effects of precipitation on radio communications. On the other hand, conditions may strongly influence the ability of a unit to perform a function. For example, the functions of finding and identifying enemy targets can be far more difficult to perform at night than during daylight hours. In many cases, soldiers are

affected to a greater degree than equipment by conditions. As a result, the study of human performance as a function of battlefield conditions is crucial to the process of estimating battlefield performance.

Standard Measures of Effectiveness for Battlefield Functions and Generic Tasks. To effectively use the operations template – battlefield functions approach, the analyst must have standard measures of effectiveness for the functions being performed on the battlefield. Many measures used in capabilities analysis are either measures of specific system performance or are aggregate measures commonly used in combat simulations (e.g., attrition rates, force exchange ratios, movement of the FLOT/FEBA). To examine the sensitivity of operation outcomes to various functions, measures that are independent of the specific means for performing functions are required. Measures of effectiveness such as accuracy (e.g., probability of a hit or circular error probabilities), lethality (i.e., terminal effects), power, durability, range, discrimination, resolution, and error rates are good examples. Time-based measures are also appropriate. Examples include rate (speed), acceleration, range (i.e., flight time without refueling), and time to perform. An example of performance measures of functions is shown in Table 1. Further discussion of the measurement of functions is contained in Appendix C (Identification of Measures of Effectiveness).

Consideration of Soldier Performance. The analyses conducted in this step must accurately consider soldier abilities as they both contribute to and constrain weapon system and unit performance. Estimates of weapon system and unit performance will, in turn, affect judgments about the adequacy of the Army's capabilities to conduct critical operations. Misjudgments at this stage of the analysis (e.g., failing to take into account the effects of fatigue on weapon system and unit performance in a scenario involving continuous operations) may cause the Army to overlook critical capability issues.

In particular, the careful delineation and consideration of conditions on the battlefield are key to the accurate assessment of combat performance in the "fog of war", since it is soldiers who are most subject to its effects. Recent development of "performance shaping functions" relate the characteristics of soldiers (e.g., cognitive) and battlefield conditions to weapon system and unit performance. The further development and use of these functions could be quite helpful to the process of estimating operational success on the battlefield.

Conduct Sensitivity Analyses. In the following steps, critical elements/functions of operations, identified in Step 2.1 of the analysis, are examined in detail to determine the impact of their performance on operations success. In particular, the goal is to determine the levels of performance on specific measures of effectiveness, required to provide reasonable assurance of operations success. These steps are illustrated in Figure 8.

Select Operational Elements/Functions. In the example shown in Figure 8, several operational elements are identified for the "conduct deliberate attack" operation. These are further broken down into functions and subfunctions that seem to be essential to mission success. For example, for the operational element employ fire support, one key function is identified as "conduct surface attack (i.e., indirect fires)".

Table 1. Example of Measures for the "Engage Enemy" Function Within the Maneuver BOS

Functions	Purpose of Function	Common Measures	Key Conditions
1.2 Engage Enemy	to reduce enemy force capability by direct fire and close combat	• decision/response time • mission completion time	• range • nature of target
1.2.1 Employ Direct Fire	to respond to targets by direct fire means	• target processing rate • decision/response time • target engagement rate	• terrain • ECM, ECCM • target density
1.2.1.2 Engage Direct Fire Targets	to cause casualties and destroy materiel	• time to detect/identify estimate range • time to first fire • mean offset error • time/rounds to adjust	• nature of target • terrain • range • visibility

Identify Performance Objectives. The purpose of the function "conduct surface attack" is to destroy or neutralize various enemy targets. In our deliberate attack scenario, these targets might include: fourteen fighting positions with overhead cover, four tanks, twelve soft skin armored vehicles, and twelve other wheeled vehicles, two unprotected ammunition and supply dumps, and a class 50 bridge. It may be determined that a minimum number or percentage of these targets has to be destroyed for the operation to be successful.

Select Measures of Effectiveness (MOE). MOE must be relatable to the elements of the operation. MOE should be directly tied to functions/generic tasks which, in turn, can be quantitatively related to the elements of an operation. Measures of a function like "conduct surface attack" could include measures such as accuracy and rate of fire. These measures, in turn, can be quantitatively related to higher level functions (e.g., employ fire support) and to the destruction of targets in an operation (e.g., deliberate attack).

Identify Sources of Capability to Perform Functions. The analyst must identify all sources of capability to perform functions, including doctrine, training, leadership, organization, and materiel. For example, in examining the means at the disposal of the commander for "conducting surface attack", the analyst might identify two means, artillery and mortars. Each of these means has a variety of ordnance, and each has a particular range capability and response time. Rates of fires may be constrained by the availability of ammunition based on the basic load of ammunition and the ability to resupply. The analyst would also have to examine the degree of training provided to the operators of these systems, their doctrine for employing these systems, the leadership involved in their employment, and the deployment of these systems in units.

Specify Battlefield Conditions. Conditions have a significant impact on performance. For example, in limited visibility conditions, target detection and adjustment of fires is much more difficult to execute. Therefore, operational and environmental conditions of the battlefield should be specified, especially those most likely to impact performance. In the case of field artillery, such conditions might include:

- range of targets,
- density of targets,
- amount of counterfire by the enemy,
- wind, and
- barometric pressure.

Apply Measures to Determine Performance on Key Operational Elements/Functions. Using the example of "conduct surface attack, suppose that results from a number of active duty artillery battalion tests indicated that it takes an average of 13 rounds of 155 HE super quick fuze to destroy fighting positions at gun target ranges between 3 and 9 kilometers.

Using information on the likely operational and environmental conditions on the battlefield, analysts could attempt to determine the likely success of destroying the enemy fighting positions.

Determine Sensitivity of Operations to Functions. In this step, the analyst examines the combat situation, using high resolution combat models, map exercises, training exercises, historical data, or other methods supplemented by expert judgment. Analysts have to be careful to acknowledge the limits of their ability to identify causes of variation in performance. Thus, each model or method has the ability to explain performance in terms of a limited set of variables. Other models or methods may be able to explain performance differences in terms of different variables. No analytical method can identify the ultimate cause of inadequate performance of some activity on the battlefield because there is no such ultimate cause. However, there are many capabilities, that if improved, can positively impact battlefield performance, and hence battlefield outcomes. The goal is to identify those functions whose performance makes the greatest difference in successfully performing military operations on the battlefield.

The analysts and combat experts must add a heavy dose of judgment to the analysis effort. The analysis should address as many battlefield conditions and activities (i.e., functions) as is feasible. The results are used to calibrate various performance capabilities against mission outcomes, without necessarily specifying the ways or means of accomplishing such improved performance levels.

An example is shown below of the kinds of output that might come from a modeling effort of a "Deliberate Attack Operation". The success of an analysis, regardless of its level of resolution, depends on the ability to use the results to estimate the sensitivity of the mission outcome to various levels of performance on a number of key activities (i.e., functions).

In the base case, the friendly force advanced to the objective area but was then ineffective, and could not hold the objective. In summary, the operation was a failure.

The analyst could run the model again varying one input parameter (e.g., increased capability, in terms of rate of fire or accuracy, to conduct surface attack) at a time. Hypothetical results of such an excursion are also shown in the table. The analyst studies the results and compares them with the base case to determine the impact of an additional capability to perform the function "conduct surface attack" on the deliberate attack operation.

In this excursion, the model results indicated that the enemy force fought briefly before breaking contact (i.e., no decisive engagement). Friendly unit is combat effective, can hold the objective, and is ready to continue operations. In summary, the operation was completed successfully.

The base case establishes overall results and contribution of each type of means to combat performance (e.g., kills). The analyst runs several iterations to check reliability of the analysis. Following this, he changes functional inputs one at a time to establish sensitivity of the outcome to that function.

Measure	Base Case	Excursion
Time to Reach Objective	120 min.	60 min.
Enemy Losses		
• Personnel	87%	50%
• Tanks	100%	50%
• Other Vehicles	90%	70%
• Bunkers Destroyed	70%	80%
Damage to Bridge	35%	75%
Friendly Losses		
• KIA/WIA/MIA	75%	19%
• Tanks/Bradleys		
- Destroyed	60%	10%
- Damaged	30%	20%
Ammo left (% basic load)	20%	45%

Summary. Sensitivity analysis serves two purposes. First, it confirms or denies the importance of the functions presumed to affect operations success. Secondly, sensitivity analysis evaluates the means for performing the functions confirmed to be important. By using the tools of operations research and the functional measures as described above, the variety of units, systems, and soldiers for performing the same function are identified and examined. The objective is to build a consolidated quantitative picture of the ability to perform the function.

The goal of this analysis is to estimate the capability of the force being analyzed to perform various battlefield functions. Some of these capabilities are found in currently fielded means (i.e., units, systems, and soldiers) that will be available in their present form for the time frame of the scenario. Other capabilities are projected or programmed to be available during the time frame being examined. The objective of the analysis is to determine whether these capabilities are sufficient to meet operational requirements. Combat capabilities originally developed with respect to certain assumptions and constraints may not be adequate given subsequent changes in warfighting concepts, technology, potential threats, alliances, or other related developments.

The product of this step is the identification of operations that are at risk due to an insufficient capability to perform one or more functions that are essential to the operations. In many cases, the weak link in the operation (e.g., a battlefield function) may be known as well. This information is used in the next step to aid in formulating capability issues.

2.3 GENERATE CAPABILITY ISSUES

During the previous step of the analysis, high risk operations are identified. In some cases, functions that are essential to these high risk operations may be targeted as potential problem areas (see Figure 8). This information is used in this step to construct lists of issues, which, if addressed, would greatly reduce the risk of Army failures in executing its assigned missions.

At this point in the capabilities analysis process, it is important to emphasize that no attempt is made to fix the means that will be identified in the solutions nor the domain for achieving improvements (i.e., doctrinal, training, leadership, organizational, or materiel) in the key functions or operations identified in Phase 1. Rather, an attempt is made to simply identify the particular functions that need to be improved and to estimate the extent to which they need to be improved. Further, these "issues" may be grouped together in packages that must be collectively implemented in order to realize the full benefit of the individual improvements.

The purpose of this step is not to develop or review detailed proposals of potential capability enhancements. However, before identifying and forwarding a particular set of issues to decision makers, analysts must ensure that technology and available resources offer a reasonable opportunity of successful resolution.

Thus, the examination and evaluation of capability issues is not done in total isolation of ideas or proposals of how to improve the performance of Army units, systems, or soldiers. This step is closely related to the conduct of sensitivity analyses in Step 2.2 in which particular capabilities are varied to determine the effect on the ability to successfully conduct operations. The emphasis in this step is on the degree to which functions need to be improved and on the feasibility of achieving these improvements.

In summary, for each issue, the function or functions whose performance is targeted for improvement must be identified. The measures of effectiveness used to define the nature of the targeted improvement must also be specified. The targeted performance levels on the function or functions to be enhanced will be specified as will the operational and environmental conditions under which the targeted performance must be achieved. Finally, the operation that is designed to benefit from the improvement will be identified. All of this sets the stage for the packaging and prioritization of capabilities issues.

2.4 PACKAGE AND PRIORITIZE ISSUES

The objective of this step is to develop a set of issues for each high risk operation that, if addressed, would enable the affected units to conduct specific operations successfully that were previously at risk. These issues serve to guide subsequent efforts to identify specific enhancements by the various Army branches and mission areas in the domains of doctrine, training, leadership, organizations, and materiel.

This step begins with an examination of an operation to determine the best mix of capabilities (identified in terms of operations elements or functions) to enable designated units to carry out the operation effectively and efficiently. Efficiency is particularly important since resources are generally constrained. Therefore, capability issue sets must be identified that can be satisfied with relatively low cost, low resource solutions. The built-in bias should be to identify issues that can be addressed through doctrinal or training initiatives since they are the least expensive to implement.

This requires that the analysts continually iterate their focus between issues tied to functions and the success of the overall operations. The key is to identify sets of issues that, on the one hand, will enable the Army to meet the requirements of the operation, and on the other hand, require the least number and degree of performance improvements.

Thus, the analysis of a deliberate attack offensive operation (see Figure 8) might indicate failure to succeed unless several improvements are made. One approach might be to improve the volume of fires, ammunition resupply, and target acquisition of the units conducting the attack. Another approach might simply involve smoke generation capabilities to cover the attacking forces. The goal is to identify a set of issues for an operation that will most simply reduce the risks associated with the operation. One key to this process is to ensure that the approach to capability improvement is consistent with the approved concepts and doctrine for the operations being examined.

Once issues are identified for one operation, they can be compared to issues identified for other operations being studied. Some similarity in issues across operations and scenarios might be expected and would signal the multiple benefits of a potential solution. That is, if the issue of reconnaissance is identified repeatedly as an issue for different operations and across different scenarios, then it may be fair to conclude that improvements to a unit's ability to conduct reconnaissance functions would benefit these units in many situations.

The frequency with which issues are identified across operations and scenarios can be used to determine the "contribution value" of a solution to that issue to the Army's ability to execute its assigned missions. In addition, the degree to which an issue exists (i.e., the size of the gap between current capabilities and the capabilities required to successfully conduct operations) can also be used to determine the "contribution value" of potential solutions.

For example, suppose that across a wide variety of operations conducted in several different scenarios under varying environmental conditions, weaknesses in target acquisition have been identified. Further, suppose that the extent of the shortfall has been estimated to be fairly significant in many cases. Therefore, the issue of "target acquisition" will receive priority, and consequently greater emphasis in the solution development phase of a capabilities analysis.

Phase 2 Summary. The product of this phase is an integrated list of issues (some could be grouped together into packages) that can provide a roadmap for the next phase of the analysis, which is concerned with the identification of proposals to improve the Army's capabilities. The Battlefield Development Plan (BDP) currently provides TRADOC's integrated listing of capability issues as shown in Figure 1 of this paper.

3.0 IDENTIFY AND ASSESS CAPABILITY IMPROVEMENTS

Given a list of capability issues as input, the purpose of this phase of the capabilities analysis process is to identify new or improved ways of performing specific battlefield functions and to estimate the performance impacts, the costs, resources, and technological risks associated with each alternative identified. Figure 9 provides an illustration of this phase.

Types of Capability Enhancements

Capability issues indicate the functions that need to be enhanced without identifying either the specific means to be improved or the mechanism (i.e., doctrine, training, leadership, organization, materiel) by which such an enhancement would be accomplished. Each branch or mission area proponent can look at the issues and at the available sources of capability to try to identify opportunities for improvement. For example, if one issue concerns the ability to destroy enemy tanks with direct fires, the Armor Center might explore potential improvements to a source of capabilities that they are responsible for such as tanks. However, this process should not exclude the consideration of ideas for improvement that do not fit cleanly into existing boundaries. For example, in trying to improve the collection of target information, the exploration of the use of remotely piloted/unmanned aerial vehicles might be pursued by various branches, including field artillery, intelligence, and aviation.

Once a unit is identified as a potential source of improved capability (e.g., aviation company), alternatives can be explored in any or all of the five domains for achieving improved performance: doctrinal, training, leadership, organizational, and materiel. Each of these domains is described in the following paragraphs.

Doctrinal Improvements. One option for capability enhancement is through doctrinal improvements. This is accomplished by making changes to the functions within an operations template, their sequencing, or their relative emphasis. For example, an attack operation involving a mechanized task force might have a variant in which the fire support function is emphasized as the main form of firepower. Increasing the fire support contribution might require fire support-related functions to be included in larger numbers or to greater depth in the operation template. The success of such doctrinal changes depends, of course, on whether the alternative method constitutes a more effective utilization of the resources in a unit or force.

Another potential doctrinal improvement, suggested in Figure 9, involves the prepositioning of ammunition with the ultimate intent of increasing the volume of fires achieved on the battlefield. Doctrinal improvements such as this involve changes to the methods for conducting operations (i.e., tactics) such as the sequencing or relative emphasis of functions or to the methods for performing functions (i.e., techniques) such as the different overwatch techniques for executing unit movement.

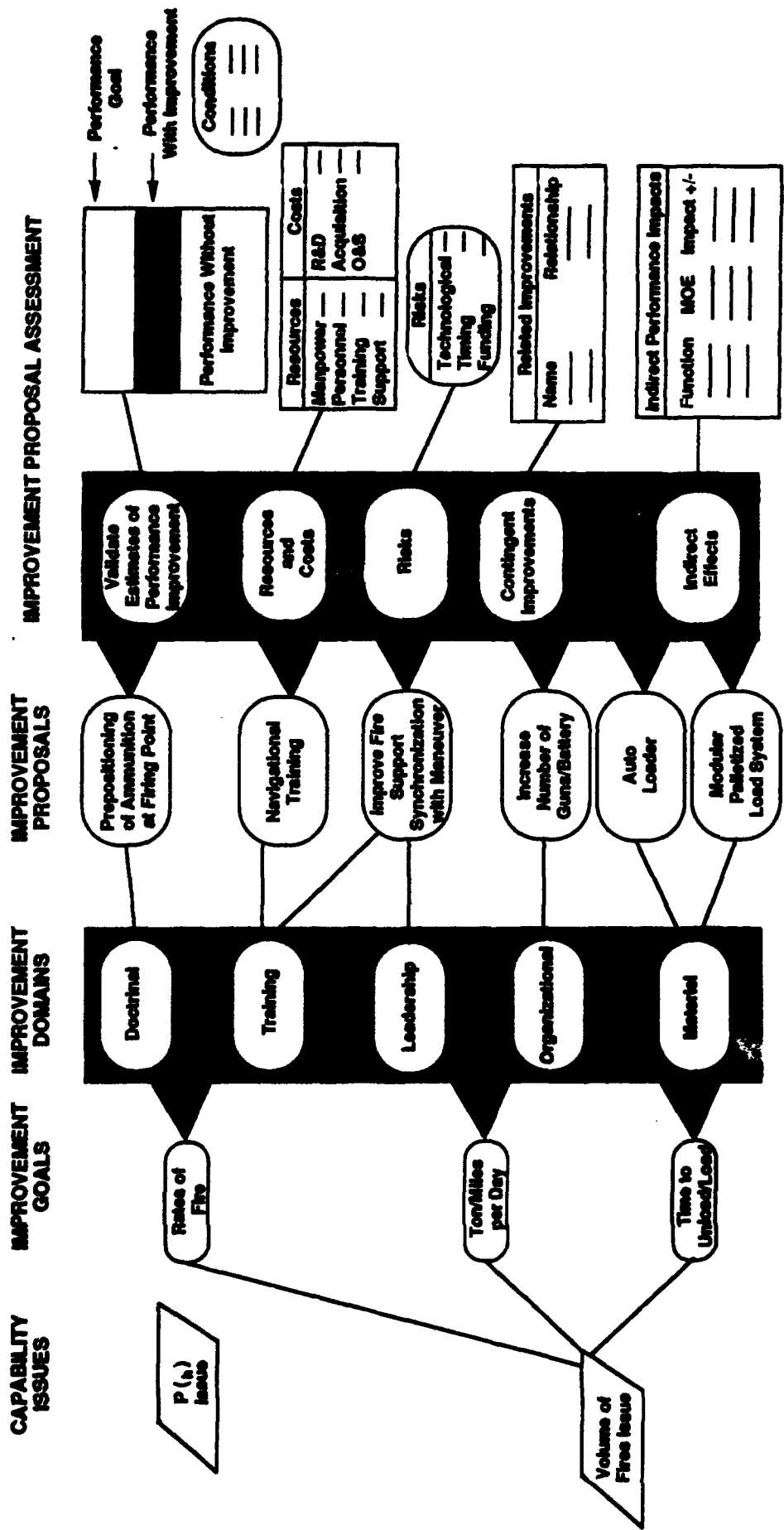


Figure 9. Example: Identify And Assess Improvements

Fundamental changes in doctrine (e.g., introduction of AirLand Battle in 1981) should not be examined in the context of the type of detailed analysis conducted in this step of the capability analysis process. Rather, such fundamental changes warfighting concepts should be agreed upon (e.g., AirLand Battle Future) prior to initiating capabilities analysis studies. The studies could then examine the ability of the current or projected force to execute such new concepts and identify specific improvements required for their implementation.

Training Improvements. A second option for capability enhancements involves the initiation of improvements to the training system as a means of enhancing combat capability. Training improvements can occur at several levels including:

- the enhancement of individual soldier training designed to improve the performance of specific soldier tasks (e.g., firing the DRAGON),
- the enhancement of crew training designed to improve the operation/maintenance performance of a weapon system (e.g., employing a howitzer to perform counterbattery tasks) or of a team (e.g., the ability of a command group to formulate plans and issue mission orders),
- the enhancement of unit training designed to improve the coordinated employment of weapon systems (e.g., tank platoon) in performance of battlefield functions (e.g., movement),
- the enhancement of combined arms unit training to improve coordinated conduct of tactical operations (e.g., training of battalion task force in conducting an area defense at the National Training Center), and
- the enhancement of joint or combined force training to improve coordination of major force and supporting activities in conducting large unit operations (e.g., REFORGER exercise).

Training may be required because of the introduction of new missions, new equipment, new doctrine, or changes in the structure (i.e., TOE) of military units or organizations. It may also be required simply to maintain proficiency of skills, to enhance cohesion of units whose personnel keep rotating through it, or to prepare for specific missions that units are likely to be assigned in combat.

Leadership Improvements. A third option is to improve the quality of leadership. Such improvements can take place through either the improved selection or preparation of leaders. Advances in technology have made the challenge of leadership more difficult, rather than easier, due to the increased lethality, spatial expansion, and time compression of the combined arms battlefield. Leaders receive increasing amounts of information and have less and less time to act on it. Leaders must be selected and prepared to handle this challenge.

Organizational Improvements. A fourth option for capability enhancements is in improvements to the design of military units or organizations. Such organizational improvements are typically initiated to bring the doctrine for the unit into closer alignment to the capabilities of the unit. Thus, for example, if the doctrine for an infantry battalion required the placement of scouts on its flanks during offensive operations and the battalion lacked enough scouts in its TOE structure, either the doctrine should change or the unit structure should be modified to bring it into line with current doctrine.

Organization changes to the manning structure of units may also be necessary to bring the workload associated with equipment in the unit into balance with the numbers of personnel assigned to operate and support it. The introduction of a new tank that consumes twice as much fuel as a predecessor system may require additional personnel to perform refueling or to operate equipment needed to resupply fuel.

Solutions in the organizational domain must be offered in light of organizational constraints on the Army. At the broadest level, organizational solutions must fit within the total end-strength of the Army authorized by the Congress. Similarly, organizational improvements that require changes in manpower authorizations across branches will be constrained by the Army's willingness to consider such options.

Materiel Improvements. The fifth option for capability enhancements is technological improvement to the capabilities presently programmed to perform specific functions. This typically involves the development of materiel. It is generally the most expensive method for enhancing performance, often the least timely, and quite risky as well. However, selectively applied, technological improvements can help to accomplish various functions more accurately, more quickly, and/or more efficiently than other alternatives.

A related option for enhancing battlefield capabilities using technology involves the addition of functions to those already performed by a materiel system. The enhancement of systems by adding functions is often justified on the basis of cost savings across the performance of many functions. However, a system cannot perform all functions at once, and therefore an operation cannot benefit from this multifunctionality as much as might be hoped. Also, when a system performs one function well and you add a requirement for it to perform an additional function, it is likely that the desired performance on the additional function cannot be achieved without some cost to the performance of the first function. Thus, when you increase the maximum speed of the M1 Tank, you also reduce its transportability (due to heavier engine and drive train), increase its fuel consumption (thereby adding a requirement for resupply) and reduce its operating range (due to increased rate of fuel consumption). In the worst case, this can result in what is commonly referred to as "goldplating". On the other hand, relatively simple enhancements (i.e., perform more self recovery of combat vehicles) might be quite effective.

Capability enhancements may be identified by any organization in the Army. However, since each enhancement is likely to have consequences on other domains (i.e., a doctrinal enhancement will affect training or a materiel improvement may affect doctrine) as well as on other capabilities (i.e., an improvement in firepower may only be achievable through

a reduction in mobility), some checks and balances must be put in place to ensure that each improvement proposal is carefully coordinated with various Army organizations that are likely to be impacted in some way.

3.1 GENERATE CAPABILITY ENHANCEMENT PROPOSALS

The issues generated in Phase 2 of the analysis are stated in terms of the ability to perform one or more functions on the battlefield. Specific measures of effectiveness (MOE) may be cited in the statement of the issues, along with baseline values and desired values. In addition, information is available on the situation (i.e., METT-T), detailing operational and environmental conditions that affect performance of these critical battlefield functions.

In response to these issues, various proponents (to include branches, but also functional proponents like training developers and doctrine developers) can initiate improvement proposals for addressing these issues. As stated above, these proposals can be categorized as either doctrinal, training, leadership, organizational, materiel, or some combination. Improvement proposals will be described in response to specific capability issues and will detail (1) the functions to be enhanced, (2) measures for these functions, (3) the degree to which performance could be enhanced, and (4) the impact of various battlefield conditions on the degree of enhancement that can be achieved.

A single performance improvement proposal does not have to fully address an issue. Several performance improvement proposals may be required to fully address an issue. However, each proposal must include an estimate of the degree to which it will address a specific battlefield capability issue.

A variety of methods could be employed to systematically generate and evaluate capability enhancement proposals. Two methods are briefly described here; engineering/functional analysis and virtual prototyping.

Engineering/Functional Analysis. Functional proponents can generate improvement proposals in any of the five domains of capability (i.e., DTLOM) for any type unit involved in one of the scenarios being examined. These improvement proposals can then be examined in more detail to determine the extent of performance improvement likely to be achieved. For materiel improvements, engineering models, prototypes, or high resolution combat models can be used to predict the level of performance that can be achieved. Training, doctrinal, leadership, and organizational improvements can also be evaluated through subjective judgements by analysts, during training exercises, or with simulations. Estimates of levels of performance improvement can be compared to capability issue statements to determine the degree to which improvements can fully resolve the issues.

The major weakness of this approach is that it not designed to look across the domains of capability (i.e., DTLOM) to determine the combined effects of improvements to more than one of the domains. For example, while engineers may be able to determine that an improved combat vehicle can move 20% faster on the battlefield, they may not be able to assess the increased demand for driving and navigation skills on the operators caused

by a faster vehicle, whether current doctrine will permit forces to take full advantage of this increased speed, and whether the unit is organized properly for such an improved system.

Virtual Prototyping. A second method for generating possible solutions to battlefield capability issues has been called virtual prototyping (Alexander, 1989). In this concept, an engagement simulation is created of a future battlefield, representing both friendly and threat objectives, conditions, and forces (including systems). Virtual prototyping permits analysts to project hypothetical improvements to battlefield capabilities, including specific performance parameters in the simulation. In applying the notional improvement across several scenarios, soldiers (e.g., operators, commanders) would be trained in the utilization of the improved capability as if that capability really existed. This would provide analysts an opportunity to examine a combination of doctrinal, training, leadership, organizational, and materiel improvements before decisions have to be made on their acquisition or implementation. For example, this might provide the opportunity for doctrine developers to try out possible doctrinal improvements with man-in-the-loop simulations. It might also provide an inexpensive way of exploring and comparing the application of "multiple new technologies to determine which will provide the biggest payoff" (Alexander, 1989).

3.2 ASSESS CAPABILITY ENHANCEMENT PROPOSALS

The assessment of capability enhancement proposals is conducted to document and validate estimates of the performance benefit of a proposal, to assess the risks associated with a proposal, to assess the resources and costs associated with the proposal, to identify other contingent improvements, and to assess any indirect effects of the proposal on other functions performed on the battlefield. These areas of assessment are illustrated in Figure 9 and discussed briefly in the following paragraphs.

Validate Estimates of Performance Improvement. Each proposal should be reviewed to determine whether the estimate of performance improvement is realistic under the conditions specified. It is also important to establish the performance effects under conditions that vary from those specified. In many cases, this will involve examination of assumptions about the soldier's role in performance, whether it is in the operation of a weapon system or in the execution of military doctrine. For example, the introduction of the DRAGON antitank system presented a number of problems for the soldier that affected performance. These problems included the backblast and weight shift generated upon firing, the generation of smoke upon firing that interfered with tracking, and the bulkiness and poor design for carrying that degraded the mobility of soldiers employing it. The best proposals are those whose benefit is robust with respect to both operational and environmental conditions of the battlefield.

Assess Resources and Costs. Initial estimates must be made of the resources and costs associated with the improvement proposal. These estimates will include research, development, and acquisition (RDA) costs, if applicable, as well as O&S costs. It will include

resources such as manpower requirements (e.g., operators, maintainers, trainers), training requirements (e.g., training time, training facilities), support requirements (e.g., test equipment, consumables), etc.

Assess Risks. Each proposal must also be examined in terms of the types of risks it may be subject to. For a materiel improvement proposal, technological risks and risk related to the timing of implementation are key. For doctrinal and training proposals, risks may involve the ability to recruit the quality of soldiers necessary to implement the improvement. There also may be risks in estimates of the resources or costs associated with the implementation of the proposal. For example, proposals for the M1 tank indicated higher reliability of major subsystems on the tank. These levels of reliability were never fully achieved, resulting in higher requirements for maintenance personnel than originally estimated.

Identify Contingent Improvements. Many proposals cannot be implemented successfully without other proposals being implemented as well. For example, the implementation of doctrine for Low Intensity Conflict (LIC) requiring air transportability of units could not be achieved without organizational changes (e.g., development of the Light Infantry Divisions). Similarly, the full benefit of the MLRS system concept could not be achieved until additional ammunition resupply capability was added to the units employing the MLRS.

Assess Indirect Effects. Proposals to improve the performance of critical functions almost always require the sacrifice of performance of other functions. This is exemplified by the classic dilemma for tank designers among the mobility, firepower, and survivability of the tank. If the designer wants to increase mobility he has to increase the power to weight ratio, meaning that he has to give in on armor protection and/or on firepower, both of which could be used to save weight. Another example might involve doctrine for light infantry operations that requires soldiers to retain mobility by carefully managing their loads. However, if they must also maintain a capability to decisively engage enemy armor, which is getting increasingly hard to kill, the soldier must carry an increasingly heavy "man-portable" antiarmor weapon system. Thus, any attempt to address either the mobility or the antiarmor issue of light infantry is likely to exacerbate the other issue. The bottom line is that in order to gain in combat capability in one area, one must often give something up in another area. It is desirable that the combat value of the capability that is gained far exceed the combat value of the capability that is lost.

Phase 3 Summary. The product of this phase of the analysis is a series of capability improvement proposals. Each proposal is referenced to one or more issues and a variety of information is provided on each proposal as outlined above.

4.0 CONDUCT TRADEOFFS AND DEVELOP CAPABILITY IMPROVEMENT PLANS

The decision to implement a particular improvement depends of course on the value or combat worth of the proposal to the Army's ability to execute its assigned missions. However, in a resource constrained environment, the costs of implementing these solutions must be considered as well. Sound decisions concerning the implementation of various force modernization improvements depends on the consideration of both the benefits and costs of these alternative proposals. Figure 10 illustrates the steps involved in this phase of Army capabilities analysis.

4.1 CONDUCT TRADEOFF ANALYSES

The prioritization of alternatives is necessary because the cost of implementing all ideas for improvements far exceeds the available resources. Thus, the Army must choose to implement only a portion of the potential improvements identified. Clearly, it should choose those improvements most critical to the execution of the Army's assigned missions. Ideally, the Army could develop a single metric of combat worth of each proposal for improved doctrine, training, leadership, organizations, or materiel.

Combat worth is not the only criterion used to evaluate improvement proposals. There may be large differences in the resource requirements associated with improvements that have similar combat value to the Army. Therefore, the costs and resources associated with various improvement proposals must also be factored into the decision process. Again, in an ideal world, the Army would be able to develop a single measure of cost for each proposal for improving the Army's capabilities.

Given estimates of both the combat worth of an improvement proposal and its cost, the Army could calculate the ratio of combat worth to cost and select those proposals with the highest ratios until all of the Army's money was committed. However, as discussed in the following sections, the realities of the evaluation process are too complex for this simple model to work.

Combat Worth

The approach described above rests on two key assumptions with regard to combat worth, neither of which is fully met in the real world. The first assumption is that all improvement proposals can be reduced to a single, common metric of combat worth. The second assumption is that all proposals are independent of one another; that is, the value of each proposal is not affected by the acceptance or rejection of other proposals by the Army. In addition to these assumptions, the ability of analysts to assign a figure of merit to an improvement proposal is further complicated by (1) the timing of the improvements and (2) by risks associated with their implementation. Each of these factors that complicate the analysis process is discussed briefly in the following sections.

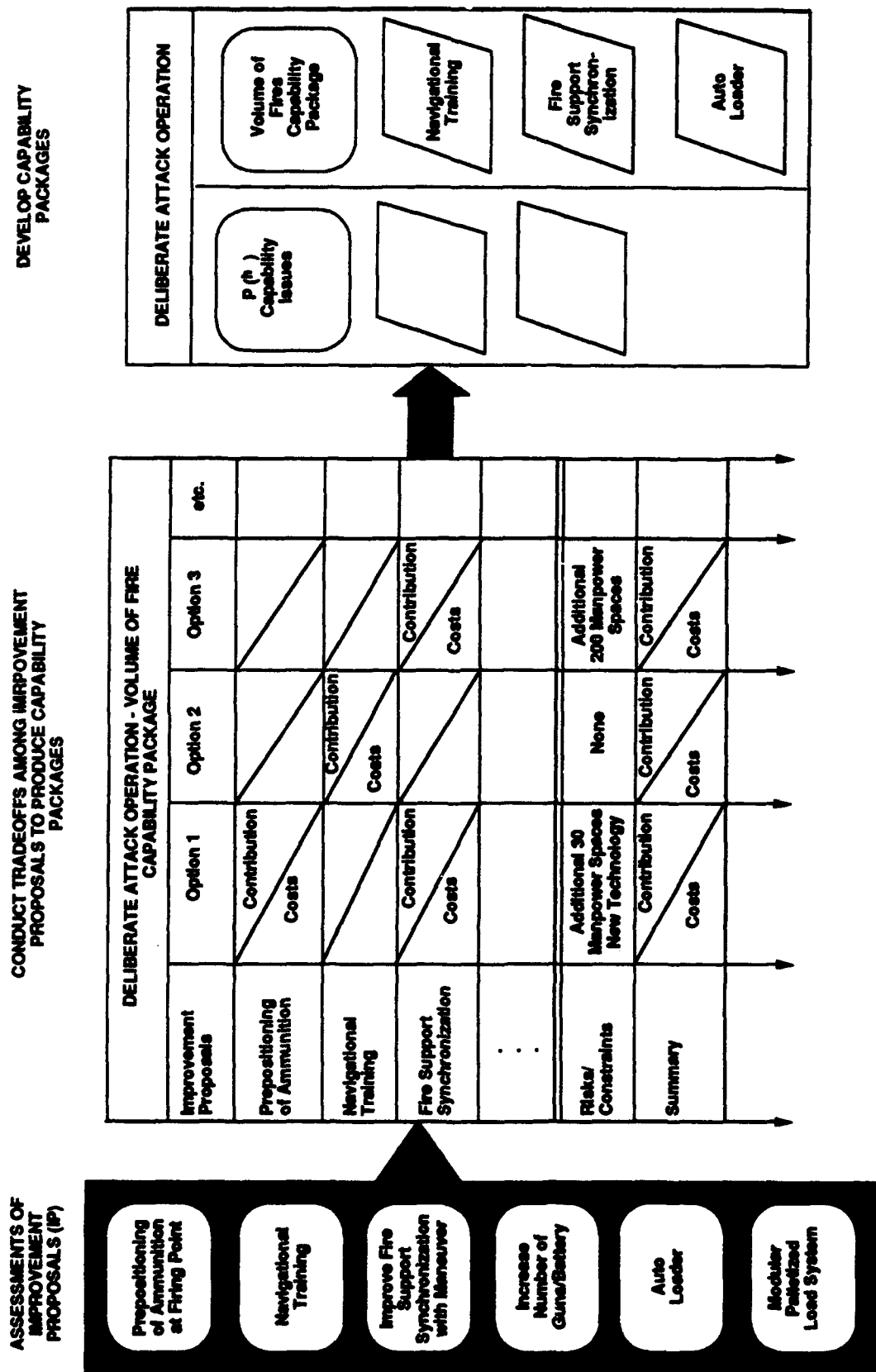


Figure 10. Example: Conduct Tradeoffs and Develop Plans (Part 1)

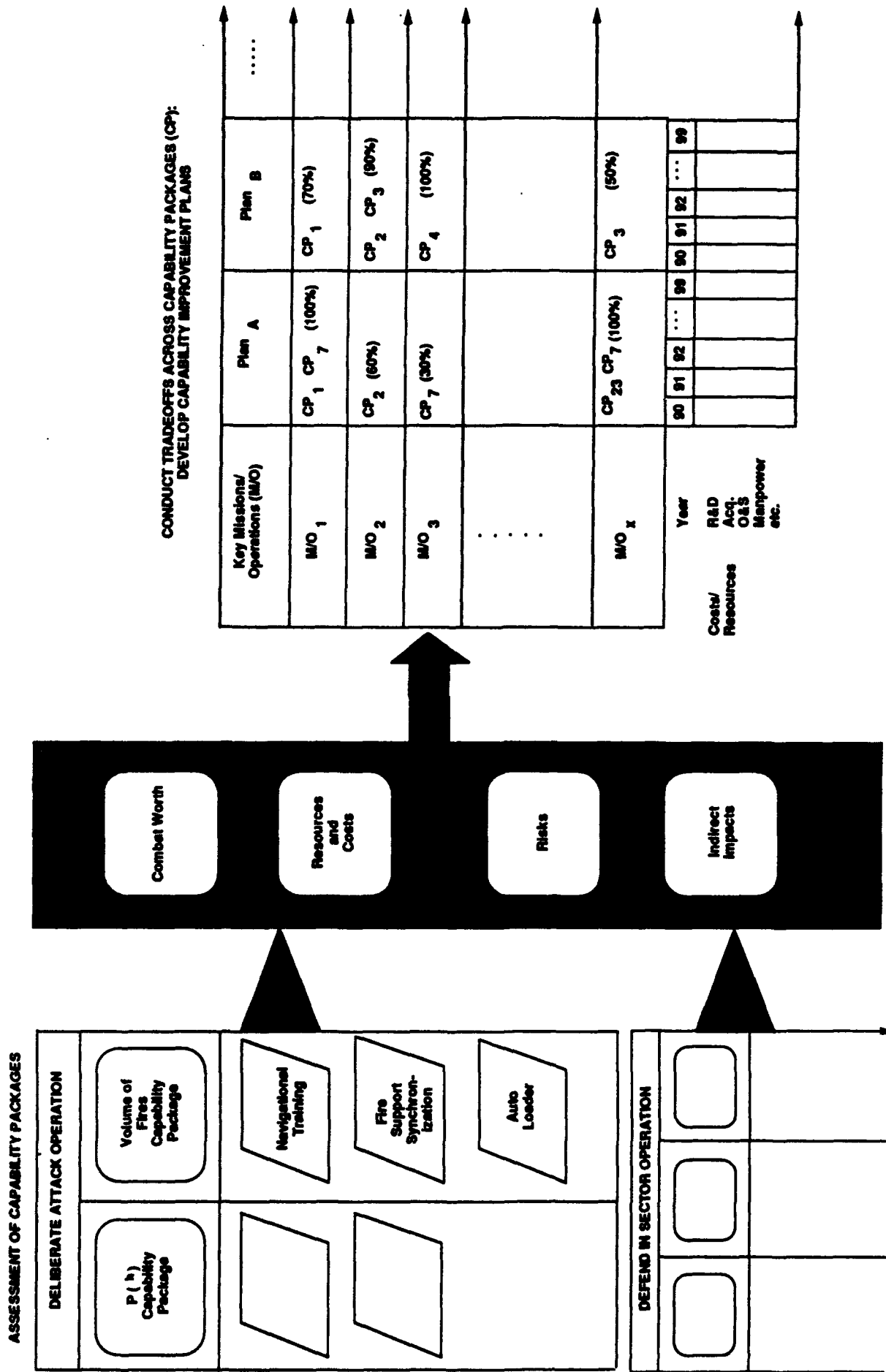


Figure 10. Example: Conduct Tradeoffs and Develop Plans (Part 2)

Single versus Multiple Measures. The notion of a single measure of combat worth is particularly appealing to those familiar with the analysis of financial investment alternatives which are often compared in terms of return on investment (ROI). However, the contribution value of a potential improvement to operational success has a number of aspects. For example, in a typical operation, various criteria of success could include whether the objective was achieved, the number of casualties incurred, the time required to accomplish the mission, the amount of ammunition expended, etc. The assessment of an improvement must take into account the impacts of the improvement on each aspect of mission success. One potential improvement may be extremely effective in providing the firepower necessary to accomplish the mission but do a poor job of protecting the crew, resulting in a high casualty rate. Thus, the combat worth of a potential improvement may have to be expressed in terms of multiple criteria.

Independence Among Proposals. This assumption concerns whether the combat worth of a potential improvement is dependent on the implementation of other improvements. Thus, the value of a new main battle tank with increased firepower may only be realized if the units with these tanks also get an improved ammunition resupply capability. Therefore, the full "combat worth" of the improved main battle tank may only be realized if another, separate improvement is implemented. In making an analogy to business, an investment in increased production capacity may only pay off if an increase in the investment in marketing is also made so that increased production capacity will not just be available, but required.

Timing of Proposals. The timing issue concerns the relative combat worth of two proposals, one of which can be implemented in the near term (less than two years) and the other in the mid (five to seven years) or long term. Clearly, it is better to be able to field an enhanced weapon system sooner rather than later. One might even be satisfied with a less improved system if it were ready to be fielded in a significantly shorter time than an alternative, albeit more capable alternative. Product Improvement Plans (PIPs) offer this type of approach. In comparing the effectiveness of financial investments, one would equate returns on investment from different time frames by establishing a discounted value of time and then applying the discount value to yield a net present value for yields from all investment alternatives. However, in the area of combat analysis, how would one establish a discount rate?

Risks Associated with Proposals. When a risk is identified in connection with the development of an improved capability, one has to discount the projected effectiveness of the proposal according to its degree of risk when making comparisons to improvement proposals that have less or no risk. In a financial investment example, high risk investments require a premium return for the investors to make them more attractive relative to investment alternatives with less risk. Thus, investors require higher potential performance from investments that carry higher risk.

Resource and Cost Impacts

The implementation of any force modernization proposal also imposes various incremental costs on the Army (it would be nice if some of these proposals actually required fewer resources or costs). Ideally, all costs could be expressed in terms of dollars and only a single measure would be required. However, this is not the case. There are R&D costs, acquisition costs, operations and support (O&S) costs, as well as a number of resource categories (e.g., qualitative and quantitative manpower requirements). Some of these resource categories are constrained, requiring that at the branch or total Army level, certain resource levels cannot be exceeded.

Analysis of resources and costs of various improvement proposals presents similar problems to that of the analysis of "combat worth". Multiple measures may be required, various cost and resource categories are not independent, the timing of expenses for different proposals is different, and a number of risks exist in the estimation of costs and resources. It is not unusual, for example, for real cost growth to occur between the time the decision is made on an improvement proposal (even when holding technical specifications constant) and when an improvement proposal is implemented. Different enhancement proposals are subject to different levels of risk of cost growth: emergent technologies almost always are more expensive to implement than estimates, even conservative ones, can anticipate.

Constructing Capability Packages

Once measures of combat worth and of resource and cost impacts are developed, the analyst must attempt to consolidate these measures for a single operation and set of conditions.

Constructing Capability Packages for a Single Operation. The goal of this step is to develop packages of solutions that meet the requirements implied by the capability issues generated during Phase 2. The requirement is not for an optimal solution but rather for one that "satisfies" the issues identified in Phase 2, thus enabling the Army to successfully execute its critical missions. As shown in Figure 10 (Part 1), an attempt is made to package various improvement proposals in a set that will comprehensively address the capability issues arising from concerns about the ability to successfully perform a critical military operation (i.e., deliberate attack in a European scenario).

Prior to this step, the focus of the analysis has been limited to the analysis and comparison between individual improvement proposals. In this step, sets of improvement proposals designed to address the issues related to the execution of a specific mission or operation are analyzed and compared in terms of the benefit-cost mix of each potential solution set to determine the most robust set of improvements. For example, Option 1 shown in Figure 10 (Part 1) includes a doctrinal improvement (prepositioning of ammunition) and a training improvement (improve fire support synchronization with maneuver), but does not include the materiel fix of an autoloader. Another option may include the autoloader and several other improvement proposals. These options are compared in this step in terms of the aggregate ratio of contribution to costs as well as in terms of risks and constraints associated with each set of improvement proposals.

4.2 PRIORITIZE IMPROVEMENT PROPOSALS/PACKAGES

The basis for comparing improvement proposals or packages of improvement proposals across operations is the ratio of the performance benefit of the improvement to the amount of resources required to support the improvement (adjusted to net present value and adjusted for risk). The performance benefit must be tied to the types of operational capabilities that will be enhanced and the criticality of these operational capabilities (i.e., the ability to conduct key military operations). In Phase 1 of the methodology, various operations were identified based on their criticality to the Army's role in supporting the national military strategy of the United States and on the perceived difficulty of successfully executing these operations. The goal in this step of the analysis is to identify that set of capability improvements, within existing resource constraints, that will bring the Army closest to achieving full mission capability for all assigned and potential missions.

For example, if the Army is examining mechanisms for supporting key operations in missions related to the defense of Western Europe, one capability enhancement being explored might be a target acquisition capability for deep targets. Suppose that a satellite enhancement is being compared to an unmanned aerial vehicle (UAV) for this task. Further suppose that they have about equal benefit/cost value. One would then want to examine other operations, some current (LIC operations in Central America), and some possible (drug interdiction) to determine the potential value for these operations as well. The capability enhancements that are most robust with respect to a variety of situations and conditions will be those that produce the greatest return on Army investment dollars.

The partial or full capability of improvement packages to support operations other than those they were specifically designed for may make a critical difference in assessing its overall combat worth. The generalizability of capability improvements is indicative of combat capabilities that are flexible and adaptable to a variety of contingencies, especially unexpected ones.

Constructing Capability Packages Across Operations. After constructing capability packages for individual operations thought to be at risk, tradeoffs must be conducted across these packages to determine the most effective and affordable set of capability packages to the Army. This must be accomplished as part of the process of developing integrated Capability Improvement Plans. This step is illustrated in Part 2 of Figure 10.

In this step, the importance of various missions or situations can be used to weight the values calculated for a potential improvement across situations. For example, an improvement proposal designed to enhance operations in a low intensity conflict or counterdrug mission might be valued higher than one designed to enhance operations in another scenario of lesser importance.

Some capability packages may be extremely cost-effective at addressing issues related to one operation but may make little contribution to the many other operations identified at risk during Phase 2 of the analysis. Other capability packages may only be moderately cost-effective at addressing the operations they were designed to enhance, but may make

significant contributions to many other operations as well. In these cases, the costs only have to be counted once while the benefits can be summed across the operations they contribute to. This is illustrated in Part 2 of Figure 10 where Capability Package #7 (CP7) makes a contribution to Mission/Operation #1, as well as to other missions or operations. The contributions can be summed across all capability packages included in a Capability Improvement Plan, but the costs and resources associated with the package are only counted once.

What may be a strong capability package from a single branch/proponent vantage point may contribute less to the total force (population of missions and operations) than the second best branch/proponent solution when all options are considered. In addition, a high performance payoff improvement may bring with it unacceptable resource burdens. Making the big picture decisions is a real challenge since analysts and leaders must have at least a working knowledge of the diverse situations across many capability/mission areas in order to make combat worth comparisons.

Thus, capability packages may be mutually supportive or mutually constraining. The challenge in this step is to be able to produce sets of capability packages that are relatively compatible with one another, and if possible, mutually reinforcing. Thus, each of several capability packages would successfully address a particular operation or mission without interfering with or degrading the ability of the Army to execute other operations.

It is one thing to have the necessary artillery, aviation, and other modernization plans. It is quite another to meld them together into an Army plan for the future which maximizes their contribution to the combined arms battlefield and stays within realistic budget and resource constraints.

Finally, in some instances a package may be proposed whose potential is so significant, such as the atomic bomb, that it may be worth pursuing regardless of technical risk involved, the time required for development, or even the costs and resources associated with it. However, one must be careful to carefully assign such status only to truly revolutionary improvements.

4.3 DEVELOP CAPABILITY IMPROVEMENT PLANS

Capability improvement plans document the capability investments planned for the Army on a time-phased schedule. In addition to tracking the investments in various programs over time, these plans track the return on investment in terms of "potential" battlefield performance.

The Army must develop plans that yield the highest return on investment dollars based on a net present value comparison, discounted for implementation schedule of the proposed enhancements and for the inherent risks of the planned enhancements.

Decision tables can then be constructed (see Figure 10, Part 2) that array various capability packages (including their performance benefits, resource and cost impacts, and risks or constraints) against the missions and operations (and their importance) they are designed to support.

These capability packages (CPs) can then be presented to decision makers along with the key elements of information they need to select and/or modify various packages to meet the overall cost and resource constraints of the Army while achieving the highest level of performance enhancement possible (weighted by the importance of various missions).

The overall plans must meet a large number of criteria: they must be effective; they must maintain an acceptable level of risk in both resources/costs and performance; they must produce a force with a robust capability that can be adapted to a wide variety of situations; they must provide the right balance between technology and human abilities so as to maintain a functional allocation among hardware, software, and soldiers that is practical and effective; and finally, they must be carefully balanced both horizontally and vertically across the Army.

Phase 4 Summary. The product of this phase is a plan, integrated across functions, operations, capability sources (i.e., doctrine, training, leadership, organization, and materiel), implementation time, branches and other proponents, and risks. This plan must also fit within various resource constraints, including constraints on manpower spaces, training resources, R&D costs, acquisition costs, and Operations and Support costs.

Summary

This section of the report detailed a concept for executing analyses of Army capabilities. The effectiveness of such analyses cannot be determined at the completion of a study nor when plans are devised and published. The plans that emerge from the analysis process can only be validated after they are implemented, and then, only when the Army's ability to execute its assigned missions is tested on the battlefield.

Use of Analysis Results in the Materiel Acquisition Process. If the analysis process is sound, then the information generated during the process must be maintained as requirements generated during the process are implemented. The next section of this report uses the Army's Materiel Acquisition Process as an example to show how analysis results, as distinguished from the decisions or plans, can be used in the development of materiel systems to ensure that fielded systems will, in fact, do what the analysis predicted. Thus, the development plans generated from Army analysis do not represent the end of a process; they represent the beginning of a process to actually produce an Army with a more effective and efficient warfighting capability.

LINKING CAPABILITIES ANALYSIS TO THE IMPLEMENTATION OF FORCE MODERNIZATION INITIATIVES

Capability improvement plans generated during capabilities analysis identify the key areas where the Army needs to improve to prepare itself for the future. These plans are mission oriented insofar as they link very specific improvement proposals (e.g., requirement for improved doctrinal guidance on the conduct of reconnaissance during offensive operations at the battalion level) to key missions and operations that may be at risk.

The specific improvement proposals that comprise the improvement plans are implemented by a variety of organizations throughout the Army. One way to categorize these improvements is in terms of their improvement domain; that is, doctrine, training, leadership, organization, or materiel. This categorization is important because different organizations implement different types of improvement proposals. For example, improvements to doctrine may be implemented by TRADOC proponent or branch schools, by the Command and General Staff College (CGSC), by the Army War College, or by Major Commands (MAJ-COMs). Alternatively, materiel improvements may be implemented by the Army Materiel Command (AMC) or its various Materiel Support Commands (MSCs) in conjunction with the combat developer from TRADOC.

When improvement proposals are sorted by implementing organizations, these organizations may become aware of interrelationships among the proposals that would have been difficult to identify during the capabilities analysis process.

For example, suppose that the Infantry Center and School had the responsibility for implementing (1) a requirement for light infantry to improve their training of load carrying by light infantry in order to improve mobility and (2) a requirement for improved training of light infantry in operating in a chemical environment. If no more training time or resources are allocated to light infantry, it may be difficult to fully implement both of these requirements. A second example might be (1) a materiel requirement for an M1A1 tank to be more easily transportable via C-17 aircraft and (2) a materiel requirement for the M1A1 tank to have an enhanced main gun. The ability to achieve one requirement may interfere with the achievement of the other. Similar conflicts may occur across domains as well. For example, the development of a more lethal "man-portable" antitank weapon system may be in conflict with a training initiative to enhance the mobility of light infantry.

As a result of conflicting requirements, the organizations responsible for implementing plans developed during capabilities analysis have a tremendous challenge in integrating all improvements in systems and units. This integration is further complicated by the interrelationships among the five capabilities domains. Thus, at the level of capability plans there may be a relationship between a doctrinal (e.g., attack enemy tanks from the top or the side) and materiel improvements (e.g., improved main gun). Further, implementing an improvement in one domain may affect the other domains. For example, the introduction of a new main gun on a tank will undoubtedly affect doctrinal procedures for its employment as well as training of gunnery tasks. These secondary impacts are considered as part of

the primary improvement (e.g., improved main gun) and not as a separate improvement. These secondary improvements are not expected to yield performance improvements on their own; only to support the primary improvements.

In order to examine the implementation of capability improvements in more detail, the remainder of this section focuses on a single domain; materiel improvements. However, a detailed examination of how materiel improvement plans are integrated and implemented should have some parallels with the other domains. Thus, even if the reader's primary interest is in the domain of training, the following section should be relevant to the task of integrating a number of different, but interrelated improvements in that domain.

Linking Capability Improvement Plans to the Weapon System Acquisition Process

In order to describe the implementation of capability improvement plans in more detail, we have decided to focus on the process of implementing capability improvements in the materiel domain. For materiel improvements, integration must first be accomplished at the weapon system level. This process is shown in Figure 11.

The remainder of this section has four objectives. First, it describes how performance requirements for individual weapon systems can be derived from the inputs provided from the capabilities analysis process described in this report. Second, it describes the role of MAN-PRINT issues in the weapon system requirements development process. Third, it describes how emerging tools developed by the Army Research Institute could be used to aid this process. Fourth, it identifies new tools and techniques (e.g., automated data bases) which could be developed to further improve the weapon system requirements development process.

We recommend that performance requirements for individual weapon systems be developed in three phases. In the first phase, the capability improvement plans developed in the capabilities analysis process would be reviewed to identify all plans impacting a particular type of system. In the second phase, the system's objectives and the constraints under which it must be operated and maintained would be documented in an Organizational and Operational (O&O) plan. In the third phase, the detailed functional requirements for the system would be developed. In the subsections which follow a more detailed description of each of these three phases is presented.

Construct of System Capability Packages

During execution of capabilities analysis, improvement plans are developed for improving key battlefield functions. These plans describe the mechanisms (i.e., doctrine, training, organization, leader development, and materiel) by which the Army intends to improve the execution of key missions and operations through the enhancement of selected critical functions. In this phase, these plans would be reviewed to identify all issues in these plans impacting a particular system type (e.g., tank). This review would be conducted by the proponents for that particular system type. In conducting this review, five different types of information should be considered (see Figure 12).

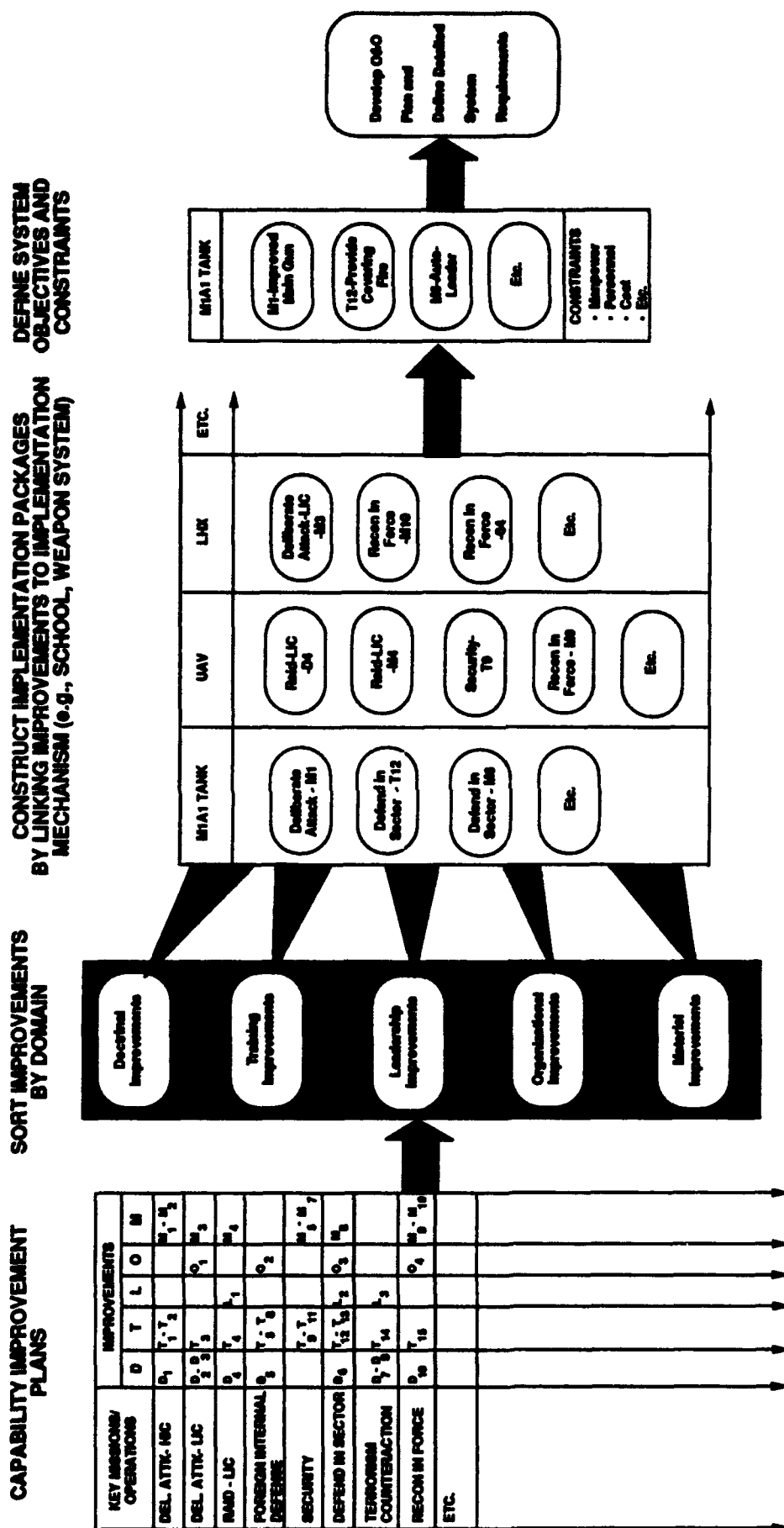


Figure 11. Example: Linkage Between Capability Improvement Plans and Implementation

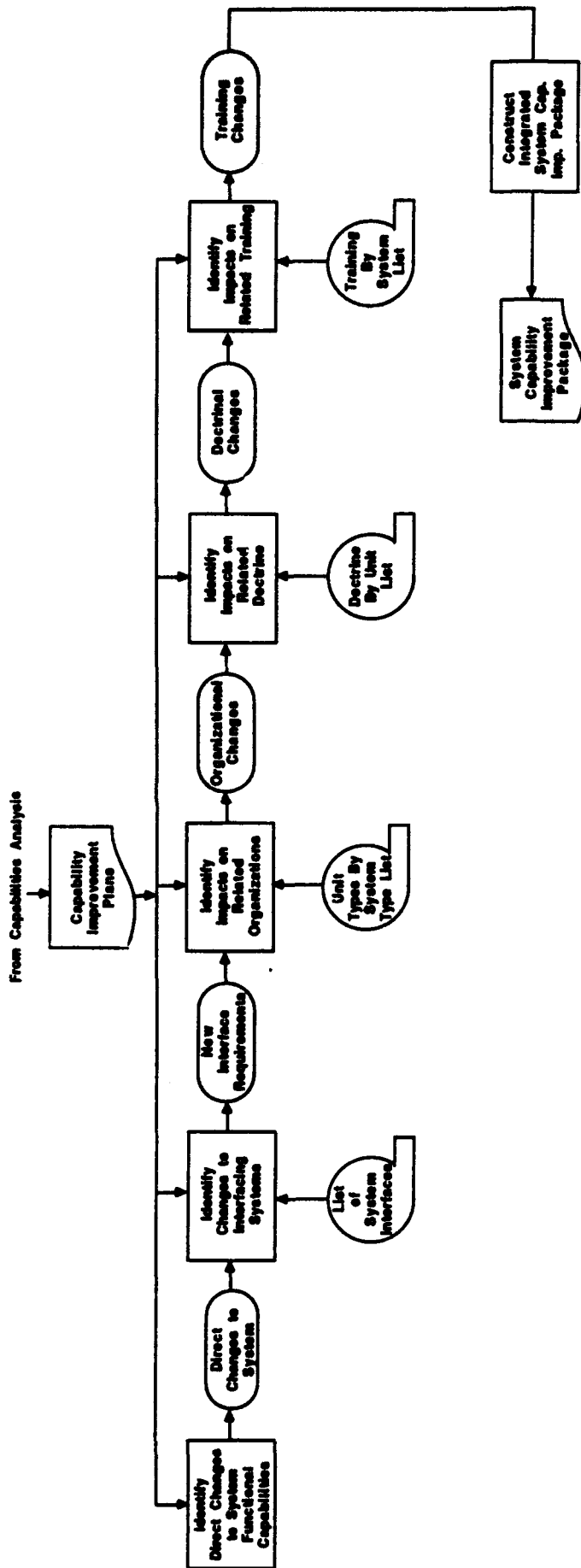


Figure 12. Construction of System Capability Improvement Package

First, individual capability plans may directly recommend functional improvements to a particular type of system. (e.g., increase the range of the tank by 500 meters).

Second, the capability plans may recommend changes to systems with which that particular type of system interfaces. These changes may, in turn, necessitate changes in the system of interest. There are three different types of interfaces with other systems:

- **Physical Interfaces**—such as the interfaces between a tank and its ammunition resupply vehicle.
- **Informational Interfaces**—such as the data links between a tank's FM radio and a satellite communication system. Here the primary focus is on what information is transmitted rather than on how it is transmitted.
- **Functional Interfaces.** This refers to the fact that a system is designed to be operated in integrated fashion with other types of systems on the battlefield. Thus, changes in the functional capabilities in these other systems may require a change in the way a particular system is designed or used. For example, increasing the speed of a personnel carrier used in mechanized infantry units may necessitate changes in the other vehicles which are part of that unit.

To facilitate the identification of system interfaces, a series of automated data bases could be developed. These data bases would describe the physical, informational, and functional interfaces between major system types. A user could query these data bases to identify what systems he/she should be concerned with when reviewing system capability plans.

In the third part of the capability plan review, the user would identify organizational changes to the units which are expected to get a new system. This could be facilitated by accessing an automated data base which lists units by system type.

In the fourth part of the capability review, the user would identify any changes to the doctrine associated with the units which use that type of system. This identification process could be facilitated by developing an automated data base which lists the doctrinal documents describing the employment of different systems.

In the final part of the system capability review, users would identify any changes to the training associated with the new system. The review should encompass both institutional and unit training. This identification process could be facilitated developing an automated data base which lists the institutional training courses and unit training elements associated with particular system types. Figure 13 depicts the data relationships that would underlie the data bases described above.

Define System Objectives and Constraints

The output of this phase is an O&O plan. The O&O plan lists the rationale for building the system and describes, in general terms, how it will be used and the constraints under which it must be operated and maintained. Appendix E provides a description of the current

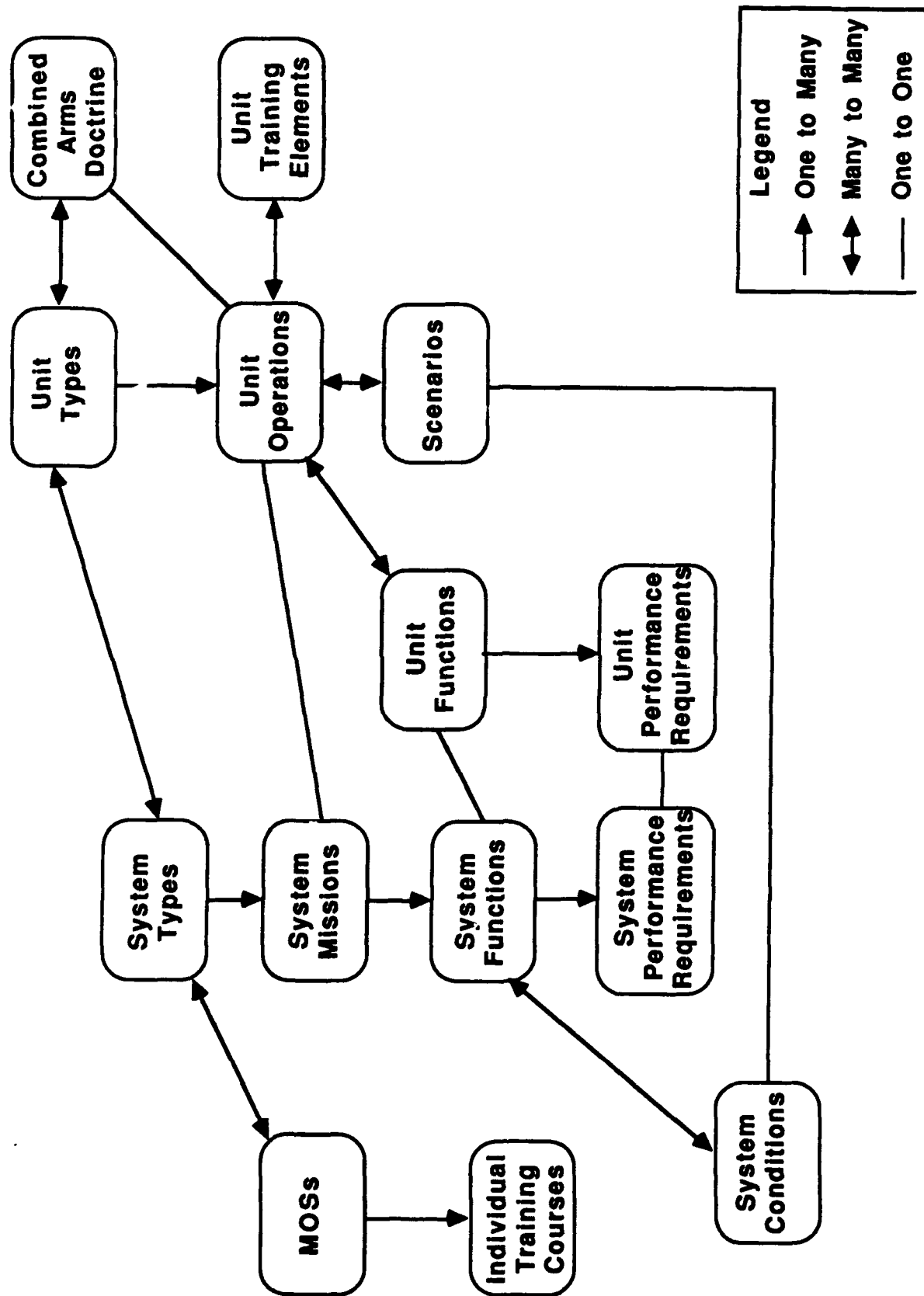


Figure 13. Overview of Potential Data Relationships

format of the O&O plan along with formats for other key requirements documents. Table 2 summarizes the format for the O&O plan. The procedures we propose maintain this general format; however, some additional detail is provided on the content of the MAN-PRINT-related portions of this plan as well as on how capability analysis products can be used during O&O Plan development. More details on an approach for developing each portion of the O&O plan are presented below:

1. Title. We propose no changes to this section.

2. Need. The needs for a particular acquisition program should be documented by referencing the appropriate sections of the capability improvement plans identified in the previous phase. These needs should be stated in the same "functionally" oriented terminology that characterized the capability improvement plans. Note that the "need" statements in this section are very brief. More detailed descriptions are provided in Section 4 (Operational Characteristics) of the O&O Plan.

3. Threat. References and extracts should be made to the same scenarios used during the capabilities analysis process.

4. Operational Characteristics. Each operational characteristic description should consist of four components--function, performance measures, desired bands of performance, and reference to the appropriate capability plan that generated the need for the required operational characteristic. The function should be taken directly from the BOB subfunctions or generic tasks (higher level BOB functions are not as relevant to individual systems). Whenever possible, quantitative performance measures should be used (i.e., measures which use a continuous scale). Also when constructing performance requirements, it is desirable to identify both time and accuracy measures. This is because for many functions there is an inherent tradeoff between time and accuracy. With more time, a greater degree of accuracy can be achieved. Thus, simply stating a time or accuracy requirement alone will not have the same effect.

Bands Of Performance. According to AR 71-9, performance requirements should be stated in "bands of performance." These bands consist of a cost ceiling and performance floor that describes a performance characteristic of a system. The cost ceiling is the most cost and operationally effective capability that the materiel developer can achieve without going over the highest acceptable cost. The performance floor is the least operational capability that the user will accept.

As part of the operational characteristic description, the conditions under which each functional performance level must be achieved should be specified. At the beginning of this section, it should be stated that, "unless otherwise specified, it is assumed that each performance requirement must be achieved under the full range of conditions specified in the System Operational, Maintenance, or Support Scenarios which should have been developed as part of the Operational Mode Summary/Mission Profile (see Section 10 of O&O plan below).

Table 2. Outline of O&O Plan

<u>Original Section</u>	<u>Proposed Changes</u>
1. Title	No Change
2. Need	Refer to Functional Capability Plans
3. Threat	Refer to Capabilities Analysis Scenarios
4. Operational Characteristics	Refer to/Refine Capabilities Analysis Improvement Statements
5. Operational Plan	No Change
6. Organizational Plan	Refer to Capabilities Analysis Units
7. System Constraints	Include a MANPRINT Section With the Following Subsection - Manpower Constraints - Personnel Constraints - Training Constraints
8. Standardization and Interoperability	No Change
9. Funding Implications	Life Cycle Cost Should Include Personnel Costs
10. Annex A- Operational Mode Summary/Mission Profile	Refer to Capabilities Analysis Operations, Functions, and Scenario Conditions

In many cases, desired performance levels cannot be achieved under all conditions. In these situations, separate performance requirements should be specified for each value or range of the condition(s) which significantly degrades performance. The development of condition degradation factors is discussed later in this section.

Table 3 provides some examples of operational characteristic descriptions that incorporate the above guidance. More detailed guidance on the development of performance requirement descriptions is provided in the section on detailed functional performance requirements.

Many operational characteristic statements can be obtained directly from capability improvement plans generated during the capabilities analysis process. Others, such as those which are generated as a result of changes in interface requirements, doctrine, organizational structure, etc., will require the generation of new statements.

It is important to emphasize that only requirements which can be directly linked to capability improvement plans are considered acceptable. In particular, a requirement should not be generated simply because a technology has been developed which can improve a particular function's performance if there is no rationale for obtaining such improvement in the capability plan.

5. Operational Plan. This section provides a high level textual description of how, what, when, and where the system will be employed on the battlefield and how the system will interface with other systems. A more detailed description of the operational uses of the system is provided in the Operational Mode Summary/Mission Profile. We propose no changes to the Operational Plan but do suggest some changes to the OMS/MP.

6. Organizational Plan. This section describes the type units that will employ and support the system and, when appropriate, the system(s) to be replaced. This information should be readily obtainable from the system capability package described above. It should be noted that the M-CON Aid developed by ARI will directly assist Army analysts in producing these products.

7. System Constraints. This section describes "constraints that may limit an acceptable solution to the need such as mobility, transportability, logistics, MANPRINT, environmental communications, directed energy survivability". This definition of constraints confuses functional requirements, and conditions with "true" constraints. Constraints should only attempt to describe other elements of the force which should be considered "fixed" during the new system's development and employment. Environmental conditions should be described in the conditions description which is part of the OMS/MP (see Section 10). Functional requirements such as mobility should be included in the operational characteristics section (see Section 4). MANPRINT constraints should be included in this section. More specifically, the MANPRINT subsection of the Constraints section should describe:

- manpower constraints--the maximum number of people who will be available in the force to man the new system.

Table 3. Example of Operational Characteristics

FUNCTION	SUBFUNCTION	PERFORMANCE REQUIREMENTS			RELEVANT CONDITIONS	ARMY MODERNIZATION MEMORANDUM	PAGE #
		MEASURE	FLOOR	CEILING			
NAVIGATE	DETERMINE (OWN) LOCATION	DISTANCE FROM TRUE LOCATION (IN METERS)	10	15	FULL RANGE LISTED IN SCENARIOS	SEPTEMBER, 1989	24
		TIME TO LOCATE (IN SECONDS)	10	15	NVFR CONDITIONS	SEPTEMBER, 1989	24
		TIME TO LOCATE (IN SECONDS)	15	15	NIFR CONDITIONS	SEPTEMBER, 1989	24
ACQUIRE TARGET	DETECT TARGET	PROBABILITY OF DETECTING TARGET WITHIN FIELD OF VIEW (IN SECONDS)	50%	70%	NVFR CONDITIONS	SEPTEMBER, 1989	27
			40%	60%	NVFR CONDITIONS	SEPTEMBER, 1989	27
		TIME TO DETECT TARGET WITHIN FIELD OF VIEW (IN SECONDS)	10	8	FULL RANGE LISTED IN SCENARIOS	SEPTEMBER, 1989	27
ACQUIRE TARGET	IDENTIFY TARGET	PROBABILITY OF CORRECT IFF	80%	90%	FULL RANGE LISTED IN SCENARIOS	SEPTEMBER, 1989	28
		TIME TO IFF A TARGET (IN SECONDS)	10	5	FULL RANGE LISTED IN SCENARIOS	SEPTEMBER, 1989	28
TRANSPORTABILITY	LOAD SYSTEM ON AIR TRANSPORT	FIT WITHIN C-17	—	—	FULL RANGE LISTED IN SCENARIOS	SEPTEMBER, 1989	64
		TIME TO LOAD (IN MINUTE)	10	20		SEPTEMBER, 1989	64

- **personnel constraints**—the type of people who will be available to man the new system.
- **training constraints**—the amount and type of training that will be available for the new system.

Manpower Constraints. The end strength of the Army is fixed by law. Consequently, new systems must be designed to be operated and maintained within fixed manpower constraints. It is important to understand the difference between manpower requirements and constraints. Manpower requirements tell you how many people will be required to man a new system. Manpower constraints describe how many people will be available to man a new system. These two types of manpower estimates may not be equal to one another. For example, a new system may require 2000 people but there may only be 100 available to man it.

This section should describe the quantitative manpower constraints for both operators and maintainers of the new system. Constraints should be identified at both the total force and single system level. The source MOSs from which the operators and maintainers of the new system will be drawn and the expected total available from each of these MOSs should also be identified.

The M-CON aid developed by ARI will determine these constraints. To set a manpower constraint, one can use the manpower actually required to operate and maintain the system to be replaced. However, the personnel actually authorized for a system may be different than the number required. In addition, because of the structure of the Army personnel system, the number of personnel who actually end up working on a system in a particular unit may be different than the number authorized. In addition, the actual number of soldiers in a particular MOS will vary over time depending on the type of people entering the Army and a particular MOS's share of those different types. The M-CON Aid permits the user to adjust the pool of available manpower requirements for each of these factors (authorizations, actual personnel strength, and projected personnel strength). It also permits users to make adjustments for the differences between total manpower requirements based on Manpower Requirements Criteria (MARC) guidance and actual unit authorizations.

The manpower constraints developed in support of the O&O plan will support the development of the Manpower Billpayer Plan which may be required at later phases of the acquisition process. Per DoD Directive 5000.53, a Manpower Estimation Report (MER) is required for all major systems. The MER documents projected manpower requirements. It estimates the total number of personnel (military, civilian, and contractor) required to operate, maintain, support, and train for a Major Defense Acquisition Program (MDAP) upon full operational deployment. This same directive requires that a Manpower Billpayer Plan (MBP) be constructed if the new system's manpower requirements will increase total end strength. The MBP requires the Army to identify from what sources the excess manpower will be drawn (given a fixed end strength, one can only increase the manpower assigned to a

particular type of system by taking slots from another manpower pool). From our perspective, an estimate of manpower constraints must be made in order to determine if there is a need for a MBP.

Personnel Constraints. The objective of personnel constraints is to provide materiel developers with information on the types of personnel who will be available to operate, maintain, and support a new system. Two types of information on personnel characteristics are provided: (1) target audience descriptions which describe the expected distribution of the personnel who will man the new system in terms of relevant personnel characteristics, and (2) quantitative personnel constraints which describe minimally acceptable boundaries for key characteristics (i.e., materiel developers must design systems which can be operated, maintained, or supported by personnel within these boundaries).

Key personnel characteristics are those characteristics which the Army uses to control entry into the Army or a particular MOS. Key characteristics include the following:

- Physical Characteristics
 - Sex
 - Anthropometric Characteristics
 - Strength
 - Sensory Acuity (visual acuity, color blindness, auditory acuity)
- Cognitive Characteristics
 - AFQT score
 - ASVAB composite score

Actually, the list above may be expanded to include any other personnel characteristic which the Army uses to control entry into the Army or MOS.

Figure 14 depicts the causal role of both types of constraint information in impacting human task performance. The Army sets cutoffs on certain critical personnel characteristics to control entry into the Army or particular MOSs. Setting such cutoffs will impact the distribution of personnel on these key characteristics both in terms of entry characteristics and distributions of these characteristics at higher paygrades. However, the cut-offs are not the only factors determining these distributions. These distributions are also impacted by the distribution of the key characteristics in the general population, the propensity to enlist of the different subpopulations at various characteristic levels, and the rates (e.g., reenlistment rates) with which these subpopulations transition through the Army personnel system.

Setting cutoffs on key characteristics will also affect the distributions of other characteristics with which it is correlated. Task performance (i.e., probability of successful task performance or mean task performance) is a function of the distribution of both sets of characteristics (key characteristics and others) along with other variables such as task type, amount and type of training, motivational factors, equipment design, etc. When setting a cutoff, one should look at mean performance of the entire population at or above the cutoff, not

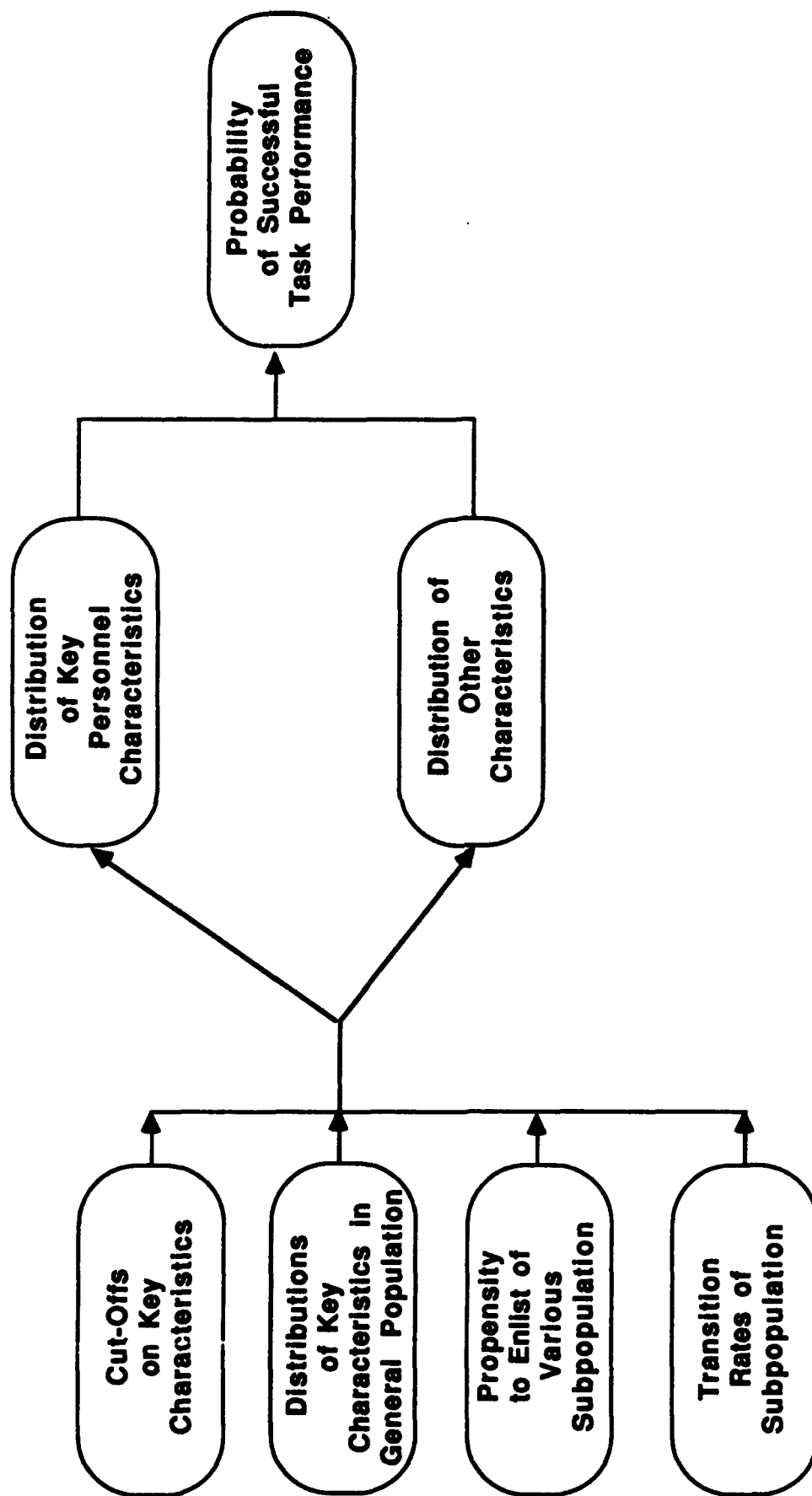


Figure 14. Relationships Between Personnel Characteristics Cut-Offs and Performance

at mean performance of the subpopulation at the cutoff. Setting a cutoff based on the latter will result in a much more stringent cutoff. Also, this approach ignores the fact that when a cutoff is set, most of the resulting population will have scores above that cutoff.

In identifying a quantitative cutoff for a personnel characteristic, two factors must be considered--the numbers of people who will be available to man the system at different levels of the personnel characteristics and the expected levels of performance associated with personnel at those levels. There is a direct tradeoff between these two factors. For example, setting a ASVAB cutoff too high will decrease availability but increase the probability of successful performance. On the other hand, setting a cutoff too low will increase availability but decrease the probability of successful performance. As part of the HARDMAN III effort, ARI is developing an aid called P-CON which will assist Army analysts in (a) estimating the future distribution of key personnel characteristics within MOSs/paygrades, (b) estimating expected levels of performance at various characteristics levels for different types of tasks or sets of existing tasks for similar systems, and (c) using the above information to examine the impact of different cutoffs on personnel availability and performance.

One problem with setting constraints on the personnel characteristics described above is that values on several of these characteristics (in particular AFQT and ASVAB composite) are not directly meaningful to system designers. Consequently, additional information is needed to make these values meaningful. In P-CON, this is established by showing designers how changes in personnel characteristics can be expected to change performance on tasks with which they are familiar. Future research could even further improve the information provided to designers by describing to them what user interfaces are acceptable for a given subpopulations (as defined by scores on the various personnel characteristics). For example, empirical research could be conducted to identify what type of human computer dialogue method is most effective for different ASVAB composite levels or what type of maintenance tools are effective for these levels. At an even more sophisticated level, research could be conducted to identify the total scope of tasks that could be accomplished by a particular ASVAB level. For example, if predictions of time to train could be made as a function of task difficulty and ASVAB level and the time to train of all existing tasks were known and a total training time constraint was set, one could tell designers what combinations of task level difficulty could be accommodated within existing training time constraints.

In addition to assisting users in identifying quantitative personnel constraints, P-CON automates much of the TAD generation process. Also, unlike current TAD generation techniques, P-CON estimates what type of personnel will be available to man the system in the future--the time when the system will actually be fielded. Table 4 provides an overview of the information currently provided in TRADOC target audience descriptions and indicates which of this information is provided by P-CON. An example of a completed TAD is included in Appendix E.

Table 4. Outline of TAD

Section A: Statistics

1. Manpower Status (MOS)
2. Manpower Availability Projections
3. Aptitude
 - a. Mental Category Distribution
 - b. ASVAB Aptitude Area Composite Distribution
 - c. Reading Grade Level Distribution
 - d. Civilian Education
4. Biographical Information
 - a. Gender Mix**
 - b. Ethnic Background

Section B: Description Information

1. Standards of Grade Authorization
2. MOS/Civilian Designation and Description
3. Anthropometric Data**
 - Common Working Positions
 - Static Muscle Strength
4. Physical Qualifications
 - PULHES
 - METSCAP
 - Vision Requirements**
5. Skills and Knowledge Trained
 - a. Institutional Training
 - b. Unit Training

** Denotes physical characteristic that must be considered as part of human engineering process

Since separate TADs must be developed for each source MOS, we recommend that only summary information be included in the constraints section of the O&O plan along with references to the complete set of TADs.

Training Constraints. Training constraints should describe: (a) the maximum amount of individual institutional training time available to train the new system (by course), (b) the maximum frequency of individual unit training, (c) any existing training media that must be incorporated into the new system's training program or operational design, (d) any other training resource constraints, and (e) training cost constraints. Table 5 provides an example of the MANPRINT constraints subsection of the O&O plan.

8. Standardization and Interoperability. We propose no changes to this section.

9. Funding Implications. As part of the life cycle cost assessment personnel and training operating costs should be considered. The AMCOS model developed by ARI should be used to estimate these costs.

10. Annex A - Operational Mode Summary/Mission Profile(OMS/MP). The OMS/MP provides more detailed information on how the system will be used. Annex A to the O&O plan has three parts--the OP Mode Summary, the Mission Profile, and the Conditions Description.

The OP Mode summary lists the specific "missions" that the system will perform and the expected frequency of those missions. Table 6 provides an example of an OP Mode Summary taken from TRADOC/AMC Pam 70-11. The careful reader will note that the "missions" listed in Table 6 are actually "operations" in the capabilities analysis conceptual system. This apparent discrepancy can be explained by the fact many systems are involved in conducting combined arms operations and that each system is performing activities (i.e., missions) in support of those operations. Even though two different types of systems may be involved in the same operation, the functions they would perform during this operation would be quite different. Listing the operations in which a system is involved (i.e., system missions), helps to link the system to the "big picture." Separate OP Mode Summaries are to be provided for "peacetime". Table 7 provides an example of "peacetime" missions from TRADOC/AMC Pam 70-11. As Table 7 indicates, these "peacetime" missions are actually training missions (vice missions that are on the low end of the conflict dimension such as low intensity conflict or drug interdiction).

To make the OP Mode Summary consistent with the capabilities analysis process, the missions in the wartime summary should either be stated in terms of: (a) the unit operations used during the capabilities analysis process or (b) Blueprint of the Battlefield functions. Most major combat arms weapon systems will use the former while most small or support systems will use the latter.

Table 5. Example of MANPRINT Constraints Subsection of O&O Plan

MANPRINT CONSTRAINTS

A MANPRINT program will be applied to the system in accordance with AR 602-2. In addition, the system will be designed to be operated, maintained, and supported within the following constraints.

Human Factors Engineering. The system will be designed so that all tasks can successfully performed by soldiers having physical characteristics in the 5th through 95 percentiles of the expected MOS population as described in Target Audience Descriptions. The system shall be designed to ensure effective performance under all environmental conditions while wearing combat and protective gear. All organizational maintenance tasks involving MOSs in CMF XX must be performed with Standard Tool Set X, Y, Z.

Manpower and Personnel. The maximum crew size for the system will be 2. The system will require no new operator or maintainer MOSs. Total operator and maintainer manpower requirements for the system will not exceed the totals listed in Table 1. Changes in source MOSs will be documented and coordinated with the proponent of that MOS. Total manpower requirements for critical MOSs (indicated by asterisk in Table 1) will not exceed the values listed in Table 1. The grade level distribution requirements for each MOS will be in accordance with the standards of grade of authorization listed in the Target Audience Descriptions. No organizational maintenance task will require more than one person. The system will be designed so that successful performance is achieved by soldiers with the expected distributions of ASVAB composite scores listed in the Target Audience Descriptions. More specifically, unless otherwise specified, it will be demonstrated that soldiers at the mean of these distributions can successfully perform critical tasks.

Training. All critical tasks will be taught in the institution. The length of institutional training for each MOS will not exceed the limits specified in Table X. Sustainment training on system-specific individual skills shall not exceed 80 hours per quarter for each MOS. Unit training will be designed to permit a 30% reduction in POL costs and a 50% reduction in ammunition costs. The system must be capable of providing embedded training to operators in gunnery and navigation.

Safety and Health Hazards¹. System must remove or design out the following hazardous conditions: (List those identified in predecessor system). Residual hazards or conditions will be reduced, or adverse effects minimized to levels acceptable by the government. For example, blast overpressure will not exceed _____; toxicity level will not exceed _____. This will be done by the development of safety-specific design features, devices, procedures, training or personnel protective equipment.

¹This section taken from the MANPRINT course.

Wartime OMS for the XYL Systems

Mission	(a) 01	(b) 01 + A1	(c) C1	(d) Number of Missions	(a) x (d) = (e) Total 01	(b) x (d) = (f) Total 01 + A1	(c) x (d) = (g) Total C1
1. Covering Force	16 Hrs	16 Hrs	18 Hrs	5	80 Hrs	80 Hrs	90 Hrs
2. Forward Line of Troops (FLOT) Defense	68	72	72	30	2040	2160	2160
3. Deep Strike	16	20	20	7	112	140	140
4. Rear Battle	48	70	70	30	1440	2100	2100
5. Counter Attack	25	30	30	5	125	150	150
6. Raid	2	2	2	1	2	2	2
7. Unengaged Tactical Movement	5	10	10	7	35	70	70
8. Reserve	5	5	60	15	75	75	900
Total Scenario	xx	xx	xx	100	3909	4777	5612

MP for the XY2 System FLOT Defense Mission

FLOT Defense Mission Tasks	Number of Occurrences	* Operating Time for Each Task	Total Operating Time
Search & Surveillance	102	30 Min	51 Hrs
Target Acquisition	46	15 Min	11.5 Hrs
Track	18	5 Min	1.5 Hr
Fire (Air)	9	2 Min	.3 Hr
Fire (Ground)	28	8 Min	3.7 Hr
Total**	xx	xx	68 Hrs

* If the System Life units are something other than time, the life units should be converted to time or means of conversions to time indicated.

** For this mission, all time that the system is not operating is required as standby time.

Peacetime OMS for the XY2 System

Mission	(a) 01	(b) 01 + A1	(c) C1	(d) Number of Missions	(a) x (d) = (e) Total 01	(b) x (d) = (f) Total 01 + A1	(c) x (d) = (g) Total C1
1. ARTEP	9.05 Hrs	11 Hrs	11 Hrs	3	27 Hrs	33 Hrs	33 Hrs
2. Division Level Readiness Exercise	2.0	5	6	7	14	35	42
3. Battalion Level Readiness Exercise	1.0	4	4	6	6	24	24
4. Platoon/Bat- tery Level Readiness Exercise	.4	1	1	39	16	39	39
5. FID Training Exercise Spt	1.4	4	4	37	52	148	148
6. ARTEP Support	9.05	11	11	6	54	66	66
7. Local Training Area	15	32	72	2	30	64	144
Total Scenario	xx	xx	xx	100	199	409	496

MP for the XY2 System ARTEP Mission

ARTEP Mission Tasks	Number of Occurrences	Operating Time for Each Task	Total Operating Time
Search & Surveillance	18	20 Min	6.00 Hrs
Target Acquisition	9	15 Min	2.25 Hrs
Track	4	5 Min	.33 Hr
Fire (Air)	2	2 Min	.07 Hr
Fire (Ground)	3	8 Min	.40 Hr
Total	xx	xx	9.05 Hrs

The mission profile is "a time-phased description of the operational events (tasks) and environments an item experiences from beginning to end of a specific mission" (TRADOC/AMC Pam 70-11). Tables 6 and 7 provide an example of an extract of an MP from TRADOC/AMC Pam 70-11). The "tasks" in the wartime missions should be taken directly from the Blueprint of the Battlefield functions.

According to TRADOC/AMC Pam 70-11, the Conditions description should describe the environmental conditions in which the system will operate in both the peacetime and wartime mission profiles. This Pam also recommends that the percentage of time that each value for the condition will be encountered be described (see Table 8). We recommend that the same basic format be employed; however, we recommend that the full range of conditions listed in the conditions taxonomy found in Appendix D be examined and key condition variables from this taxonomy be selected and described in format similar to that listed in Table 8. In identifying the key conditions, an attempt should be made to identify the condition variables which are most relevant to the functions requiring improvement including condition variables which are known to have a significant impact on human performance. A more complete set of system conditions is developed in the third phase of the system requirements development process.

Develop Detailed Functional Requirements

This section describes our proposed approach for developing detailed functional requirements. It is our view that a "good" set of functional requirements will have four characteristics. First, they must directly link the functional requirements to the critical missions/operations identified during the capabilities analysis process described in earlier chapters. Second, it must contain a comprehensive listing of all system performance requirements, not just the ones targeted for improvement. Third, it must contain an audit trail describing the source of each requirement. Fourth, it must state requirements in a standardized, unambiguous fashion.

Users of Performance Requirements Information. There are two major users of performance requirements information; Army analysts who use it to describe the characteristics of systems to be designed and contractors who use it to guide their system development.

Overview of Approach. Detailed functional requirements should be developed in a two step process. First, the detailed functional requirements are developed. Secondly, key features of the detailed functional requirements are summarized in the statement of Required Operational Capability (ROC). The ROC is designed to describe essential operational features of new systems for Army decision makers. Per AR 71-9, Materiel Objectives and Requirements, the ROC should not exceed six pages in length. The format for the ROC is presented in Appendix E.

Table 8. Example Conditions Description

CLIMATIC DESIGN TYPES (AR 70-38)	% FLEET
Hot	20
Basic	60
Cold	15
Severe	5

MOVEMENT TERRAIN
10% Primary Road
35% Secondary Road
55% Cross-Country

Components of Detailed Functional Performance Description

A description of the performance for a new system should include several essential elements of information such as (1) missions, (2) system functions, (3) operational function performance requirements or characteristics, and (4) conditions. More details on each of these elements and the process for developing them is provided in the subsections which follow.

Missions. These missions should be taken directly from the missions listed in the OMS/MP of the O&O Plan. As indicated in the discussion of the O&O Plan, the missions in the OMS should either be stated in terms of: (a) the unit operations examined in capabilities analysis or (b) Blueprint of the Battlefield functions. Most major combat arms weapon systems will use the former while most small or support systems will use the latter.

System Functions. In order to ensure that the new system is fully capable, we recommend that a complete list of system battlefield functions be developed. Development of such a list is the only way to ensure that Army will get a system that fully meets user needs.

Two types of system functions must be identified--operational and support functions. Operational functions are those which occur during actual performance of the system's missions. The list of operational functions should include autonomous functions (i.e., functions with no human involvement). As part of the autonomous functions, users should consider capabilities provided by the system as a result of its static design features. Examples of some common autonomous functions and their references to the Blueprint include:

- Provide protection against ballistic effects (6.3.1.1.4GT1)
- Provide protection against contaminants (6.3.1.1.4GT2)
- Provide protection against natural environment (6.3.1.1.4GT3)
- Provide protection against electromagnetic energy (6.3.1.1.4GT4)
- Conceal Electromagnetic Signatures (6.3.2.1.2GT1)
- Be transportable (conduct cargo transfer) (7.5.1.1.3GT4)

Note that several of these functions have direct MANPRINT implications. Autonomous functions have in the past been left out of sequence-based descriptions of the functions performed during a mission (e.g., the mission profile in the O&O plan) since they are not actually "performed" by the system during a mission.

Support functions are functions that do not occur during the operational mission. They include activities such as maintenance (i.e., RAM requirements) as well as autonomous functions such as "be transportable."

Whenever possible, system functions should be described using terminology from the Blueprint subfunctions and generic tasks. In fact, the Blueprint provides a convenient checklist for assisting Army analysts in insuring that all functions have been included. One way to further assist analysts would be to develop "libraries" of the Blueprint functions commonly associated with different types of systems. In fact, as part of its HARDMAN III effort, DRC has developed such libraries for active operational functions of 21 different types of systems. Table 9 provides an example of one of these libraries. Again, the objective of providing a checklist such as the one displayed in Table 9 is to ensure that a complete list of system functions is considered during the requirements generation process. AR 71-9, Materiel Objectives and Requirements, attempts to achieve this same objective, albeit in a less systematic manner, by providing a list of the areas that must be considered during development of a system's operational characteristics (see Appendix E).

A key question in developing a complete list of system functions is identifying the proper level to which each function should be decomposed. We recommend that each system function be decomposed down to the level at which the capabilities analysis has identified issues involving that function. Suppose, for example, that the analysis process has identified a need for an improved capability for units to locate their position on the battlefield (e.g., identify position within 5 meters of true location within three minutes). Also, suppose that, per the Blueprint, "determine location" is a generic task under the subfunction "navigate" (see Figure 15). In this case, decomposition would stop at the level of "determine location". This would mean that performance requirements would have to be identified for the other generic tasks under the "navigate" subfunction.

Performance Requirements. Performance requirements describe the level of performance that a system must achieved on various functions. Performance requirements are the most critical part of system performance specifications and are the most difficult to develop. The format for performance requirements and the approach for developing them are described in the subsections which follow.

Bands Of Performance. According to AR 71-9, performance requirements should be stated in "bands of performance " Each band consists of a cost ceiling and a performance floor. Three points need to be made about the use of bands of performance.

First, the user may only want to specify a cost ceiling for selected critical functions. The objective of the cost ceiling level is to tell the materiel developers where not to waste their developmental resources. The Army could achieve the same effect as the cost ceilings by putting a statement in the requirements document or RFP that stated that unless otherwise specified (via a performance ceiling), the Government would not pay for or give credit for (in terms of proposal evaluation) any capabilities which provide levels of performance over and above the minimum levels (i.e., the performance floors).

Second, the performance floor is really the least operational capability that the user will accept in the time frame associated with the fielding of the new system. The user may need a certain level of performance but the technology assessment conducted as part of the capabilities analysis process may have indicated a high risk in achieving that level of

Table 9. Example of System Function List

Acquire Direct Fire Ground Targets - Detect Target - Identify Target - Aim and Fire Weapon Communicate - Encode and Decode Messages - Transmit and Receive Messages - Use Countermeasure Procedures Displace System - Displace Howitzer Emplace System - Emplace Howitzer Engage Direct Fire Targets with Primary Weapons - Fire Cannon - Load and Orient Weapon - Execute Cannon Failure to Fire Procedures Engage Ground Targets with Secondary Weapons - Boresight Weapon - Aim and Fire Weapon Engage Indirect Fire Targets - Load and Orient Weapon - Fire Cannon - Execute Cannon Failure to Fire Procedures	Move Vehicle - Start Engine - Move Vehicle Navigate - Determine Location - Determine Distance - Determine Direction/Heading - Determine Elevation and Altitude Prepare for Movement - Adjust/Inspect Other Systems - Enter Data onto Onboard Computers - Perform Fire Control Alignment - Load Combat Supplies and Equipment Prepare Weapon - Prepare Range Cards - Boresight Weapon Replenish System - Load Ammunition onto System - Load Fuel onto System Provide Protection Against Ballistic Effects - Provide Protection Against Contaminants - Provide Protection Against Natural Environment - Provide Protection Against Electromagnetic Energy - Conceal Electromagnetic Signatures
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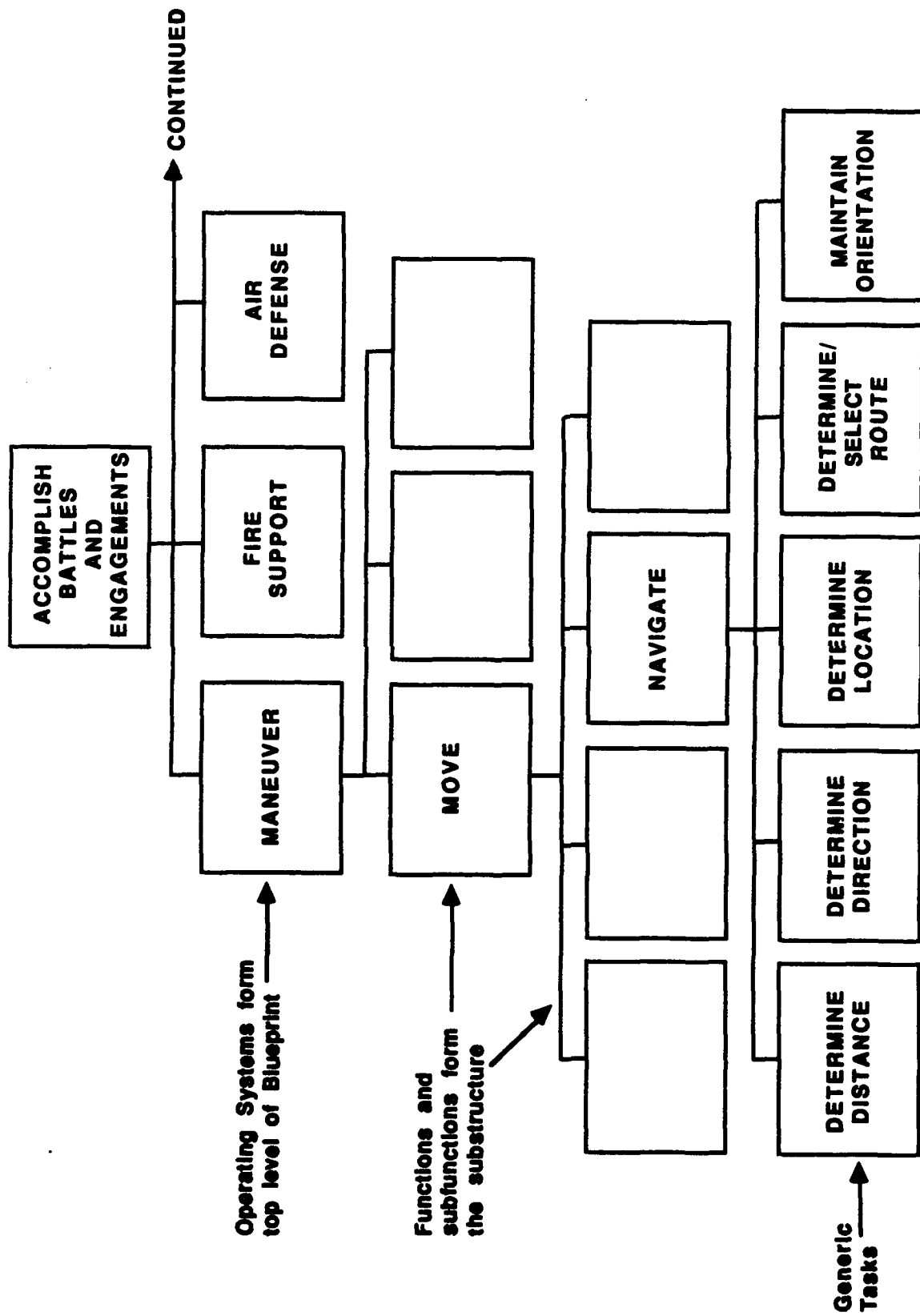


Figure 15. Example: Identifying Appropriate Level of Decomposition

performance with near term technology. Consequently, his performance requirements might have to be lowered to reflect technology constraints. The bottom line is that both technology constraints and operational requirements must be considered in identifying performance floors.

Third, the performance band concept assumes that all performance measures are continuous. However, some performance measures are discrete. In fact, some discrete measures have only two values (e.g., be transportable by C-17).

Types of Performance Measures. There are two major classes of performance measures--time and accuracy. In constructing, performance requirements, whenever possible it is desirable to identify both a time and accuracy measure and to link both measures (e.g., this level of accuracy must be achieved while performing this function in this amount of time).

Even if they cannot be linked, it is important to attempt to identify both a time and accuracy measure. This is true even if the system capabilities plan has only identified a required improvement on one of these types of measures (e.g., a time measure). In this case, it is implicitly assumed the current level of the other measure (e.g., accuracy) is sufficient. However, as was stated above, we believe that one of the central tenets of developing a good set of detailed functional requirements is to explicitly state all requirements.

Components of Performance Requirements Statements. Each time and accuracy performance requirement has three basic components: a measurement variable (e.g., range), an operational measure for that variable (e.g., distance from the target in meters), and the values for the performance band (e.g., 500-900 meters).

In addition to the three basic components listed above, the approach used to describe performance variability must also be described. Performance on almost all system measures will be variable; that is, if we measure performance on the same system across multiple trials we will obtain a range of performance values. The functional requirements document must explicitly deal with this variability. We do not want a materiel developer to say he had met the performance requirements for a particular function if he had met the required level of performance on only 1 out of 100 trials during testing. One way to deal with variability is to state all requirements (i.e., the performance floor and ceiling) in terms of mean values. For example, at the beginning of the requirements document, it should be stated that "unless otherwise specified, all requirements are stated in terms of mean values". In many cases, rather than using mean values, it will be desirable to simply state the required probability that the system must meet the requirement (e.g., 70% of time the system must achieve the desired performance level).

It is also important to state the factors that cause performance variability. There are three major sources of variability in performance -- conditions, hardware/software, and personnel. At the beginning of the requirements document, it should be stated that, unless otherwise specified, it is assumed that the mean and probability values refer to variability across each of these three types of factors. The range of applicable conditions should be contained

in the system scenarios contained in the OMS/MP of the O&O plan. The range of personnel should be described in the Personnel Constraints section of the O&O plan. Hardware/software variability need not be described — it will be part of the contractor's design process.

Conditions. As part of the requirements document, the conditions under which each functional performance level must be achieved should be specified. At the beginning of the requirements document, it should be stated that, "unless otherwise specified, it is assumed that each performance requirement must be achieved under the full range of conditions specified in the System Operational, Maintenance, or Support Scenarios which should have been developed as part of the Operational Mode Summary/Mission Profile included in the O&O plan.

In many cases, it is recognized that desired performance levels cannot be achieved under all conditions. There are some conditions which are known to significantly degrade performance and the Army is willing to accept a lower level of performance under these conditions. In these situations, separate performance requirements should be specified for each value or range of the condition(s) which significantly degrades performance.

Derived Physical Requirements. In some cases, it is relatively easy for the Government to derive physical requirements from a particular functional requirement. For example, a system may have as a functional requirement; be transportable by a C-17. Knowing the dimensions of the C-17, the Government may be able to determine the maximum height and width of the new system. Presenting these physical requirements to contractors can save time and resources. We recommend that in situations such as this, that the functional requirements be developed and specified in the same way as described above but that they be annotated to indicate any related physical requirements that are directly derived by the Government. These physical requirements would be documented in the Physical Characteristics section of the System/Segment Specification (see Appendix E).

Example of Performance Requirements. Table 3 provides an example of performance requirements statements which follow the guidance described above.

Development of Performance Requirements

Figure 16 depicts our approach for developing system performance requirements. More details on each step of this approach are provided in the following subsections.

Construct List of Other System Functions. The O&O Plan will only identify performance requirements for the critical functions identified in the capabilities analysis. However, to successfully build a system, a complete set of functional requirements must be developed. The list of system functions should include both operational and support functions. Development of the list of system functions could be facilitated if a library of functions for each system type were developed and maintained by proponent organizations.

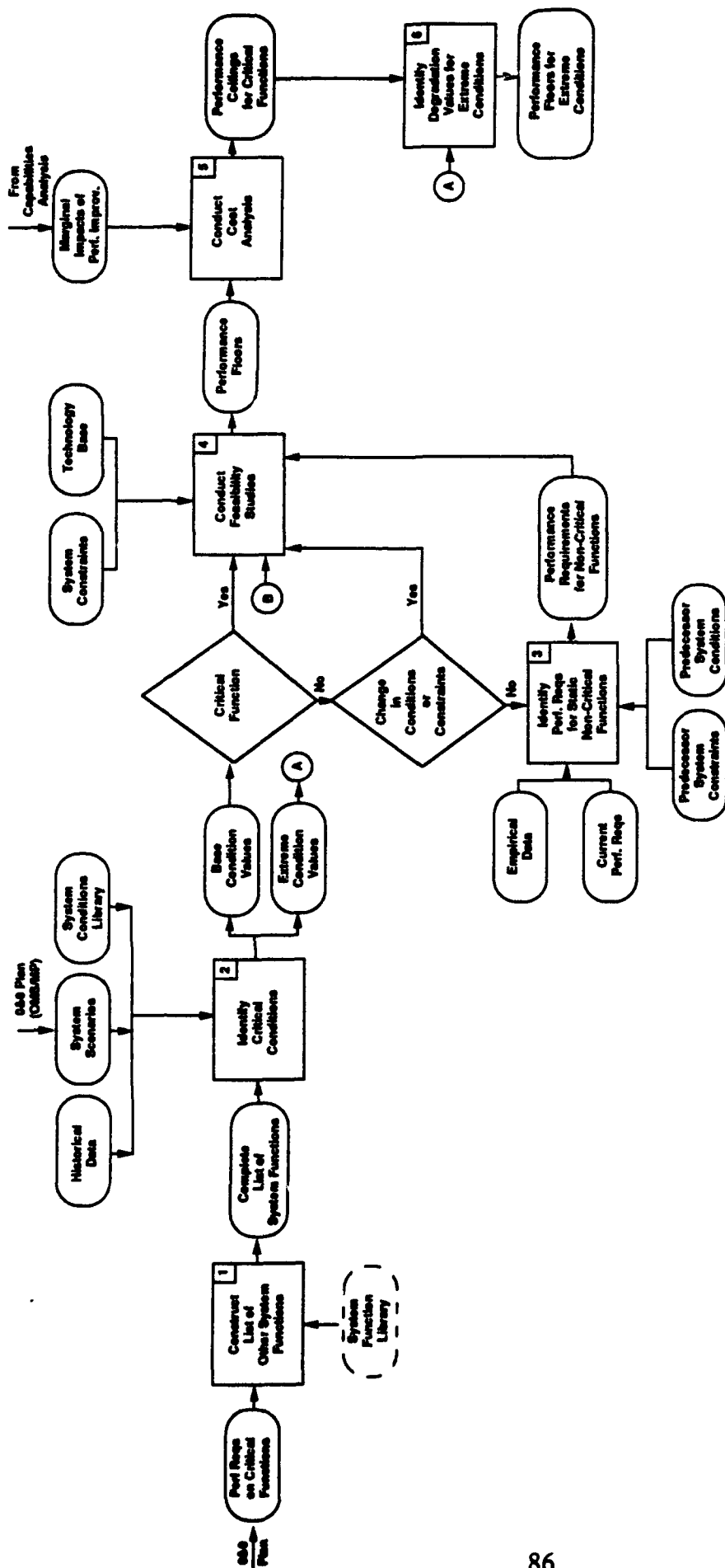


Figure 16. Method for Developing Performance Requirements

Identify Critical Conditions. Critical conditions are those conditions that significantly impact the performance of a function. The key work here is "significantly". Minor variations in conditions are captured by specifying performance in terms of mean values or required probabilities of success (i.e., per cent time performance standards must be achieved). It is assumed that during testing of the weapon system, these conditions will be allowed to vary randomly in the same way they vary in the real world. Thus, the impacts of these conditions can be treated as noise or "error" in the analysis of variance sense.

Critical conditions will vary from one function to another. During this step, critical conditions should be identified for each function. During the O&O plan, values for each condition and the associated probabilities for these values should have been identified. As part of this step, both baseline or "normal" values and extreme values for each critical condition should be identified. In subsequent steps, performance requirements will first be identified for the baseline or normal conditions. Performance requirements for extreme conditions will then be identified.

Identify Performance Requirements for Static Or Non-Critical Functions. If the function for a particular type of system is not critical (i.e., as determined by capabilities analysis) and the conditions and constraints under which that function must perform have not changed from the predecessor system to the new system, then performance information from the predecessor system can be used to generate performance requirements on that function for the new system. Ideally, empirical performance data from the predecessor system would be used to generate these requirements. However, if empirical data is not available, the user may consider using stated performance requirements for the predecessor system. However, the latter is often very risky because one must assume that the predecessor system currently meets its requirements and that these are adequate.

Conduct Feasibility Studies. This is the most complex and most difficult step in the development of performance requirements. The objective of this step is to ensure that required performance levels are achievable by a single system given projected technology, the constraints under which that system must operate, and human performance limitations. For example, two different requirements set during the analysis process might require mutually opposing technological solutions (one requirement can only be achieved by increasing the weight of the system while another can only be achieved by decreasing the system's weight). The objective of this step is to examine the feasibility of the performance requirements from a total system perspective (hardware, software, soldier). The output of this step consists of estimates of "realistic" performance floors for each critical function. Figure 17 provides an overview of the substeps involved in this step. The steps would be applied to each function.

A. Assess Level Of Human Performance Involvement. The first step is to determine if humans are likely to be involved in the performance of the function. There are many functions where humans are not involved (e.g., provide protection). If humans are not

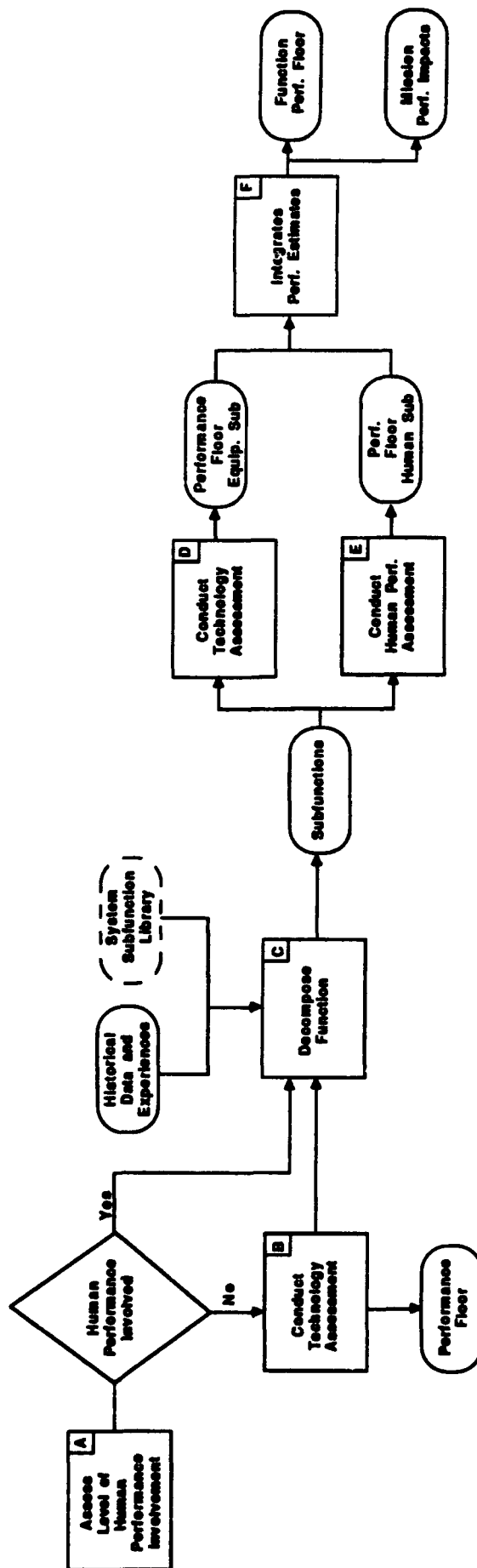


Figure 17. Method for Conducting Feasibility Analyses

involved in a particular function, only an assessment of hardware/software technological capabilities is required to determine the performance floor. If humans are involved, human performance data must be considered in the determination of the performance floor.

B. Conduct Technology Assessment. The objective of this substep is to identify the highest performance level that can be achieved with available technology or technology likely to be available when the system is fielded. This can be accomplished by reviewing technology base studies, surveying subject matter experts, applying analytical models, or building prototypes and collecting data. The performance floors identified in this step must consider the conditions and constraints under which the system must operate.

Two documents that can assist Army analysts in the technology assessment are the Mission Area Materiel Plan (MAMP) and the DA Long Range Research, Development, and Acquisition Plan (LRRDAP). According to the new draft of AR 70-1, the MAMP provides:

"a systematic, prioritized long range, research, development, and acquisition (RDA) strategy for materiel acquisitions in response to CBTDEV requirements with primary emphasis on mission area integration and in response to Army procurement requirements. The MAMP is based on the DA LRRDAP and on the CBTDEV BDP prioritization of Army battlefield deficiencies. It is defined in terms of planned system developments or materiel changes, the technology base programs necessary to implement these programs, and the time lines for these programs."

C. Decompose Functions. During this substep, the functions involving humans are decomposed until the separate subfunctions or tasks performed by humans or hardware/software are identified. The decomposition process could be facilitated by the development of libraries which contain a list of generic subfunctions for different types of systems.

D. Conduct Technology Assessment. The same technology assessment techniques described above are used to develop performance floors for subfunctions without any human involvement (e.g., the probability that a rifle will hit a target once it has been aimed and fired).

E. Conduct Human Performance Assessment. Performance floors must be identified for subfunctions that are: (a) performed solely by humans (e.g., select a target) and (b) are performed by humans using system hardware/software. It is expected that this will be accomplished by reviewing existing performance data for similar tasks, surveying subject matter experts, building prototypes and collecting data, or applying detailed analytical models. The performance floors identified in this step must consider the baseline conditions and constraints under which the system must operate. Of particular importance are human stressor variables, personnel constraints (the type of people who will be available for the new system), and training constraints (the type and amount of training that will be available for the new system).

ARI is developing two tools which can directly assist analysts in developing estimates of performance for human tasks. First, ARI is developing an automated aid called Personnel-Based Evaluation Aid (PER-SEVAL) that: (a) provides baseline (i.e., current) performance estimates for 21 different types of systems and (b) provides a set of performance shaping functions that allow analysts to adjust performance estimates to take into account the impacts of changes in human stressor variables, personnel characteristics, and amount of sustainment training. Using PER-SEVAL, analysts may collect performance data from a population with certain personnel characteristics, amount of training, and set of conditions and then use the performance shaping functions to estimate how a population with different personnel characteristics and/or amount of training would perform under different conditions. This is particularly helpful with new systems since it allows users greater flexibility in extrapolating from test data or data from similar systems.

The second tool which ARI is developing that can assist users in estimating task performance is Human Operator Simulator (HOS). HOS provides a capability for estimating human task performance from the "bottom-up." It does this by providing micromodels that contain algorithms that can predict the timing and accuracy of minute human cognitive-perceptual and psychomotor action. (Harris, et al. 1988). All of the algorithms are based on empirical data obtained in experimental studies. The cognitive-perceptual models presently include decision-making, short term memory, and visual perception (central or foveal vision only). The psychomotor models include eye movements, hand movements, handprinting, simple control manipulation (i.e., toggle, pushbutton, rotary, trackball), and walking. One advantage of a "bottom-up" approach to human performance estimation such as HOS is that it is very sensitive to minute design or technology changes. The disadvantage of the HOS approach is that it requires very detailed data to run. ARI currently has a project to integrate HOS with Micro SAINT a task-level based human simulation modeling tool. The objective of this effort is to maintain HOS's advantages (detailed psychological models) while eliminating its disadvantages (unfriendly interface and forced entry at extremely detailed levels of data input). This will be accomplished by permitting users to access the HOS psychological models to represent the details of particular tasks in a Micro SAINT network.

F. Integrate Performance Estimates. Performance estimates for subfunctions must be combined to produce performance estimates for individual functions. These performance estimates must then be compared with the performance requirements set for these functions during the capabilities analysis process (these will be listed in the O&O plan). If the requirements appear achievable the analysis process may stop. If not, tradeoffs must be conducted among system performance capabilities. This involves changing function performance and observing the resultant impacts on system mission success (i.e., the success of the system in performing its assigned functions during unit operations). Because of the complex relationships between individual soldier task performance, crew/system performance, and unit performance, conducting such tradeoffs is not an easy process. Figure 18 provides an overview of these relationships. Individual soldier task performance is determined by five major classes of variables--personnel characteristics, training, system design (hardware and software design), job design, and external conditions. Personnel characteristics include stable

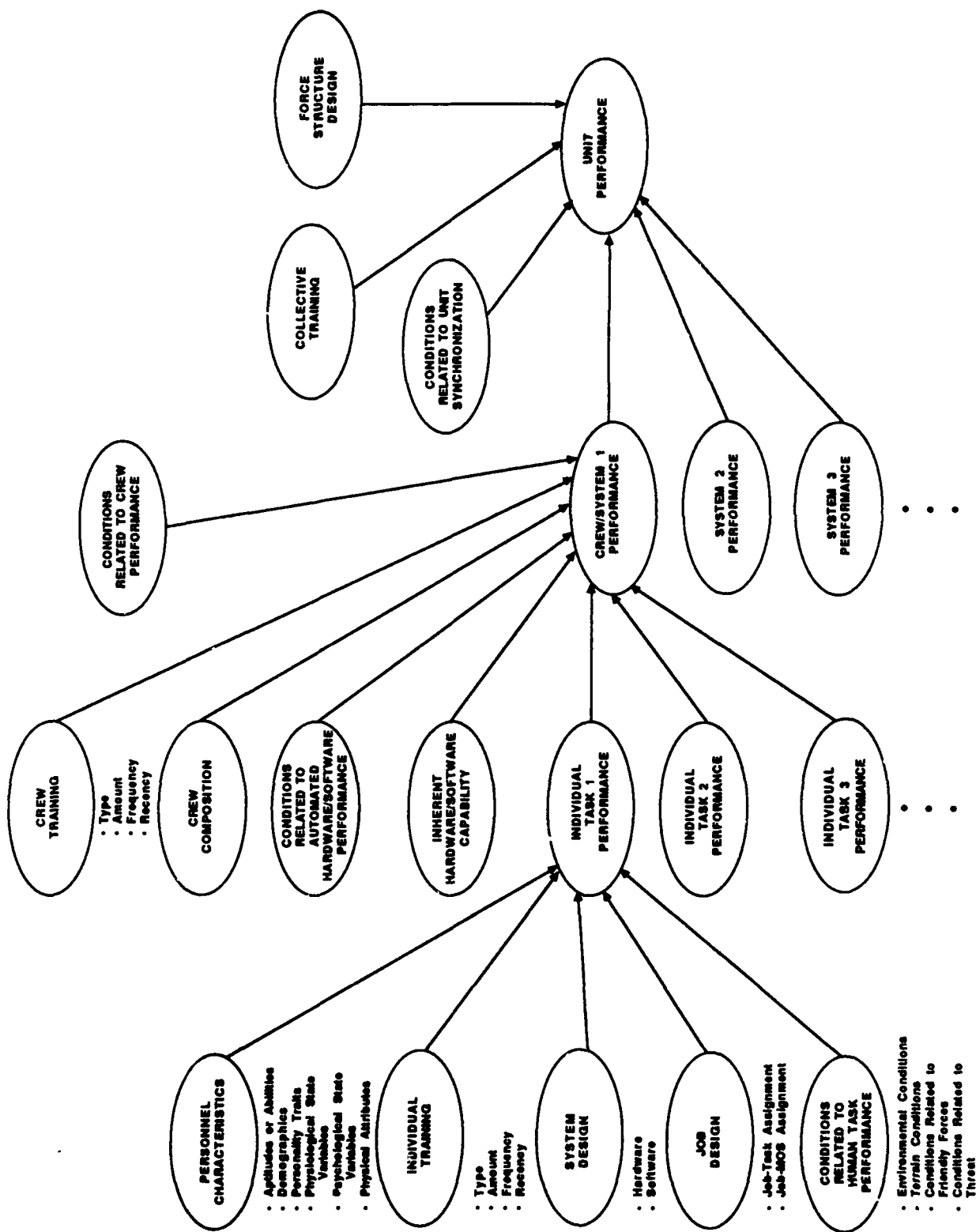


Figure 18. Causal Relationships Underlying Performance

or enduring characteristics such as abilities or aptitudes, personality traits, physical attributes, and demographics as well as more temporary characteristics such as physiological state variables and psychological state variables.

Overall crew or system performance is a function of: (a) how well soldiers perform their individual tasks, (b) crew coordination, and (c) how well the system hardware/software performs non-human functions. Crew coordination is a function of crew training, crew composition, and external conditions that directly impact crew coordination for a particular mission. System hardware/software performance is a function of the inherent (i.e., non-human) capabilities of the hardware/software under these same external conditions. For example, the terminal effects of tank rounds are not impacted by human task performance. Once a round has been loaded, aimed, and fired, the destruction it causes is solely an attribute of the equipment. The capability of the system to perform non-human functions is dependent on a set of conditions that may or may not be the same as the conditions which impact human task performance. That is, a particular condition may impact equipment performance and have no impact on soldier or crew performance.

Estimation of function or mission performance is straightforward when the causal relationships between subfunctions and the overall function performance is additive. For example, this is often the case for time to perform measures which are performed sequentially. Estimation of function performance becomes more difficult when the causal relationships between subfunctions and overall function and mission performance becomes more complex. For example, in many cases, the performance of a function must be represented as an algebraic function of the performance levels achieved on the individual subfunctions. In these cases, algorithms must be generated to capture these algebraic functions. In more complicated cases, not only are the causal impacts of subfunctions on function performance determined by complex functions, but the sequencing of individual subfunctions within a function varies in a dynamic fashion. This will occur when the initiating cues for an individual subfunction depend on the external environment or the level of success achieved on other subfunctions either within or outside of the parent function.

Major techniques for conducting tradeoffs include surveying subject matter experts, rapid prototyping, and simulation modeling. Because of the complex judgments that must be made, effective use of subject matter experts (SMEs) to make these judgments is often not a viable option. To make this technique more viable, tradeoff decisions must often be extensively decomposed to the point where experts are asked to make relatively simple judgments. Use of SMEs is most effective when combined with one of the other techniques.

Rapid prototyping can provide empirical data on function and mission performance associated with different system design alternatives. For example, ARI-Fort Knox is currently using the SIMNET-D to collect performance data that reflects the introduction of new armored vehicle command and control systems. The performance data collected from SIMNET-D directly reflects the performance achievements of both hardware/software and

humans in performing their own individual subfunctions. With increasing emphasis on the evolutionary development of new systems and advances in simulator technology, one can expect more extensive use of rapid prototyping simulators such as SIMNET-D.

The best analytical tool representing the complex sequential and causal relationships among tasks is simulation modeling. To fully capture relationships between human performance variables, human task performance, overall system or function performance, four different classes or levels of models are needed (see Table 10).

Task Models (e.g., HOS models). Provide a detailed representation of individual human tasks. These models are very sensitive to minute changes in hardware/software but have extensive input data requirements.

Crew Performance Models (e.g., MAN-SEVAL/PER-SEVAL models). Represent the crew tasks involved in performing a particular mission. The models are helpful in assessing the interrelationships among crew tasks and the impacts of these tasks on overall mission performance. One weakness of these models is that they tend to only provide very high level representations of extra-crew events such as the threat or other friendly systems. Because of this, they are often not useful in conducting detailed assessments of the combined effects of having several different new system in a particular unit.

Combat Models. High resolution combat models (e.g., battalion level and below) can be used to examine the integrated impact of having a number of the new systems in a particular unit. They are also helpful in situations in which improvements in the new system function can improve (or degrade) the performance of other systems and these changes in performance impact the overall success of the unit in performing its designated operation. For example, a new tank may be given an improved capability to locate it's position on the battlefield. Using this capability together with it's existing laser range finding capabilities, it may now be able to more accurately determine the location of targets. This capability may, in turn, improve the accuracy of indirect fires, contributing to mission success.

Hardware/Software Models. Provide detailed representations of autonomous hardware/software subfunctions.

Conduct Cost Analysis. During this step, performance ceilings should be identified for critical functions. The ceilings should be identified in a three step process. First, as a result of the capabilities analysis process, levels of performance may have been identified for functions beyond which there is no significant improvement in unit operations. If so, these analyses should be reviewed. Second, if these analyses were not conducted during the capabilities analysis and resources permit, they could be conducted at this time. Basically, this involves systematically varying the function performance level and examining the resulting impacts on operation success. Third, cost analyses must be conducted to identify the life cycle cost of achieving various levels of performance over and above the performance floors. As part of these analyses, the AMCOS model developed by ARI should be used to assess personnel and training costs.

Table 10. Rules of Different Types of Simulation Models

TYPE	DESCRIPTION	LIMITS	EXAMPLE
Task Models	Provide detailed representations of individual human tasks. This level of detail produces more accurate predictions of human performance.	Has very extensive input data requirements. Typically, this restricts use to all but a few very critical tasks	Human Operator Simulator (HOS)
Crew Performance Models	Represent tasks performed by crew in operating a single system during a mission. These models are most useful for assessing task concurrency and estimating mission time.	These models typically contain very simplified representations of other friendly systems, the threat, and the external environment	Personnel-Based Evaluation Aid (PER-SEVAL)
High Resolution Combat Models	Represent activities of several systems in performing a unit operation. These models provide the best capability for assessing the impacts of functional improvements on the performance of other types of systems.	Typically, these models have ignored impacts of human performance variables	JANUS/T
Hardware/Software Models	Provide detailed representation of specific autonomous hardware/software functions	Models have very narrow focus. Often ignore environmental conditions.	TOW-Missile Systems Simulations

Identify Degradation Values for Extreme Conditions. During this substep, performance floors are identified for the extreme values of critical conditions. Ideally, these performance floors should reflect historical data obtained on the impact of extreme conditions on similar types of systems. If such data is not available, it may be necessary to survey subject matter experts. Separate analyses will probably be required to assess the impacts of extreme conditions on hardware/software and human functions.

One tool which can be used to assess the impact of environmental stressors on human performance is PER-SEVAL. PER-SEVAL contains stressor degradation algorithms that degrade task performance to reflect the presence of six critical stressors: heat, humidity, cold, noise, Mission-Oriented Protective Posture (MOPP) gear, and continuous operations (lack of sleep). The PER-SEVAL Aid integrates stressor degradation algorithms already available in the human factors literature and organizes these algorithms by the task types in our task taxonomy. The PER-SEVAL Aid uses an algorithm developed by the Army's Ballistic Research Laboratory to aggregate the impacts of multiple stressors. It is expected that additional stressors will be added to PER-SEVAL as empirical data on these stressors is collected.

Summary of MANPRINT Role in System Requirements Determination Process

MANPRINT factors play two key roles in the determination of requirements for new systems. First, MPT constraints place significant limits on the quality and quantity of personnel who will be available to man the new system. Because of this, MPT constraints must be identified early in the acquisition process and incorporated in the system O&O plan. Second, when developing detailed performance requirements of a system's functional requirements, "realistic" performance floors must be identified. For functions that require human involvement, "realistic" performance estimates cannot be developed without considering human performance limitations.

Need for Updating System Performance Requirements

A system's requirements should be continuously updated after it is fielded. There are several reasons for this. First, actual empirical data on system performance will be continuously obtained on the system throughout its life cycle. Requirements should be updated to reflect the actual performance of the system. Second, the factors on which the requirements are based (e.g., threat, conditions, constraints) may also change.

Both contractor-related requirements documents (e.g., the Prime Item Development Specification or PIDS) and Army requirements documents (e.g., O&O plan) should be updated to reflect the updated requirements.

Development of Audit Trail

The source(s) of each requirement in the system's detailed functional requirements document should be identified and included in a separate section of that document. As a system evolves, these sources may change. Automation of the audit trail via a relational data base

management system can facilitate the documentation process. For example, if a particular data source becomes obsolete, it is a relatively simple process to query the data base to identify all requirements related to that source.

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LIST OF ACRONYMS

AFA	Architecture for the Future Army
AFQT	Armed Forces Qualifying Test
AMC	Army Materiel Command
AMCOS	Army Manpower Cost Model
AMM	Army Modernization Memorandum
ARI	Army Research Institute
AMTP	Army Mission Training Plan
ARTEP	Army Training and Evaluation Program
ASVAB	Armed Services Vocational Aptitude Battery
BDP	Battlefield Development Plan
BFMA	Battlefield Functional Mission Areas
BOS	Battlefield Operating Systems
BP	Battle Plan
CAA	Concepts Analysis Agency
CACDA	Combined Arms Center Development Activity
CFV	Calvary Fighting Vehicle
COEA	Cost and Operational Effectiveness Analysis
CBRS	Concept Based Requirements System
CEP	Circular Error Probability
CGSC	Command and General Staff College
CMF	Career Management Field
CP	Capability Package
CS	Combat Support
CSS	Combat Service Support
DCSCD	Deputy Chief of Staff for Combat Developments
DCSOPS	Deputy Chief of Staff for Operations
DID	Data Item Description
DoD	Department of Defense
DRC	Dynamics Research Corporation
DTLOM	Doctrine, Training, Leadership, Organization, and Materiel
ECM	Electronic Countermeasures
EPW	Enemy Prisoners of War
FEBA	Forward Edge of Battle Area
FLRRDAP	Field Long Range Research, Development, and Acquisition Plan
FLOT	Forward Line of Own Troops
FM	Field Manual

GT	Generic Task
HARDMAN	Hardware vs Manpower
HE	High Energy
HOS	Human Operator Simulator
HQDA	Headquarters, Department of the Army
JCS	Joint Chiefs of Staff
JRTC	Joint Readiness Training Center
KI	Killed in Action
LIC	Low Intensity Conflict
LID	Light Infantry Division
LOC	Lines of Communication
LRRDAP	Long Range Research, Development, and Acquisition Plan
MAA	Mission Area Analysis
MAJCOM	Major Command
MAMP	Mission Area Materiel Plan
MANPRINT	Manpower and Personnel Integration
MAN-SEVAL	Manpower-Based Evaluation Aid
MARC	Manpower Requirements Criteria
MBP	Manpower Billpayer Plan
M-CON	Manpower Constraints Aid
MDAP	Major Defense Acquisition Programs
METL	Mission Essential Task List
METT-T	Mission, Enemy, Terrain, Troops Available - Time
MER	Manpower Estimation Report
MIA	Missing in Action
MLRS	Multiple Launched Rocket System
MOA	Memorandum of Agreement
MOE	Measures of Effectiveness
MOPP	Mission-Oriented Protective Posture
MOS	Military Occupational Specialty
MPT	Manpower, Personnel, and Training
MSC	Materiel Support Command
MOUT	Military Operations On Urbanized Terrain
NCA	National Command Authority
NTC	National Training Center
OMS/MP	Operational Mode Summary/Mission Profile
O&O	Operational & Organizational

OPLANS	Operational Plans
O&S	Operation & Support
PA&E	Program Analysis & Evaluation
P-CON	Personnel Constraints Aid
PER-SEVAL	Personnel-Based Evaluation Aid
PIDS	Prime Item Development Specification
PIP	Product Improvement Plan
RAM	Reliability, Availability, and Maintainability
RFP	Request for Proposal
ROC	Required Operational Capability
ROI	Return on Investment
RDA	Research, Development, and Acquisition
SME	Subject Matter Expert
SRL	Systems Research Laboratory
SSS	System Segment Specification
TAD	Target Audience Description
TDR	Training Device Requirement
TEA	Training Effectiveness Analysis
TEXCOM	Test and Experimentation Command
TOE	Table of Organization and Equipment
TRADOC	Training and Doctrine Command
TRAC	TRADOC Analysis Command
UAV	Unmanned Aerial Vehicle
UW	Unconventional Warfare
VHSIC	Very High Speed Integrated Circuitry
WIA	Wounded in Action

GLOSSARY

Battlefield Operating Systems – the major functions occurring on the battlefield, performed by the force to successfully execute operations (battles and engagements) by the Army.

Capability Issue – refers to the capability of the force to perform a function or task on the battlefield; if the function could be performed better, it would significantly improve the ability of the U.S. Army to execute its assigned missions. A capability issue can arise from either the need to correct a weakness or the opportunity to exploit an enemy weakness.

Conditions – those variables of a battlefield environment or situation in which a unit, system, or soldier is expected to operate that may affect performance.

Doctrine – fundamental principles by which military forces or elements thereof guide their actions in support of national objectives. It is authoritative but requires judgment in application. Doctrine includes tactics, techniques, and procedures.

Functions – activities or processes that occur over time without implying how they will be accomplished or what instruments or methods will be used to perform them.

Generic Task – a discrete event or action, not specific to a single unit, weapon system, or soldier, that enables a function to be accomplished.

Measure – a criterion expressing the extent to which a combat system (i.e., unit, system, soldier) performs a function or task assigned to it under a specific set of conditions.

Mission – the task, together with the purpose, which clearly indicates the action to be taken and the reason therefor.

Objective – the physical object of the action taken, e.g., a definite tactical feature, the seizure and/or holding of which is essential to the commander's plan.

Operation – military actions or processes for carrying on combat, including movement, supply, attack, defense, and maneuvers needed to gain the objectives of any battle or campaign.

Operational Element – component activities or functions required as part of the conduct of a military operation. For example, a "deliberate attack" operation includes operational elements such as communicate, recon terrain, indirect fire support, and fuel.

Potential Battlefield Capabilities – refers to the highest level of performance attainable using state-of-the-art technology, optimal training strategies, balanced organization, and integrated doctrine. This represents the unconstrained potential capability of the Army to perform various activities on the battlefield.

Projected Battlefield Capabilities – refers to the level of performance predicted for some future time frame based on the successful implementation of planned force improvements. This represents the constrained potential of the Army to perform various activities on the battlefield.

Required Battlefield Capabilities – refers to those battlefield functions that must be performed (and the degree to which they must be performed) to execute warfighting doctrine and approved operational concepts (NOTE: also referred to as requirements or required capabilities).

Scenario – a graphic a narrative description of the area, environment, forces, and events of a hypothetical armed conflict during a predetermined time frame. It reflects currently approved assumptions, Red and Blue force structures, terrain, operational art, and tactics. A base case scenario portrays approved doctrinal and operational concepts in selected situations under simulated conditions.

Standard – a measure of the requirement to perform a function or task on the battlefield. Performance standards are expressed in a manner that permits them to be objectively measured. For example, performance standards can be expressed in terms of time (e.g., rounds per minute, time to transmit messages) and accuracy (e.g., percent hits, error rate).

Task – a clearly defined and measurable activity accomplished by units, systems, or soldiers. Tasks are specific activities which contribute to the accomplishment of encompassing missions or other requirements.

APPENDIX A

TAXONOMY OF MILITARY OPERATIONS

Military operations are, by definition (JCS Pub 1-02), military actions or processes for carrying on combat, including movement, supply, attack, defense, and maneuvers needed to gain the objectives of any battle or campaign.

Our position is that there are three fundamental categories of operations: Offensive, defensive, and transitional. Each category of operations requires the coordination of a variety of capabilities on the battlefield. Within each category, there are a number of operation types. The different types of operations within a category are similar in the kinds of capabilities they require from the force executing them (e.g., mobility, firepower). However, they are distinguishable from one another in the way (i.e., sequencing, relative emphasis) that these capabilities are applied in support of their objectives. Thus, it should be possible to develop templates of each operation type that depict generally the capabilities involved and the sequence of their applications.

The doctrinal literature often includes joint, combined, and contingency operations as categories of operations. These do not represent different categories of operations or different types of operations from those referred to above. Rather, these operations are distinguished from other operations in terms of the source, coordination, and timing of the means utilized rather than by how these means are applied on the battlefield.

The three major categories of operations are shown in Table A-1 along with a listing of the operation types that fall under each category. These operations types are described in the following paragraphs.

1. OFFENSIVE OPERATIONS

A combat operation designed primarily to destroy the enemy. Offensive operations may be undertaken to secure key or decisive terrain, to deprive the enemy of resources or decisive terrain, to deceive and/or divert the enemy, to develop intelligence, and to hold the enemy in position. Offensive operations include deliberate attack, hasty attack, movement to contact, exploitation, pursuit, and other limited-objective operations. The offensive is undertaken to seize, retain, and exploit the initiative, and, as such, is a principle of war (FM 101-5-1, p. 1-53).

1.1 MOVEMENT TO CONTACT (NATO: ADVANCE TO CONTACT)

An offensive operation designed to gain initial ground contact with the enemy or to regain lost contact (FM 101-5-1, p. 1-49).

Table A-1. Fundamental Operations

<u>1. Offensive Operations</u> Movement to Contact Hasty Attack Deliberate Attack Counterattack Spilling Attack Exploitation Pursuit Special Purpose Recon in Force Breakout Feint Demonstration Raid	<u>2. Defensive Operations</u> Security Main Battle Area Mobile Area Retrograde Delay Withdrawal Retirement Special Purpose Reserve Deep Rear	<u>3. Transitional Operations</u> Linkup Passage of Lines Relief in Place Meeting Engagement
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1.2 HASTY ATTACK

An offensive operation for which a unit has not made extensive preparations. It is conducted with the resources immediately available in order to maintain momentum or to take advantage of the enemy situation (FM 101-5-1, p. 1-8).

1.3 DELIBERATE ATTACK

An attack planned and carefully coordinated with all concerned elements based on thorough reconnaissance, evaluation of all available intelligence and relative combat strength, analysis of various courses of action, and other factors affecting the situation. It generally is conducted against a well-organized defense when a hasty attack is not possible or has been conducted and failed (FM 101-5-1, p. 1-8).

1.3.1 Counterattack

Attack by a part or all of a defending force against an enemy attacking force, for such specific purposes as regaining ground lost or cutting off or destroying enemy advance units, and with the general objective of regaining the initiative and denying to the enemy the attainment of his purpose in attacking. In sustained defensive operations, it is undertaken to restore the battle position (BP) and is directed at limited objectives (FM 101-5-1, p. 1-20).

1.3.2 Spoiling Attack

A limited-objective attack made to delay, disrupt, or destroy the enemy's capability to launch an attack (FM 101-5-1, p. 1-8).

1.4 EXPLOITATION

An offensive operation that usually follows a successful attack to take advantage of weakened or collapsed enemy defenses. Its purpose is to prevent reconstitution of enemy defenses, to prevent enemy withdrawal, and to secure deep objectives (FM 101-5-1, p. 1-31).

1.5 PURSUIT

An offensive operation against a retreating enemy force. It follows a successful attack or exploitation and is ordered when the enemy cannot conduct an organized defense and attempts to disengage. Its object is to maintain relentless pressure on the enemy and completely destroy him (FM 101-5-1, p. 1-57).

1.5.1 Direct Pressure

A force employed in a pursuit operation that orients on the enemy main body to prevent enemy disengagement or defensive reconstitution prior to envelopment by the encircling force. It normally conducts a series of hasty attacks to slow the enemy's retirement by forcing him to stand and fight (FM 101-5-1, p. 1-26).

1.5.2 Encircling

A force employed in a pursuit to envelop an enemy force which has lost the capability to defend or delay in an organized fashion. It seeks to cut off escape routes and, with direct pressure forces, attacks and destroys the enemy force (FM 101-5-1, p. 1-29).

1.5.3 Follow and Support

A committed force which follows a force conducting an offensive operation, normally an exploitation or pursuit. Such a force is not a reserve but is committed to accomplish any or all of these tasks: destroy bypassed units; relieve in place any direct pressure or encircling force which has halted to contain the enemy; block movement of reinforcements; secure lines of communication (LOC); guard prisoners, key areas, and installations; secure key terrain; and control refugees (FM 101-5-1, p. 1-33).

1.6 SPECIAL PURPOSE

1.6.1 Reconnaissance In Force

A limited-objective operation conducted by, at least, a battalion task force to obtain information, and to locate and test enemy dispositions, strengths, and reactions. Even though a reconnaissance in force is executed primarily to gather information, the force conducting the operation must seize the opportunity to exploit tactical success. If the enemy situation must be developed along a broad front, the reconnaissance in force may consist of strong probing actions to determine the enemy situation at selected points (FM 101-5-1, p. 1-60).

1.6.2 Breakout

An offensive operation conducted by an encircled force. A breakout normally consists of an attack by a penetration force to open a gap through the enemy for the remainder of the force to pass (FM 101-5-1, p. 1-12).

1.6.3 Feint

An offensive operation intended to draw the enemy's attention away from the area of the main attack, which induces the enemy to move his reserves or to shift his fire support in reaction to the feint. Feints must appear real; therefore, some contact with the enemy is required. Usually a limited-objective attack ranging in size from a raid to a supporting attack is conducted (FM 101-5-1, p. 1-31).

1.6.4 Demonstration

An attack or a show of force on a front where a decision is not sought, made with the aim of deceiving the enemy. It is similar to a feint with the exception that no contact with the enemy is sought (FM 101-5-1, p. 1-24).

1.6.5 Raid

An operation, usually small-scale, involving a swift penetration of hostile territory to secure information, to confuse the enemy, or to destroy his installations. It ends with a planned withdrawal upon completion of the assigned mission (FM 101-5-1, p. 1-59).

2. DEFENSIVE OPERATIONS

Operations conducted with the immediate purpose of causing an enemy attack to fail. Defensive operations also may achieve one or more of the following: gain time; concentrate forces elsewhere; wear down enemy forces as a prelude to offensive operations; and retain tactical, strategic, or political objectives (FM 101-5-1, p. 1-23).

2.1 SECURITY

Those operations designed to obtain information about the enemy and provide reaction time, maneuver space, and protection to the main body. Security operations are characterized by aggressive reconnaissance to reduce terrain and enemy unknowns, gaining and maintaining contact with the enemy to ensure continuous information, and providing early and accurate reporting of information to the protected force. Security operations include screening operations, guard operations, covering force operations, and area security operations. Area security operations normally are associated with rear battle operations. The other types of security operations may be oriented in any direction from a stationary or moving force (FM 101-5-1, p. 1-64).

2.1.1 Screening

A screening force maintains surveillance, provides early warning to the main body, impedes and harasses the enemy with supporting indirect fires, and destroys enemy reconnaissance elements within its capability (FM 101-5-1, p. 1-64).

2.1.2 Guard

A guard force accomplishes all the tasks of a screening force. Additionally, a guard force prevents enemy ground observation of and direct fire against the main body. A guard force reconnoiters, attacks, defends, and delays as necessary to accomplish its mission. A guard force normally operates within the range of the main body indirect fire weapons (FM 101-5-1, p. 1-64).

2.1.3 Covering

A covering force accomplishes all the tasks of screening and guard forces. Additionally, a covering force operates apart from the main body to develop the situation early and deceives, disorganizes, and destroys enemy forces. Unlike screening or guard forces, a covering force is a tactically self-contained force (FM 101-5-1, p. 1-64).

2.2 MAIN BATTLE AREA

That portion of the battlefield extending rearward from the forward line of own troops (FLOT) and in which the decisive defensive battle is fought to defeat the enemy attack (FM 101-5-1, p. 1-43). Note: Typical main battle area defensive missions are: defend in sector, defend a battle position, defend a strongpoint.

2.2.1 Mobile

Employ a combination of offensive, defensive, and delaying action to defeat the enemy attack. Focus is on the destruction of the attacking force by permitting the enemy to advance into a position which exposes him to counterattack and envelopment by a mobile reserve (FM 100-5, p. 134).

2.2.2 Area

Defending forces are deployed to retain ground, using a combination of defensive positions and small mobile reserves to absorb the enemy into an interlocked series of positions from which he can be destroyed largely by fire (FM 100-5, p. 134).

2.3 RETROGRADE

An organized movement to the rear or away from the enemy. It may be forced by the enemy or may be voluntary. Such movements may be classified as withdrawal, retirement, or delaying operations (FM 101-5-1, p. 1-62).

2.3.1 Delay

An operation usually conducted when the commander needs time to concentrate or withdraw forces, to establish defenses in greater depth, to economize in an area, or to complete offensive actions elsewhere. In the delay, the destruction of the enemy force is secondary to slowing his advance to gain time (FM 101-5-1, p. 1-24). Note: Typical delay missions are delay in sector and delay forward of a specified line for a specified time or event. Alternate position and successive position are techniques used by commanders and forces to conduct delay operations.

2.3.2 Withdrawal

A retrograde operation in which a force in contact with the enemy frees itself for a new mission (FM 101-5-1, p. 1-75).

2.3.3 Retirement

A retrograde operation in which a force out of contact moves away from the enemy (FM 101-5-1, p. 1-62).

2.4 SPECIAL PURPOSE

2.4.1 Reserve

Operations of a force withheld from action to decisively counterattack enemy vulnerabilities, reinforce forward defensive operations, block penetrating enemy forces, or react to a rear area threat (FM 100-5, p. 148).

2.4.2 Deep

Deep operations are all actions which support the friendly scheme of maneuver and which deny to the enemy commander the ability to employ his forces not yet engaged at the time, place, or in the strength of his choice.

2.4.3 Rear

Rear operations are those actions, including area damage control, taken by all units and host nation singly or in a combined effort, to secure the force, neutralize or defeat enemy operations in the rear area, and ensure freedom of action in the deep and close-in battles (FM 101-5-1, pp. 1-22 and 1-59).

3. TRANSITIONAL OPERATIONS

Operations to retain or regain the initiative and freedom of action when unfavorable or unexpected circumstances are encountered during major types of operations. Transition operations force reconsideration and alteration of plans and actions which can then develop into one of the fundamental types of operations.

3.1 LINKUP

A meeting of friendly ground forces, such as when an advancing force reaches an objective area previously seized by an airborne or air assault force, when an encircled element breaks out to rejoin friendly forces, or when converging maneuver forces meet (FM 101-5-1, p. 1-42).

3.2 PASSAGE OF LINES

Passing one unit through the positions of another, as when elements of a covering force withdraw through the forward edge of the main battle area, or when an exploiting force moves through the elements of the force that conducted the initial attack. A passage may be designated as a forward or rearward passage of lines (FM 101-5-1, p. 1-54).

3.3 RELIEF IN PLACE

An operation in which a unit is replaced in combat by another unit. Responsibilities for the combat mission and the assigned sector or zone of action of the replaced unit are assumed by the incoming unit (FM 101-5-1, p. 1-61).

3.4 MEETING ENGAGEMENT

A combat action that occurs when a moving force, incompletely deployed for battle, engages an enemy at an unexpected time and place. The enemy force may be either stationary or in motion (FM 101-5-1, p. 1-46).

3.5 OTHER OPERATIONS

In addition to the three categories of operations described thus far, other types of activities routinely undertaken during offense, defense, and transition actions are often called "operations". Many of them have separate doctrinal manuals that specifically address their execution. For example, there are:

- survivability "operations",
- unconventional warfare "operations", and
- limited visibility "operations".

Each of these "type" operations is different in certain respects from the three general categories described above. First of all, survivability refers to activities performed by particular units or forces on the battlefield (i.e., engineers). Similarly, civil affairs "operations" really refers to activities performed by civil affairs units. In each case, these units may participate and contribute to all three major categories of operations but these activities themselves do not constitute operations.

Secondly, the term unconventional warfare refers to a particular type of threat on the battlefield. Each category of operations (i.e., offensive, defensive, and transitional) must apply to a variety of threats. However, the application of "how to" guidance for conducting operations will vary across significantly different threats.

Thirdly, limited visibility refers to a special environment on the battlefield. The execution of operations in special environments requires knowledge about the impacts of the special environment on the performance of various functions and tasks. These environments will generally affect all categories of operations, although the effects may vary across the type of operation.

In summary, operations are general constructs that describe activities on the battlefield that apply across units, threat types, and environments. However, the term "operations" is commonly applied to activities that are really less than operations. They are less than operations in that they address activities of a specialized unit, activities against a specific threat, or activities in a specific environment on the battlefield. While these types of "operations" do not meet our definition of operations, they remain an essential part of the military's lexicon and therefore cannot be ignored. Each of these categories of "operations" contains a number of types. These are shown in Table A-2 and described in the following paragraphs.

4. FUNCTIONAL/UNIT OPERATIONS

Those battlefield functions and military element specific actions routinely conducted as integral to the process of carrying on combat and generally inseparable from fundamental offense, defense, and transitional operations.

4.1 DECEPTION

A military operation conducted to mislead the enemy. A unit conducting a deception operation may or may not make contact with the enemy (FM 101-5-1, p. 1-22).

4.2 DENIAL

An operation designed to prevent or hinder enemy occupation of, or benefit from, areas or objects having tactical or strategic value (FM 101-5-1, p. 1-25).

4.3 PSYCHOLOGICAL (PSYOPS)

A planned psychological activity in peace and war directed towards enemy, friendly, and neutral audiences, in order to create attitudes and behavior favorable to the achievement of political and military objectives (FM 101-5-1, p. 1-57).

4.4 RECOVERY

Extricating damaged or disabled equipment and moving it to locations where repairs can be made. Recovery is the primary responsibility of the using unit (FM 101-5-1, p. 1-61).

Table A-2. Other "Operations"

<u>4. Functional/Unit Operations</u> Deception Denial Psychological Recovery Air Movement Survivability Airborne Air Assault Amphibious	<u>5. Special Operations</u> Peacekeeping Terrorism Counteraction Foreign Internal Defense Peacetime Contingency Strike Rescue and Recovery Show of Force Unconventional Warfare	<u>6. Special Environment Operations</u> Crossing or Breaching River Crossing Mobility Counterobstacle Countermobility Military Operations on Urban Terrain (MOUT) Limited Visibility
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4.5 AIR MOVEMENT

Operations using airlift assets, primarily helicopters, to move combat, combat support (CS), and combat service support (CSS) forces and/or equipment whose primary purpose is not to engage and destroy enemy forces (FM 101-5-1, p. 1-3).

4.6 SURVIVABILITY

The development and construction of protective positions such as earth burms, dug-in positions, overhead protection, and countersurveillance means to reduce the effectiveness of enemy weapon systems (FM 101-5-1, p. 1-68).

4.7 AIRBORNE

An operation involving the movement of combat forces and their logistic support into an objective area by air (FM 101-5-1, p. 1-2).

4.8 AIR ASSAULT

Operations in which air assault forces (combat, combat support (CS), and combat service support (CSS)), using the firepower, mobility, and total integration of helicopter assets in their ground or air roles, maneuver on the battlefield under the control of the ground or air maneuver commander to engage and destroy enemy forces (FM 101-5-1, p. 1-1).

4.9 AMPHIBIOUS

An attack launched from the sea by naval and landing forces embarked in ships or craft involving a landing on a hostile shore (FM 101-5-1, p. 1-5).

5. SPECIAL OPERATIONS

Military operations conducted by specially trained, equipped, and organized DOD forces against strategic or tactical targets in pursuit of national military, political, economic, or psychological objectives. They may support conventional military operations, or they may be prosecuted independently when the use of conventional forces is either inappropriate or infeasible. Sensitive peacetime operations, except for training, are normally authorized by the National Command Authority (NCA) and conducted under the direction of the NCA designated commander. Special operations may include unconventional warfare (UW), counter-terrorist operations, collective security, PSYOPS, and civil affairs measures (FM 101-5-1, p. 1-67).

5.1 PEACEKEEPING

Military operations conducted for the purpose of restoring or maintaining peace. They may be undertaken in response to a request for assistance made to either a multinational organization or to the United States directly (TRADOC Pam 525-44, p. 11). Note: Peacekeeping missions include cease fire supervision and maintenance of law and order.

5.2 TERRORISM COUNTERACTION

Operations taken to counter the terrorist threat. Antiterrorism defensive measures to reduce vulnerability to terrorist attack and counterterrorism offensive measures taken against terrorists (TRADOC Pam 525-44, p. 18).

5.3 FOREIGN INTERNAL DEFENSE

Participation by civilian and military agencies of a government in any of the action programs taken by another government to free and protect its society from subversion, lawlessness, and insurgency (JCS Pub 1, p. 150).

5.3.1 Civil Affairs

Operations conducted by civil affairs, engineer, medical, logistics, military police, and administrative elements to restore stability, contribute to national development, and promote support for the government (TRADOC Pam 525-44, p. 14).

5.3.2 Psychological

Planned psychological activities in peace and war directed towards enemy, friendly, and neutral audiences, in order to create attitudes and behavior favorable to the achievement of political and military objectives (FM 101-5-1, p. 1-57).

5.4 PEACETIME CONTINGENCY

Operations that involve the early use of combat forces to immediately correct an unacceptable situation. Such operations are normally sudden, violent, and short in duration, and may be conducted unilaterally or with an allied force (TRADOC Pam 525-44, p. 16).

5.4.1 Strike

An attack for a specific purpose other than gaining or holding terrain. Conducted to peremptorily remove a potentially hostile capability or as a punitive measure, strike operations are characterized by brief, violent action coupled with a rapid disengagement and swift withdrawal (TRADOC Pam 525-44, p. 16).

5.4.2 Rescue and Recovery

Either covert or overt operations to rescue US citizens or others, and the location, identification, and recovery or acquisition of sensitive equipment or items critical to US national security. The execution of rescue and recovery operations can be either opposed or unopposed by hostile forces (TRADOC Pub 525-44, p. 16).

5.4.3 Show of Force/Demonstration

Operations that indicate national intent and resolve. Armed conflict is not intended but may occur. Combined exercises involve the overt marshaling of forces or resources with the purpose of influencing both friendly and enemy attitudes (TRADOC Pam 525-44, p. 17).

5.4.4 Unconventional Warfare

A broad spectrum of military and paramilitary operations conducted in enemy-held, enemy-controlled or politically sensitive territory. Unconventional warfare includes, but is not limited to, the interrelated fields of guerrilla warfare, evasion and escape, subversion, sabotage, and other operations of a low visibility, covert or clandestine nature. These interrelated aspects of unconventional warfare may be prosecuted singly or collectively by predominantly indigenous personnel, usually supported and directed in varying degrees by (an) external source(s) during all conditions of war or peace (JCS Pub 1, p. 379).

6. SPECIAL ENVIRONMENT OPERATIONS

Steps that must be taken to overcome the effects of special environmental conditions on operations.

6.1 CROSSING OR BREACHING

Operations which are necessary for friendly forces to move to the far side of an obstacle.

6.1.1 River Crossing

An operation conducted as a part of and in conjunction with other operations to overcome a water obstacle rapidly. Tactical objectives assigned by higher headquarters may or may not include terrain objectives within the bridgehead; however, terrain objectives and/or space are required to ensure the security of the force and crossing sites (FM 101-5-1, p. 1-62). Note: River crossing techniques are hasty and deliberate river crossing.

6.1.2 Mobility

Obstacle reduction by maneuver and engineer units to reduce or negate the effects of existing or reinforcing obstacles. The objectives are to maintain freedom of movement for maneuver units/weapon systems and critical supplies (FM 101-5-1, p. 1-48).

6.1.3 Counterobstacle

Those actions taken to counteract an enemy obstacle system (FM 101-5-1, p. 1-20).

6.2 COUNTERMOBILITY

The construction of obstacles and emplacement of minefields to delay, disrupt, and destroy the enemy by reinforcement of the terrain. The primary purpose of countermobility operations is to slow or divert the enemy, to increase time for target acquisition, and to increase weapon effectiveness (FM 101-5-1, p. 1-20).

6.3 MILITARY OPERATIONS ON URBANIZED TERRAIN (MOUT)

All military actions planned and conducted on a topographical complex and its adjacent natural terrain where man-made construction is the dominant feature. It includes combat-in-cities, which is that portion of MOUT involving house-to-house and street-by-street fighting in towns and cities (FM 101-5-1, p. 1-46).

6.4 LIMITED VISIBILITY

Operations conducted at night and during other periods of reduced visibility (FM 101-5-1, p. 1-42).

APPENDIX B

METHODOLOGY FOR THE DEVELOPMENT OF OPERATIONS TEMPLATES

Terms such as offensive operations, defensive operations, and assault and route reconnaissance, are used to differentiate among the various types of military operations. These operational terms are used to articulate doctrine, providing a number of distinct approaches for different units (or type units) to achieve similar battlefield results.

The differences among operations are based on (a) the intent or purpose of the operation, (b) the particular set of functions comprising the operation and their relative emphasis, and (c) the timing and sequencing of component functions. Thus, different operations may be devised or selected for accomplishing the same mission. This is not surprising, since missions are comprised of one or more operations orchestrated to achieve the commander's intent. Operations are thus the building blocks of missions.

The importance of operations as constructs is that they provide a general doctrinal schema or script for how to achieve some result, independent of situation-specific conditions. An offensive operation, for example, is characterized as having four phases: planning, movement to contact, attack, and consolidation/reconstitution. These phases differentiate the offense from the general defensive operation which has these phases: planning, terrain reconnaissance, occupation of positions, coverage of obstacles by fires, and consolidation/reorganization. For each of these operations, however, battlefield conditions may dictate additional actions. For instance, engineer functions may be needed in either the offense or defense to breach or create obstacles. Such functions, although critical for a given situation, are viewed as conditional and may not be central to the schema for the operation.

Operations are described in the military language of tactics, techniques, procedures, and soldier and unit tasks. The doctrinal literature relies on a narrative format, illustrated with maps and symbols, to describe the features and conduct of operations. An additional tool which would improve the description and analysis of operations is the operational template. An operational template is a flow diagram containing the essential and defining activities of an operation, arrayed to show the relative temporal sequence of events. An example of an operational template is shown in Figure B-1.

The purpose of an operational template is to provide a simple representation of the essential features of a battlefield operation. Operational templates can be developed for specific operations classified as offensive, defensive, and transitional (see Appendix A - Taxonomy of Military Operations). Templates are constructed from doctrinal literature, and use operational military terminology. This makes the template easily employed by doctrine writers, unit personnel, trainers, combat developers, and analysts.

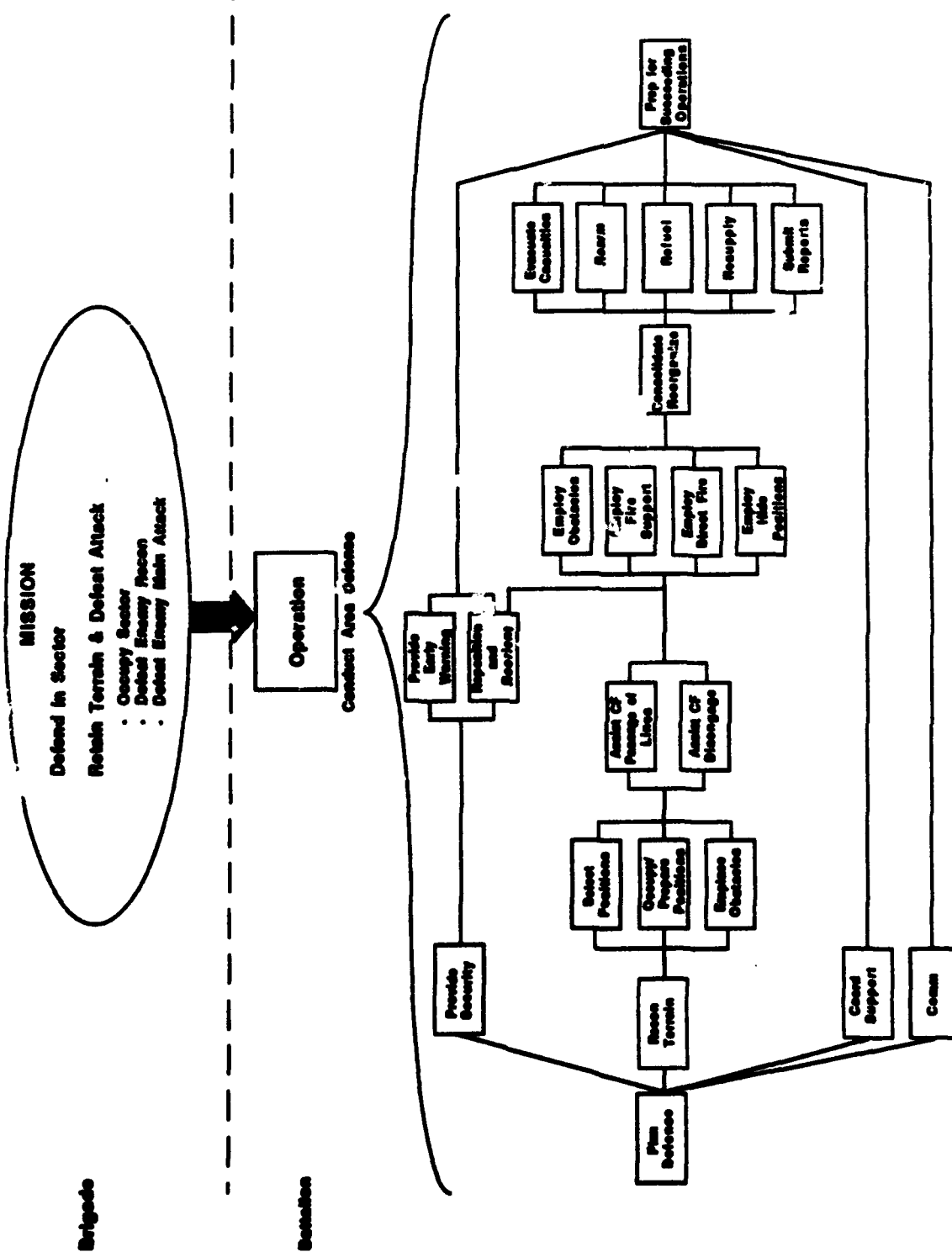


Figure B-1. Example of Operations Template

In its basic form, an operations template summarizes the essential elements of an operation. Beginning with the basic structure, the user can modify a template for a variety of applications. Different Army branches or functional areas (e.g., armor, aviation) can tailor templates with tactics and techniques unique to their particular execution of that operation. Used in this way, the template shows the similarities of how different branches perform the same operation.

In the application of operations templates to specific missions, templates may have to be supplemented with additional functions based on the characteristics of the physical and operational environment. This can be accomplished by adding functions or by referring to other operational templates. For example, the need to represent a significant air threat to an offensive operation can be shown by augmenting the offensive operation template with air defense functions (e.g., early warning, attacking airborne targets).

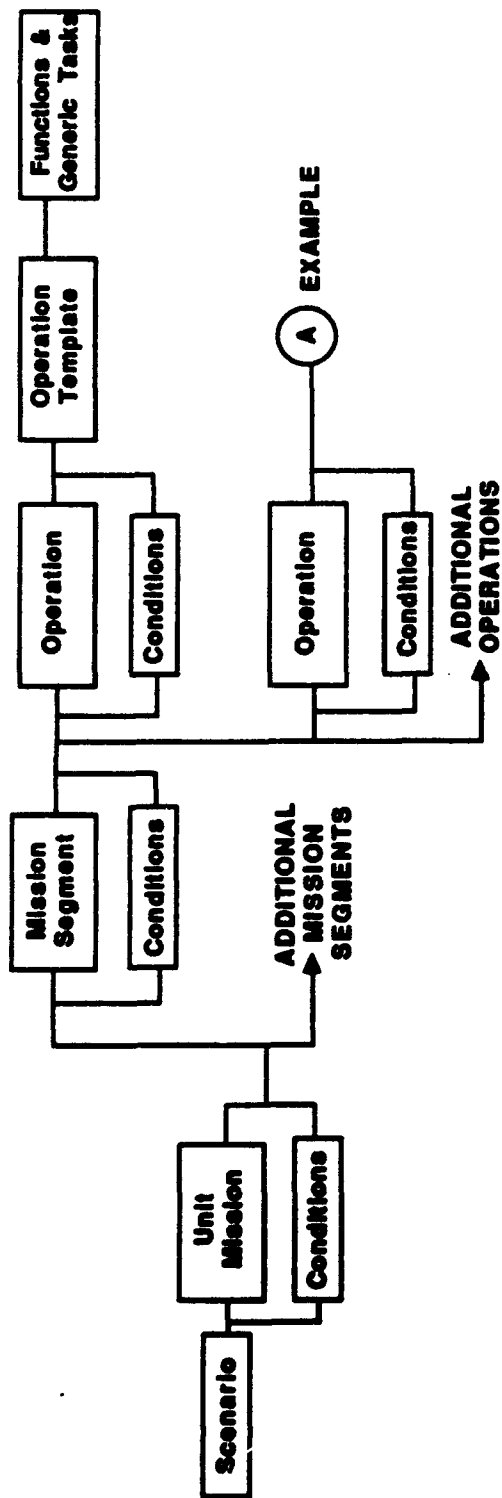
In addition to tailoring the templates in applying them to specific situations, the operational templates can be related to functions from the Blueprint of the Battlefield. In many cases, doctrinal terms used in operational templates refer to a specific collection of functions executed together to accomplish a particular phase of the operation. In other words, operational elements are a form of shorthand for a collection of battlefield functions focused on a specific result.

For many kinds of analyses, the decomposition and translation of operational elements into Blueprint functions permits the examination of various capabilities for accomplishing the intended result. For example, the analysis of an attack might require detailed examination of the means for moving infantry troops within the area of operations. Subfunctions of the Maneuver BOS, as well as from the Mobility and Survivability and Combat Service Support BOSs, might be required to determine a capability issue related to that portion of the operation. Given the mission and battlefield conditions context of the analysis, Blueprint functions may be selected and linked to the operational element relevant to any phase of the operation. Figure B-2 depicts how functions can be linked to operational template terminology.

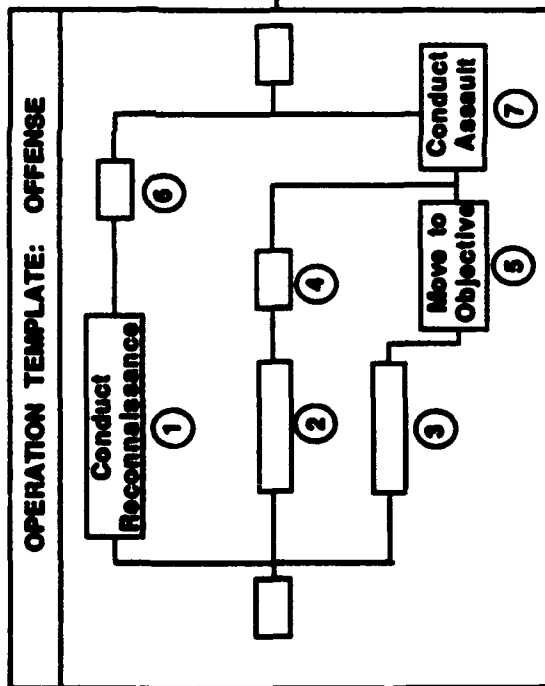
One advantage of the operational template is simplicity in depicting the flow of actions. Clarity is achieved by limiting operational element to those essential for describing the operation.

A second advantage of the operational template is the method for representing relative temporal relationships. As a result, continuous procedures like command and control are represented once and shown to take place throughout the operation. This avoids the situation where a function is cited repeatedly throughout an operation.

The overall goal of the operational templates is to describe the general flow of combat actions, and to represent the supporting capabilities at the functional level. The template itself is clear and uncluttered, and summarizes the doctrinally correct actions and phases that characterize a particular operation. Optional approaches to achieving the required battlefield results are explored at the level of functions and generic tactical tasks.



FUNCTIONS AND GENERIC TASKS	
Action Block	Functions & GTs
① Conduct Reconnaissance	1.1 Move 5.1 Collect Info. 6.3.4 Provide Security 4.1.1 Communicate etc
⋮	
⑤ Move to Objective	1.1 Move 6.3.2 Provide OPSEC 7.3.2.2.3 GT2 Recover Tracked Vehicle 5.1.2 Collect Target Info etc
⋮	
⑦ Conduct Assault	See Assault Template



NOTE: MISSION SEGMENTS ARE OPTIONAL. USED FOR COMPLEX MISSIONS OR SIGNIFICANTLY ALTERED BATTLEFIELD CONDITIONS.

Figure B-2. Linkage Between an Operations Template and Battlefield Functions/Generic Tasks

Operational templates are not found in current doctrinal manuals, but may be developed from doctrine for any operation. Helpful considerations on identifying and choosing which operational templates to generate are found in Taxonomy of Military Operations (Appendix A). Guidance for developing specific templates are shown in Table B-1.

Table B-1. Guidelines for Constructing Operations Templates

Feature	Description
Sources of Operational Information	Primary: Field Manuals Secondary: Mission Essential Task Lists, ARTEPS, AMTPs
Design	Plan the general organization of the template around doctrinally prescribed elements of the operation. Maximum number of action blocks is about 20. Functions and generic tactical tasks should appear in a separate list.
Battlefield Conditions	Conditions affect the selection of actions, functions, and generic tactical tasks. Conditions do not appear in the template.
Action Blocks	Choose actions which are prominent in the discussion of the operation or otherwise emphasized as essential, important, or critical. Use operational terms as much as possible. Refer to functions from the Blueprint of the Battlefield when necessary. Watch for transitions from descriptions of one type of operation to another. This signals a new operation which may need to be represented. Summarize functionally similar actions as a single operational element (e.g., represent close air support, mortar fires, and artillery support as "employ fire support"). Present command and control functions early in the sequence. Avoid planning cycle schematics. Represent actions, not elements of the force performing the action (e.g., "perform reconnaissance", not "employ scout platoon").

Table B-1. Guidelines for Constructing Operations Templates (continued)

Feature	Description
Action Blocks	Represent complex actions as one action block, but decompose it into operationally meaningful elements (e.g., reconstitute should be decomposed into such actions as care of casualties, redistribute supplies and so on). Represent recurring actions once (e.g., movement, communications, reconnaissance). The same action may be repeated if its character changes significantly during the operation (e.g., ground movement into an area but extraction by air). Collect various forms of the same action in one place regardless of when they occur in the operation. For example, represent communications once. Use of radios, messengers, and flares is represented by separate generic tasks linked to the communications action block. Reference other operations as a single action block.
Interconnections	Flow is from left to right. Stack sub-elements of an action block. Arrange action blocks in temporal sequence. Avoid multiple external inputs and outputs. Converge actions on a single result or terminating point of the template. Decision points and conditional branches are not represented.

APPENDIX C

IDENTIFICATION OF MEASURES OF EFFECTIVENESS

INTRODUCTION

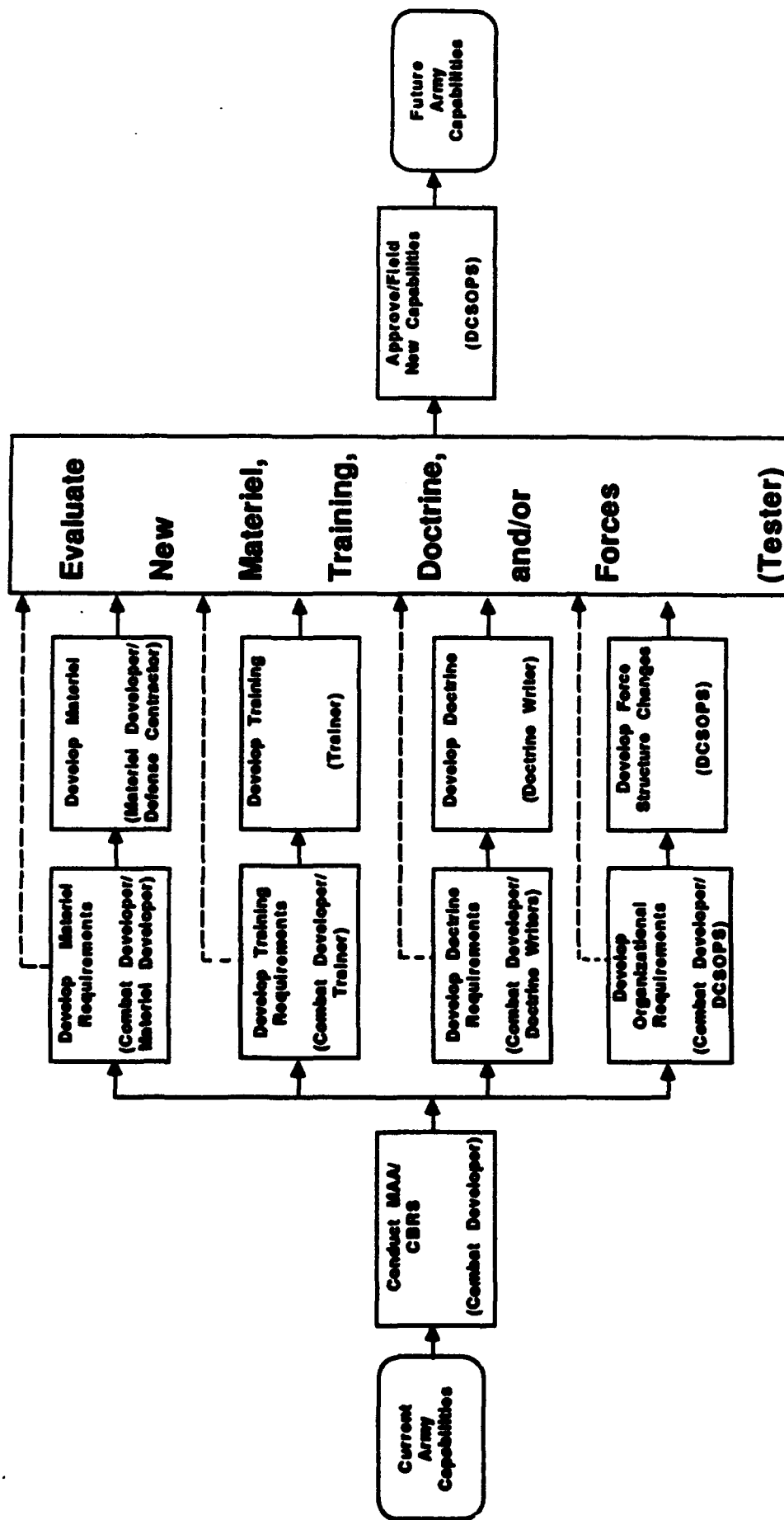
The purpose of this appendix is to discuss a process for identifying measures of effectiveness for use in the Army's Concept Based Requirements System (CBRS) and to define a set of "common" measures for use in studies and analysis. Common measures would permit different systems that perform similar tasks or functions on the battlefield to be compared. A measure is:

"a criterion expressing the extent to which a combat system (i.e., unit, system, soldier) performs a function or task assigned to it under a specific set of conditions"

Thus, measures provide a way to describe or assess combat capabilities. Measures used to describe existing combat capabilities may also be used to describe future or desired combat capabilities. Used in this way, measures may guide the development, evaluation, and introduction of new capabilities into the Army. Figure C-1 depicts these relationships and indicates how many different organizations are involved in the process leading to the development of new Army capabilities.

Because of the large number of organizations involved in the development of new Army capabilities, it is crucial that they each can understand and use the same measures of combat capability. If they cannot all understand and apply the same measures, one organization will be unable to communicate a performance standard to others. As a result, the likelihood will decrease that the future Army capabilities envisioned during the MAA/CBRS process will ever be realized on the battlefield. Furthermore, if a new system or unit was fielded that did not live up to expectations, it would be difficult to diagnose the source of the problem.

The MAA and CBRS processes are conducted by the Training and Doctrine Command (TRADOC) for the purpose of identifying and prioritizing Army warfighting requirements for improved capabilities in the areas of doctrine, training (including leader development), organizations, and materiel. Through studies and analyses TRADOC establishes requirements. AMC then develops materiel prototypes. TEXCOM evaluates and field tests these prototypes to determine their combat worth. These processes support the general process of force modernization directed by Headquarters, Department of the Army (HQDA).



C-2

Figure C-1. Relationship of MAA/CBRS Processes to the Development of New Army Capabilities

Concept of Combat Worth

A key premise underlying this paper is that force modernization decisions should be made on the basis of combat worth. That is, improvements to the Army's doctrine, training, force structure, or materiel systems must be justified in terms of the likely impact on possible future combat operations. The improvements to the Army's combat capabilities worth considering are those that most greatly enhance the ability of the Army to execute its assigned missions.

In order to compare alternative proposals for force modernization during the MAA/CBRS processes, the Army must compare, preferably in a quantitative manner, the combat worth of various proposals. Unfortunately, there is no simple metric for "combat worth". Weapon systems do not have inherent combat worth. Rather, they derive their combat worth from their ability to contribute to the execution of various operations on the battlefield.

Combat Worth for Operations

There are many different types of operations that could be conducted on the AirLand battlefield (see Appendix A). The value of a weapon system for the conduct of one operation may be different than its contribution to other operations. For example, the contribution of bridging equipment may be very different in offensive operations than in an operation to defend a battle position.

Operations generally require the contribution of many different weapon systems for their successful execution. Therefore, it is difficult to determine the relative value of two different weapon systems for an operation, particularly when they both may be essential.

A combat operation is a complex process consisting of different, but interdependent elements. If any of these elements is not performed; is performed, but not to an adequate level; or is performed to an adequate level but at the wrong time or place, the entire operation may be jeopardized. The elements of an operation are not unique to that operation. The same elements may be required in the execution of many other operations, albeit to a different degree, at a different time, or at a different place (see Appendix B).

A template for an operation, Conduct Area Defense, is shown in Figure C-2. This template was constructed using doctrinal manuals for battalion operations. The elements are identified using operational terminology and in the sequence they would typically occur. For example, while preparing defensive positions, one element to be performed is the emplacing of obstacles.

It is the aggregated and synchronized output of these elements of the operation that determine the success of the operation. An operations template does not represent the relationships among elements in sufficient detail to enable the analyst to accurately aggregate from operations elements to the entire operation. However, it provides a guide and start point for such aggregation.

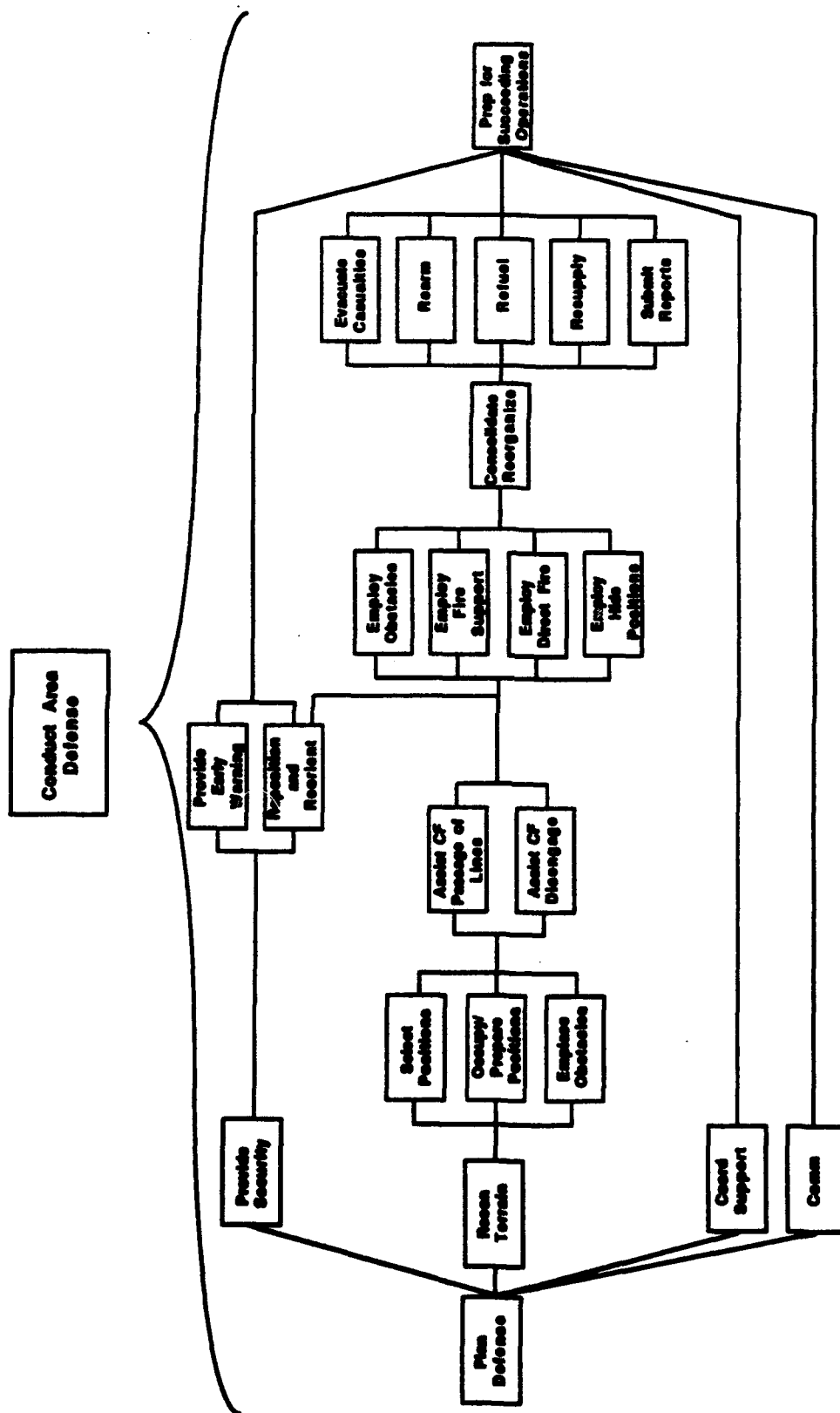


Figure C-2. The Elements of an Operation to Conduct an Area Defense

Identifying the Elements of Operations

While the "combat worth" of a weapon system cannot be measured directly, it may be possible to measure the ability of a weapon system to perform a particular element of an operation. Thus, if one element of a combat operation is to see the battlefield, it may be possible to measure the ability of various assets (units, systems, or soldiers) to perform that element. How many of these elements are there, and what are they?

TRADOC has recently developed a pamphlet (TRADOC Pam 11-9, July 1988) that identifies "functions" performed by units, systems, and soldiers on the battlefield. The pamphlet is called the Blueprint of the Battlefield. The "functions" identified in this Blueprint, while not identical to the doctrinally identified elements of operations, can easily be related to these elements. Therefore, it may be possible to use the "functions" identified in the Blueprint as surrogates for operations elements. The stated purpose of the Blueprint is to serve:

"as a common reference system for field commanders, combat developers, analysts, trainers, and planners to analyze and integrate the actions the Army performs in combat. The Blueprint consists of numerically indexed function or generic task statements, each element defined and arranged hierarchically according to seven battlefield operating systems (BOSs)..... BOSs are the major functions occurring on the battlefield, performed by the force, to successfully execute operations. The seven BOSs are (1) maneuver, (2) fire support, (3) air defense, (4) command and control, (5) intelligence, (6) mobility and survivability, and (7) combat service support."

Thus, the Blueprint attempts to comprehensively list all those functions performed by the Army on the battlefield. The functions in the Blueprint were identified with the following criteria in mind:

- the functions must be directly relatable to means on the battlefield. Also, different means that do similar things on the battlefield must be able to plug into the same function,
- all of the functions in the Blueprint must represent independent activities (i.e., it must consist of elements that are independent of one another), and
- all of the functions must be measurable and the measures must be meaningful apart from the situation in which they were measured. Thus, while rates of fire can be meaningfully applied to different situations, rates of casualties inflicted is highly situation dependent.

Given that the Blueprint is comprehensive, it may provide an analytical placeholder for all of the elements of all types of military operations. As such, it may represent the complete domain of performance elements that the Army could choose to address in force modernization proposals.

The functions contained in the Blueprint are generic with respect to the units, systems, or soldiers that are capable of performing them. Thus, a function in the Blueprint such as Emplace Obstacles (6.2.2) could be performed by a variety of means, to include units, systems, or soldiers.

Ideally, measures of the ability to perform a Blueprint function would apply across different means on the battlefield. This would permit analysts to look across means and operations to identify the functions which, if enhanced, would produce the greatest benefit on the battlefield. It would also permit the analyst some flexibility in targeting various candidate means for improvement.

Identification of Measures for Functions

Functions like "employ air defense weapons" to engage air targets can be measured along multiple dimensions. That is, in speaking about the capability of units, systems, or soldiers to fire on air targets on the battlefield, one could be referring to:

- the maximum effective engagement range of the system,
- the probability of a hit,
- the probability of a kill (given a hit),
- the time required to fire, and
- the time lapse between firing and closure.

One can develop similar lists of measures for most of the functions in the Blueprint. Upon closer examination, these measures can generally be reduced in some form to the constructs of time or effectiveness.

Measures of rate (speed), acceleration, range (i.e., flight time without refueling or miles driven before refueling), or time to perform all capture to some degree the notion of measuring the performance time. In most cases, the shorter the time required for the performance of the activity, the better.

Measures of accuracy (e.g., probability of a hit or circular error probabilities), lethality (i.e., terminal effects), power, durability, range (i.e., maximum effective range of a gun or missile, or of a transmitter), discrimination, resolution, and error rates all capture the notion of effectiveness in some sense.

These measures, while sensitive to the conditions under which functions are performed, can be measured directly. Different units, systems, and soldiers that perform a function can be compared in terms of these measures.

Aggregation of Measures

In many cases, measures used in combat simulations are aggregated measures such as attrition rates, force exchange ratios, movement of the FEBA, etc. These are summary measures from combat simulations that are often used to judge the success of missions and operations within the context of a simulation. These measures are heavily context bound and cannot be used to describe or make general comparisons between the capabilities of various units, systems, or soldiers independent of the situations in which they were derived.

Let's examine a case where sensitivity analyses are conducted to determine the impact of changes in individual weapon system performance or characteristics on combat simulation outcomes. Suppose that a combat simulation revealed that the current force could achieve a force exchange ratio of 2.5/1. However, it was felt that a 3/1 ratio was required. Therefore, the probability of a hit for a tank was increased, and, as a result, a 3/1 force exchange ratio was achieved. There are several problems with trying to actually express the value of the improvement in terms of force exchange ratios.

First of all, as a result of using aggregated measures like force exchange ratios, the benefit of an improvement cannot be generalized to other situations where force exchange ratios are used. This includes comparisons of improvements to the same or different weapon systems. However, decisions about the value of force modernization proposals should not be based on a single situation or threat.

Secondly, while a combat simulation can easily accept changes in performance parameters (e.g., probability of a hit), these performance parameters may not represent a reasonable or complete envelope of performance for the system. Thus, changing the performance parameter for a system's probability of a hit may cost the system performance on some other function. Thus, in order to increase the probability of a hit, improved sights and tracking mechanisms may be required. These improvements may increase the weight of the system and therefore decrease its mobility; they may also increase the workload on the soldier operating the equipment, therefore detracting from other aspects of his performance. However, these negative side effects of system improvements may not be reflected in the combat simulation that produced a dramatic improvement in force exchange ratios. These side effects of a system improvement need not be negative ones. For example, improvements in the maneuverability of helicopters that make helicopters more effective in avoiding detection by the enemy may also increase the ability of helicopters to transport supplies or soldiers.

Distinction between Measures and Conditions

In attempting to identify and define measures for functions, one must clearly distinguish between the variable(s) being measured and variables that, while not being measured, may affect the ability to perform a function. A simple example can be used to illustrate the problem.

Take the example of the function to "Engage direct fire targets". One measure of this function might be the maximum effective range of a weapon system. Thus, what is the furthest distance at which a weapon system can successfully engage a target? Another measure of the same function might be the accuracy of a weapon system in terms of probability of a hit $[p(h)]$. However, in order to compare accuracy across systems or across situations, variables that affect accuracy must be controlled. In this case, the range to the target has a major impact on accuracy in terms of the measures described above. Therefore, before comparisons can be made between systems or situations, the conditions (e.g., range) must be specified.

The fact that the concept of "range" can serve both as a measure and a condition could create some confusion. However, there is no alternative if one expects to make valid performance comparisons across weapon systems or across combat situations.

Impact of Conditions on Combat Worth

Conditions are those variables of a battlefield environment or situation in which a unit, system, or soldier is expected to operate that may affect performance.

Earlier in this paper we cited the importance of comparing different weapon systems that perform the same functions under similar conditions. However, in order to determine the value of a particular weapon system, it is also important to vary conditions to determine which weapon systems are least sensitive to variables in the natural or operational environment. For example, the Army has explored the potential use of space-based lasers for use in performing target designation for precision guided munitions. Under certain conditions, such lasers can be far more effective than any other alternative. However, clouds severely attenuate laser beams in the visible and near infrared spectrum because of the water content of clouds; this is precisely the part of the electromagnetic spectrum used by precision guided weapons. In geographic areas such as the Soviet Union and Europe, conditions of cloud cover exist over 50% of the time in all seasons (Light, 1987). This greatly diminishes the value of a space-based approach to target designation.

An attempt to completely define the domain of conditions that should be considered in the measurement of combat worth is documented in a report entitled "A Taxonomy of Battlefield Conditions" (see Appendix D). This report provides additional examples of how conditions affect performance of units, systems, and soldiers on the battlefield and how these impacts might affect assessments of the value of potential improvements in combat capability.

Identification of Measures

In the next section of this paper, measures are identified for a number of functions listed in the Blueprint of the Battlefield. After identifying measures for each of the Battlefield Operating Systems (BOS), several examples of the application of these measures are presented.

MEASURES OF EFFECTIVENESS

In this section, measures will be discussed and identified for each BOS and many of the functions underlying the BOS. After discussing measures for each of the BOS, an illustration of the use of measures in evaluating a weapon system will be presented.

Measures for the Maneuver BOS

The Maneuver BOS has three major functions; move, engage the enemy, and control terrain. Each of these will have a unique set of measures.

Move. The basic tactical purpose of the "Move" function is to position a unit, system, or soldier in an advantageous position relative to the enemy. The measures used in this BOS should reflect the ability of friendly forces to move. Unfortunately, the measures selected cannot reflect the relative aspect of the move function because this aspect is threat dependent, and therefore could not be compared across situations or scenarios. The emphasis of measures used to describe the capability of units, systems, or soldiers to move must be on the rate of movement, the time required to begin movement, the ability to sustain movement (i.e., durability, operating range) over time, and the ability to move accurately (i.e., navigate). For ground movement, the terrain represents a key condition affecting performance, and for air movement the weather and light conditions have major impacts on movement. Table C-1 presents some examples of specific measures within the "Move" function.

Engage Enemy. The basic purpose of engaging the enemy is to inflict casualties and damage on the enemy. Once again, there is a relative aspect to this function, because casualties and damage will be affected by the type of targets, their level of protection, their detectability, range, etc. The measures selected, in order to be applicable across situations, must focus on the capability of the force rather than on the result in a specific situation. Thus, appropriate measures include time to fire, rate of fire, effective range of fire, accuracy of fire (e.g., against stationary, moving targets), terminal effects of the munitions used, etc. The major conditions affecting performance include target characteristics (e.g., range, size, hardness). Table C-2 presents some examples of specific measures within the "Engage Enemy" function.

Control Terrain. The basic purpose of controlling terrain is to use it to friendly advantage and to its use to the enemy. The ability to control terrain is, of course, dependent on the nature of the enemy and his capabilities. The measures of the ability to control terrain must be limited to those abilities of the friendly force that contribute to the control of terrain. Measures might include the time required to emplace weapons, the ability to accurately adjust indirect fires, the time required to prepare positions, etc. The conditions that will have the greatest impact on performance will be associated with the type of terrain involved.

Table C-1. Measures for the "Move" Function Within the Maneuver BOS

Functions	Purpose of Function	Common Measures	Key Conditions
1.1 Move	to achieve mobility and positional advantage using terrain and formation	• deployment time • multiple techniques and formations • movement rate (distance, speed, time)	• enemy interdiction • terrain
1.1.1 Position/ Reposition Forces	to use mobility to secure/ retain positional advantage	• average response/ completion time • time to change position/ formation • rate of advance	• terrain • weather
1.1.1.3 Move Through Air	to achieve air mobility advantage	• operating range/ speed/duration • formation/flight envelope options	• air superiority/ air defense status • weather • day/night

Table C-2. Measures for the "Engage Enemy" Function Within the Maneuver BOS

Functions	Purpose of Function	Common Measures	Key Conditions
1.2 Engage Enemy	to reduce enemy force capability by direct fire and close combat	• decision/response time • mission completion time	• range • nature of target
1.2.1 Employ Direct Fire	to respond to targets by direct fire means	• target processing rate • decision/response time • target engagement rate	• terrain • ECM, ECCM • target density
1.2.1.2 Engage Direct Fire Targets	to cause casualties and destroy materiel	• time to detect/identify targets • time to first fire • mean offset error • time/rounds to adjust	• nature of target • terrain • range • visibility

Measures for the Fire Support BOS

The Fire Support BOS has two major functions; processing ground targets and engaging ground targets.

Process Ground Targets. The basic purpose of processing ground targets is to convert intelligence information on the enemy (e.g., targets) to information necessary for engagement of targets with indirect fire weapon systems. The most obvious measures of this ability include the time required to develop targeting information, the accuracy of this information (relative to the accuracy of the input data), and the degree to which friendly weapon systems are utilized against targets for which they are appropriate. The conditions that most strongly affect performance are the number and variety of targets, and their degree of movement.

Engage Ground Targets. The basic purpose of engaging ground targets is to inflict casualties or damage on the enemy. The nature of the targets, their number, disposition, activity, etc., will affect friendly force ability to successfully engage them. The measures of this capability may include rate of fire, accuracy of fire (e.g., CEP), minimum and maximum effective range, terminal effects (e.g., explosive power, cratering, jamming), etc. The conditions that will affect performance include the protection levels of enemy positions and their range.

Measures for the Air Defense BOS

The Air Defense BOS has three major functions; processing air targets, attacking enemy air targets, and denying airspace to the enemy.

Process Air Targets. The basic purpose of processing air targets is to convert intelligence information on the enemy (e.g., targets) to information necessary for engagement of enemy air targets with friendly weapon systems. The most obvious measures of this ability include the time required to develop targeting information, the accuracy of this information (relative to the accuracy of the input data), the degree to which friendly weapon systems are utilized against targets for which they are appropriate. The conditions that most strongly affect performance are the number and variety of targets, and their degree of movement.

Engage Air Targets. The basic purpose of engaging air targets is to destroy or neutralize them. The nature of the targets, their number, disposition, activity, etc., will affect friendly force ability to successfully engage them. The measures of this capability may include rate of fire, accuracy of fire (e.g., $p[h]$), maximum effective range, terminal effects (e.g., $p[k]$, jamming), etc. The conditions that will affect performance include the altitude and range of enemy air targets, weather, etc.

Deny Airspace to the Enemy. The basic purpose of denying airspace to the enemy is to control the airspace above the ground battle. The ability to perform this function depends on the ability to place friendly forces in positions where they can dominate the airspace. The measures of this capability may include the time required to emplace units and systems for engaging air targets, the ability to achieve high $p[h]$ potentials in the airspace being

covered, the size of the airspace that can be covered, the altitudes that can be covered, etc. The conditions that can affect performance of this function include the weather and the altitude of air targets.

Measures for the Command and Control BOS

The Command and Control BOS has four major functions; acquiring and communicating information and maintaining status, assessing the situation, determining actions, and directing and leading subordinate forces.

Acquire and Communicate Information and Maintain Status. The purpose of this function is to acquire and maintain information for use by military leaders at all echelons and to disseminate guidance, plans, orders, etc. to units, systems, and soldiers. The measures selected for this function must reflect the timeliness of the process, the capacity of the systems to handle information, and the accuracy with which information can be acquired and maintained. Measures could include the time required to prepare information for transmission, transmission time, and the time required to prepare it for military leaders. Additional measures could include storage capacity, print capacity, and accuracy of the transmission as well as the accuracy of distribution. The major conditions affecting performance of this function relate to the total information load on the system, the size of the area over which communications are being conducted (i.e., range), the electronic environment (natural and induced), etc.

Assess Situation. The purpose of this function is to evaluate incoming information on the status of the tactical battle to determine if action must be taken to initiate any changes. Measures for this function must address the ability to review, digest, and evaluate new information in light of all prior information. Measures could include the time required to synthesize new information with prior information and the accuracy with which determinations can be made that some action must be taken or that no action is necessary. The conditions that will impact performance include the information load as well as the size and scope of the operation being conducted.

Determine Actions. The purpose of this function is to identify alternative courses of actions, analyze them, and decide on a preferred one. Measures of this function should reflect the rapidity with which this process is carried out and the effectiveness of the course of action selected. Actual measures might include the time required to decide on a course of action, the doctrinal correctness of the course of action (can only be subjectively determined), the degree to which the probability of success will be enhanced by the new course of action (can only be subjectively determined), and the degree to which all available assets (i.e., units, systems soldiers) are being utilized in the plan. The conditions that affect performance include the quality and clarity of the information on which the decision must be made, the size and scope of the operation being conducted, etc.

Direct and Lead Subordinate Forces. The purpose of this function is to ensure that the commander's concept of an operation is understood and properly implemented. Measures of this function should address the clarity of orders and the speed with which they are

promulgated to the field. Orders should be as brief as possible given the nature of the operation being described. Possible measures include the time required to issue orders, the brevity and clarity (i.e., lack of ambiguity) of the orders (can only be subjectively determined), and the ability of the military leader to add combat value to his subordinate units through his personal involvement or presence (difficult to measure or predict but easy to estimate in retrospect). The conditions that most affect performance may be the scope and complexity of the operations being conducted and the quality of the information available to military leaders.

Measures for the Intelligence BOS

The Intelligence BOS consists of three functions; collecting intelligence, processing information, and preparing intelligence reports.

Collect Intelligence. The basic purpose of this function to collect information on the enemy, weather, and geographic features that supports the development of a timely and accurate picture of the tactical situation on the battlefield. Clearly, the enemy is not a passive player in this process. The enemy will try to withhold such information from friendly forces and will attempt to mislead friendly forces as to the intention and disposition of his forces. The most obvious measure related to the collection of weather information might be the accuracy of forecasts (or elements of forecasts such as the degree of cloud cover, temperature, winds, etc.) as a function of how far in advance projections are made. Measures for the collection of information on the enemy could include the accuracy of the identification of enemy units or targets (what kind and friendly vs. enemy), the accuracy of locating enemy units or targets on the battlefield, and the timeliness of the information. The key conditions influencing the performance of this function include the weather, the electronic environment, the distance between friendly forces and enemy forces, etc.

Process Information. The purpose of this function is to take raw information and convert it into intelligence information that can be used to support the commander's planning process. Measures for this function must address the ability to evaluate new information in light of prior information, reconcile information from different sources, determine impacts of new information on current and projected operations, reassess enemy intentions, and develop targeting information. The value of any intelligence information concerning the enemy rapidly declines over time. Measures of this function include the time required to process intelligence information, the accuracy of the intelligence (e.g., in terms of distinguishing friendly from enemy targets and in locating them), the accuracy of predictions about the enemy's future actions (can only be determined subjectively, or after the fact), etc. The conditions which have the greatest influence on performance include the scope and quantity of incoming information, its quality, and its timeliness.

Prepare Intelligence Reports. The purpose of this function is to document intelligence information for use by military leaders. Measures for this function include the time required to prepare reports, the brevity and clarity of the reports (can only be evaluated subjectively),

and the consistency between the reports and the intelligence information generated. The conditions which have the greatest impact on performance are the scope and quantity of intelligence information, its internal consistency, etc.

Measures for the Mobility and Survivability BOS

The Mobility and Survivability BOS consists of three major functions; providing mobility, providing countermobility, and enhancing survivability.

Provide Mobility. The purpose of this function is to provide freedom of movement on the battlefield for friendly forces in the face of natural (i.e., terrain) or induced (i.e., enemy) obstacles. The execution of this function is dependent on the particular situation of the friendly forces. Measures for this function might include the capacity of friendly forces for reducing and clearing constructed obstacles and mines, the ability of systems or units to self-breach gaps, the maximum size gaps that can be breached, the rate at which road or airfield repairs can be made (e.g., tons of asphalt patching per hour), etc. The major conditions that will impact performance include terrain and the type and extent of constructed obstacles.

Provide Countermobility. The purpose of this function is to create obstacles to the enemy's mobility on the battlefield. The effectiveness of these obstacles will depend heavily on the nature of the terrain involved and the capabilities of enemy forces. Measures of this ability could include the capacity for emplacing constructed obstacles or mines (i.e., types of obstacles, size of obstacles), the rate at which mines can be emplaced (e.g., in terms of numbers or explosive power), the durability or persistence of obstacles (e.g., chemical), and the ability to accurately place obstacles. Conditions that will affect performance include the capabilities of enemy forces (land-based obstacles will not be effective against an enemy air threat), the mobility capabilities of the enemy, weather (e.g., wind currents, temperature gradients), etc.

Enhance Survivability. This function involves taking actions to protect friendly forces by active means (e.g., preparing protective positions) or passive means (e.g., denying friendly indicators to the enemy or purposely misleading the enemy). Performance depends in large part on the capabilities of the enemy in a particular situation. Measures for this function might include the protection levels (e.g., ballistic, chemical) of fighting positions, of weapon systems, or of personal equipment and the time required to prepare positions or don the protective equipment. Measures might also include the degree to which friendly auditory, electronic, or visual indicators are generated by friendly forces (the less the better), the capacity (or rate) of friendly forces to decontaminate personnel and systems, the rate at which explosive ordnance can be defused, the capacity for projecting smoke/or other obscurants (i.e., in terms of amount, range, persistence, reduction in visibility), the ability to provide the enemy with false indicators. etc. The conditions which impact performance include the weather and terrain.

Measures for the Combat Service Support BOS

The Combat Service Support BOS consists of the following functions; fixing, manning the force, distributing, providing sustainment engineering, and providing military police support.

Fix. The basic purpose of this function is to preserve the availability of weapon systems and equipment. Measures of this function include the rate at which systems can be recovered from the battlefield, the time required to diagnose and to repair systems, the availability of parts (e.g., time to acquire parts), and the rate at which equipment can be returned to units on the battlefield. The conditions that will affect performance include the severity of the problems requiring repairs, the amount of equipment requiring repairs, etc.

Man the Force. The basic purpose of this function is to provide the soldiers and support them with field services, personnel service support, and health services. Measures for this function include the capacity (or time required) to provide field services (e.g., feeding, laundry), maintain personnel strength, or provide soldier support activities (e.g., time to deliver mail), provide finance services, conduct chaplaincy activities, perform public affairs services, provide legal service support, and to provide health services. In many cases, measures of effectiveness or accuracy may be appropriate as well. For example, the accuracy of medical diagnoses, number of errors in performing pay services, and the quality of the food served (can only be determined subjectively) might be used. The conditions which will affect these functions includes the relative location of the battlefield to the service support resources involved, the size and scope of the operations supported, etc.

Distribute. The purpose of this function is to provide all classes of supplies, equipment, and personnel to units as needed. Measures for this function include the rate at which supplies can be pushed or pulled forward (e.g., short tons per day, short ton miles per day), time required to load or unload transport vehicles, time required to procure or produce supplies, error rates in filling requirements for supplies, quality of supplies delivered (e.g., accuracy of maps, degree of resolution found in maps), etc. The conditions affecting performance include the quality of the transportation networks (e.g., roads), the distance over which distribution channels must operate, and the distance between the battlefield and the sources of supply. Table C-3 presents some examples of specific measures within the "Distribute" function.

Provide Sustainment Engineering. The purpose of this function is to restore, build, and maintain facilities that support combat operations. Measures for this function include the rate at which these activities can be conducted and sustained (e.g., miles of pipeline laid per day, number of feet drilled per day in well drilling), quality of construction materials produced (e.g., strength, durability), etc. Conditions affecting this function will be weather, terrain, etc.

Provide Military Police Support. The purpose of this function is to collect, evacuate, and intern enemy prisoners of war (EPW) and to enforce military law and order. Measures for these functions could include the capacity for moving and storing EPW and the ability

Table C-3. Measures for "Provide Transport Services" Function Within the Combat Service Support BOS

Functions	Purpose of Function	Common Measures	Key Conditions
7.5.1 Provide Transport Services	to provide for terminal operations and movement of materiel and personnel by any means	• loading/unloading rate • storage capacity • total volume/quantity/weight transported per day	• quality of transportation network • weather
7.5.1.2 Move/ Evacuate Cargo, Equipment and Personnel	to move physical resources on conveyances	• total volume/quantity/weight transported per day (e.g., short-ton miles)	• transportation network • weather
7.5.1.2.1 Move by Surface	to conduct surface transport	• carrier payload capacity • payload options per day short-ton miles	• terrain • transportation network development/status • hostile activity

to maintain law and order. For example, the maintenance of military law and order could be measured by the number of reported violations (i.e., preventative measure), the number of arrests (i.e., investigative measure), or a combined measure that reflects the effectiveness of the military police in making arrests for each reported violation, and in getting convictions for each arrest. The conditions will include the size and scope of the operations being conducted, to include measures of the total number of EPW, the size and political disposition of the civilian population in the area of operations, etc.

VARYING PERSPECTIVES ON THE VALUE AND USE OF MEASURES

The need for measures by various organizations involved in developing Army capabilities will vary depending on several factors. First, the perspective of the battlefield of various organizations could be quite different. For example, the measurement perspective of one organization might focus on combined arms operations while another organization might focus on the rate of movement attainable by an individual vehicle (e.g. Infantry Fighting Vehicle).

Secondly, the purpose for measurement may vary across organizations. One organization may be interested in predicting the consequences of function and task performance on operations (e.g., in force analysis studies) while another organization may be interested in the assessment of units, weapon systems, or soldiers against design or performance standards.

Combat Developer

The combat developer is responsible for the conduct of the Concept Based Requirements System (CBRS) and the Mission Area Analysis (MAA) process in order to identify problems and to recommend solutions in the areas of doctrine, training, leadership, organizations, and materiel. The focus of performance measurement in this context should be on operations that the Army must be able to conduct on the battlefield. It is the success or failure of these operations that should lead the Army to improve its capabilities. It is difficult, however, to make a direct translation between operational success and specific improvements to weapon systems. Therefore, linkages must be made between operations and the functions and tasks that enable the conduct of the operations. Operations templates may serve this purpose.

Using operations templates, assessments can be made of the doctrine (i.e., tactics and techniques) employed to conduct operations as well as the capabilities to perform various functions or tasks as determined by the organization of units, their training, and their equipment. Improvements to any function or task can then be examined in terms of the effects on the overall operation. The doctrine can also be varied to determine if different mixes of capabilities or different tactics can by itself improve operational performance.

Recommendations concerning specific changes in functional or task capabilities can be made in terms of quantified measures associated with the functions. These changes would, in turn, be linked to measures or indicators of overall operational success.

Doctrine Developer

The focus of measurement for the doctrine developer is on the ability of units to successfully execute operations. Operations are conducted through the synchronization of a variety of means that perform functions critical to the success of the operation. For example, in a recent RAND Corporation report (Goldsmith & Hodges, 1987), it was shown that offensive operations rarely succeeded at the National Training Center (NTC) when units failed to perform adequate reconnaissance. A review of the relevant doctrine indicated that insufficient emphasis was given in doctrinal manuals towards performing reconnaissance in the offense.

The doctrine developer must have a template of various operations that indicates which various functions or tasks must be performed, to what degree they must be performed, when they must be performed, and where they must be performed in order for an operation to be successful. Measures are required to quantify the extent to which these functions must be performed. Without such measures, there is no way for commanders to assess their ability to carry out operations. Thus, in the example given above, the unit commander must have some idea of the amount of resources he must devote to performing reconnaissance in order to ensure mission success.

Training Developer

The focus of measurement for the training developer is generally on those soldier, system, or unit tasks that are most critical to the mission of the unit (i.e., for unit training) or to the job of the soldier (i.e., for individual training). The selection of tasks, and consequently, measures for those tasks, depends on the use of the concept of "battle focus" to limit training to "a reduced number of vital tasks that are essential to mission accomplishment" (FM 25-100).

In addition to training for combat, trainers may examine the opportunities available to increase force capabilities through training. The focus here is on tasks that, if performed better, will favorably impact the force's ability to execute assigned operations. For example, in conducting offensive operations at the NTC, it was found that units failed to perform reconnaissance tasks adequately. While part of this failure may have been due to a lack of emphasis of the reconnaissance tasks in the doctrine, its correction will require greater emphasis by trainers. This training emphasis could correct a problem that might lead other organizations (e.g., defense contractors) to look towards other types of solutions, such as improved hardware.

The ability of the training developer to select measures is constrained by what can be measured. These measures do not reflect the full domain of possible performance measures and may not permit the trainer to measure the most critical aspects of performance. For example, the ability to engage enemy aircraft from the ground may not be directly measurable unless dummy targets or simulators are available. In the absence of such devices, trainers might have to focus on measures such as "the time required to set up a weapon and properly prepare it to fire".

The trainer's interest in measures is also limited to those aspects of performance that can be influenced by training (i.e., limited to aspects of human performance). Thus, trainers would not be interested in measuring the maximum engagement range of a weapon system. Rather, they might be interested in the ability of a gunner to determine whether a target is within range and then quickly and accurately aim and fire his weapon system at it.

Materiel Developer

The focus of performance measurement for the "materiel developer" will be on the tasks or functions performed by materiel systems. Measures of performance will be at the system/hardware level.

The "materiel developer" could view performance from several different perspectives. One perspective would look at performance solely in terms of the hardware. In this sense, the design of the hardware is what gets evaluated against performance goals. Thus, performance measures for a tank might be maximum maneuver speed or accuracy of the main gun ($p(h)$). Conditions might be set for assessing either of these measures. The subject of a performance test would be the design of the hardware.

However, from this hardware perspective, what might not be clear is the expected contribution of the soldier to performance. The speed with which a tank moves and the $p(h)$ of the main gun of a tank depend in large part on the ability of soldiers who operate the tank. While a tank may be capable of moving 50 km per hour, it may never achieve that speed on the battlefield. While the design of the main gun on the tank may permit a $p(h)$ of .7, it may never come close to achieving that degree of accuracy in a battlefield environment. In both cases, the soldier is a critical element of achieving design performance.

The second perspective would view the development of materiel as a system that includes both hardware and the soldier. From this perspective, the design of the hardware is a constraint on performance of the system. Thus, if the main gun of a tank is perfectly aimed at a target and, over repeated firings, has a $p(h)$ of .75, this provides a constraint on system performance. Even perfect performance by the gunner in aiming the main gun will not achieve any higher level of performance. However, the gunner may fall well short of the .75 $p(h)$ for any number of reasons. He may not be able to clearly see the target, aim the gun at the target, or fire the weapon while aiming. In particular, the soldier's performance may be sensitive to battlefield conditions. The conditions required for testing the "system" may be quite different than those required for testing the "hardware".

Operational Tester

The focus of measurement for the operational tester is on the "operation" of a weapon system or unit under realistic battlefield conditions. Measures used in operational testing will address previously defined standards of performance concerning the execution of selected functions and tasks by the system. The conditions must be carefully selected to represent the full range of conditions the system may have to operate under.

The purpose of measurement for the operational tester is to determine if the unit or system being tested can do what it was designed to do. The measures will therefore be limited to those variables addressed in requirements documents for that unit or system. For example, one of the requirements for the Light Infantry Division (LID) was that it be transportable by air in no more than 500 aircraft sorties. One requirement for the AAWS-M anti-tank weapon system is that it be able to destroy a Soviet tank with a frontal shot.

It is assumed in operational testing that, if a weapon system or unit meets the operational test standards, the resulting capability enhancement will enable the affected units to successfully execute operations that they could not execute without the additional capability. However, the perspective of the operational tester may not include, in some cases, the larger operational perspective. Thus, the development of the Cavalry Fighting Vehicle (CFV) resulted in a vehicle that could perform some specific tasks more effectively (e.g., engage enemy armored vehicles) than its predecessor. Operational tests demonstrated the effectiveness of the CFV on these tasks. However, when it was fielded, it was also observed that units equipped with the CFV did not perform their reconnaissance missions any better than units equipped with the predecessor system. A larger perspective in the operational testing process might have revealed that since units performing reconnaissance missions are advised not to decisively engage the enemy, it is not surprising that units equipped with CFVs performed no better on reconnaissance missions than units equipped with M113s.

Defense Contractor

The focus of measurement for the defense contractor will be on the requirements specified in his contract. If the contract only specifies hardware measures of performance, the defense contractor will be concerned with hardware performance and may ignore broader measures of the effectiveness of the system, that for example, might include consideration of the soldiers who must operate and maintain the hardware. If the contract specifies conditions under which performance must be demonstrated, then the contractor will focus on those conditions. If the contract fails to specify such operational conditions, the contractor will have little incentive to devise realistic ones for development purposes.

As with the case of the operational tester, the defense contractor will tend to focus on specified requirements and may neglect the bigger picture of units conducting operations on the battlefield.

Summary

The identification and use of measures in the CBRs process is essential to the effective quantification of capability issues, to the description and evaluation of potential capability improvements, and to the development and implementation of an integrated decision making system that produces the best overall investment strategy for the US Army.

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APPENDIX D

TAXONOMY OF BATTLEFIELD CONDITIONS

The measurement of military performance is key to fielding effective, ready forces. It is essential in conducting successful combat developments analysis, wherein the ability of friendly forces to execute assigned missions is examined and judgments are made about the adequacy of programmed forces and areas where performance should be enhanced. It is also essential prior to the fielding of new weapon systems and units to ensure that they will have the desired effects on the battlefield. Finally, it is essential as part of both the individual and collective training process to ensure that the ability of troops and units to perform their assigned tasks and missions meets or exceeds Army standards.

The measurement of military performance is difficult for several reasons. One reason is that performance is a complex construct. For example, it is difficult to develop a single overall measure of the performance of a tank battalion. Part of the difficulty is due to the fact that a tank battalion is capable of many different types of performance. It can maneuver on the battlefield; it can fire on the enemy; it can occupy terrain; it can survive attacks by the enemy; it can do many other things. As a result, it is difficult to reduce these many capabilities to a single measure of performance. Furthermore, even if it was decided to measure only one dimension of performance; say, mobility, the measurement of performance would still be difficult. This is because even one dimension of performance can be examined in terms of a wide range of measures. For example, the mobility of a tank battalion could be measured in terms of:

- its maximum range without refueling,
- the rate of speed with which it can move on land,
- time required to initiate movement, etc.

A second reason why the measurement of performance is difficult is due to the fact that performance is influenced by a number of variables external to the performance being measured. In this paper, we refer to these variables as conditions. Conditions are defined as:

“those variables of a battlefield environment or situation in which a unit, system, or soldier is expected to operate that may affect performance.”

In the example of a tank battalion used above, mobility will be influenced by terrain, weather, and other aspects of the battlefield situation. Specifically, the operating range of a tank battalion will be influenced by the terrain, which will, in turn, influence the rate of fuel consumption. The range will also be influenced by weather (e.g., fuel consumption may

be greater in cold climates). Finally, range will be influenced by the availability of fuel in the battalion at the start of an operation. These variables; that is, terrain, weather, and support status, are conditions that influence the performance of a tank battalion.

Therefore, in order to measure the mobility of a tank battalion, the state of these employment conditions must be specified. If the mobility of a tank battalion was assessed without specifying the status of conditions that can affect mobility, the resulting measure would be useless. It would be useless because no specific level of performance could be ensured on the battlefield without knowing under what conditions that level of performance would have to be achieved. Similarly, if a mobility standard was set for the development and fielding of a new type of tank battalion, one would not know whether the battalion actually achieved that standard unless some set of conditions could be agreed upon for the assessment of the battalion.

Thus, conditions must be specified for combat developments scenarios, for weapon system operational testing, and for realistically assessing unit, collective, and individual training and readiness.

Does a comprehensive conditions taxonomy already exist? The answer is no. There are a number of sources of information on conditions, but in each case the conditions list is either notional, specific to a limited set of conditions, or limited in its applicability. A partial list of these sources includes:

- FM 30-10. Military Geographic Intelligence (Terrain), March 1972.
- AR 70-38. RDT&E of Materiel for Extreme Climatic Conditions,
- TRADOC Pam 71-15. User Testing Methodology and Procedures, March 1983.
- MIL-STD-1165. Glossary of Environmental Terms (Terrestrial), March 1968.
- FM 21-33. Terrain Analysis, May 1978.
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Given the lack of a uniform source and the requirement for a comprehensive conditions list conducting capabilities analysis in the Army, such a list was developed. Before proceeding too far, it became evident that the term "conditions" must not only be carefully defined but also carefully distinguished from other related terms.

Definition of Conditions

As stated earlier, conditions are variables of the battlefield environment or situation that can affect performance. Thus, the air temperature would qualify as such a variable because (1) it is a variable of the battlefield environment (actually, of the natural environment) and (2) it can affect the performance of military functions and tasks.

Other examples of conditions are not as clear. For example, if one were examining the performance of a field artillery system or unit, one function that might be assessed is the ability of the system to engage targets. Several measures could be specified to assess performance, including:

- the accuracy of fires,
- the response time and delivery rate of fires,
- the lethality of fires, and
- the range of fires.

If you decided to measure accuracy, you would want to list the conditions that affect it. Obviously, one condition that affects accuracy is the relative position, or range, to the target being fired at. In general (except for precision guided munitions), the greater the range the worse the accuracy. Thus, in measuring accuracy of fires, one important condition to consider is range.

To complicate matters, however, range can also be a measure of the performance of a field artillery system. Thus, both the dimension of performance being examined and the measure used to index performance combine to provide a perspective that determines which variables will be conditions of performance and which ones will be measures of performance.

As a result, conditions may, for some applications, serve as measures of performance.

Conditions of the operational environment, such as factors associated with enemy forces that affect performance, must also be distinguished from the mission, functions, and tasks performed by the force. Thus, the mission may be to defend a position against an attack by a mechanized enemy force. The specific characteristics of the enemy force that affect the ability of the friendly force to execute it's mission are conditions of the operational environment. These conditions are not inherent in the mission, but are variable depending on the characteristics of the forces involved (friendly and enemy) and on any constraints imposed on the use of military force.

Macro- and Micro-Conditions

Conditions can refer to the general level of conditions variables found on the battlefield (macro-conditions) or to localized, specific conditions variables (micro-conditions). For example, climate represents the average weather for a region. This is certainly a macro-condition. It is general both with respect to place (i.e., region) and time (i.e., season). A terrain major landform is also a macro-condition because it is general with respect to place. Thus, even in a mountainous region, there may be a suitable location for an airfield.

Weather is more of a micro-condition, because it refers to the state of the atmosphere at a particular time. For example, the air temperature is 75 degrees F at a particular time and place. Also, the specific characteristics and location of a canyon, mesa, butte or other surface relief feature would constitute a micro-condition.

For the purposes of performance measurement, the specification of micro-conditions is generally required, particularly when the specific time or location of a condition will affect the outcome of performance measurement.

Organization of Conditions

Users would undoubtedly prefer an ordered, indentured list of conditions to one that is unstructured. One reason is that an ordered list may allow the user to work in a top-down fashion in constructing a set of conditions. In order to develop a structured list, several criteria must be identified which can be used to organize the conditions into smaller groups. First of all, conditions can be separated into those that are part of the area environment and those operational conditions that are linked to the forces on the battlefield. The environmental conditions include the natural elements of the weather and terrain. The operational environment pertains to conditions related to both friendly and enemy forces that influence performance.

Area environmental conditions can be classified into categories on two dimensions. The first dimension is whether the condition is natural or induced. Natural conditions are more enduring than induced conditions. Natural conditions, in this sense, include structures such as roads, buildings, airfields, etc., because of their permanence. Induced conditions are those temporary conditions created in support of military operations, such as an induced chemical environment. The second dimension is whether the condition is atmospheric or terrestrial (i.e., weather, terrain).

Operational environmental conditions pertain to the implications on performance of the disposition, composition, and strength of both friendly and enemy forces as well as any constraints placed on the friendly force. Thus, the ability to detect targets depends on conditions of the operational environment such as location of the targets, movement, degree of target dispersion, size of the targets, etc. Similarly, the ability to remain undetected by enemy forces (through OPSEC) depends on various characteristics of the friendly forces as well as the capabilities and disposition of enemy forces.

This appendix presents a list of conditions organized by the categories described above as a taxonomy or indented list. The organization will help users to both comprehend the list as well as to apply it.

Criteria for Assessment

An effective conditions list is one that is comprehensive, efficient, and applicable. By comprehensive, we mean that it includes all those conditions that have significant impacts on the performance of military units, systems, and soldiers. By efficient, we mean that it contains the smallest number of elements necessary to represent the entire domain of conditions. By applicable, we mean that it is understandable to users and that it is relevant to a variety of users (i.e., combat developers, trainers, operational testers).

OVERVIEW OF CONDITIONS TAXONOMY

A conditions taxonomy delineates and defines the entire set of environmental and operational factors that affect the performance of military forces. A number of sources already exist for these types of factors; dictionaries of environmental terms, field manuals for specific operating environments, and pamphlets describing analytic processes (e.g., operational testing).

In order to organize the conditions taxonomy in a manner acceptable to military analysts, planners, and commanders, constructs were used with which they are familiar. These constructs include analyses of the area of operations, commander's estimates of the situation, and the military decision making process.

A top level view of the spectrum of combat conditions is shown in Figure D-1. The traditional elements of this taxonomy are reflected by the "Area Environment" which includes the natural environment as well as military and civilian alterations to it. The conditions taxonomy also includes those conditions caused by the nature of the military operation itself and the resistance (by the threat forces) to its execution. We have termed these as conditions of the "operational environment" and defined them as the situational factors that affect the employment of military forces on the battlefield. This includes constraints associated with the mission and factors associated with the enemy and the friendly situations.

Area Environment

The area environment consists of those factors that are "natural" insofar as they are unaltered for military purposes or unimproved by civilization. The area environment also includes those relatively permanent aspects of the environment created by the military (e.g., military airfields) or by civilization (e.g., transportation routes) that affect military operations.

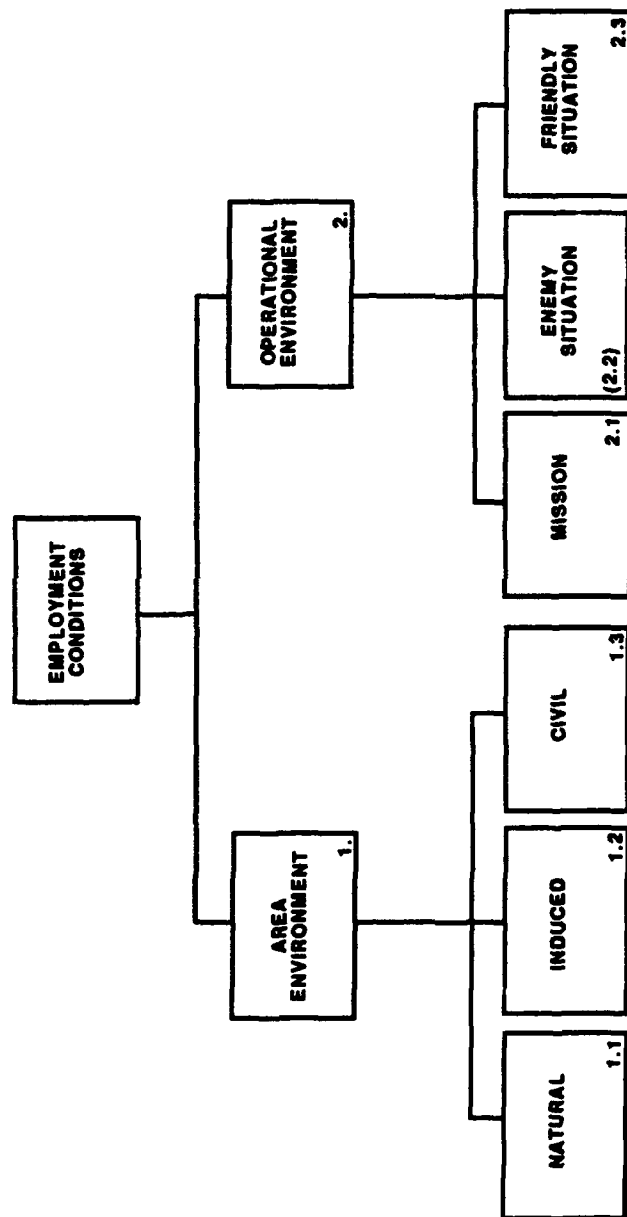


Figure D-1. Conditions Affecting Military Operations

The conditions comprising the natural environment are shown in Figure D-2. The two major factors of the natural environment are weather and terrain. Weather factors reflect the status of the atmosphere as it affects military operations. Weather patterns may also be identified and placed into climatic categories (i.e., macro-conditions).

Terrain features include those relatively permanent aspects of terrain that have implications for military operations. These could include surface relief, characteristics of the surface itself, drainage, vegetation, and products of civilization (such as built-up areas and transportation routes).

Induced conditions of the environment, summarized in Figure D-3, are those impermanent aspects of the environment created in support of military operations. They include various types of nuclear, chemical, electromagnetic, obstacle, obscurant, and illumination effects.

The civil environment encompasses the customary beliefs, social norms, behavior patterns, institutions, and other products associated with ordinary community life. The factors of the civil environment are displayed in Figure D-4. These factors affect the ability to conduct military operations free of interference, or with support, from the civilian sector in the area of operations.

Operational Environment

The operational environment, as shown in Figure D-5, includes those factors of the mission, enemy situation, and friendly situation that may affect how military units, systems, and soldiers are employed and perform.

Missions specify the performance objectives of a military action as well as describing the type of military action to be carried out. However, there are other aspects of the mission that act as conditions, influencing the ability of military forces to achieve their assigned objectives. These factors include constraints of time, space, and support as well as constraints on the use of various military capabilities such as nuclear and chemical weapons.

Factors associated with the enemy situation such as the disposition, composition, and strength of his forces will also influence the performance of military forces. As a result, these factors act as conditions on the friendly force. For example, the extent to which enemy forces are dispersed will influence the ability of friendly forces to detect enemy targets.

Factors associated with the friendly situation such as the disposition, composition, and strength of his forces will also influence the performance of friendly military forces. For example, the ability of friendly forces to hit enemy targets will be affected by the movement of friendly forces. Also, the dispersion of friendly forces will affect their ability to survive enemy fire support attacks.

Summary

Table D-1 provides the complete listing and definitions of the conditions taxonomy.

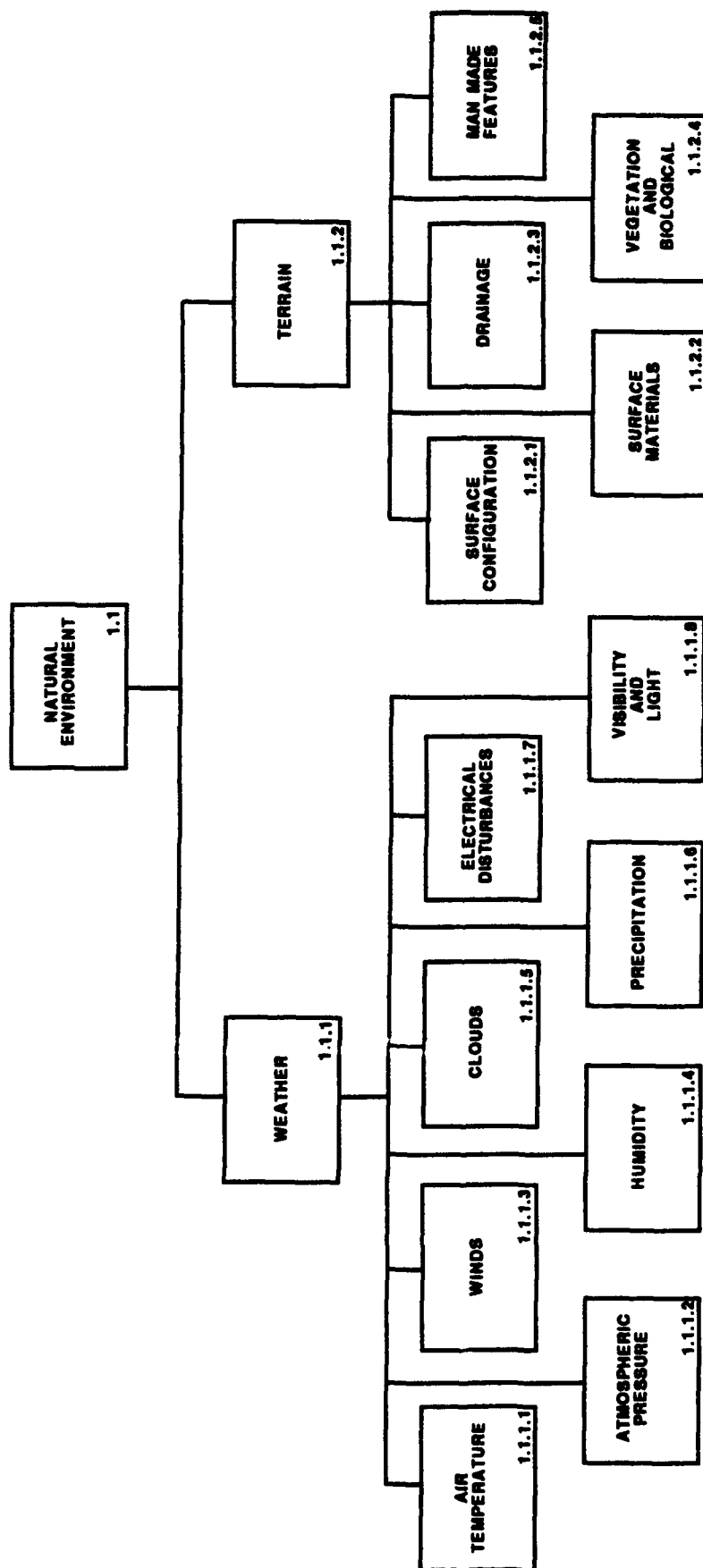


Figure D-2. Area Environment (Natural)

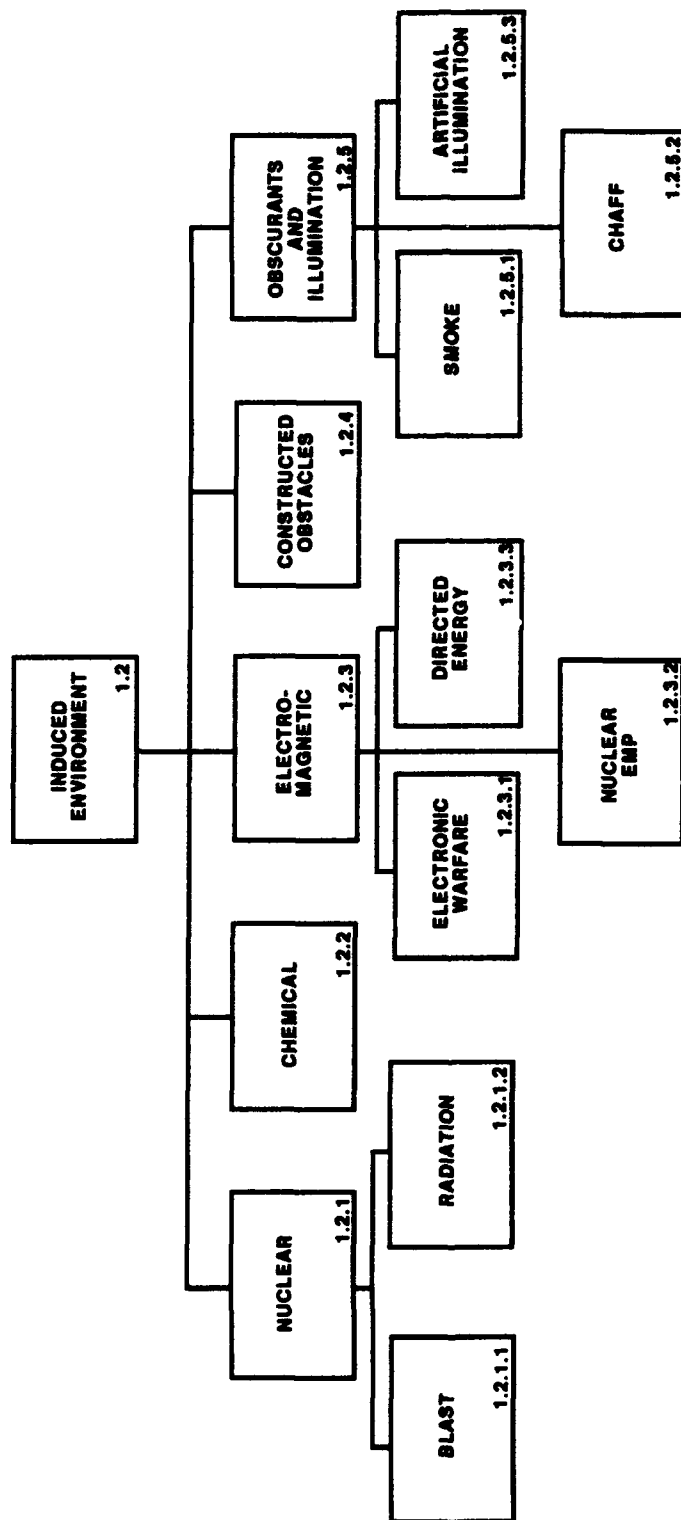


Figure D-3. Area Environment (Induced)

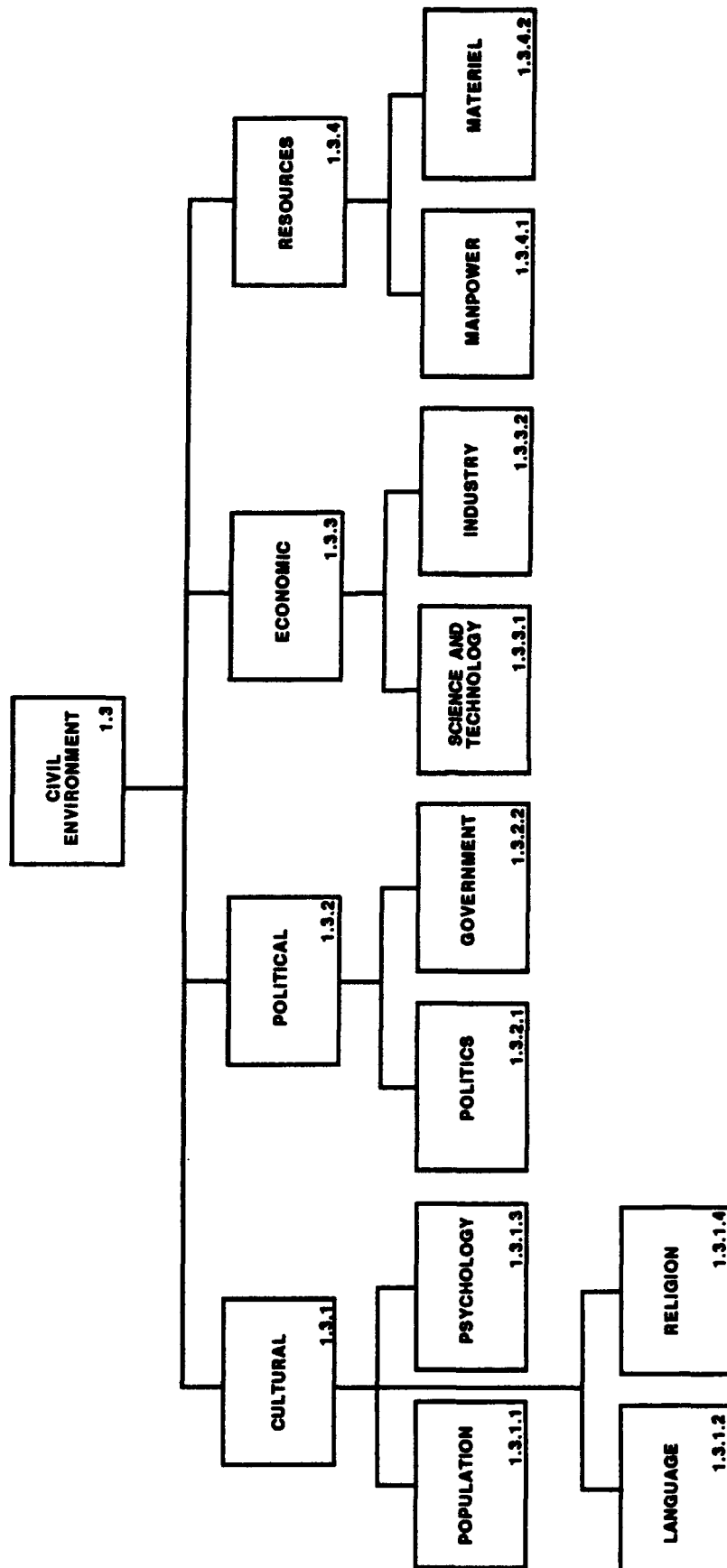


Figure D-4. Area Environment (Civil)

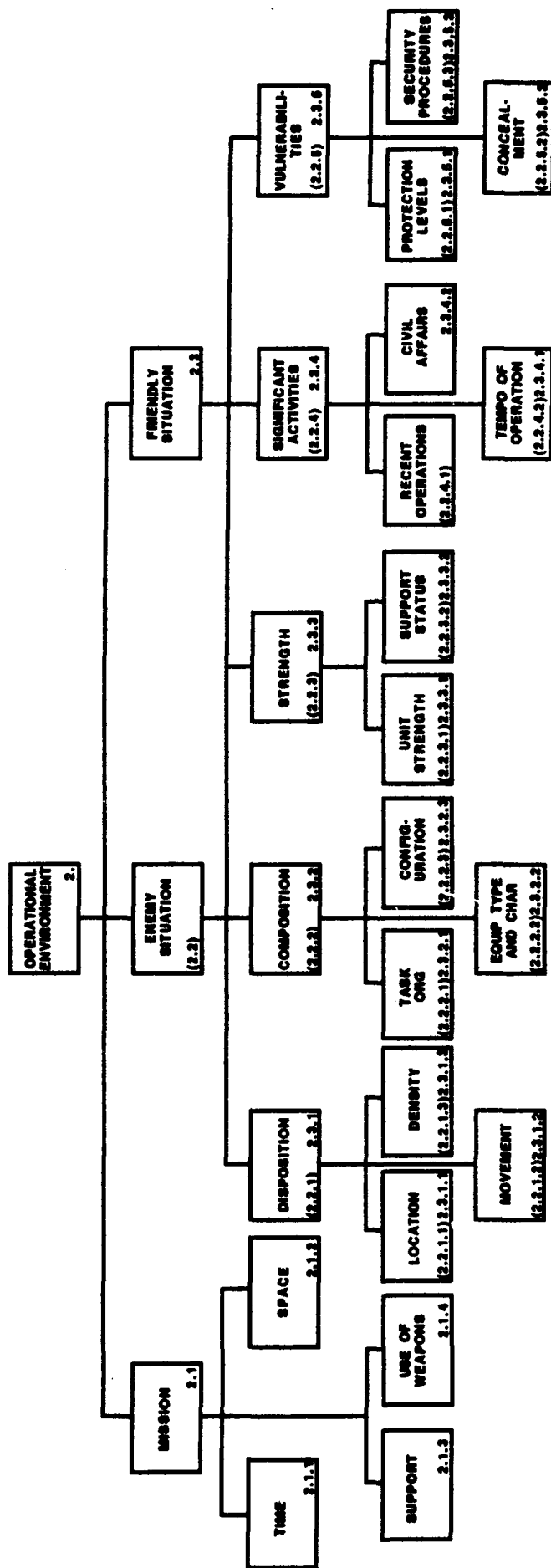


Figure D-5. Operational Environment

TABLE D-1
CONDITIONS TAXONOMY

1. Area Environment – The total set of physical conditions of the environment (natural or man-induced) that influence the performance of units, systems, and soldiers.

1.1 Natural Environment – The physical environment unaltered for the purpose of military operations.

1.1.1 Weather – State of the atmosphere. General variation and pattern of changes in atmospheric conditions determine regional climate type: tropical, dry, humid, and polar.

1.1.1.1 Air Temperature

1.1.1.1.1 Range

1.1.1.1.2 Variability

1.1.1.1.3 Extremes

1.1.1.1.4 Duration

1.1.1.1.5 Altitude Above Ground

1.1.1.2 Atmospheric Pressure

1.1.1.3 Winds

1.1.1.3.1 Direction

1.1.1.3.2 Speed

1.1.1.3.3 Turbulence

1.1.1.4 Humidity

1.1.1.5 Clouds

1.1.1.5.1 Type

1.1.1.5.2 Height (base and top)

1.1.1.5.3 Coverage (clear, scattered, broken, overcast)

1.1.1.6 Precipitation

1.1.1.6.1 Type (visible moisture)

1.1.1.6.2 Duration (continuous, intermittent, shower)

1.1.1.6.3 Intensity (fall rate, visibility reduction)

1.1.1.7 Electrical Disturbances

1.1.1.7.1 Lightning

1.1.1.7.2 Solar Storms

1.1.1.8 Visibility and Light

1.1.1.8.1 Smoke

1.1.1.8.2 Dust

1.1.1.8.3 Fog

1.1.1.8.4 Haze

1.1.1.8.5 Illumination

1.1.1.8.5.1 Twilights Beginning/Ending

1.1.1.8.5.2 Moon Phase/Rise/Set

1.1.1.8.5.3 Star Brilliance

TABLE D-1
CONDITIONS TAXONOMY (Continued)

1.1.2 Terrain – A portion of the earth's surface, including natural (physical, biological) and manmade features. The distinction between natural and manmade features is not clearcut. Any and all natural terrain factors can be changed by human activities. Note: Terrain conditions are inputs to analysis of military aspects of terrain on courses of action (key terrain, observation and fields of fire, concealment and cover, obstacles, and avenues of approach).

1.1.2.1 Surface Configuration (Relief/Elevation) – The geometric shape, size, arrangement, and profile of the earth's surface features. Patterns or areas of similar major relief features define major landforms: plains, hills, and mountains.

1.1.2.1.1 Minor Relief Features

- 1.1.2.1.1.1 Highground (mesas, buttes, ridges, dunes)
- 1.1.2.1.1.2 Depressions (basins, canyons, wadis)
- 1.1.2.1.1.3 Breaks in Highground (passes, gaps)
- 1.1.2.1.1.4 Special Features (talus slopes, boulder fields)

1.1.2.1.2 Microrelief Features (low escarpments, stream banks, pits, dikes, swales, kames, moraines)

1.1.2.1.3 Elevation/Slope

- 1.1.2.1.3.1 Shape (convex, concave, uniform)
- 1.1.2.1.3.2 Angle (percent, degrees, gradient)

1.1.2.2 Surface Materials

1.1.2.2.1 Soil

- 1.1.2.2.1.1 Composition (gravel, sand, silt, clay)
- 1.1.2.2.1.2 Depth
- 1.1.2.2.1.3 Moisture
- 1.1.2.2.1.4 Layering

1.1.2.2.2 Rock

- 1.1.2.2.2.1 Formation Class (igneous, sedimentary, metamorphic)
- 1.1.2.2.2.2 Thickness

1.1.2.2.3 Trafficability (Cross-country)

1.1.2.3 Drainage

1.1.2.3.1 Watersheds, Watercourses, and Water Bodies (stream, river, creek, canal, lake)

- 1.1.2.3.1.1 Flow Velocity, Tidal Effects, Flooding Potential
- 1.1.2.3.1.2 Crossings
- 1.1.2.3.1.3 Banks/Shore (composition, height, condition)
- 1.1.2.3.1.4 Adjacent Terrain
- 1.1.2.3.1.5 Dimension (width, depth)

1.1.2.3.2 Wet Areas (Swamp, marsh, bog, paddy)

- 1.1.2.3.2.1 Inundation Causes
- 1.1.2.3.2.2 Crossings
- 1.1.2.3.2.3 Flooding Potential

TABLE D-1
CONDITIONS TAXONOMY (Continued)

- 1.1.2.4 Vegetation and Biological
 - 1.1.2.4.1 Trees
 - 1.1.2.4.1.1 Canopy Height and Closure
 - 1.1.2.4.1.2 Density and Trunk Diameter
 - 1.1.2.4.2 Shrubs (hedgerows)
 - 1.1.2.4.3 Grasses and crops
 - 1.1.2.4.4 Microorganisms
- 1.1.2.5 Man-made Features – Relatively permanent man-made changes to the natural landscape. These features generally support the civilian infrastructure although, in wartime, they may support military operations.
 - 1.1.2.5.1 Building and Settlement
 - 1.1.2.5.1.1 Urban
 - 1.1.2.5.1.2 Rural
 - 1.1.2.5.1.3 Industrial (factories, mines)
 - 1.1.2.5.2 Transportation Routes
 - 1.1.2.5.2.1 Highways
 - 1.1.2.5.2.2 Railways
 - 1.1.2.5.2.3 Pipelines
 - 1.1.2.5.2.4 Structures and Crossings
 - 1.1.2.5.2.5 Ports, Harbors, Airfields
 - 1.1.2.5.3 Military Sites/Fortifications
 - 1.1.2.5.4 Utility and Communication Networks
- 1.2 Induced Environment – Impermanent changes to the physical environment resulting from actions designed to support military operations.
 - 1.2.1 Nuclear
 - 1.2.1.1 Blast
 - 1.2.1.2 Radiation
 - 1.2.1.2.1 Nuclear (initial, residual)
 - 1.2.1.2.2 Thermal
 - 1.2.2 Chemical
 - 1.2.3 Electromagnetic
 - 1.2.3.1 Electronic Warfare
 - 1.2.3.2 Nuclear Electromagnetic Pulse
 - 1.2.3.3 Directed Energy
 - 1.2.4 Constructed Obstacles
 - 1.2.5 Obscurants and Illumination
 - 1.2.5.1 Smoke
 - 1.2.5.2 Chaff
 - 1.2.5.3 Artificial Illumination

TABLE D-1
CONDITIONS TAXONOMY (Continued)

1.3 Civil Environment – Customary beliefs, social norms, behavior patterns, institutions and all other products of, or pertaining to, ordinary community life.

1.3.1 Cultural

1.3.1.1 Population

1.3.1.2 Language

1.3.1.3 Psychology

1.3.1.4 Religion

1.3.2 Political

1.3.2.1 Politics

1.3.2.2 Government

1.3.3 Economic

1.3.3.1 Science and Technology

1.3.3.2 Industry

1.3.4 Resources

1.3.4.1 Materiel

1.3.4.2 Manpower

2. Operational Environment – Factors related to forces on the battlefield that affect their performance.

2.1 Mission Constraints – Those constraints on military actions that affect the ability of a military force to achieve its assigned objectives.

2.1.1 Time

2.1.2 Space

2.1.3 Support

2.1.4 Use of Weapons (nuclear, chemical)

2.2 Enemy Situation – Factors related to the enemy force that could affect mission accomplishment.

2.2.1 Disposition

2.2.1.1 Location (grid, altitude)

2.2.1.2 Movement (direction, rate)

2.2.1.3 Density (point, area)

2.2.2 Composition

2.2.2.1 Task Organization

2.2.2.2 Equipment Types and Characteristics

2.2.2.3 Configuration (mission equipment, loads)

2.2.3 Strength

2.2.3.1 Unit Strength (committed, reinforcements)

2.2.3.1.1 Personnel (percent of authorized, moral, training)

2.2.3.1.2 Equipment (percent combat ready)

TABLE D-1
CONDITIONS TAXONOMY (Continued)

- 2.2.3.2 Support Status
 - 2.2.3.2.1 Combat Support (air, nuclear, chemical)
 - 2.2.3.2.2 Combat Service Support
- 2.2.4 Significant Activities
 - 2.2.4.1 Recent Operations
 - 2.2.4.2 Tempo of Operations
- 2.2.5 Vulnerabilities
 - 2.2.5.1 Protection Levels (ballistic, chemical, electronic)
 - 2.2.5.2 Concealment (positioning)
 - 2.2.5.3 Security procedures
- 2.3 Friendly Situation – Factors related to friendly forces that could affect mission accomplishment.
 - 2.3.1 Disposition
 - 2.3.1.1 Location (grid, altitude)
 - 2.3.1.2 Movement (direction, rate)
 - 2.3.1.3 Density (point, area)
 - 2.3.2 Composition
 - 2.3.2.1 Task Organization
 - 2.3.2.2 Equipment Types and Characteristics
 - 2.3.2.3 Configuration (mission equipment, loads)
 - 2.3.3 Strength
 - 2.3.3.1 Unit Strength (committed, reinforcements)
 - 2.3.3.1.1 Personnel (percent of authorized, morale, training)
 - 2.3.3.1.2 Equipment (percent combat ready)
 - 2.3.3.2 Support Status
 - 2.3.3.2.1 Combat Support (air, nuclear, chemical)
 - 2.3.3.2.2 Combat Service support
 - 2.3.4 Significant Activities
 - 2.3.4.1 Tempo of Operations
 - 2.3.4.2 Civil Affairs
 - 2.3.5 Vulnerabilities
 - 2.3.5.1 Protection Levels (ballistic, chemical, electronic)
 - 2.3.5.2 Concealment (positioning)
 - 2.3.5.3 Security Procedures

USES FOR CONDITIONS TAXONOMY

A comprehensive, efficient conditions taxonomy has a number of obvious uses in supporting performance measurement. Some of these uses include:

- scenario development,
- studies and analysis,
- unit/system design and development,
- field testing, and
- unit training.

As Figure D-6 illustrates, these uses are not independent of one another. It is important that battlefield conditions be traceable from scenarios, to studies and analysis, and right on through unit training.

The Conditions Sampling Problem

The complete list of conditions in the conditions taxonomy and the complete range of levels for each condition provide an enormous domain of possible environments in which military operations could take place. Therefore, in any application of the conditions taxonomy, it will be impossible to examine a very large sample of conditions from the total domain available. As a result, care must be taken to select a set or sets of conditions that:

- are reasonable and internally consistent, given the likely threats to US security,
- do not avoid conditions that, while unlikely, could have serious consequences on the use of military force (e.g., chemical threat), and
- includes combinations of conditions that strongly interact with one another.

Each set of conditions makes a unique set of demands on the military forces being examined. Consequently, care should be taken not to generalize the performance found under one set of conditions to other possible sets of conditions. The following paragraphs describe the various applications for a conditions taxonomy.

Scenario Development

A scenario is defined in TRADOC Reg 71-4 (1987) as "a graphic and narrative description of the area, environment, forces, and events of a hypothetical armed conflict during a predetermined time frame. It reflects currently approved assumptions, Red and Blue force structures, terrain, operational art, and tactics. A scenario portrays approved doctrinal and operational concepts in selected situations under simulated conditions". From the perspective of assessing performance, scenarios are important in that they provide a framework for

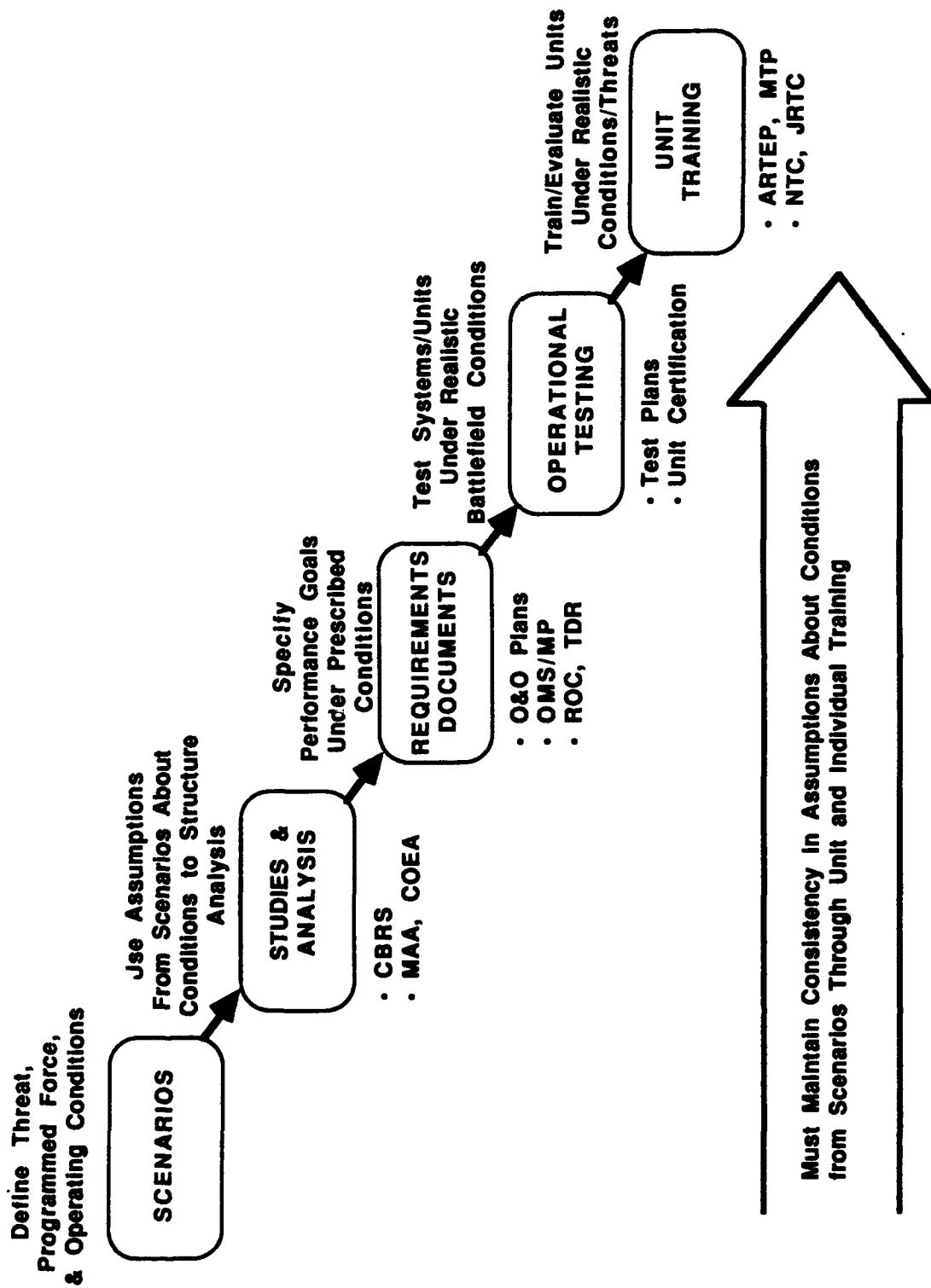


Figure D-6. Importance of Specifying Combat Conditions

measuring and comparing the effectiveness of alternative forces and doctrine. The specification of the environment, situation, and conditions is a key element of providing a useful structure.

As stated in TRADOC Pam 11-8, "Scenarios provide a common framework of selected situation and real world conditions...that enable analysts to investigate force capabilities under a wide variety of situations, terrain, and environmental conditions". A common framework of conditions would appear to be most useful in standardizing the construction of these scenarios.

Studies and Analysis

The Army routinely conducts studies of doctrinal, training, organizational and materiel effectiveness. The focus of these studies can be on units, systems, or soldiers. The objective is almost always to assess performance or to find ways to improve battlefield performance (i.e., operational effectiveness). The result of a study could, for example, be a recommendation for development of a new weapon system. Of course, proposals for new weapon systems would have to state the levels of performance required by the system. As stated in TRADOC/AMC Pam 70-11, "an integral part of the analysis is the determination of...the conditions under which (tasks) are performed".

If, after conducting a study, a decision is made to proceed with a materiel development, an Operational and Organizational (O&O) Plan must be prepared. Part of the O&O Plan is an Operational Mode Summary and Mission Profile, which is simply a list of assumptions about the conditions under which the weapon system will have to operate.

Unit/System Design and Development

The preparation of requirements documents and subsequent design and development of units and systems must include attention to conditions of the battlefield that affect performance. For example, in preparing Required Operational Capability (ROC) statements, AMC/TRADOC Pam 70-2 states that "Performance characteristics must be responsive to battlefield conditions for continuous combat (such as full ECM, directed energy, obscurants, electromagnetic environmental effects, rain, fog, haze, and dust).

Similarly, TRADOC/AMC Pam 70-11 states that the specification of conditions "helps the design engineers develop equipment that will operate in the full range of environmental conditions the system is expected to encounter".

Field Testing

The fielding of new systems or units requires that they be mission capable. The purpose of field testing is to ensure that units and systems meet the demands imposed on them by the battlefield. TRADOC Pam 71-3 states that "Test conditions are the conditions under which the test will be conducted. Included is a statement of those factors (the independent variables) expected to critically influence the operational effectiveness of the tested system

and how each factor is to be treated in the test. For example, weather is a factor which is considered. Weather conditions in a test might be favorable versus adverse; or there may be several weather conditions such as hard rain, light rain, fog, overcast, and clear; or there might be a more complex set of weather conditions taking into account wind speeds, precipitation rates, temperature gradients, and humidity. In any case, the conditions required in the test are stated. Other factors include tactical situations, terrain, day/night, personnel fill level, state of training, and any other conditions which might reasonably be expected to influence the operational effectiveness of a system in the field."

In the development of a test design a number of key elements of the Test Design Plan Review Checklist (TRADOC Pam 71-15) pertain to conditions on the battlefield. Some of these questions include:

- Are all the factors (conditions) which might reasonably be expected to influence the operational effectiveness....listed?
- Is there at least one condition (level) stated for each factor (condition)?
- Are stated conditions as operationally realistic as possible?
- Are combinations of conditions stated?

In summary, the test plan must describe a set of realistic battlefield conditions that show *interaction among threat, friendly actions, and environment involving the tested system*". Realistic battlefield environmental conditions are those natural and artificial (tactical) (friendly and/or enemy induced) elements employed for the conduct of operational testing.

Unit Training

After systems and units are fielded, unit commanders are responsible for maintaining readiness. This is accomplished through the use of a mix of training and evaluation tools (e.g., ARTEP, Mission Training Plans) as well as rotations through field training centers (e.g., NTC, JRTC). To properly accomplish training in these situations, conditions must be specified under which systems and units may be expected to operate. Thus, if it is expected that the Army will fight in a chemical environment, training should be conducted either in a simulated chemical environment or in a way that provides evidence of the ability of a unit or system to execute it's assigned missions in that environment.

LIST OF REFERENCES

- FM 30-10. Military Geographic Intelligence (Terrain), March 1972.
- AR 70-38. RDT&E of Materiel for Extreme Climatic Conditions.
- TRADOC Pam 71-15. User Testing Methodology and Procedures, March 1983.
- MIL-STD-1165. Glossary of Environmental Terms (Terrestrial), March 1968.
- FM 21-33. Terrain Analysis, May 1978.
- TRADOC Pam 11-8. Studies and Analysis Handbook, July, 1985.
- FM 101-5. Staff Organization and Operations (Appendix D - Analysis of the Area of Operations), May 1984.

APPENDIX E

FORMATS FOR ARMY REQUIREMENTS DOCUMENTS

This appendix contains information on how to format requirements documents associated with Army weapon system acquisitions. The following format information is provided:

<u>TITLE</u>	<u>PAGE</u>
Format for Operational and Organizational Plan	E-2
Format for Justification for Major System New Start (JMSNS)	E-3
Format for Required Operational Capability (ROC), Joint Service Operational Requirement (JSOR)	E-4
Sample Target Audience Description	E-5
Data Item Description for the System/Segment Specification (SSS)	E-14

Format for Operational and Organizational Plan

B-1. Title

- a. Descriptive program title.
- b. CARDS Reference Number: (assigned by ODCSOPS after approval).

B-2. Need

- a. Describe the need for a materiel capability to eliminate one or more operational deficiencies.
- b. State where in the MAA (or other study) the deficiency is identified. Describe the operational deficiency to be eliminated or the opportunity to be exploited.

B-3. Threat

- a. *Threat to be encountered.* Describe the threat capability, current and projected, the proposed system will be required to defeat on the battlefield. If it will not defeat a threat capability, then so state.
- b. *System vulnerability.* Describe the threat capability, current and projected, to destroy, neutralize, or degrade the operational effectiveness of the proposed system.

B-4. Operational Characteristics

Describe in broad bands the main operational characteristics of the capability. (For example, a capability is needed to defeat enemy armor at "X-Y" kilometers; to lift a payload of "X-Y" thousand pounds; transport "X-Y" number of troops with combat gear for "A-B" kilometers, etc.)

B-5. Operational Plan

Describe in general terminology how, what, when, and where the system will be employed on the battlefield and how it will interface with other systems.

B-6. Organizational Plan

Identify the type units that will employ and support the system and, when appropriate, the system(s) to be replaced.

B-7. System Constraints

Describe constraints that may limit an acceptable solution to the need, such as mobility, transportability, logistics, MANPRINT, environmental, communications, directed energy survivability, etc.

B-8. Standardization and Interoperability

- a. Discuss other services' interest in the program identified during staffing. Identify similar programs contemplated by other services or allied nations.
- b. Describe standardization, interoperability or commonality constraints that apply, because of other Army, other service or allied nation missions, tasks, relationships or systems.

B-9. Funding Implications

Provide gross estimates of: (a) total RDTE cost, (b) total procurement cost, (c) unit cost, (d) life cycle cost.

B-10. Annex A

Operational Mode Summary/Mission Profile Annex. List tasks and conditions for frequency and urgency viewed for system employment in military operations. The mission profile is logically derived from the operational and training concept. It provides additional information for developing system operational characteristics. This annex will be removed later from the O&O Plan, updated and appended to the ROC as appendix D.

Format for Justification for Major System New Start (JMSNS)

A. Defense guidance element. Identify the element of defense guidance to which the system responds.

B. Mission and threat. Identify the mission area (numbers and title) and describe the role of the system in the mission area. Discuss the Defense Intelligence Agency (DIA) validated projected threat and the shortfalls of existing systems in meeting the threat. Comment on the timing of the need and the general priority of this system relative to others in this mission area.

C. Alternative concepts. Describe known alternatives that will be considered during concept exploration (including product improvements). If an alternative has already been selected, state the reasons for rejecting those that have not been selected and any further tradeoffs that remain for the selected system.

D. Technology involved. For known alternatives, discuss maturity of the technology planned for the selected system design and manufacturing processes, with particular emphasis on remaining areas of risk.

E. Funding implications. Discuss affordability, including the level of funding the Army is willing to commit to satisfy the need. When a concept has been selected, provide gross estimates of total RDTE cost, total procurement cost, unit cost and life cycle cost.

F. Constraints. Describe, as applicable, key boundary conditions for satisfying the need, such as survivability, logistics, and manpower (MANPRINT) constraints, computer resources, S&I within NATO or other DOD components, and critical materials and industrial base required.

G. Acquisition strategy (AS). Provide summary of salient elements of proposed acquisition strategy, such as program structure, competition, and contracting.

**Figure C-1. Justification for Major System
New Start format**

Format for Required Operational Capability (ROC), Joint Service Operational Requirement (JSOR)

D-1. Title

- a. Descriptive program title.
- b. Category (major or non-major).
- c. CARDS Reference Number: (assigned by ODCSOPS after approval).

D-2. Need/threat

State what is needed. Briefly describe the threat and operational/training deficiency that dictates need for the system. Include the enemy's capability to detect, identify, locate, avoid, suppress, destroy or otherwise counter the system. Describe the anticipated threat response over time to support evolutionary development when applicable. (Classified threat information will be annotated to show the document(s) from which the threat was derived.)

D-3. IOC

State by FY and Quarter.

D-4. Operational/organizational plan

In a brief paragraph state the following:

- a. How the equipment will be employed.
- b. The types of units that will use and support the equipment. (Attach the approved O&O Plan with the Operational Mode Summary/Mission Profile as annex D)

D-5. Operational characteristics

Describe only the essential operational features of the system. Included are counter-countermeasure capabilities, physical security, environmental quality control, mobility, transportability, and reliability, availability, and maintainability. Performance must be responsive to battlefield conditions for continuous combat (such as full ECM, directed energy, smoke aerosols, obscurants, electromagnetic environmental effects (E3), rain, fog, haze, and dust). Performance characteristics will be expressed in bands of performance. Reliability and maintainability will be stated as single values in terms of operational requirements. During development, commercial, other service, NATO, or other allied nation characteristics of existing or planned systems should be considered for inclusion. This will provide a basis for system interoperability, coproduction, or standardization. The requirements and provisions for the following must be considered:

- a. Compatibility with existing systems.
- b. Continuity of Operations (CONOPS) of a BAS.
- c. Security.
- d. Transportability and mobility.
- e. Reliability, availability, and maintainability.
- f. Standardization, including commonality for components, software, ammunition, power, TMDE, etc.
- g. International standardization agreements.
- h. Nuclear survivability and NBC contamination survivability.
- i. Individual and collective protection equipment.
- j. Adverse weather and reduced visibility conditions (smoke and obscurants), operations, and military operations on urbanized terrain, where applicable.
- k. Communications.
- l. Airdrop, airlift certification, and jumpack.

- m. Lighten the force.
- n. Camouflage.
- o. Climatic design types.
- p. Special purpose deception materiel.
- q. Directed energy survivability.
- r. P³I (include timeframe for block modifications).

D-6. Technical assessment

For an NDI, briefly outline planned market investigation effort and/or military suitability evaluations. Include a brief paragraph describing the technical effort required. Address major areas for full scale/abbreviated development in terms of scope, technical approach, and associated risks in the medium or low categories.

D-7. System support assessment

Briefly describe the system support plan. Include statement that the system support plan will be available for testing during IOTE and the system support package will be validated prior to IOC.

D-8. MANPRINT assessment

a. *Manpower/force structure assessment.* Estimate manpower requirements per system, per unit, and total Army (Active, ARNG, USAR). Include an assessment of alternatives to reduce manpower requirements by component. If increases in force structure are required, then a tradeoff analysis must be conducted.

b. *Personnel assessment.* Identify personnel constraints by operator, maintainer, repairer, and other support MOS. Describe the aptitude of the intended operator, maintainer, and repairer. An analysis must be conducted to assess any changes to the MOS structure or MOS workload. A summary of the relationship of soldier performance to measures of system effectiveness should be included.

c. *Training assessment.* Discuss overall training strategy to include the need for system training devices (TD) and embedded training requirements. The TD requirements will be documented in appendix 5. New equipment training (NET), operator, maintenance personnel training, technical manuals (TM) and training materiel requirements will be stated in terms of need for both institutional and unit training.

d. *Human Factors Engineering (HFE).* Identify the need for a HFE analysis and address the HFE considerations and constraints.

e. *System safety.* Address system safety requirements and safety considerations and constraints.

f. *Health hazard assessment (HHA).* Address health hazard requirements and health hazard considerations and constraints.

D-9. Standardization and Interoperability

a. Discuss other services, foreign nations interest in the program identified during

staffing. Identify similar programs contemplated by other services or allied nations (RSI).

b. Describe standardization, interoperability or commonality constraints that apply because of other Army, allied nations, or other service missions, tasks, relationships, or systems.

D-10. Life cycle cost assessment

This assessment will be expressed in terms of the life cycle phases of development production, military construction, fielding, and sustainment costs (costs will include software costs). Also, include the design to cost goals. This information is contained in annex A.

D-11. Milestone schedule

Provide a listing of significant events with dates by FY and Quarter to occur between approval of document, and the IOC date. The following should be included:

- a. ROC or JSOR approval.
- b. MDR I (IPR or ASARC/JRMB).
- c. TT/IOTE begin and end (if required).
- d. MDR II (IPR or ASARC/JRMB) (if required).
- e. TT/IOTE begin and end (if required).
- f. MDR III (IPR or ASARC/JRMB).
- g. IOC.

D-12. Appendix 1—Rationale

This provides an audit trail and full rationale for determining how the characteristics in paragraph 5 of the basic document were derived. Use of the term "self-explanatory" is prohibited.

D-13. Appendix 2—COEA

Attach an executive summary of the COEA or AA.

D-14. Appendix 3—RAM Rationale

Executive summary of the RAM Rationale Report (AR 702-3).

D-15. Appendix 4—Operational Mode Summary/Mission Profile

Updated from O&O Plan.

D-16. Appendix 5—Training Device (when required)

A separate appendix is required for each TD. Appendices should be numbered 5a, 5b, 5c, etc. The format for training devices is at appendix F.

D-17. Annexes

- a. Annex A, Life Cycle Cost assessment.
- b. Annex B, O&O Plan. Attach the approved O&O Plan.
- c. Annex C, Coordination. List primary major commands, other services allied nations, and activities with which coordination was effected. Provide full rationale for nonacceptance of comments, if any.

SAMPLE Target Audience Description (TAD)

MOS 44B : Metal Worker
 CMF 63 : Mechanical Maintenance
 Branch 10 : Ordnance
 SVAB Composite : GM Actual Cutoff : 90

Section A: STATISTICS

1. Manpower Status (FY 1988)

Skill Level	1	2	3	4	5	
Grade(s)	E1-E4	E5	E6	E7	E8-E9	Total
Authorized	983.0	247.0	0.0	0.0	0.0	1230.0
Operating	1249.0	265.0	0.0	0.0	0.0	1514.0
Oper/Auth	1.27	1.07	0.00	0.00	0.00	1.23

2. Manpower Availability Projections

Skill Level	1	2	3	4	5	
Grade(s)	E1-E4	E5	E6	E7	E8-E9	Total
Current 1988	1249	265	0	0	0	1514
Projected 1989	1048	322	0	0	0	1370
Projected 1990	913	353	0	0	0	1266
Projected 1991	867	370	0	0	0	1237
Projected 1992	943	374	0	0	0	1317
Projected 1993	992	372	0	0	0	1364
Projected 1994	1077	368	0	0	0	1445
Projected 1995	1078	368	0	0	0	1446
Projected 1996	1076	369	0	0	0	1445
Projected 1997	1073	371	0	0	0	1444

3. Aptitude (in percentages)

A. AFQT - Mental Category Distribution

		Categories				
		I	II	IIIA	IIIB	IV
Current 1988		2.8	18.0	24.0	43.6	11.6
Projected 1989		2.8	17.3	24.1	44.5	11.3
Projected 1990		2.9	16.9	24.2	44.8	11.1
Projected 1991		3.2	16.3	24.3	45.4	10.8
Projected 1992		3.3	15.9	24.5	45.9	10.4
Projected 1993		3.4	15.3	24.6	46.5	10.1
Projected 1994		3.5	14.9	24.8	46.8	9.9
Projected 1995		3.6	14.9	24.8	47.0	9.8
Projected 1996		3.6	14.7	24.8	47.2	9.7
Projected 1997		3.6	14.5	24.9	47.3	9.6

B. ASVAB Aptitude Area Score Distribution

		<75	<85	<95	<105	<115	<125	<135
Current 1988		2.5	10.2	19.7	29.4	24.3	11.1	2.8
Projected 1989		2.5	10.3	19.8	29.5	24.2	11.0	2.7
Projected 1990		2.5	10.3	19.9	29.6	24.1	10.9	2.7

Projected	1991	2.5	10.4	20.0	29.7	24.0	10.8	2.7
Projected	1992	2.5	10.4	20.1	29.7	24.0	10.7	2.7
Projected	1993	2.5	10.4	20.1	29.8	23.9	10.5	2.7
Projected	1994	2.5	10.4	20.2	29.9	23.9	10.5	2.7
Projected	1995	2.5	10.4	20.2	29.9	23.8	10.4	2.7
Projected	1996	2.5	10.5	20.3	29.9	23.8	10.4	2.7
Projected	1997	2.5	10.5	20.3	29.9	23.7	10.3	2.7

C. Reading Grade Level Distribution

		<7	7-9	9-11	11-12	>12
Current	1988	1.8	37.0	22.8	35.1	3.3
Projected	1989	1.8	37.2	23.0	34.7	3.3
Projected	1990	1.8	37.2	23.1	34.5	3.4
Projected	1991	1.7	37.3	23.2	34.1	3.7
Projected	1992	1.7	37.2	23.4	33.9	3.8
Projected	1993	1.6	37.3	23.6	33.6	3.9
Projected	1994	1.6	37.3	23.7	33.5	3.9
Projected	1995	1.6	37.3	23.7	33.5	4.0
Projected	1996	1.6	37.4	23.8	33.3	4.0
Projected	1997	1.5	37.4	23.8	33.2	4.0

D. Civilian Education

		HSG	Non-HSG
Current	1988	98.5	1.5
Projected	1989	98.8	1.2
Projected	1990	98.6	1.4
Projected	1991	98.6	1.4
Projected	1992	98.6	1.4
Projected	1993	98.6	1.4
Projected	1994	98.5	1.5
Projected	1995	98.5	1.5
Projected	1996	98.5	1.5
Projected	1997	98.5	1.5

4. Biographical Information (in percentages)

A. Gender Mix

		Male	Female
Current	1988	96.5	3.5
Projected	1989	96.6	3.4
Projected	1990	96.4	3.6
Projected	1991	95.8	4.2
Projected	1992	95.4	4.6
Projected	1993	95.2	4.8
Projected	1994	94.9	5.1
Projected	1995	94.7	5.3
Projected	1996	94.5	5.5
Projected	1997	94.3	5.7

SECTION B: DESCRIPTIVE INFORMATION (Source AR 611-201)

1. Standards of Grade Authorization (AS of OCT 87)

Duty Position	Code	Rank	Number of Positions authorized*									
			1	2	3	4	5	6	7	8	9	10
Welder**	44B10	PFC		2	2	2	2	3	3	3	4	4
Welder***	44B10	SP4	1				1	1	1	2	2	3
Welder****	44B20	SGT			1	2	2	2	3	3	3	3

*Blank spaces in this column indicate not applicable.

**Grades of additional positions will be in same pattern.

Metal worker repairer, Radiator repairer, Metabl drop kit repairer,
Marine hull repairer, Metal body painter

***Metal worker repairer, Radiator repairer, Metabl drop kit repairer,
Marine hull repairer

****Metal worker repairer, Marine hull repairer

2. MOS/Civilian Designation and Description

a. Operator MOS: Metal Worker

b. Additional Skill Identifiers (ASIs):

None

c. Security Clearance: None

d. Job Description: The metal worker supervises, inspects, installs, modifies, and performs maintenance on metal body components, radiators, fuel tanks, hulls, and accessories of Army watercraft and amphibians. Other major duties for MOS 44B are at the following skill levels:

(1) MOSC 41B10. Welds ferrous and nonferrous metals using oxyacetylene, electric arc, and inert gas welding equipment, and repairs, repaints, and installs metal body components, radiators, fuel tanks, modifies other related items, and repairs hulls and accessories of Army watercraft and amphibians.

(2) MOSC 44B20. Performs intermediate maintenance metal worker tasks.

e. Related Civilian Occupation

(1) DOT classification

- (a) Blacksmith - 610.381-010
- (b) Drop hammer operator - 610.462-010
- (c) Welder, combination - 819.384-010
- (d) Thermal cutting machine operator - 816.482-010
- (e) Automobile body repairer - 807.381-010
- (f) Automobile radiator mechanic - 620.381-010

(2) Federal civil service classification

- (a) Automotive/engineer body and federal repairing - WG 3809
- (b) Automotive or engineer repairing, radiator - WG 3814
- (c) Blacksmithing - WG 3704
- (d) Welding, acetylene, or electric - WG 3703
- (e) Brazing and soldering - WG 3720
- (f) Flame cutting - WG 3702
- (g) Heat treating - WG 3712
- (h) Painting - WG 4102

4. Physical Qualifications

- a. PULHES Profile: 222222
- b. MEPSCAT Rating: Very heavy
- c. Vision Requirements: Normal color

5. Skills and Knowledge Trained

- a. Tasks Trained During Institutional Training

Perform Sheet Metal Welding

Weld in the Overhead Position with Oxyacetylene Equipment

Weld Pipe with Oxyacetylene Equipment

Perform Brazing Operation

Weld Aluminum Metals with Oxyacetylene Equipment

Cut Low Carbon Steel

Maintain/Replace Components on Oxyacetylene Equipment

Perform Metal Bonding Overlay

Perform Flame Hardening and Tempering

Identify Metals

Forehand Weld with Oxyacetylene Equipment

Weld in the Flat Position with Oxyacetylene Equipment

Weld in the Horizontal Position with Oxyacetylene Equipment

Weld in the Vertical Position With Oxyacetylene Equipment

Adjust Torch to Three Basic Flames

Case Harden Low Carbon Steel

Set Up Metal Bonding Overlay Equipment

Maintain Metal Bonding Overlay Equipment

Set Up Oxyacetylene Welding/Cutting Equipment

Perform Surface Buildup

Perform Overhead Position Welding

Perform Pipe Welding

Arc Weld on Armor Plate

Cut Metal with Air-Arc

Perform Flat Position Welding on Stainless Steel

Perform Maintenance on Engine Driven Welder

Perform Flat Position Welding on Stainless Steel

Perform Flat Position Welding

Perform Horizontal Position Welding

Perform Vertical Position Welding

Perform Cast Iron Welding

Prepare Material for Welding

Set Up Arc Welding Equipment

Adjust Amperage Using Remote Control Unit

Perform Horizontal Position Welding

Perform Vertical Position Welding

Perform Overhead Position Welding

Perform Flat Position Welding

Adjust Welding Equipment

Set Up Welding Equipment

Perform Maintenance of MIG Welding Equipment

Perform Horizontal Position Welding on Aluminum

Perform Flat Position Sheet Metal Welding

Perform Horizontal Position Welding on Stainless Steel

Perform Vertical Position Welding on Stainless Steel

Perform Overhead Position Welding on Aluminum

Cut Laminated Safety Glass

Grind Glass

Install Glass Frames and Weatherstripping

Maintain Glassworking Tools and Equipment

Remove Glass Frames and Weatherstripping

Cut Plain Glass

Install Glass

Remove Glass

Repair Radiators

Disassemble Radiators

Clean Oil Coolers

Clean Radiator

Assemble Radiator

Test Radiator

Remove Radiator

Install Radiator

Remove Fuel Tanks

Repair Terneplate Fuel Tanks

Install Fuel Tanks

Prepare Fuel Tank-Steam for Repair

Test Fuel Tanks

Inspect Fuel Tanks

Perform Roughing and Aligning

Perform Hammer Finishing
Perform Metal Shrinking Operations
Repair Vehicle Shelters
Perform Sheet Metal Repair
Fabricate Panel
Replace Cross Member Rivets
Perform Spray Painting
Sharpen Twist Drills
Operate Drill Press
Maintain Assigned Tool Kit
Apply Body Plastics/Fillers
Adjust Vehicle Body Components
Perform Frame Repairs
Perform Floatation Barrier Repairs
Remove Vehicle Hardware
Install Vehicle Hardware
Remove Vehicle Body Components
Maintain Metalbody Tools and Equipment
Perform Fiberglass Repair
Remove Vehicle Door Panels
Replace Vehicle Door Panels
Install Vehicle Body Components
Perform Sanding Operations (Electric)
Perform Hand Sanding
Perform Filing Operations
Perform Hydraulic Body Jack Operations
Analyze Repair Sequence

Determine Paint Failures

Perform Flotation Barrier Repairs

Solder Galvanized Steel with Oxyacetylene Torch

Silver Solder Low Carbon Steel in the Flat Position

Silver Solder Dissimilar Metals

Solder with Flame Heated Iron

Solder with Electric Iron

Braze Low Carbon Steel with Oxyacetylene Torch

Braze Cast Iron with Oxyacetylene Torch

Braze Dissimilar Metals in Flat Position

Braze Dissimilar Metals in Horizontal Position

Prepare Metal for Soldering

Prepare Shop Drawings and Sketches

Lay Out Workpiece

Perform Hand Filing

Operate Metal Shears

Conduct Before/During/After Operation Checks and Services of Assigned Vehicle

Prepare Equipment Inspection and Maintenance Worksheet

b. Tasks Trained During Unit Training

Supervise Welding and Cutting with Oxyacetylene Equipment

Supervise Heat Treating Operations

Arc Weld on Nonferrous Metals

Supervise Arc Welding Operations

Supervise Maintenance of Engine Driven Welder

Perform Stress Relief by Peening

Perform Intermittent Backstep Welding

Inspect Welds

Supervise MIG Welding Operations

Supervise TIG Welding Operations

Supervise Removal/Installation of Glass

Supervise Glass Cutting Operation

Supervise Maintenance of Glassworking Tools and Equipment

Remove Glass

Supervise Radiator Repair

Supervise Oil Cooler Repair Operations

Supervise Radiator Cleaning

Supervise Radiator Testing

Supervise Maintenance of Radiator Tools and Equipment

Repair Aluminum Fuel Cells

Supervise Metal/Fiberglass Body Repairs

Supervise Painting Operations

Supervise Maintenance of Metalbody Tools and Equipment

Supervise Maintenance of Paint Tools and Equipment

Supervise Operations of Metalworking Tools

Supervise Soft Soldering Operations

Supervise Silver Soldering Operations

Supervise Brazing of Dissimilar Metals

Supervise Drilling Operations

Interpret Welding Symbols

DATA ITEM DESCRIPTION			Form Approved OMB No. 0704-0188	
1. TITLE SYSTEM/SEGMENT SPECIFICATION		2. IDENTIFICATION NUMBER DI-CMAN-80008A		
3. DESCRIPTION/PURPOSE 3.1 The System/Segment Specification (SSS) specifies the requirements for a system or a segment of a system. Upon Government approval and authentication, the SSS becomes the Functional Baseline for the system or segment. (continued on page 2)				
4. APPROVAL DATE (YYMMDD) 880229	5. OFFICE OF PRIMARY RESPONSIBILITY (OPR) AF-10	6a. DTIC APPLICABLE	6b. GIDEP APPLICABLE	
7. APPLICATION/INTERRELATIONSHIP 7.1 This Data Item Description (DID) contains the format and content preparation instructions for data generated under the work tasks described by paragraph 3.1.3.1 of MIL-STD-490. 7.2 The Contract Data Requirements List should specify whether this document is to be prepared and delivered on bound 8 1/2 by 11 inch bond paper or electronic media. If electronic media is selected, the precise format must be specified. (continued on page 2)				
8. APPROVAL LIMITATION		9a. APPLICABLE FORMS		9b. AMSC NUMBER F4328
10. PREPARATION INSTRUCTIONS 10.1 Content and format instructions. Production of this specification using automated techniques is encouraged. Specific content and format instructions for this specification are identified below. a. <u>Response to tailoring instructions.</u> In the event that a paragraph or subparagraph has been tailored out, a statement to that effect shall be added directly following the heading of each such (sub)paragraph. If a paragraph and all of its subparagraphs are tailored out, only the highest level paragraph heading need be included. b. <u>Use of alternate presentation styles.</u> Charts, tables, matrices, or other presentation styles are acceptable when the information required by the paragraphs and subparagraphs of this DID can be made more readable. c. <u>Page numbering.</u> Each page prior to Section 1 shall be numbered in lower-case roman numerals beginning with page ii for the Table of Contents. Each page starting from Section 1 to the beginning of the appendixes shall be consecutively numbered in arabic numerals. If the document is divided into volumes, each such volume shall restart the page numbering sequence. (continued on page 2)				
11. DISTRIBUTION STATEMENT DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.				

3. DESCRIPTION/PURPOSE (continued)

3.2 The SSS provides a general overview of the system or segment that may be used by training personnel, support personnel, or users of the system.

7. APPLICATION/INTERRELATIONSHIP (continued)

7.3 The word "system" is used generically in this DID to mean either a system or a segment, as applicable.

7.4 System division into segments normally occurs if parts of the system are:

- a. Assigned to different contractors or government organizations
- b. Intended to be added in an evolutionary or incremental manner
- c. Planned for major modification.

7.5 This DID supersedes DI-CMAN-80008 dated 4 June 1985.

10. PREPARATION INSTRUCTIONS (continued)

- d. Document control numbers. For hardcopy formats, this document may be printed on one or both sides of each page (single-sided or double-sided). All printed pages shall contain the document control number and the date of the document centered at the top of the page. Document control numbers shall include revision and volume identification, as applicable.
- e. Multiple (sub)paragraphs. All paragraphs and subparagraphs starting with the phrase "This (sub)paragraph shall..." may be written as multiple subparagraphs to enhance readability. These subparagraphs shall be numbered sequentially.
- f. Identifiers. The letters "X", "Y", and "Z" serve as identifiers for a series of descriptions. For example, the subparagraphs of 10.1.5.2.1.1 shall be structured as follows:

- 3.2.1.1 (First system state name)
 - 3.2.1.1.1 (System mode I)
 - 3.2.1.1.1.1 (System capability A)
 - 3.2.1.1.1.2 (System capability B)
 - 3.2.1.1.1.3 (System capability C)
 - 3.2.1.1.2 (System mode J)
 - 3.2.1.1.2.1 (System capability W)
 - 3.2.1.1.2.2 (System capability X)
 - etc.
- 3.2.1.2 (Second system state name)
 - etc.

10. PREPARATION INSTRUCTIONS (continued)

g. Document structure. This specification shall consist of the following:

- (1) Cover
- (2) Title page
- (3) Table of contents
- (4) Scope
- (5) Applicable documents
- (6) System requirements
- (7) Quality assurance provisions
- (8) Preparation for delivery
- (9) Notes
- (10) Appendixes.

10.1.1 **Title page.** The title page shall contain the information identified below in the indicated format:

[Document control number and date: Volume x of y (if multi-volume)]

[Rev. indicator: date of Rev.]

SYSTEM SPECIFICATION
(OR SEGMENT SPECIFICATION)

FOR THE

[SYSTEM NAME]

CONTRACT NO. *[contract number]*

CDRL SEQUENCE NO. *[CDRL number]*

Prepared for:

[Contracting Agency Name, department code]

Prepared by:

[contractor name and address]

Authenticated by _____
(Contracting agency)

Approved by _____
(Contractor)

Date _____

Date _____

10. PREPARATION INSTRUCTIONS (continued)

10.1.2 Table of contents. This specification shall contain a table of contents listing the title and page number of each titled paragraph and subparagraph. The table of contents shall then list the title and page number of each figure, table, and appendix, in that order.

10.1.3 Scope. This section shall be numbered 1 and shall be divided into the following paragraphs.

10.1.3.1 Identification. This paragraph shall be numbered 1.1 and shall contain the approved identification number, title, and abbreviation, if applicable, of the system to which this SSS applies.

10.1.3.2 System overview. This paragraph shall be numbered 1.2 and shall briefly state the purpose of the system to which this SSS applies.

10.1.3.3 Document overview. This paragraph shall be numbered 1.3 and shall summarize the purpose and contents of this document.

10.1.4 Applicable documents. This section shall be numbered 2 and shall be divided into the following paragraphs.

10.1.4.1 Government documents. This paragraph shall be numbered 2.1. This paragraph shall begin with one of the following two paragraphs, as applicable: (1) "The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement." (2) "The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement, except for specification (enter number of next higher-tiered specification) listed below." The following paragraph shall appear at the conclusion of the list of documents: "Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the contracting agency or as directed by the contracting officer." Government documents shall be listed by document number and title in the following order:

SPECIFICATIONS:

Federal
Military
Other Government Agency

STANDARD:

Federal
Military
Other Government Agency

DRAWINGS:

(Where detailed drawings referred to in a specification are listed on an assembly drawing, it is only necessary to list the assembly drawing.)

10. PREPARATION INSTRUCTIONS (continued)

OTHER PUBLICATIONS:

Manuals
Regulations
Handbooks
Bulletins
etc.

10.1.4.2 Non-Government documents. This paragraph shall be numbered 2.2 and shall begin with the following paragraph: "The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement." The source for all documents not available through normal Government stocking activities shall be listed. The following paragraph shall be placed at the conclusion of the list when applicable: "Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal Agencies." Non-Government documents shall be listed by document number and title in the following order:

SPECIFICATIONS:

STANDARDS:

DRAWINGS:

OTHER PUBLICATIONS:

10.1.5 System requirements. This section shall be numbered 3 and shall be divided into the following paragraphs and subparagraphs to specify the requirements for the system to which this specification applies.

10.1.5.1 Definition. This paragraph shall be numbered 3.1 and shall provide a brief description of the system. This description shall address pertinent operational, and logistical considerations and concepts. A system diagram shall be provided.

10.1.5.2 Characteristics. This paragraph shall be numbered 3.2 and shall be divided into the following subparagraphs to describe the requirements for system performance and physical characteristics.

10.1.5.2.1 Performance characteristics. This subparagraph shall be numbered 3.2.1 and shall be divided into the following subparagraphs to specify the system's capabilities in the context of the states in which the system can exist and the modes of operation within each state. Each capability of the system shall be specified in a uniquely identified subparagraph in order to provide for objective qualification.

10.1.5.2.1.1 (State name). This subparagraph shall be numbered 3.2.1.X (beginning with 3.2.1.1) and shall identify and provide a brief description of a state in which the system can exist (e.g., weapon idle, weapon ready, weapon deployed).

10.1.5.2.1.1.1 (Mode name). This subparagraph shall be numbered 3.2.1.X.Y (beginning with 3.2.1.1.1). This subparagraph shall identify and provide a brief description of a mode of operation (e.g., surveillance, threat evaluation, weapon assignment, target designation and acquisition, fire control resolution) within the system state identified above.

10. PREPARATION INSTRUCTIONS (continued)

10.1.5.2.1.1.1.1 (System capability name and project unique identifier). This subparagraph shall be numbered 3.2.1.X.Y.Z (beginning with 3.2.1.1.1.1), shall specify a capability of the system by name and project unique identifier, and shall describe its purpose. This subparagraph shall also identify the applicable parameters associated with the capability and shall express them in measurable terms. If a capability of a mode has been previously defined, this subparagraph shall reference rather than duplicate that information.

10.1.5.2.2 System capability relationships. This subparagraph shall be numbered 3.2.2 and shall summarize the relationships between system capabilities and the states and modes of the system.

10.1.5.2.3 External interface requirements. This paragraph shall be numbered 3.2.3 and shall be divided into the following subparagraphs to describe requirements for interfaces with other systems. Detailed quantitative interface requirements may be defined in separate specifications or Interface Control Documents (ICDs) and referenced herein. All referenced ICDs are considered part of this specification.

10.1.5.2.3.1 (System name) external interface description. This subparagraph shall be numbered 3.2.3.X (beginning with 3.2.3.1) and shall identify an external system with which this system interfaces. This subparagraph shall describe the interfaces to the external system. This subparagraph shall identify the purpose of each interface and shall describe the relationship between each interface and the states and modes of the system. When possible, each interface shall be specified in detailed, quantitative terms (e.g., dimensions, tolerances, loads, speeds, communications protocol).

10.1.5.2.4 Physical characteristics. This subparagraph shall be numbered 3.2.4 and shall specify the requirements for the physical characteristics (e.g., weight limits, dimensional limits) of the system. Additional considerations for determining physical requirements include:

- a. Transportation and storage
- b. Security
- c. Durability
- d. Safety
- e. Vulnerability
- f. Color

10.1.5.2.4.1 Protective coatings. This subparagraph shall be numbered 3.2.4.1 and shall specify, if applicable, protective coating requirements to assure protection from corrosion, abrasion, or other deleterious action.

10.1.5.2.5 System quality factors. This paragraph shall be numbered 3.2.5 and shall be divided into the following subparagraphs to specify the applicable requirements pertaining to system quality factors.

10.1.5.2.5.1 Reliability. This subparagraph shall be numbered 3.2.5.1, shall specify reliability requirements in quantitative terms, and shall define the conditions under which the reliability requirements are to be met. This subparagraph may include a reliability apportionment model to support apportionment of reliability values assigned to system capabilities for their share in achieving desired system reliability.

10.1.5.2.5.2 Maintainability. This subparagraph shall be numbered 3.2.5.2 and shall specify quantitative maintainability requirements. The requirements shall apply to maintenance in the planned maintenance and support environment and shall be stated in quantitative terms. Examples are:

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- a. Mean and maximum down time, reaction time, turnaround time, mean and maximum times to repair, mean time between maintenance actions.
- b. Maximum effort required to locate and fix an error.
- c. Maintenance man-hours per flying hour, maintenance man-hours per specific maintenance action, operational ready rate, maintenance hours per operating hour, frequency of preventative maintenance.
- d. Number of people and skill levels, variety of support equipment.
- e. Maintenance costs per operating hour, man-hours per overhaul.

10.1.5.2.5.3 Availability. This subparagraph shall be numbered 3.2.5.3 and shall specify the degree to which the system shall be in an operable and committable state at the start of the mission(s), where the mission(s) is called for at an unknown (random) point in time.

10.1.5.2.5.4 Additional quality factors. This subparagraph shall be numbered 3.2.5.4 and shall specify system quality requirements not defined in the above subparagraphs (e.g., integrity, efficiency, or correctness requirements of the system).

10.1.5.2.6 Environmental conditions. This paragraph shall be numbered 3.2.6 and shall specify the environmental conditions that the system must withstand during transportation, storage, and operation, such as:

- a. Natural environment (e.g., wind, rain, temperature, geographic location)
- b. Induced environment (e.g., motion, shock, noise, electromagnetic radiation)
- c. Environments due to enemy action (e.g., over-pressure, explosions, radiation).

10.1.5.2.7 Transportability. This subparagraph shall be numbered 3.2.7 and shall specify any special requirements for transportation and materials handling. In addition, all system elements that, due to operational or functional characteristics, will be unsuitable for normal transportation methods shall be identified.

10.1.5.2.8 Flexibility and expansion. This subparagraph shall be numbered 3.2.8 and shall specify areas of growth which require planning for system flexibility and expansion. In addition, this subparagraph shall specify specific system elements which require spare capacity to support flexibility and expansion.

10.1.5.2.9 Portability. This subparagraph shall be numbered 3.2.9 and shall specify requirements for portability which are applicable to the system to permit employment, deployment, and logistic support.

10.1.5.3 Design and construction. This paragraph shall be numbered 3.3 and shall be divided into subparagraphs that specify minimum system design and construction standards which have general applicability to system equipment and are applicable to major classes of equipment (e.g., aerospace vehicle equipment, and support equipment) or are applicable to particular design standards. To the maximum extent possible, these requirements shall be specified by incorporation of the established military standards and specifications. Requirements which add to, but do not conflict with, requirements specified herein may be included in individual configuration item specifications. In addition, this paragraph shall specify criteria for the selection and imposition of Federal, military, and contractor specifications and standards.

10.1.5.3.1 Materials. This subparagraph shall be numbered 3.3.1 and shall specify those system-peculiar requirements governing use of materials, parts, and processes in the design of system equipment. Special attention shall be directed to prevent unnecessary use of strategic or critical materials. (A strategic and critical materials list may be obtained from the contracting agency.) In addition, requirements for the

10. PREPARATION INSTRUCTIONS (continued)

use of standard and commercial parts and parts for which qualified products lists have been established shall be specified in this paragraph.

10.1.5.3.1.1 Toxic products and formulations. This subparagraph shall be numbered 3.3.1.1 and shall specify requirements for the control of toxic products or formulations to be used in the system or to be generated by the system.

10.1.5.3.2 Electromagnetic radiation. This subparagraph shall be numbered 3.3.2 and shall contain requirements pertaining to limits on the electromagnetic radiation which the system is permitted to generate.

10.1.5.3.3 Nameplates and product marking. This subparagraph shall be numbered 3.3.3 and shall contain requirements for nameplates, part marking, serial and lot number marking, software media marking, and other identifying markings required for the system. Reference may be made to existing standards on the content and application of markings.

10.1.5.3.4 Workmanship. This subparagraph shall be numbered 3.3.4 and shall specify workmanship requirements for equipment to be produced during system development and requirements for manufacture by production techniques.

10.1.5.3.5 Interchangeability. This subparagraph shall be numbered 3.3.5 and shall specify the requirements for system equipment to be interchangeable and replaceable. Entries in this paragraph are for the purpose of establishing a condition for design and are not to define the conditions of interchangeability required by the assignment of a part number.

10.1.5.3.6 Safety. This subparagraph shall be numbered 3.3.6 and shall specify those safety requirements which are basic to the design of the system, with respect to equipment characteristics, methods of operation, and environmental influences. This paragraph shall also specify those safety requirements which prevent personnel injury and equipment degradation without degrading operational capability (e.g., restricting the use of dangerous materials where possible, classifying explosives for purposes of shipping, handling and storing, abort/escape provisions from enclosures, gas detection and warning devices, grounding of electrical system, cleanliness and decontamination, explosion proofing).

10.1.5.3.7 Human engineering. This subparagraph shall be numbered 3.3.7 and shall specify human engineering requirements for the system or for specific configuration items. This paragraph shall reference applicable documents (e.g., MIL-STD-1472) and specify any special or unique requirements (e.g., constraints on allocation of capabilities to personnel and communications, and personnel/equipment interactions). This paragraph shall include those specific areas, stations, or equipment which would require concentrated human engineering attention due to the sensitivity of the operation or criticality of the task; i.e., those areas where the effects of human error would be particularly serious.

10.1.5.3.8 Nuclear control. This subparagraph shall be numbered 3.3.8 and shall specify system requirements for nuclear components, such as:

- a. Component design
- b. In-flight control
- c. Prevention of inadvertent detonation
- d. Nuclear safety rules.

10.1.5.3.9 System security. This subparagraph shall be numbered 3.3.9 and shall specify security requirements that are basic to the design of the system with respect to the operational environment of

10. PREPARATION INSTRUCTIONS (continued)

the system. This subparagraph shall also specify those security requirements necessary to prevent compromise of sensitive information or materials.

10.1.5.3.10 Government furnished property usage. This subparagraph shall be numbered 3.3.10 and shall specify any Government Furnished Equipment (GFE) to be incorporated into the system design. In addition, this paragraph shall specify any Government Furnished Information (GFI) and Government Furnished Software (GFS) to be incorporated into the system. This list shall identify the Government furnished property by reference to its nomenclature, specification number, and/or part number. If the list is extensive, it may be included as an appendix to this specification and referenced in this paragraph.

10.1.5.3.11 Computer resource reserve capacity. This subparagraph shall be numbered 3.3.11 and shall specify the required computer resource reserve capacity (e.g. memory, timing, etc.).

10.1.5.4 Documentation. This paragraph shall be numbered 3.4 and shall specify the requirements for system documentation such as specifications, drawings, technical manuals, test plans and procedures, and installation instruction data.

10.1.5.5 Logistics. This paragraph shall be numbered 3.5 and shall specify logistic considerations and conditions that apply to the operational requirements. These considerations and conditions may include:

- a. Maintenance
- b. Transportation modes
- c. Supply-system requirements
- d. Impact on existing facilities
- e. Impact on existing equipment.

10.1.5.6 Personnel and training. This paragraph shall be numbered 3.6 and be divided into the following subparagraphs to specify the requirements for personnel and training.

10.1.5.6.1 Personnel. This subparagraph shall be numbered 3.6.1 and shall specify personnel requirements which must be integrated into system design. These requirements shall be stated in terms of numbers plus tolerance and shall be the basis for contractor design and development decisions. Requirements stated in this paragraph shall be the basis for determination of system personnel training, training equipment, and training facility requirements. Personnel requirements shall include:

- a. Numbers and skills of support personnel for each operational deployment mode and the intended duty cycle, both normal and emergency.
- b. Skills and numbers of personnel that shall be allocated to the operation, maintenance, and control of the system.

10.1.5.6.2 Training. This subparagraph shall be numbered 3.6.2 and shall include the following training requirements:

- a. Contractor and Government responsibility for training. This subparagraph shall also specify the concept of how training shall be accomplished (e.g., school, contractor training).
- b. Equipment that will be required for training purposes.
- c. Training devices to be developed, characteristics of the training devices, and training and skills to be developed through the use of training devices.

10. PREPARATION INSTRUCTIONS (continued)

- d. Training time and locations available for a training program.
- e. Source material and training aids to support the specified training.

10.1.5.7 Characteristics of subordinate elements. This paragraph shall be numbered 3.7 and shall be divided into the following subparagraphs to identify and describe each segment of the system. This subparagraph shall describe the relationships between the segments.

10.1.5.7.1 (Segment name and project unique identifier). This subparagraph shall be numbered 3.7.X (beginning with 3.7.1) and shall provide the following information for the segment:

- a. State the purpose of the segment
- b. Provide a brief description of the segment
- c. Identify the system capabilities the segment performs.

10.1.5.8 Precedence. This paragraph shall be numbered 3.8 and shall either specify the order of precedence of the requirements or assign weights to indicate the relative importance of the requirements.

10.1.5.9 Qualification. This paragraph shall be numbered 3.9 and shall state the requirements for verification or validation, as applicable, of capabilities in a specific application. Each qualification test shall be identified in a separate subparagraph and the specific application shall be described. Requirements shall be included for the conditions of testing, the time (program phase) of testing, period of testing, number of items to be tested, and any other pertinent qualification requirements.

10.1.5.10 Standard sample. This paragraph shall be numbered 3.10 and, if applicable, shall describe requirements for the production of one or more standard samples. Standard samples shall be limited to the illustration of qualities and characteristics that cannot be described using detailed test procedures or design data or that cannot be definitively expressed.

10.1.5.11 Preproduction sample, periodic production sample, pilot, or pilot lot. This paragraph shall be numbered 3.11 and, if applicable, shall describe requirements for producing a preproduction or periodic production sample, a pilot model, or a pilot lot.

10.1.6 Quality assurance provisions. This section shall be numbered 4 and shall be divided into the following paragraphs to specify the requirements to show how the requirements of sections 3 and 5 shall be satisfied.

10.1.6.1 Responsibility for inspection. This paragraph shall be numbered 4.1 and shall assign responsibilities for performance of inspections of delivered products, materials, or services for determining compliance with all specified requirements.

10.1.6.2 Special tests and examinations. This paragraph shall be numbered 4.2 and shall specify any special tests and examinations required for sampling, lot formation, qualification evaluation, and any other tests or examinations as necessary. Each test and examination shall be described in a separate subparagraph.

10.1.6.3 Requirements cross reference. This paragraph shall be numbered 4.3 and shall correlate each system requirement in sections 3 and 5 to the quality assurance provisions specified in section 4. This paragraph may reference a requirements cross reference table which may be provided as an appendix to this specification.

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10.1.7 Preparation for delivery. This section shall be numbered 5 and shall specify requirements for the preparation of the system and all its components for delivery, including packaging and handling. This section shall include requirements to document any non-standard practices in appropriate system and item specifications. This section may impose requirements to comply with standard practice by referencing appropriate military specifications and standards to be used as the basis for preparing Section 5 of each specification for system end items.

10.1.8 Notes. This section shall be numbered 6 and shall contain any general information that aids in understanding this document (e.g., background information, glossary). This section shall contain an alphabetical listing of all acronyms, abbreviations, and their meanings as used in this document.

10.1.8.1 Intended use. This paragraph shall be numbered 6.1 and shall briefly state the purpose of the system to which the SSS applies in terms of the mission and threat addressed by the system.

10.1.8.1.1 Missions. This subparagraph shall be numbered 6.1.1 and shall describe the missions of the system to the extent that such missions affect design requirements. This description shall include operational information, such as tactics, system deployment, operating locations, and facilities.

10.1.8.1.2 Threat. This subparagraph shall be numbered 6.1.2 and shall describe the characteristics of potential targets, the characteristics of current and potential enemy weapon capabilities relevant to the system, and any additional threat considerations that affect the system design. This information may be contained in a separate document and referenced in this subparagraph if it is classified.

10.1.9 Appendixes. Appendixes may be used to provide information published separately for convenience in document maintenance (e.g., charts, classified data). As applicable, each appendix shall be referenced in the main body of the document where the data would normally have been provided. Appendixes may be bound as separate documents for ease in handling. Appendixes shall be lettered alphabetically (A, B, etc.), and the paragraphs within each appendix be numbered as multiples of 10 (e.g., Appendix A, paragraph 10, 10.1, 10.2, 20, 20.1, 20.2, etc.). Pages within each appendix shall be numbered alpha-numerically as follows: Appendix A pages shall be numbered A-1, A-2, A-3, etc. Appendix B pages shall be numbered B-1, B-2, B-3, etc.