Research Note 84-133

ANALYSIS OF COMMON LANGUAGE COMMUNICATION REQUIREMENTS OF MANPOWER, PERSONNEL AND TRAINING (MPT) FACTORS IN MATERIEL SYSTEM ACQUISITION

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This report describes the conduct and results of a study to analyze and address three critical issues in controlling the manpower, personnel, and training (MPT) impacts of evolving weapons systems. Critical decisions involving MPT characteristics of systems, and where in the acquisition process and by whom these decisions are made are identified. A means of communicating these decisions to designers in an effective manner and promoting compliance with desired MPT characteristics of systems trhough design is discussed in detail. Finally, approaches to verifying that effective communication of MPT

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contraints has been made and that MPT issues are considered in systems design are presented, and issues to be resolved in future developments are discussed.

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BRIEF

<u>Requirement</u>

The improved capabilities of new weapons systems to be introduced into the Army inventory over the next 30 years are expected to cause related increases in the complexity of materiel systems. Current systems regularly exceed the capabilities of the personnel available to operate and maintain the systems, due to unnecessary system complexity. Also, the number and qualifications of personnel who will compose the future Army are expected to continue to be limited due to legislative and demographic trends which will continue into the future. If these two parallel trends continue, a crisis situation where the Army possesses highly capable materiel systems but lacks personnel with the capabilities needed to maintain and operate the systems is likely.

Since the trend toward fewer, potentially less capable personnel is unlikely to change in the foreseeable future, attention must be directed toward the characteristics of materiel systems which make the systems "complex" (i.e., difficult to operate and maintain). One major reason why materiel systems are "complex" is that little attention is given to the capabilities and limitations of potential system operators and maintainers during system design. This lack of attention is due to a number of factors, one of the most important of which is a general lack of knowledge, on the part of engineers who design materiel systems, of tools and techniques which can be used in the materiel system design process to evaluate and control the impacts of designs upon manpower and personnel requirements and training (MPT). In turn, a major cause of designer lack of knowledge of human factors assessment and design techniques and principles is that human factors principles and techniques are not provided in a language with which the design engineer is familiar. Thus, there is a need for a "common language" by which the government can communicate its requirements and desires about the MPT characteristics of evolving materiel systems to materiel system designers and verify that the requirements are understood, complied with, and are effective in controlling the MPT impacts of systems design.

This leading effort was conceived to deal with three basic, first-order issues leading to the development of such a "common language." These were:

> Identify the critical decisions made in the materiel system acquisition process which have the most impact on the MPT characteristics of systems, where in the acquisition process these decisions are made, and who has responsibility for the decisions;

- Identify the most effective means of communicating "critical" MPT decisions to designers so that the decisions and associated technologies and data are effectively utilized by the designers to control the MPT impacts of system designs;

- Determine means of verifying that system designers understand the nature and importance of MPT decisions, utilize those decisions and related technologies to influence materiel system design, and that the decisions and their utilization have desired ultimate impacts on the MPT characteristics of fielded systems.

Procedure

A detailed examination of the materiel system acquisition process was made through study of selected reports and documents, to identify candidate "critical" MPT decisions made in the acquisition process. From the candidate "critical" decisions, a panel of highly experienced personnel selected the decisions to be considered those with the most impact upon materiel system MPT factors. The same panel studied the issues of communicating the decisions to designers and verifying the understanding, utilization, and impact of the decisions and associated relevant information, and arrived at first approximations to attributes of a "common language" and verification procedures. The conclusions and findings of the panel were subsequently refined and developed into a set of preliminary characteristics or attributes of the desired "common language."

Findings

A small set of extremely topic-specific MPT-impacting decisions which can be made early in the system acquisition process and thus be communicated to designers from the very outset of their involvement in system design were identified. These decisions, or system MPT characteristics, are in two broad areas: (1) decisions which specify allowable or permissible characteristics of MPT factors of systems to be developed; and (2) decisions which specify characteristics of the materiel systems to be designed which have profound influence on the MPT characteristics of the ultimate personnel/materiel system.

It was next determined that communication of the "critical" decisions identified must take place in the form of firm constraints upon the MPT characteristics of the total personnel/materiel system to be designed. These constraints should be a major part of the system performance specification, on a coordinate level with materiel performance requirements. The constraints provided for a particular system should have the following additional attributes:

- Deal with specifically defined system MPT characteristics or materiel system characteristics with major MPT impact.

- Rationale and justification for constraints presented to support designers' understanding of constraint impact and importance.

- Constraints stated in specific quantitative terms to provide understandability and verification of compliance.

- Guidance to tools, techniques, and data to assist designers in contraint compliance provided (designer's handbook).

- Effective consequences of failure to meet MPT constraints incorporated in system development contractual documents (MPT factors "warranties").

Finally, the issue of verification of designers' understanding of and efforts to comply with constraints, and the ultimate impacts of the constraints was addressed. Verification of designers' comprehension of the nature, impact, and importance of MPT-related design constraints is proposed to take place through evaluation of designers' proposals for system development, wherein specific initiatives and plans to deal explicitly with MPT impacts of design are to be required. Plans and initiatives to meet MPT constraints will form a major evaluation factor in selection of designers in the system acquisition process. Verifying that designers actually consider MPT impacts of design during the evolution of materiel sytems can be made through requiring explicit evaluation and documentation of MPT factors in design tradeoff decisions and periodic review of the MPT implications of evolving system designs by the government. Evaluating the ultimate impact of imposing MPT constraints on design can only be done by measuring the attained MPT characteristics of fielded systems, and comparing the attained parameters with the constraints placed on those factors prior to design.

Two major issues to be resolved in further development of the "common language" communication process were identified in this work. The first is a need to study and rationalize the process by which initial MPT decisions are made during system concept formulation phases of system acquisition (before the designers' involvement) to ensure that information which is needed to make critical MPT decisions, upon which constraints are based, is developed and utilized. The second issue is a need for an integrated "designer's handbook" which presents principles, techniques, and data required to knowledgably address MPT impacts of system design in a form and format suitable for use by the working design engineer and engineering manager.

Utilization of Findings

The findings of this work represent a first step in developing a means to control and intelligently constrain the MPT impacts of new materiel systems, through enhancing the process of communication about critical MPT issues between the government and materiel system designers. Considerable refinement of the basic, first-approximation principles derived in this study will be necessary to create and implement an effective, practical, and workable system for controlling MPT factors of designs. The next step in the evolution of a "common language" for government-designer communications should be to explicitly address the major issues identified in this work.

INTRODUCTION

In order to improve its effectiveness in accomplishing the overall defense mission, the Army will add a large number of new and innovative weapon systems to its inventory, within the next 20-30 years. Although these systems will provide new and improved capabilities, the systems will be complex. This implies that more capable (and perhaps more numerous) personnel will be required to operate and maintain the new systems.

Contrasted to requirements for an increased number of personnel and more capable personnel to support new systems are increasing limitations on the size of the Army force and tighter personnel budgets. If these two trends continue, there will come a point when the Army has on hand a large number of very capable weapons systems based on the latest technologies, but no one capable of operating and maintaining them. To prevent this hypothetical outcome, one or the other of the trends involved must be reversed. It is unlikely that the Congress will see fit to authorize a greatly expanded Army personnel budget to the extent that would be required to support Ph.D. PFCs; hence, the weapon systems of the future will have to be designed to be operated by the sorts of personnel who are available. The operations and maintenance characteristics of the systems must be matched to the skills and knowledge of the personnel available.

One reason that today's weapon systems are "complex" (i.e., difficult to operate and maintain) is that system designers have had a free rein to apply the latest technologies to create increasingly advanced system capabilities, but have been allowed to ignore the implications of these expanded capabilities in terms of the characteristics of the personnel who operate and maintain the systems. It has been well-established over decades of research that the characteristics of materiel systems determine the required characteristics of system operators and maintainers, and that materiel systems should be designed with the capabilities and limitations of the target population in mind. A vast body of data on the capabilities and limitations of personnel has been generated by human factors researchers, operations researchers, psychologists, and systems engineers. Techniques for determining the implications of many aspects of hardware designs upon personnel performance requirements have also been created and validated. Yet these data and techniques remain unused.

There are several possible reasons for this state of affairs:

1. The designers of materiel systems may not be aware of the existence of the data and techniques.
2. Designers may be aware of the data and discount the importance of the data to their efforts.
3. Designers may not know how the data applies to what they are trying to do, or how to use it.
4. The designer just may not care.

While all of these reasons may apply to some extent at any given time, it is suspected that the third reason (don't know how the data applies or how to use it) may be responsible for many of the problems that exist today. Since designers are not sure how or why data (concerning the ways in which hardware characteristics affect the performance of people) apply to his design problem, he simply ignores the data and goes on designing hardware. The ultimate impacts of this state of affairs are not hard to observe: competition by the various armed services, and branches within the services, for competent personnel who are desperately needed to operate and maintain needlessly complex hardware systems; proliferation of NCOs within all the services; extended equipment downtime because nobody knows how to isolate hardware malfunctions--examples are legion.

Since one possible reason for the failure of designers to incorporate data and techniques which can minimize manpower and training requirements is uncertainty about how such data and techniques can be integrated into their design process (with consequent reluctance to attempt to utilize these tools), a problem of communication exists. One reason for the existence of this communication problem is that data and techniques for identifying the impacts of materiel system characteristics on manpower and training needs have, in large part, been created in professional communities other than those associated with engineering design. This means, practically, that a different "language"--i.e., professional terminology than that used by engineers--has been used in describing concepts, data, principles, etc. which link hardware design factors to human factors. Thus, the engineers don't understand what human factors people are talking about, don't understand why human factors is important, and don't understand how to use human factors data. This is not always the case, but is probably more typical than not.

Coupled to the problem of different professional languages may also be a "not invented here" syndrome associated with particular engineering design organizations. In this situation, the designer feels that he is the "expert" on all facets of design, and someone else's solutions "can't possibly work in our approach." In any case, one factor in the failure of designers to apply appropriate data and technology to minimize the manpower and training requirements of their designs is the use of broadly different terminologies by human factors people (who develop those technologies) and the design engineers (who should use the technologies); i.e., lack of a "common language" between the two communities. The effort described in this report was initiated to study this "common language" problem.

The purpose of the present study has been to address three global areas dealing with the problem of a "common language." These three areas are:

1. Define the major decisions in the system acquisition process where manpower, personnel, and training (MPT) characteristics of an evolving materiel system are determined, and when and by whom these decisions are made. This portion of the effort defines the critical MPT parameters which must be transmitted to designers to ensure control of system MPT impacts.
2. Identify the means by which critical MPT decisions can most effectively be transmitted to designers so that the decisions and related information and technologies are effectively utilized by designers.

This part of the work identifies the characteristics or attributes of the required "common language."

3. Determine the best means for ensuring that system designers in fact understand the parameters communicated to them and utilize those parameters and associated data and techniques in the design process. Additionally, identify how the ultimate impact on system MPT characteristics of imparting required MPT parameters to designers can be determined. This portion of the effort outlines a verification strategy for ensuring that the "common language" communications are effective.

The remainder of this report discusses the general approach taken in analyzing and investigating these three critical issues, and the findings and conclusions of the analysis effort. Additionally, a concluding section is presented which discusses in some detail future developments needed to further develop and implement the "common language" approach in order to control materiel system MPT impacts.

APPROACH

In order to identify the attributes of a common language for communication of Manpower, Personnel, and Training (MPT) information between those individuals and organizations within the government which conceptualize and utilize new materiel systems (planners/users) and members of the engineering design community who operationalize materiel systems in hardware and software (designers), several successive, incremental activities were performed. Each activity built upon the collective results of previous activities, and led into successor activities directly, to ensure that all findings were interrelated and compatible. The activities performed were:

1. Identify types of decisions made in the materiel system acquisition process which are relevant to the life cycle MPT impacts of a materiel system.
2. From the decisions identified in the previous activity, select the decisions which have the greatest potential impact upon MPT issues during the life cycle of a materiel system (critical decisions).
3. Identify the point(s) in the materiel system acquisition process at which critical decisions are made, and who is responsible for these decisions.
4. Determine the most effective means of communicating critical MPT decisions to the engineering design community so that the importance and potential impact of MPT issues

are clearly realized by designers and incorporated into materiel system decisions.

5. Identify means of verifying that designers understood and incorporated MPT data and requirements in design decisions, and that these data and requirements have the desired long-term, life cycle impacts on the MPT characteristics of materiel systems.

Procedures which were followed in performing these activities are summarized in the paragraphs below.

The first activity performed was to examine the system acquisition process in detail to determine what types of decisions impact the life cycle MPT characteristics of materiel systems under development. Since the system acquisition process has been extensively studied and documented, a search of literature was performed to identify public domain and Army studies and reviews which could provide details of the acquisition process and data on decision making regarding MPT issues. Due to the limited time available for this effort, it was not possible to review all the documents, regulations, directives, and study reports which were identified as potentially relevant. Since a total review was not possible, attention was directed toward studies and analyses which dealt with MPT issues in system acquisition, rather than with source documents which describe the ideal form of the system acquisition process. It was felt that such study and analysis reports would provide more insight into the reality of the system acquisition process than would another review of the idealized details of the process. Documents reviewed in this activity are listed in Appendix A.

An initial review of the selected documents revealed that there are a great many decisions made at a variety of levels during the acquisition process which have potential impacts upon the ultimate MPT characteristics of a materiel system. Many of the decisions identified in this "first pass" were evaluated as being relatively molecular decisions, which only in the aggregate would be useful by or communicable to materiel system designers. The decision was made to concentrate attention and effort on MPT-impacting decisions that can be "visible" and meaningful to the designer and can influence design decisions both at the system design and component design levels, rather than on the "lower-level" decisions which "feed" major MPT characteristics and requirements. Several subsequent reviews of source documents led to an increasingly focused "picture" of decisions and issues which are of greatest importance to life cycle MPT impacts.

The decisions which were identified during the review of documents was eventually consolidated into a list which contained major decision-making activities and processes which occur in system acquisition with potential MPT impact, through the full-scale engineering development phase of system development. As this list was compiled, the points in the system acquisition process where each decision is made or refined, and the agency responsible for each decision were identified and associated with the decision items. Attention was directed to early phases of system acquisition, since decisions in later phases (especially production and deployment of a materiel system) are of little importance to the overall design of the materiel system, which is usually relatively complete at this stage.

The list of decisions, decision points, and decision makers was distributed to a working group of senior ASA personnel for review and comment prior to a meeting whose purpose was to select the most critical MPT-impacting decisions from the candidate list. A one-day meeting of the working group resulted in a consensus as to which decisions should be considered most critical to the life cycle MPT impacts of a materiel system. During the same meeting, an extensive discussion of methods of communicating these critical decisions to designers, verifying understanding of MPT data, and incorporating such data into design decisions was held. The working group reached agreement on the basic parameters of means of communication of MPT issues and verification approaches during this discussion.

Following the working group meeting, the basic "common language" parameters were further refined, and a list of major characteristics of the communication process (both from the government to designers and vice versa) was prepared. These characteristics form the basis of the discussion of "common language" requirements in the following sections of this report.

RESULTS AND CONCLUSIONS

At the core of toblem addressed in this study lies the fact that future materiel systems must be designed to function with an optimal minimum demand on human resources to operate and maintain the materiel systems, since limits on available personnel will only continue to increase in the future. The demand for minimum use of personnel in turn mandates that the design of materiel systems support this requirement. In order that the designers of materiel systems create systems to meet specific manpower criteria, the designers must be aware of the specific criteria to be met, and must also be aware of the consequences of failing to meet the criteria. Communication of MPT criteria to the hardware designer therefore must incorporate three basic issues: content (what to communicate), process (how to communicate), and verification (ensuring effective communication has been made).

To understand the characteristics of the communication process discussed below, it is necessary to understand the motivations and processes of hardware or materiel systems design. Engineering design of a system, at its base, consists of choosing among a large set of alternative approaches, to develop a system that performs a defined set of functions. Limitations can be and are introduced in the process of making design choices between alternatives, which effectively bound or constrain the choices available to the designer. The set of functions to be performed by the final design represents the broadest possible constraint on design, since efficient engineering includes only those components and capabilities which are needed to cause the system to meet its performance requirements. Constraints at many different levels are typically introduced in the design of a materiel system. For example, a requirement may exist that a system draw no more than a certain amount of power in operation, or that only a certain volume be occupied by the system. These requirements constrain the designer to the use of low-power components, and either low-volume components or high component density, respectively. On another level, it may be required that a system incorporate displays which can be read in direct sunlight. This requirement constrains the designer to utilize only display technologies with sufficient brightness, contrast, etc. to be read in the sun. Within each set of constraints on system characteristics, however, the designer typically has a variety of choices which will produce equivalent functional results. Conversely, if no constraints exist with regard to a particular aspect of design, the choice possibilities which will produce equivalent functional designs are quite broad.

The above discussion must be considered along with other factors to arrive at a complete picture. The designer is not only faced with the problem of producing a system with the required functional qualities, but also with problems of cost and availability of components to implement the various possible design alternatives, standard engineering and manufacturing practices and tooling which must be followed, and the need to produce the final system at a profit (the larger, the better). Each of these and many other variables act as constraints upon the designer, who must simultaneously meet or approximate all of the constraints imposed while at the same time producing a system with the required capabilities and functional qualities. The major point of this exposition is that, given firm constraints, a designer will attempt to design a system within those constraints, but in areas where no constraints are levied, the least costly and time-consuming approaches will be chosen and followed with little regard to the peripheral consequences of those approaches, as long as the firm constraints remain satisfied. The above is a gross oversimplification, of course, because it effectively ignores the complex tradeoffs that occur in the design process when many contraints must be simultaneously met. The point is clear, however: given constraints, the designer will design to meet those constraints, but in unconstrained areas where choices abound, the least costly approach will be adopted with little regard to consequences outside explicit constraints, as long as the basic performance parameters of the system are met.

As an example, consider the designer who is required to design a relatively slow switching network with no other constraints (power, volume, etc. are considered immaterial). The designer is faced with a choice between simple triode vacuum tubes and transistors as the primary switching elements in this network, but knows that tubes (in this application) last 20 times as long as transistors, but cost three times as much per switching element. Further, tubes can be installed in sockets, but the individual transistors have to be soldered to printed-circuit boards (for the sake of this argument; transistor sockets also exist). The network will perform to specification with either kind of component. Which component will the designer choose, given no other constraints? We suspect that transistors will be chosen, because they are cheaper (initially) per unit item, do not require mounting sockets (they are soldered in), consume less power (implying a smaller, less expensive power supply), and can be packed more tightly per unit volume. Consider, however, the impacts on maintainability of this simple choice. When the switching network fails, the effort to isolate the failure to one defective component is about equivalent for tubes and transisitors, given an efficient troubleshooting strategy, test equipment, etc. The effort to replace a defective transistor is much greater than that to replace a tube, since replacing a tube requires only unplugging the defective tube and substituting a new tube to effect the repair; with a transistor, the defective component must be unsoldered and removed; the new component protected with heat sinks, and then soldered back into the circuit board. Replacing a transistor therefore is much more time consuming (and problem-prone) than replacing a tube. Further, the transistors have only one-twentieth the expectable life of tubes, requiring twenty times as many replacement actions (on the average) as tubes over the life cycle of the switching network. The network using tubes is clearly more maintainable than that using transistors, yet the "better" engineering solution of using transistors is chosen because no constraints were placed on system maintainability.

While the above is a simplified example, it does serve to illustrate the point that designers tend to meet explicit requirements or constraints (or parameters, etc.) which are levied on the ultimate system being designed, but give relatively little attention to the consequences of design characteristics which do not impact the attainment of system performance requirements or cause explicit constraints to be violated. This argument can be logically extended to include portions of the total system which are not hardware; i.e., the personnel and training components of a system. If no limits or constraints are placed on the impact of a system design on personnel or training, then the design choices made during evolution of the materiel system will condition the functions, numbers, characteristics, and qualifications of personnel required to operate and maintain the system, and the amounts and kinds of training required for personnel to be able to operate and maintain the system. Conversely, if specific constraints upon the manpower and training impacts of a system are provided to the designer, in addition to system functional and performance requirements, these constraints will condition hardware design choices by the designer at both the overall system and component levels of design so as to meet all of the criteria simultaneously. It is common practice in materiel system acquisition to specify and constrain the performance parameters and other designated characteristics of the hardware portion of the system. Designers manage to develop hardware systems which usually meet strictly materiel performance objectives, under such constraints. It is reasonable to assume, then, that if designers also have the impacts of their designs constrained with respect to impacts upon the "other" side of the total system--manpower and training requirements--they will be able to produce effective materiel systems which do not violate explicit MPT constraints.

Following the reasoning above, it is concluded that the most effective, understandable, and verifiable means of communicating critical information regarding MPT requirements and decisions to materiel system designers is through the provision of explicit constraints upon personnel and training characteristics of the total system, on a par with strictly materiel requirements such as firepower, range, speed, survivability, and so forth, as system performance parameters. In essence, the designer should be given clear limits on the requirements for personnel and training associated with the materiel system under development, just as he is provided with performance parameters for hardware, and constrained to meet MPT goals as well as hardware performance goals. *Thus, the designer must be placed in the position* of "designing to constraint" not only in hardware, but in a total system development, including the materiel system and the people who operate and maintain that system.

This conclusion leaves three basic points unanswered, however. These are:

1. What aspects of manpower and training requirements (or decisions on the part of the government) should be communicated to the designer to constrain materiel system design?
2. How should constraints be communicated to the designer to ensure understanding of the criticality and nature of the

constraints and compliance with the constraints in design?

3. How can the government verify that the designer understood and complied with the constraints provided and that the constraints have the desired life cycle MPT impacts on system requirements?

Discussion of each of these critical issues form the remainder of this section of the report.

Critical MPT Decisions

Review and study of the system acquisition process (SAP) in early stages of this effort led to preparation of a list of decisions involving MPT issues, the phases of the SAP where decisions are initially made or refined based on experience, and identification of the agencies responsible for those decisions. This list is reproduced as Appendix B of this report. A major finding of the review of the SAP was that decisions made before full-scale engineering development of a prospective system begins typically remove 80-90 percent of the original degrees of freedom in system MPT issues (Fulkerson, 1974). Since decisions made early in the SAP have the most potential influence upon system design, most of the emphasis on identifying decision areas and decision points was concentrated on early phases of the SAP (through advanced development and, to an extent, full-scale development). One of the major conclusions of this analysis was that initial decisions based on estimates and analysis of comparison fielded systems, and made early in the SAP, tend be to refined by later experience, but are rarely overturned (O'Connor, Fairall, and Birdseye, 1982). It is recognized that decisions at early SAP phases tend to be general, rather than specific, which leads to a reluctance to put the decisions forth in requirement documents such as the LOA, CFP, and ROC. Even though general, decisions regarding MPT issues at early stages of the SAP are most likely to be critical to the design of hardware. The designer should be made aware of these decisions from the very outset of the design process, rather than having to "retrofit" a hardware design to accommodate MPT decisions after many specific design decisions have been made. Thus, if even very general MPT parameters can be communicated to a designer at the beginning of the design process, the general, broad parameters may be more potent in influencing design to meet desired MPT characteristics than will extremely specific, detailed data which may be developed only after one or more iterations of design have occurred. It is considered critical that MPT parameters be introduced into materiel system design from the first exposure of the designer to the materiel system concept (generally, this occurs when the Statement of Work (SOW) for advanced development contracts is prepared and distributed as part of an RFP).

Under the assumption that the earliest possible introduction of MPT constraints can have the greatest impact on design, even though constraints are broad and general, the process of evolving MPT data was reexamined. The purpose of the reexamination was to identify critical early decisions which are appropriate for use as design constraints or parameters. The criteria used for selection of these critical decisions were as follows:

1. Data are generated to support first approximations to these decisions during the concept exploration phase of system acquisition, in at least detailed concept form. Each of the decisions selected is at least nominally addressed by analysis or studies before the Concept Formulation Package (CFP) is finalized.
2. The decision area must be one which can be stated as at least a loosely quantitative parameter (numbers of people, weeks of training, mean time to repair, etc.) based on initial estimates and possibly refined later in the acquisition process.
3. The decision area must be ultimately verifiable in terms of MPT life cycle impact by direct comparison of available manpower and training data to requirements levied upon the materiel system designer.
4. The decision area must deal with overt, ultimate characteristics of the materiel system which have major long-term MPT impacts.

Two general areas were identified as sources of MPT constraints for designers. The first area includes direct estimates of MPT parameters which can be stated in terms of desirable personnel and training system characteristics for a materiel system. The second area deals with characteristics of the materiel system itself which can indirectly act to influence ultimate MPT requirements. Taken together, the early decisions made in these areas have the greatest potential impact on life cycle MPT requirements of a system under development.

The parameters or characteristics identified in these areas as having the greatest potential effect on system life cycle MPT requirements are summarized in Table 1. It is recognized that these parameters are stated at a rather global level, but it is believed that this level of expression is likely to be the most effective way of causing the designer to be aware of MPT constraints from the very outset of the design process. Further, these parameters are stated at a level of detail which is likely to be available even during early stages of system acquisition, as a result of concept exploration studies and analyses, and as such are available as early constraint items for use in advanced development procurements (there is no defensible reason to ignore MPT impacts at this stage, even though hardware concepts are being evaluated at the brassboard stage--if a system continues to production, the manpower and training requirements inherent in the basic hardware design choices will carry forward from the initial design).

Communicating the Decisions (Common Language Attributes)

Given that decisions and parameters are available to be communicated to a designer in order that his design choices be constrained to certain ultimate MPT impacts, a means must exist to communicate those constraints to the designer. To identify potentially effective channels for such communication, a review of the existing formal

Table 1

Critical Decisions Made in Materiel System Acquisition Having the Greatest Potential Life-Cycle Manpower, Personnel, and and Training (MPT) Impacts on System Design

Decisions Describing Desirable MPT Characteristics of Materiel System

- Allocation of system functions to operators (versus hardware)
- Number of operator personnel per copy of hardware system
- Skill levels and MOSs for operator personnel
- Desired training time and milieu for operator personnel (to minimum proficiency)
- Operator training device requirements (number and purpose)
- Unit structures (TOE) desirable for operation and support of materiel system
- Desired number of maintenance personnel per level of maintenance to support one copy of materiel system (maintenance manhour requirements is a rough equivalent)
- Desired training time and milieu for each category of maintenance personnel
- Maintenance training device requirements (number and purpose)

Decisions Describing Materiel System Characteristics That Influence MPT

- System maintenance concept: number of levels of maintenance structure and allocation of maintenance functions to levels
- Desired reliability and availability levels of overall materiel system, subsystems, and support systems
- Desired maintainability characteristics of materiel system (allowable downtime time to repair, built-in or automated test capabilities and requirements, etc.)

channels of communication between the government and designers/contractors was performed to determine whether manpower and training constraints might be implemented effectively through such channels. Emphasis in this review was on the following considerations:

1. An effective means of imparting MPT constraints to designers should parallel the means by which other constraints and requirements (i.e., materiel system characteristics) are communicated.
2. The means of communication should provide clear emphasis that MPT constraints are at least equivalent to materiel system performance requirements in importance, and that the two areas are interdependent aspects of the total system to be designed.
3. The means of communication should incorporate ways to evaluate whether MPT constraints and their intent are understood by the designer.

A summary of the results of the effort to identify and define common language attributes is presented as Table 2. This table identifies each attribute and presents a brief explanation of the attribute. In addition, the manner in which each attribute has been dealt with in the past is discussed, and possible applications of the attribute to future materiel system procurements are set foth in the column headed "Application (Past/Future)."

Only one existing channel of communication between the government and system designers/contractors which is common in all materiel system acquisitions and fulfills the characteristics listed above was identified. This channel is the system specification document which composes

Table 2

Summary of Common Language Attributes and Applications

Attribute	Explanation	Application (Past/Future)
Constraint statements on MPT characteristics	Desired MPT characteristics of materiel system to be developed must be stated as design constraints (or parameters, etc.) specifying MPT aspects of system to be achieved by system designs	Past: CFP and ROC have discussed parameters as targets, goals, etc.; not as constraints Future: MPT requirements constrained as firm parameters of systems coordinate with materiel performance characteristics
Constraints to be explicit components of system specifications/ RFPs	Explicit MPT contraints introduced as part of overall system performance specifications/ parameters in RFP; designers required to meet MPT factors or parameters simultaneously with materiel system parameters	Past: RFPs have not contained MPT constraints, rather, reference to "applicable standards, specifications, etc." is made--no firm MPT parameters specified Future: Explicit tradeoffs made of MPT and materiel characteristics prior to exploratory development procurement action; system performance specifications in RFP include explicit, detailed, mandatory MPT characteristics in addition to materiel performance requirements and characteristics

Table 2 (continued)

Summary of Common Language Attributes and Applications

Attribute	Explanation	Application (Past/Future)
Constraints deal with specific system MPT characteristics to be achieved in design	Specific MPT parameters of the system(s) to be developed are addressed in constraint statements explicitly on item-by-item basis rather than by inference or default	Past: MPT characteristics addressed globally and by reference in procurement actions (e.g., in accordance with MIL-STD-/MIL-SPEC-etc.); detailed requirements for specific MPT system characteristics not stated forthrightly Future: Specific parameters and values to be achieved vis-a-vis MPT characteristics or systems specified as design criteria
Rationale and justification for selection of MPT constraints explicitly provided to designers	Derivation of MPT constraints and constraint values provided to promote designer comprehension of the importance of particular MPT constraints and the reasons constraints are imposed on resulting designs	Past: Not possile to determine whether MPT factors rationale has ever been formally provided to designers; no channels for this information are known to exist Future: Source data, means of derivation of MPT constraints, and tradeoff inputs and outputs influencing MPT constraints presented as rationale and justification of constraints on system MPT characteristics

Table 2 (continued)

Summary of Common Language Attributes and Applications

Attribute	Explanation	Application (Past/Future)
Constraints stated in quantitative terms	Explicit quantitative values provided for MPT characteristics to be constrained to ensure clarity and specificity of communication of Government's criteria	Past: Specific, quantitative values of MPT influencing hardware characteristics (e.g., AMMH, MTTR, etc.) are frequently supplied as hardware parameters; direct MPT characteristics (operator manning, training time requirements, etc.) are rarely specific or quantitative, but tend to be qualitative. Future: Specific quantitative values of all constrained MPT characteristics supplied as performance parameters of total man/machine materiel system to be designed in system specification
Guidance to assist in constraint compliance provided	Handbook or "roadmap" of techniques, tools, data, and guidance to assist designers in meeting MPT characteristics and constraints in the design process is provided for all MPT-constrained procurements	Past: No integrated support for materiel system designers provided; guidance scattered among design handbooks, specifications, Military Standards--not integrated nor in a form to support designers' needs

Table 2 (continued)

Summary of Common Language Attributes and Applications

Attribute	Explanation	Application (Past/Future)
Guidance to assist in constraint compliance provided (continued)		Future: To-be-developed handbook of MPT analysis and design assessment techniques for designers provided to designers as Government-furnished resource. Handbook contains all relevant human factors, manpower, training, personnel system, etc. techniques, data conceptual tools, and guidance to aid designer in incorporating MPT considerations into design and meet system MPT constraints as well as materiel performance objectives
Constraints are verifiable both during system development and in the field	Verification of Compliance with and efforts to meet constraints on system MPT parameters is possible due to constraint specificity, quanti- fication, and consideration of need to verify both design decisions concerning the constraints and the ultimate impact of constraints on fielded system MPT requirements	Past: MPT requirements not quantitative, therefore not verifiable Future: Explicit, planned reviews of design decisions and tradeoffs impacting system MPT parameters provided for in the design process as an in-process verification procedure; ultimate verification of effects of constraints possible by comparing quantitative MPT constraint parameter values to obtained MPT characteristics of operational system

Table 2 (continued)

Summary of Common Language Attributes and Applications

Attribute	Explanation	Application (Past/Future)
Effective consequences of failure to meet constraints on MPT characteristics of systems	Clear, overt, explicit consequences for failure to meet system MPT constraints to be introduced as part of the materiel system design/development contract; known economic consequences to designers for failure to achieve MPT objectives	Past: This attribute never known to have been implemented for system MPT characteristics Future: By designing materiel system, designer "warrants" MPT characteristics of system; penalties for failure to meet MPT constraints a part of acquisition/development contracts

a major portion of the Statement of Work for materiel system procurements. The specification document contains requirements for materiel system performance in terms of detailed criteria which the system must meet in order to fulfill its mission. In this context, it is possible to introduce explicitly MPT-impacting constraints on an equivalent level with materiel system performance requirements as part of the system performance specification. Since explicit response to all aspects of requests for proposals is typically required of a prospective contractor, an opportunity to evaluate a designer/offeror's understanding of MPT constraints--in his proposal--is present. Thus, it is considered possible to make explicit MPT constraints a part of system specifications governing the designer.

It is recognized that the idea of placing explicit MPT constraints and requirements in system performance specification/RFPs may cause some uneasiness on the part of readers of this report. This in an understandable reaction, since there is certain to be some resistance on the part of designers/contractors to being constrained to particular manpower and training impacts of system designs. In order to be effective, MPT constraints MUST be stated as explicit performance requirements for the total materiel system to be developed. No other means of making MPT constraints effective is apparent. While there are many alternative ways of presenting MPT requirements/constraints to designers, the only likely means of causing the constraints to be effective is to require that the system comply with those constraints; the only available way to effect this outcome is to make compliance with the constraints a contractual requirement. Other, less formal means of presenting desired MPT constraints and information to designers cannot have the force and complusion to mandate compliance and thus to cause the constraints to truly constrain.

Having reached the conclusion that the most ultimately effective means of imparting MPT information to designers is to include explicit constraints upon various MPT parameters of the total system to be designed, as provisions of system performance specifications in development contracts, some additional attributes of constraints which will help to ensure effective communication can be discussed. First, MPT constraints should overtly deal with specific parameters of the personnel/materiel system, rather than with bodies of data such as specifications, standards, regulations, procedural guides, or handbooks, which describe ways in which the constraints can be met, or techniques (i.e., "tools"). A great many "tools" for dealing with MPT aspects of systems now exist (e.g., ISD handbooks, human factors engineering guides, system analysis procedures, etc.), and are typically addressed or referenced in materiel system specification packages. Therefore, the designer is already at least nominally provided with many of the "tools" to be used in complying with MPT constraints. The question of developing means to help the designer select the appropriate "tools" to aid in meeting MPT constraints is an important one, but development of such a means is beyond the scope of this effort. Explicit constraints dealing with very specifically defined, but general MPT characterisics (listed Table 1) must be provided in order to control the MPT impacts of system design.

Next, a rationale for the choice of particular MPT constraint or parameter values must be provided to the designer in order to justify and explain the particular choices of constraints which have been levied. If a rationale is not provided, designers will not understand the importance of the contraint; i.e., they will not understand "why" the constraint has been levied, therefore, they may ignore the constraint. The rationale for most of the parameters which would be constrained can be captured during mission area analysis and concept formulation phases of the acquisition process and presented as justification for constraint value choices. Mission area analysis should identify MPT-related deficiencies or problems in present systems which a materiel system under development will replace; these deficiencies can form the basis for development of MPT constraints during concept formulation. The results of these developments form the basic rationale for MPT constraint choices. It is considered vital for the designer to understand not only what constraints are levied upon the MPT characteristics of the materiel system he is to design, but also the derivation and intrinsic importance of those requirements.

A further desirable characteristic of MPT constraints to be levied on the designer is that the constraints be clearly quantitative. A quantitative goal (number of operators, number of weeks of training, maximum number of allowable annual maintenance manhours per system copy, etc.) is clear and easy to understand, and provides an uncompromised criterion. Qualitative statements of constraints (i.e., "the system shall be designed to operate with a minimum number of personnel") are less easy to understand as constraints and leave considerable and undesirable latitude to the designer. Permitting such latitude would totally defeat the purpose of constraining the MPT characteristics of a system under design; in fact, such pseudo-constraints are presently used in materiel system design contractual documents, with disappointing results.

Yet another attribute of MPT constraints should be guidance as to how the constraints can be satisfied during the design and evolution of a materiel system. As mentioned previously, many "tools" and techniques for examining and analyzing various MPT implications and consequences of materiel system design characteristics are available. These "tools" are typically in the form of regulations, standards, directives, etc., and often are contradictory in purpose, procedures, recommendations, requirements, and so forth. A consequence of this situation is that the designer has no clear guidance for dealing with MPT issues during design. This results in only cursory attention to MPT issues (since the designer does not have a clear picture of how to get to the desired results) and possibly "pencil-whipping" of required documentation of MPT investigations during design. It was mentioned earlier that development of a "roadmap" delineating "tools" for helping the designer meet MPT constraints on design is beyond the scope of the present effort. It is considered of major importance in future efforts, however, that such a "roadmap" be developed and made available to designers along with explicit constraints on MPT characteristics of system designs.

A characteristic of the constraint set on MPT impacts which was implied but not stated previously was that compliance with the explicit constraints be ultimately verifiable by examining the characteristics of the materiel system developed, in the operational environment. This characteristic ties closely to that of the desired quantitative nature of constraints. If it is initially specified that a materiel system be designed (for example) to be fully operational using x number of operator personnel in y defined positions, it is vital to be able to examine the operational effectiveness of the system under those conditions to determine if the constraints were, in fact, met. This represents ultimate verification of the success and impact of the constraints.

Finally, in order to be effective, constraints must be associated with effective consequences for failure to meet the constraints. This is another topic which may cause some uneasiness in many quarters, akin to the overall concept of placing explicit MPT constraints in the requirements and specifications of system development RFPs. It is a hard psychological and practical fact, however, that behavior cannot be modified without consequences to unwanted behavior. In this case, the "unwanted behaviors" are failure to give consideration and attention to the MPT impacts of a system under design, coordinate with engineering design and materiel system performance issues. A trend has arisen in recent years in the direction of including performance warranties in strictly hardware-oriented aspects of materiel system procurement. This approach introduces explicit and overt economic consequences to the designer and producers of materiel systems, which hopefully causes more detailed attention to be paid to materiel system factors that could cause the overall system to fail to meet warranted performance characteristics. It seems reasonable to introduce similar consequences to failures to meet MPT constraints. For example, if minimum proficiency training time and cost for operators of a materiel system exceed constraints levied from the outset of the design process, the system designer could be forced to absorb the portion of training costs that exceed those that would exist if specified constraint values had been met. This, of course, supposes that the constraints imposed are reasonable and achievable. It is a risk in using MPT constraints to influence materiel system design that the imposed constraints may not be achievable, given other desired characteristics of the system and its performance objectives. There are, however, a number of opportunities early in the system acquisition process where it is possible to detect unreasonable constraints, the most obvious being the materiel concept tradeoff analyses conducted during the development of the CFP in the concept exploration phase of acquisition. At this point, mission performance parameters, technology factors, logistic implications, and manpower and training considerations are traded off to arrive at selection of a best technical approach for further development in the advanced development phase of acquisition. If explicit attention is given to potential MPT requirements and constraints during the tradeoff process, it seems unlikely that genuinely unachievable constraints will be generated. It is not clear to what extent MPT factors are considered during the tradeoff process at present, but is should be feasible to address potential MPT constraints during this process, to ensure that unreasonable constraints are not introduced.

Verification

Having imposed constraints upon the MPT impacts of the design of a materiel system, it is also necessary to be able to verify that the designer understood the nature and implications of the constraints imposed, and that the constraints were considered in making design choices. It is further necessary to be able to determine whether the constraints were ultimately complied with and had the desired effects upon the MPT characteristics of the system. These three verification problems are addressed in the following paragraphs. A summary of the verification strategy discussed below is presented graphically in Figure 1.

The problem of verifying the ultimate impact of constraints on system MPT characteristics is the most straightforward of the verification issues, and so will be dealt with first. Verifying that a materiel system design fully complies with imposed MPT constraints cannot be done until production versions of the system are deployed and integrated into the Army operational inventory. At this point, operational training of personnel to operate and maintain the system has taken place, and experience is beginning to accumulate regarding the adequacy of performance of the materiel system as supported by Army personnel in its mission role. In the operational environment, a materiel system comes under the scrutiny of a variety of measurement and evaluation systems which tap personnel requirements, training requirements, operational effectiveness of the materiel system, and so forth. Data generated by the various measurement systems can be aggregated to create a composite picture of the true operational MPT

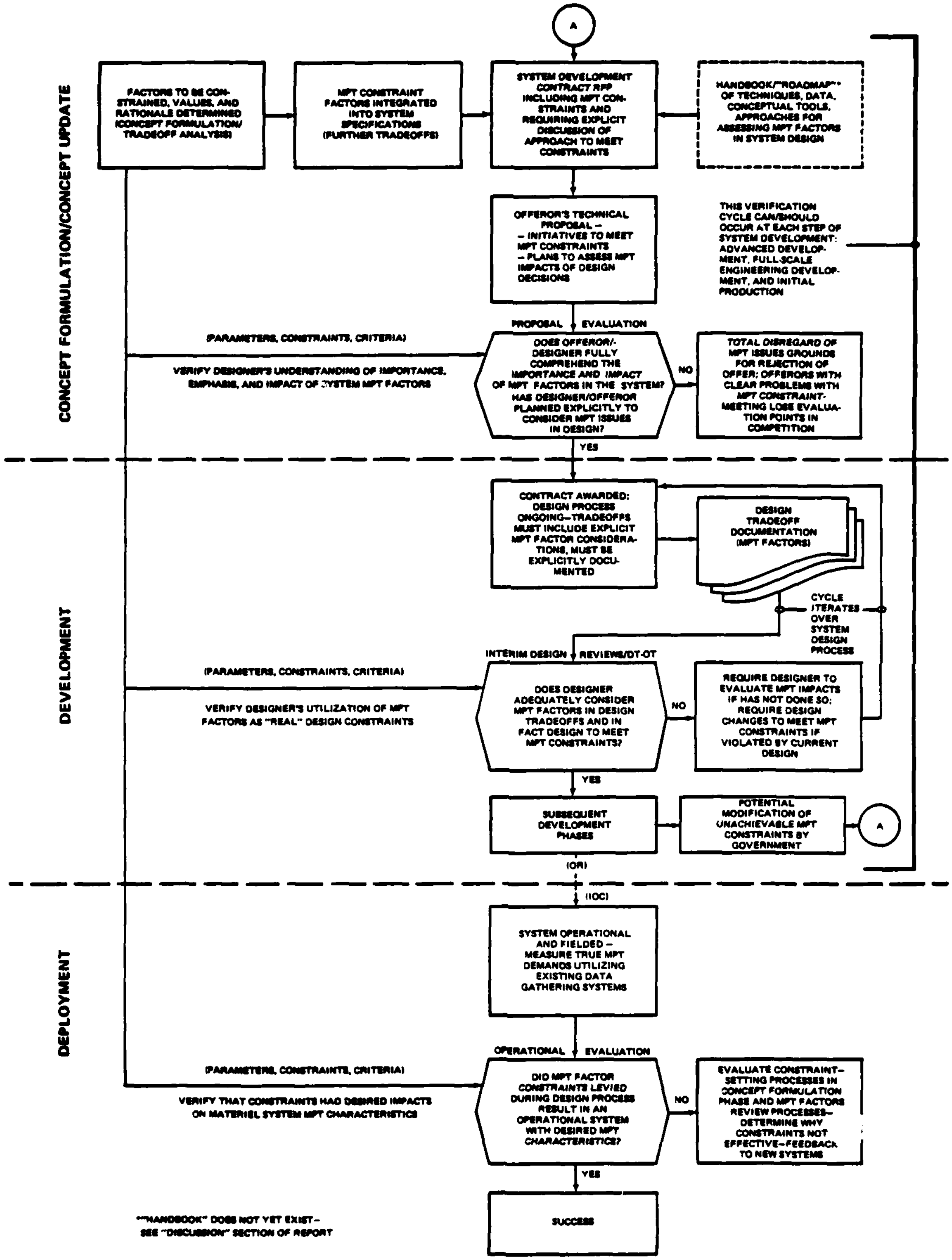

Figure 1. MPT Constraint Verification Processes

parameters of the system, and compared to the original MPT constraints to determine whether these constraints have been met. The operational performance of the total system in its mission role must be considered along with evaluation of the satisfaction of MPT constraints, however. If the overall personnel/materiel system fails to meet its stated performance goals, yet the imposed MPT constraints are satisfied, there is the possibility that inappropriate MPT constraints in some manner contributed to such a failure. Given that the MPT constraints were given appropriate attention during system concept formulation, and that experience with other materiel systems is taken into account, such an outcome will not be likely.

It is beyond the scope of the present effort to identify data sources and means of aggregating data to provide a detailed methodology for determining whether MPT constraints imposed on system design have the desired ultimate impacts upon life cycle MPT characteristics of systems under development. Evolution of such a methodology must await future efforts. The point of the above discussion is clear, however: in order to measure the ultimate impact of MPT constraints, the actual MPT characteristics and operational effectiveness of the fielded system must be assessed against the parameters specified as constraints. Existing evaluation and assessment data systems at least nominally provide data which can be utilized to identify the actual MPT characteristics of a materiel system in the operational inventory.

The problems of verifying whether designers understand the nature and intent of MPT constraints and whether the design choices made by the designers are in fact influenced by the constraints are less straightforward than evaluating the ultimate impact of imposed constraints. Since it has been suggested that communication of constraints to designers take place by formal means which are presently established (system performance specifications), a logical source of verification information is through formal channels of communication from the designer to the government, associated with the system development effort.

The obvious source for evaluating the contractor's initial understanding of the intent, purpose, and importance of MPT-impacting constraints is the technical proposal and associated supporting documentation provided by the prospective designer in competitive bidding. The designer/offeror's comprehension of the importance and implications of specific constraints regarding the MPT impacts of the system can be assessed through requiring the designer/offeror to set forth in his proposal the initiatives he plans to implement to ensure that MPT constraints are considered at all levels and phases of system design. The comprehensiveness and clarity of the plans set forth by the designer/offeror will reflect his understanding of the emphasis placed on MPT issues and impacts, and the importance of MPT considerations as a factor in total system design, parallel to the importance of materiel system performance factors. In fact, evidence of understanding of the intent and purpose of MPT constraints and detailed plans to ensure that MPT constraints will be made can be made a significant portion of the evaluation factors for award of the prime design/ development contract for a materiel system. Failure to demonstrate that the intent, nature, and importance of MPT constraints has been considered and evaluated, and efforts to comply with the constraints have been incorporated in planning the system design process, will weigh against the designer/offeror. This approach to ensuring that MPT constraints and factors are considered by designers takes advantage of a system which is already in place and operational. There is, however, one potentially very serious problem which must be addressed in order for this approach to be useful. This is the development of the "roadmap" linking potential MPT constraints to techniques and technologies to assist designers in meeting those constraints, mentioned earlier in this report. In order for the designer to be able to meet MPT impact constraints, he must be provided a reasonably clear picture of how those constraints can be satisfied while addressing other major design issues, notably that of ensuring that the materiel system meets its performance objectives. It is critical, then, if designers are to be required to design to MPT constraints, usable methods of employing available techniques to evaluate the MPT implications of evolving system designs be known to the designer. Given that the designer is aware of the existence and utility of techniques to assess the MPT impacts of designs (not always or even frequently the case at present), explicit plans to utilize those techniques and "tools" can be integrated into his design effort. It is the presence of such plans in the designer/offeror's material system design proposal which can be evaluated to assess whether designer/offerors in fact comprehend the nature, intent, and importance of MPT constraints.

The problem of verifying that designers actually consider MPT constraints, and attempt to meet these constraints (and use tools for incorporating MPT information into design decisions) is closely coupled to verifying both the ultimate impact of the imposed MPT constraints and the designer's understanding and comprehension of the intent and nature of the constraints. While it is absolutely vital that the designer consider MPT impacts and constraints in the design process, and that these constraints genuinely influence his design choices, verifying that the designer has done so during the course of design is a complex problem. Again, existing requirements for formal communication between the designer and the government may provide opportunities to verify whether the designer in fact incorporates MPT constraints into the design process.

In a typical contract effort to design a materiel system, the designer is required to produce a wide variety of documentary products which substantiate design progress and the characteristics of the system design. Since the designer performs many tradeoff evaluations in the course of a design effort, it may be feasible to examine the factors used in major tradeoff decisions to determine whether impact upon MPT factors was considered in the tradeoff process, and whether tradeoffs resulted in design decisions which trend toward satisfaction of MPT constraints. An example of such a tradeoff would be the process of choosing whether to use common test equipment versus built in automatic test facilities for fault isolation in an electronic system. Both solutions are potentially manpower and training intensive, but at different levels: use of common test equipment implies highly-trained, capable personnel interacting extensively with the prime equipment to perform fault isolation, while built-in automatic test implies a lower requirement for direct interaction with the prime equipment, by personnel with less expertise (and, hence, requiring less training). On the other hand, built-in test equipment can go bad itself, requiring additional trained manpower to repair, and leaving the prime system down (since there is no way to perform the fault isolation tasks that were relegated to the automated test equipment). Also, the use of built-in test/automated test at the organizational maintenance level has the tendency to push maintenance workload "up" the maintenance system to intermediate and depot levels, requiring larger numbers of trained personnel (probably more highly trained than at the organizational level) at higher levels of maintenance, additional test equipment, etc. The choice between the two would be based on a complex tradeoff analysis incorporating considerations of reliability (of both prime and test equipment), system maintenance concept, equipment availability requirements, manpower demand at all levels of maintenance, and training requirements.

Unless specific manpower and training requirements are considered in this sort of tradeoff (along with a host of other relevant factors), the implications of the approach selected on MPT factors will remain undefined well into subsequent phases of design. Requiring documentation of tradeoffs to include the specific impacts of the various tradeoff alternatives upon manpower and training requirements represents one feasible approach to assessing the extent to which designers actually attempt to meet imposed MPT constraints. There are a number of formal communication events which might be used to document the extent to which MPT constraints and impacts are considered in design decisions and tradeoffs. The most potentially useful of these events for assessing whether MPT factors are considered in design decisions are Interim Design Review Conferences. At these conferences, the designer presents specific details of the evolving design and discussion of such issues as tradeoffs performed, the results of those tradeoffs, problems encountered, and so forth. The designer can be required to demonstrate, during design reviews, that critical MPT factors have in fact been considered and evaluated during system design tradeoffs, and that approaches which in fact tend to minimize potential MPT demands in the ultimate system have been adopted. While it may not be (and probably is not) feasible or cost-effective for the designer to jointly evaluate in detail the impacts of all tradeoff decisions on MPT factors, trends of designers' decisions with respect to MPT impact can be identified by examining major tradeoff processes and outcomes. Thus, if a designer consistently fails to include consideration of MPT impacts in major system tradeoff decisions or consistently chooses approaches which imply greater demands for trained manpower, his lack of sensitivity to the MPT impact of his design will be evident.

DISCUSSION

A central problem in ensuring that materiel system designers take manpower, personnel and training (MPT) issues into account in the system design process is the communication of the government's decisions about the allowable impact of a materiel system on MPT requirements, and verifying that designers incorporate these limits into their designs. This effort has addressed this problem at a preliminary, general level. The critical categories of MPT information which should be addressed have been defined, it has been determined that these decisions will be most effective if stated in terms of system performance parameters or constraints, and general approaches for verifying the understanding and utilization of the constraints by designers and the ultimate impact of the constraints on MPT requirements have been addressed. The means by which MPT requirements should be communicated to designers and the verification approaches identified form an outline of a "common language" for the exchange of MPT information between the government and designers. A diagram illustrating the overall concept of utilizing the "common language" to communicate MPT requirements to designers and verifying designers' understanding and utilization of MPT requirements is presented as Figure 2.

It must be emphasized that this effort represents only a first approximation to the definition and implementation of a means of

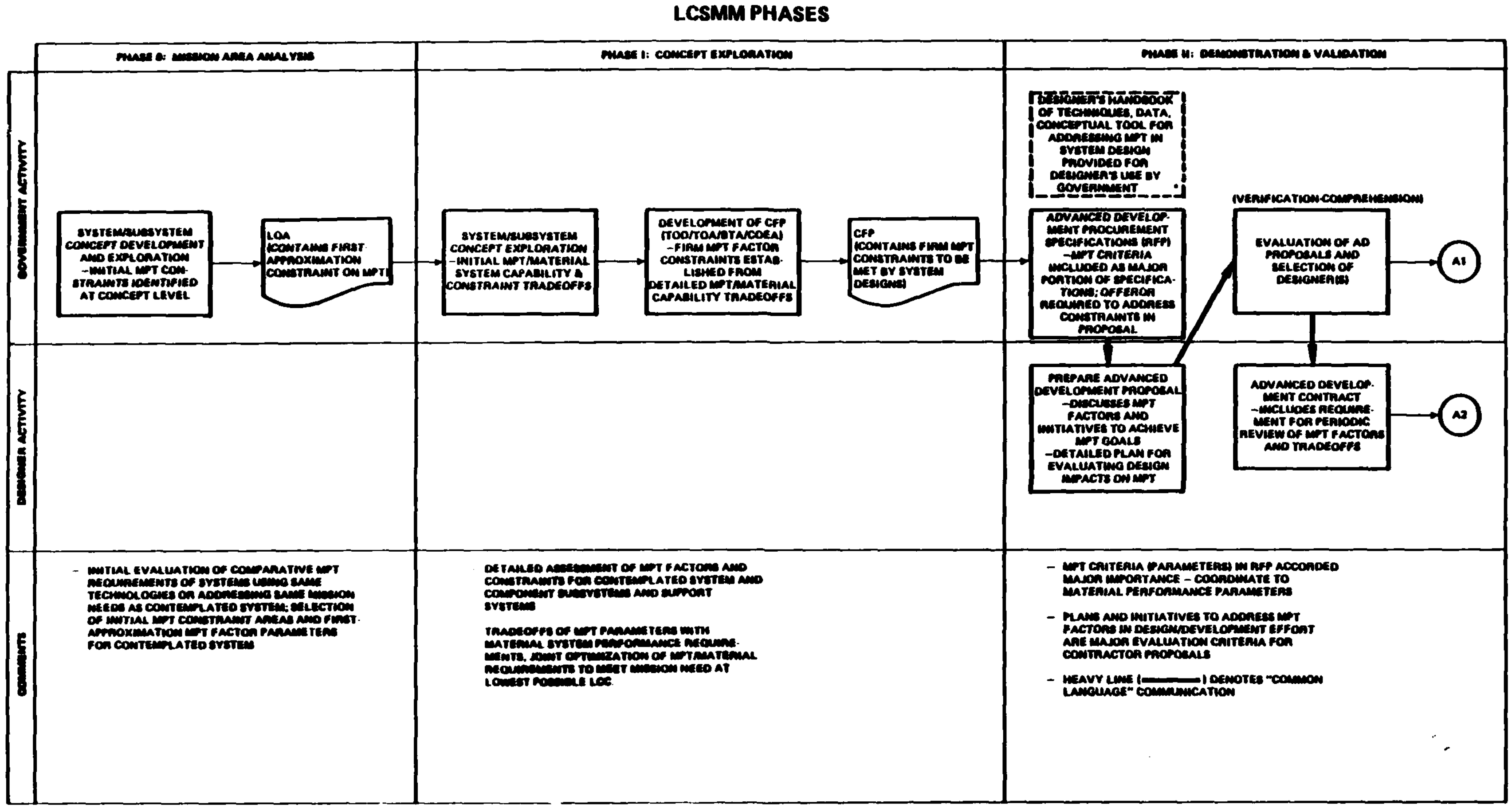

Figure 2. "Common Language" Communication Flows in Materiel System Acquisition

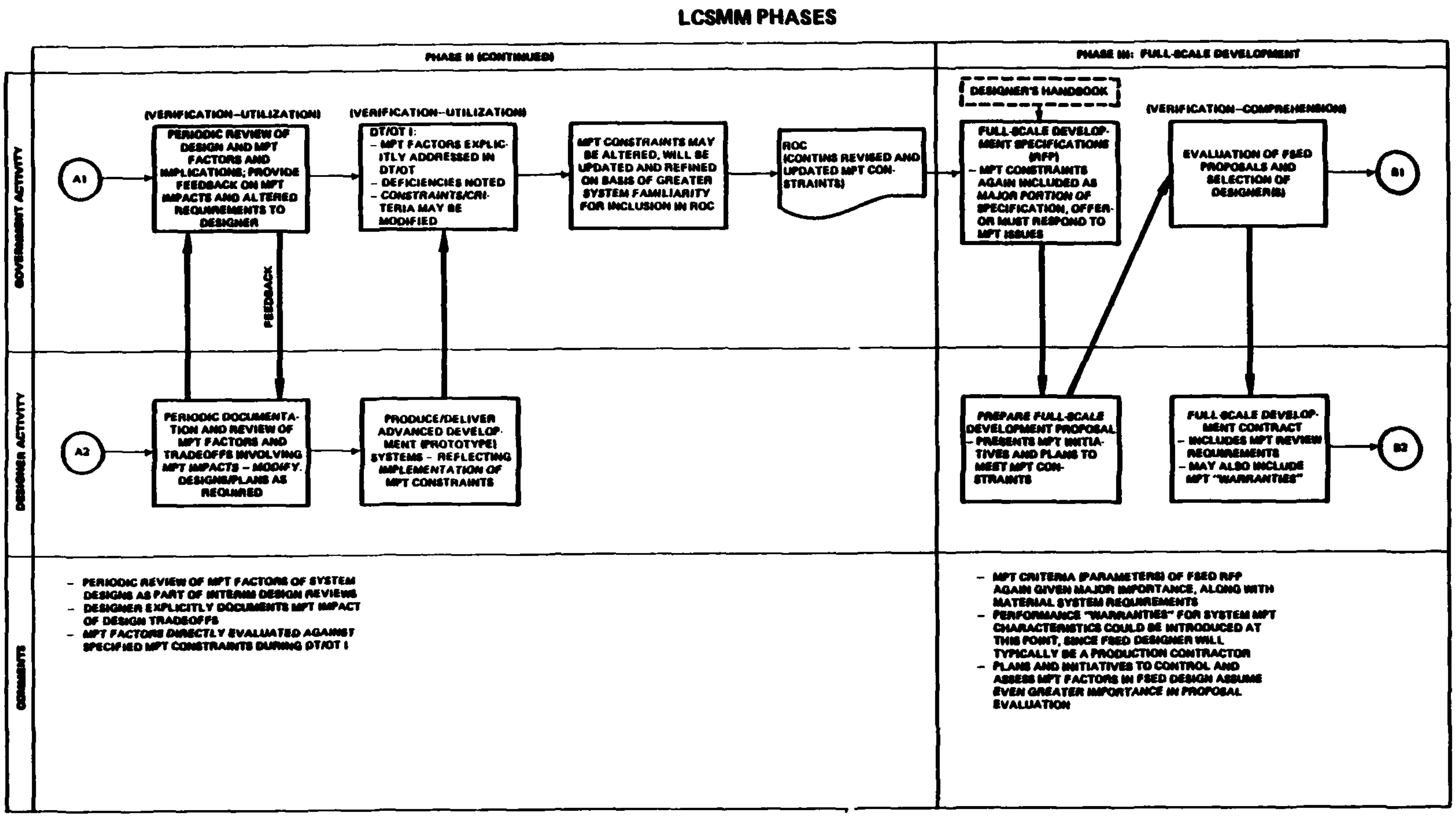

Figure 2. "Common Language" Communication Flows in Materiel System Acquisition (cont.)

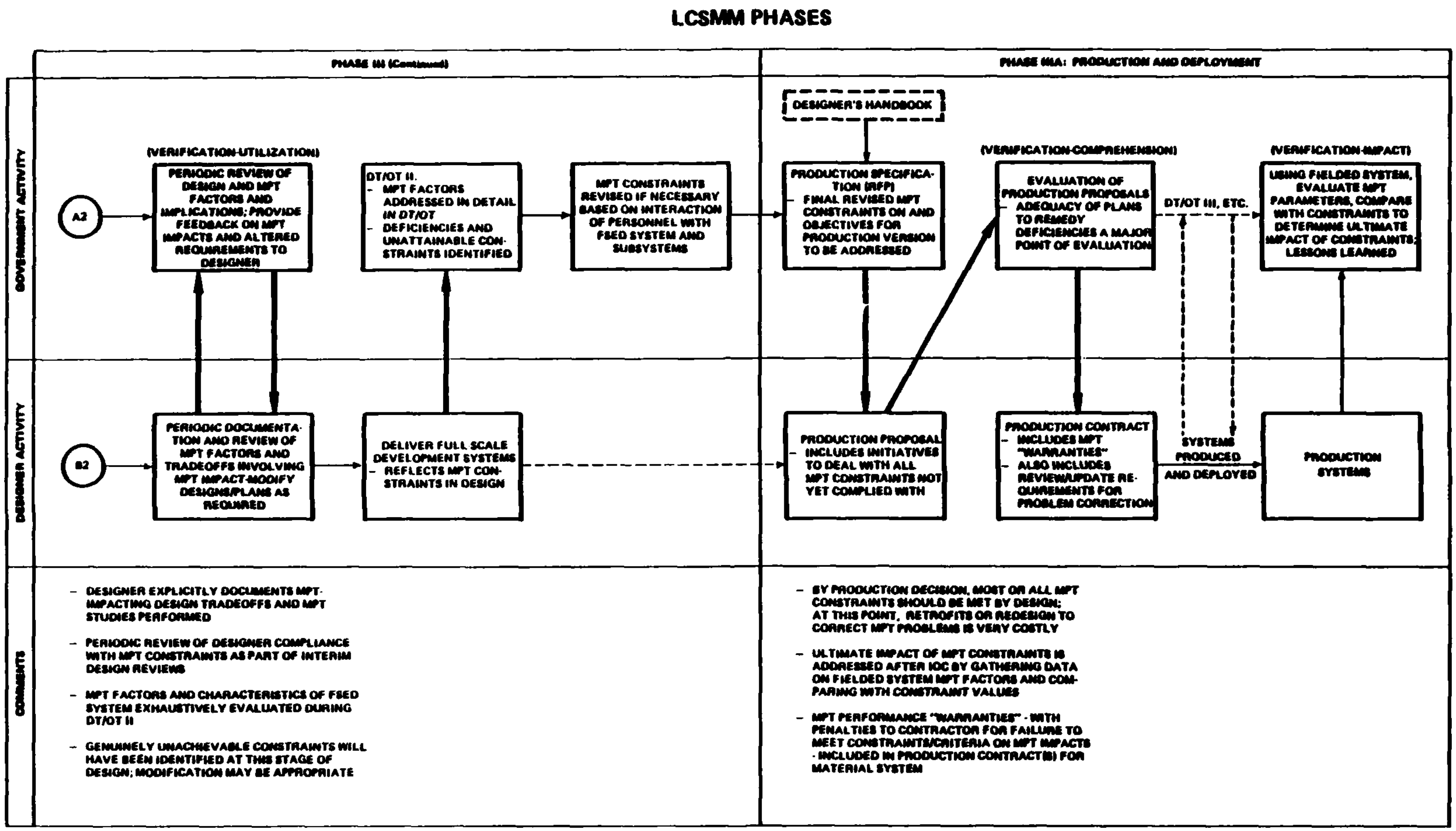

Figure 2. "Common Language" Communication Flows in Materiel System Acquisition (cont.)

controlling the impact of materiel system design upon the ultimate requirements for manpower, personnel, and training of a total system. A number of critical issues remain to be addressed in order to define and implement an effective "common language." Two critical developments which have been identified in the course of performing the present work are discussed below. It is considered absolutely essential that those two developments be undertaken prior to implementing MPT impact constraints in the design process. Those developments will provide needed tools and techniques to ensure that well-conceived and achievable MPT constraints are formulated, and that designers have the means available to comply with the constraints.

1. The decision process leading to the establishment of MPT requirements early in the system evolution process (concept exploration) is not well defined or well operationalized. Although certain developments and events which should provide initial data on which to base MPT decisions are specified as part of the LCSMM process (training and logistic support analyses), it is not known to what extent these developments produce data which are sufficiently comprehensive and complete to drive MPT decisions. An investigation of the quality of data generated during system and subsystem concept exploration efforts and the applicability of this data to MPT decisions would provide resolution of this question. It is suspected that the emphasis on detailed analyses to support training and

logistic planning, which should provide basic data and estimates for establishing MPT requirements and constraints, varies widely across system developments. It is clear from examination of the structure of the LCSMM that a possibility exists for analyses and data generation efforts to be product-oriented, rather than goal-oriented. By this it is meant that many analyses may be undertaken for the sole purpose of providing documentation for higher-level (e.g., DSARC or ASARC) decision-making, rather than directed toward ensuring that the most effective life cycle cost-efficient personnel/materiel system possible is produced. No evidence of a structured, results-oriented process for analyzing and defining the potential MPT impacts of system concepts is present in any of the documents reviewed in this work. Several studies have defined the need for such a process, however (e.g., Rhode, Skinner, Mullin, Friedman, Franco, and Carroll, 1980).
An approach to identifying how such a process should be structured and the procedures which might be adopted in the process might begin by working backward from the "critical decisions" defined earlier in this report. The information required to make each of those decisions would be defined, in terms of specific data items, and the processes that should be performed to derive the data would define a "criterion" against which to evaluate the data generated

and procedures utilized in decision-making in past or current acquisitions. Several representative system acquisitions would then be selected for study, to determine what data actually are generated by analyses and studies during concept exploration efforts, and how these data feed into the decision-making process. Emphasis in this study of the representative acquisitions would be on identifying cases in which needed data are not generated or where the quality and quantity of the data are not sufficient to support critical MPT decisions, and determining the reasons why such data are not generated. The study would further attempt to identify the degree of structure and coordination that typically exists in MPT-oriented studies and analyses during system concept exploration in the representative acquisition efforts, and where additional structure and information would facilitate efficient analyses and decisions. It is understood that this will not be an easy process: the audit trail for decisions during early phases of system acquisition is often obscure (especially with systems which are near introduction into the inventory, or already fielded), personnel involved in the decision and analysis processes may have long since moved on to other responsiblities, etc. However, in order to influence and rationalize the system concept exploration process with respect to MPT considerations, it must first be known what processes are used and what products are produced by the tradeoffs, analyses and studies during this phase, and how useful and utilized the outputs of the processes are. If, as it is suspected, the processes and products are idiosyncratic to individual system developments, the introduction of defined process and structure to the task of defining and studying MPT impacts and trading off MPT impacts and materiel system characteristics will prove of value, if only as a framework.

After the representative system acquisitions have been examined individually, the results of the process studies would be combined to form an overall critical-incident-based picture of the errors, omissions, and discontinuities that were identified in the process of studying and analyzing the MPT factors of contemplated systems, during concept exploration and development. This would include consideration of reasons why critical data were not generated, were not sufficient for decision-making, or were not used (and combinations of these). This critical incident analysis would be used to define the evolutions and processes in system concept exploration where additional structure is needed or where processes are inadequate (or do not exist) for generating needed data. Each of the identified needs would then be explored in detail to determine whether techniques and procedures presently exist which could be applied during the concept exploration process to improve the quality and impact of data on system

MPT issues. Where such techniques exist, the specific points where the techniques and/or procedures would be introduced would be identified and approaches for their introduction specified. In addition, an overall data and decisions flow model for the generation and application of MPT data during concept exploration, based on the initial step of the study, but much more refined to include all the processes, products, and decisions identified in the critical incident study, would be prepared. This model would serve as a framework for evolving the structure of early stages of the system acquisition process to ensure that appropriate, timely and complete consideration and study of MPT issues is made during critical decision-making and tradeoffs, based on the most accurate and complete data which can be made available.

2. Perhaps the most important and valuable future development which has been identified in this effort is the need for a "roadmap" to guide designers in the use of existing techniques, procedures, and data to minimize the MPT requirements of systems under design. A great many highly useful tools and techniques and extensive data have been developed by the human factors and training communities which can be directly applied to evaluating design characteristics and decisions for gross or detailed impact upon manpower and training requirements. These include guidelines for function allocation to humans versus hardware, task and

skill analylsis techniques, man/machine interface design principles and evaluation tools, training requirements analysis procedures, maintainability design principles, and many others. All of these tools and techniques are potentially usable in the hardware design process to evaluate and control the impacts of materiel system design characteristics upon requirements for personnel and training, if used in an appropriate and timely manner.

As mentioned in the Introduction to this report, one primary reason why these techniques and data are not used by engineering designers is that the designer does not understand the purpose and application of the tools and techniques in the design process. It is clear that the designer will need to be able to apply techniques and data to define the MPT impacts of design decisions and thus intelligently trade off design alternatives, in order to be able to meet all of the constraints upon the resulting design, from both the MPT viewpoint and that of materiel system performance objectives. Yet the designer is ignorant of the usefulness and utilization of the existing tools to help make these determinations. The designer thus needs to be provided with explicit guidance on the nature, scope, and applicability of the available tools, techniques, and data.

In order to create a "designer's roadmap," it will be necessary to compile all of the existing techniques and bodies of data dealing with human performance capabilities and limitations and the relationships of these characteristics to hardware design factors, training requirements, etc. The available techniques and the materiel system design process will then have to be evaluated jointly, to determine where and to what extent in the design process each technique and data should be applied (many of the techniques can be applied at the front end of the design process to generate design parameters and constraints directly addressing hardware design factors). From this study, a handbook of techniques and data which are useful in evaluating MPT impacts of design alternatives and providing guidance to the designer can be derived. The handbook must include guidance for the designer as to the limitations of each technique and data set, how each can be applied during the design process, and how the information that can be derived from applying the procedures, data, etc. can help the designer to meet MPT constraints on the characteristics of his system. The handbook should also include explicit guidance as to how procedures are to be applied, what data are appropriate for what kinds of decisions or tradeoffs, and most especially acknowledge the limitations of the techniques and data provided. The handbook should be a practical document for use by the working design engineer and engineering manager, which stresses the intimate relationships between hardware design factors on the one hand and manpower and human performance characteristics on the other. Several different levels of presentation may be appropriate for inclusion in the designer's handbook, including detailed data summaries (and how and when to to apply the data), procedures for performing various kinds of analyses (and when and why the analyses are appropriate), and general principles for optimizing human factors impacts of design.

The two needed developments discussed above address critical future developments in the development of a means to control and constrain the MPT requirements of evolving materiel systems. On the government side of the system acquisition process, it has been proposed that the procedures and techniques for addressing MPT issues in system concept development be explored in depth to determine how to make those procedures more complete and responsive to the critical needs of decision makers who determine what factors will be traded off (and in what ways) to attain maximum materiel system performance with an optimal minimum of requirements for manpower and training. On the designer's side of the picture, a need clearly exists to make available and usable to the designer the data and techniques which will assist the designer in designing capable systems with minimum requirements for trained people to operate and maintain the systems. It is recommended that vigorous efforts along both lines of progress be pursued beginning in the near future, to take the next step in creating a "common language" which will foster efficient and effective use of resources to minimize ultimate MPT impacts of future Army systems.

APPENDIX A

SOURCE DOCUMENTS REVIEWED TO IDENTIFY CRITICAL MPT-RELATED DECISIONS IN SYSTEM ACQUISITION

APPENDIX A

SOURCE DOCUMENTS REVIEWED TO IDENTIFY
CRITICAL MPT-RELATED DECISIONS IN
SYSTEM ACQUISITION

Altman, J. W., Kirk, F. G., Munger, S. J., and Purifoy, G. R., Jr. Human performance considerations in the early design of information systems: a conceptual model. Pittsburgh, PA: American Institutes for Research, July 1968.

Bonder, S. A review of Army force modernization and associated manpower, personnel, and training processes. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, January 1981. (Working Paper PUTA 81-2).

Fulkerson, G. R. Manpower, personnel, and training requirements in weapons system acquisition. Proceedings of DARPA workshop on "Front-end anlaysis to emerging training systems," 12 September 1979.

Hanson, V. L. and Purifoy, G. R., Jr. TSM guide to training development and acquisition for major systems. Valencia, PA: Applied Science Associates, Inc., December 1977. (Final Report on Contract DAHC19-77-C-0016 with U.S. Army Research Institute for the Behavioral and Social Sciences).

O'Connor, F. E., Fairall, R. L., and Birdseye, E. H., Case studies of manpower, personnel, and training problems associated with the material system acquisition process: identification and analysis of selected manpower, personnel, and training issues in the establishment of requirements for the UH-60 helicopter and the multiple launch rocket system. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, May 1982. (Working Paper SMTA 82-1.)

Rhode, A. S., Skinner, B. B., Mullin, J. L, Friedman, F. L., Franco, M. M., and Carroll, R.M. Manpower, personnel and training requirements for material system acquisition. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, October 1980. (ARI Research Product RP 80-27).

United States Department of the Army. Life cycle system managment model for Army systems. DA Pamphlet 11-25, 21 May 1975.

APPENDIX B

LISTING OF PROCESSES AND DECISIONS DURING MATERIEL SYSTEM ACQUISITION WHICH IMPACT MANPOWER, PERSONNEL, AND TRAINING REQUIREMENTS

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Mission Area Analysis Phase (LCSMM Phase 0)

Subsystem Analyses (After MENS, before LOA) - coordinated through JWG (TRADOC/DARCOM).

- Develop subsystem concepts iteratively: top-level design/MPT tradeoffs (not explicit or empirically based).

- Perform concept front-end analysis (TRADOC Proponent School: training developments).

  - Analyze and identify functions to be performed in system operation (mission profile).

  - Identify comparability of existing systems to proposed/needed system capability to determine if existing systems can be used for analyses/projections (operational comparability/technological comparability).

  - Contrast required operational functions to data from comparable systems (occupational surveys) to produce task listings [this is the first point in the process where task data is generated; can condition later decisions].

  - From task listings and occupational survey data, identify critical tasks and estimate priority of task training for critical tasks; perform gross task analyses.

  - OUTPUT: training planning document (portions).

- Perform logistic support planning (TRADOC Proponent School/DARCOM).

  - Perform HFE analysis of system concept to identify probable operation and maintenance issues and areas of concern and emphasis (mission profile).

  - Acquire technical data on "comparable" (technological or operational-use) systems to be used for logistic and training requirements analysis.

. Develop training support concept based on "comparable" system data (training facilities estimates, initial training device requirements).

. Create initial manpower/personnel concept (numbers of people, probable skill levels, comparable MOS's) - based on "comparable" system data.

. Create initial maintenance concept (levels of maintenance, possible distribution of maintenance functions to levels) based on "comparable system data HFE analyses.

- Develop individual/collective training concepts (TRADOC Proponent School/DTD).

  . Identify preliminary individual/collective training needs based upon available data for "comparable" systems (iterative developments).

    • Tasks to be trained (based on occupational-survey-based "task analysis").

    • Collective versus individual tasks.

    • Maintenance versus operational tasks.

    • Training modes and distribution of tasks across modes.

    • Training device and documentation requirement estimates.

    • Evaluation requirements (SQT, ARTEP).

  . Develop initial estimates of training resource requirements (based on "comparable" system data, studies, estimates).

  . Develop initial training concept.

  . Develop initial training strategy.

  . Results in Outline Individual and Collective Training Plan (OICTP) - inputs to initial CTEA and Best Technical Approach (BTA) selection.

- All subsystem analysis outputs (training planning document, logistic planning document, OICTP) input into LOA paragraph V (manpower).

    . Training development milestones/schedule developed for LOA.

After LOA approval, PM office established, TSM appointed within TRADOC, Special Task Force (STF)/Special Study Group (SSG) appointed by CG TRADOC to pursue further concept development studies in Phase I. STF/SSG includes TSM, PM representative, DARCOM CD representative, logistics (DCSLOG) representation.

Concept Exploration Phase (LCSMM Phase 1)

- Identify system alternatives to meet identified need.

System Design Concept Exploration

- Generation of organizational and operational concepts (TRADOC Proponent School - DCD).
  - Number of systems required to fulfill operational need (est. from MENS, mission profile).
  - How systems will be employed in combat to meet need.
  - Unit structure to operate and support systems (similar systems, missions).
  - Personnel characteristics to operate and maintain systems (earlier HFE and manpower/maintenance concepts, special adjunct studies - often contract).
  - All of the above are traded off - conceptually - during design iterations and concept development.
  - Results of organizational and operational concept definition are primary feeder data for TQQPRI, BOIP I, and ILS plans.
- Generation of force level guidance (ODCSOPS, Staff studies).
  - Analyze impact on force structure of proposed system concepts (using mission profile assumptions and MENS descriptions, organization/operational concepts statements).
  - Tradeoffs of impact on force structure to accomplish mission; feeds back into organizational/operational concepts, introducing constraints on force level impact (recommendations).

Material Concept Investigation (PM office, TSM, Proponent School-Combat Developments)

- Evaluation of state-of-art technology to address mission need.
- Exploration of manpower impacts of technologies.
  - Identification of special skill/knowledge requirements of technological alternatives (strong possible impacts on selection and training).

- Evaluation of training system capability to support technology and personnel performance requirements - includes CTEA of alternative concepts.

- At this point, a set of system concepts which may fulfill the agreed-on mission need has been defined. The alternative concepts are next evaluated comparatively, in the preparation of the:

Concept Formulation Package (CFP) (Coordinated by STF/SSG)

- Trade-Off Determination (DARCOM PM Office).

  - Explicit identification of technical approaches considered in material concept investigation.

  - Estimation of required RDT&E to develop each approach.

  - Define alternatives to be examined.

  - Identify areas where tradeoffs are to be performed (technological risk, cost, schedules, system capabilities, logistic support, MPT) - explicit tradeoff issues defined. Criteria may be established.

- Trade-off Analysis (TOA) (DARCOM PM/TRADOC proponents/ contractor support).

  - Gather data (estimtes) on which to base tradeoffs ("comparable" systems, concept estimates, desired baselines, etc.).

  - Conduct trade-off studies between approaches (MPT, ILS, HFE issues should be considered and weighted in trade offs. Criteria established in TOD must be addressed.

- Best Technical Approach (BTA) (TRADOC/DARCOM: STF/SSG)

  - Selection of the favored technical approach for further development and inclusion as preferred approach in CFP.

  - Considers cost, MPT, ILS factors assessed in TOA.

- Cost and Operational Effectiveness Analysis (COEA) (Proponent School- Analysis).

  - Evaluate and trade off acquisiton/operation costs for total system, probable operational effectiveness against threat, etc.

- From TOD, TOA, BTA, CTEA, and input data (system and material concepts), Concept Formulation Package (CFP) is prepared, which describes system concepts selected for development and their ramifications in terms of schedule, cost, effectiveness, manpower, training, and logistic support.

- The CFP feeds directly into the draft Decision Coordinating Paper (DCP), which is modified by several development and planning updates while in draft form:

- Training Development Requirements Update (TRADOC Proponent School and TSM - Updates OICTP.

  . Reassess and reformulate if necessary:

    ° List of critical/high training risk tasks (input from concept FEA as updated by CFP decisions).

    ° Training device requirements (updated estimate based on refinements and selection during CFP process).

    ° Identify SPA requirements at relatively global level (input from concept FEA, trade-offs and constraints during DCP anlaysis).

- Training Management/Administration Planning Update (TSM).

  . Revise OICTP requirements, refine on basis of better focus on system gained during CFP analyses.

- Another, parallel, stage in development of the draft DCP is preparation of a Program Management Plan (PMP), which describes proposed acquisiton stategy and procedures. The PMP (prepared by the DARCOM PM office, with coordination with TSM, Proponent School, ODCSLOG, and OTEA) is a critical point for introducing or reinforcing constraints which may impact MPT, since it contains the following:

  . Coordinated Test Program Plans.

    ° Training test plan (training concepts, effectiveness, devices, etc.), based on training concepts document prepared in Phase 0.

    ° First cut at training test plans for developmental and operational testing.

    ° Updated OICTP, including plans for further manpower and personnel developments.

° Logistic support plan, including RAM objectives and ILS development plan.

After ASARC review, the DCP is revised to take into account recommendtions by ASARC. To support final DCP I, an Integrated Program Summary (IPS) is prepared by ODCS (research, development and acquisition), which includes MPT support data as follows:

- ILS development plan.
- R&M design goals.
- Manpower requirements:
  - ° System activity level (number and utilization of systems).
  - ° Sensitivity of manpower to alternative system concepts (from TOD, TOA).
  - ° Innovative maintainability and productivity concepts to be included in development plans.
- Training Requirements.
  - ° Implications of alternative system concepts for training.

Once DSARC aproval to enter demonstration and validation phase has been obtained, PMP is updated along with preparation of the contract RFP for the demonstration and validation phase, and DT/OT I test criteria and plans.

Demonstration and Validation Phase (LCSMM Phase II)

- Develop technological approaches/systems and select system that best fulfills need as described in LOA.

- PMP Update and RFP/SOW Input: (DARCOM PM/TRADOC TSM/Proponent School).

  - Personnel/training requirements and specifications to be following by contractor.

  - Statement of plans/objectives for individual and collective training and evaluation (from OICTP; evaluated at DT/OT I).

  - Plan and objectives for development of training materials to support operation and maintenance test/evaluation at DT/OT I (contractor requirements).

  - RAM requirements to be met by contractor systems to be developed.

- The above are integrated into the SOW and should be utilized as proposal evaluation criteria. At this stage, MPT requirements should be stated in design-to-constraints terms.

- Contractor: Interprets requirements and objectives, prepares proposal.

  - After award.

  - Conducts LSA in accordance with contract requirements (ideally). Typically, LSA/LSAR is given less attention then desirable. Delivery of LSA data during demonstration and validation contracts should be required, to: (A) verify that analyses to support training and logistics developments have in fact occurred as specified; (B) support development of TQQPRI and BOIP after DT/OT I and selection of single system for FSED).

  - Conducts training FEA and develops training materials to support training at DT/OT I.

  - Verifies OICTP estimates with actual developmental data.

- Development of DT/OT I Coordinated Test Plans (DARCOM/TECOM/TRADOC/OTEA).

  - Criteria for training materials and training objectives satisfaction.

. Supportability criteria (reliability, maintainability, operability).

. Criteria for assessing design problems that impact RAM.

. Criteria for manpower assessment.

. Criteria for assessing training concept/feasibility:

  • Training device prototypes (performance, adequacy, comprehensiveness).

  • Documentation (SPA, SM, TM).

  • Human performance standards.

  • Supportability of planned training developments (PMP).

. Criteria for ILS/Logistics issues:

  • RAM.

  • Manpower/personnel requirements.

  • Maintenance related design/material problems.

- After DT/OT I, Logistics Support requirements and Training/TDR requirements are updated to reflect data and results from DT/OT test and evaluation, for the system(s) selected for full-scale engineering development. These updates and analyses are reflected inthe Required Operational Capability (ROC) document.

- Logistic Support Concept Update (DARCOM).

  . Re-evaluate adequacy of RAM in light of objectives and achievements in DT/OT I. Modify requirements if too lenient or cannot be met.

  . Examine adequacy of LSAR produced during contractor efforts for ability to support QQPRI, BOIP, MOS determinations at tentative/first-cut stage.

- Refine Training/Training Device Requirements and Prepare Individual/Collective Training Plan (ICTP) (TRADOC Proponent School/TSM).

  . Evaluate TDR adequacy and update requirements as necessary.

- Assess value of training concept against DT/OT results and revise/update.

- Assess documentation performance (SPA, SM, TM, TEC) during DT/OT - modify/update plans and requirements, etc.

- Identify probable training pipeline and quotas.

- Assess new equipment training requirements and include in overall training plan.

- Prepare tentative QQPRI (TQQPRI) from DT/OT contractor LSA data, OT experience, and operational/organizational concepts (DARCOM PM/MRSA/TRADOC Proponent School).

  - Crew/operator estimates (with MOS estimates).

  - AMMH estimates (by MOS) for each level of maintenance.

  - Duty positions (with task listings) for maintenance and operation.

  - Lists of skills, knowledge, qualifications for personnel to operate, maintain system (include physical and mental standards).

- Prepare Basis of Issue Plan (BOIP) I (TRADOC Proponent School) using TQQPRI, O&O concept, BOIP feeder data (describes Prime Item and Support Equipment).

  - Define tentative initial unit structure to support, operate system.

  - Contains unit manpower estimates.

  - Also contains equipment distribution requirements.

  - Feeds into MILPERCEN MOS determinations.

- Prepare Required Operational Capability (ROC) Document (TRADOC).

  - Describes system selected from those developed in Phase I to be further devleoped in full-scale development (Phase III).

  - Includes updated logistic support plan (ILS Plan).

  - Presents revised and updated training and training support estiamtes for system (ICTP).

- Updated CTEA and COEA performed for system to be developed.

- In support of the (brief) ROC, an Updated Program Management Plan (PMP) is prepared under the direction of a reconvened or reappointed STF/SSG. DARCOM PM is prime mover for update of PMP for full-scale development. The update PMP contains several MPT--related segments, based on post--DT/OT I analyses.

  - Initial BOIP I--personnel, MOS, and tentative unit structure for system and support systems for using units.

  - System development plans, including RAM objectives and criteria for full-scale development (PM Office).

  - Coordinated test plan for DT/OT II and intermediate testing.

    - Training test plan (TSM).

    - DT/OT II test plans (not yet detailed criteria).

  - Personnel and training requirements developments.

    - New skill, MOS requirements from TQQPRI (TSM, MILPERCEN).

    - New Equipment Training (NET) plans.

    - The ICTP and plans for its implementation during testing (TSM, Proponent School).

    - Training device requirements update.

    - Training facilities estimates and plans.

  - Logistic support plans (PM).

    - Identification of critical supportability issues (identified through DT/OT I testing and HFE evaluation) and plans for dealing with issues.

    - RAM objectives/criteria for FSED system(s).

    - ILS plan and objectives.

The ROC and updated PMP form the basis for the ASARC/DSARC decision coordinating paper (DCP) II. Upon DSARC approval to continue, FSED is begun.

Full-Scale Engineering Development (LSCMM Phase III)

- Preparation of criteria for RFP/SOW Source Selection (PM Coordination).

  . For the FSED/Prototype contract SOW, several "constraint" areas are critical to MPT impacts of both the prototype and the potential follow-on operational systems. These include:

    ° HFE criteria which prototypes must meet.

    ° LSA/LSAR data requirements and schedules.

    ° Validation/verification of training needs, tasks, skills and knowledge.

    ° Documentation criteria.

    ° Validation of training device requirements.

    ° Etc.

- Coordinated Test Plan Inputs for DT/OT II (PM).

  . Test Objectives, Plans for DT II (tests: TECOM/AMSAA).

    ° Training materials validation plan and criteria.

    ° RAM criteria.

    ° Maintenance task validation and performance criteria.

    ° Manpower and skill requirements criteria.

    ° Documentation criteria (TM, FM, SPA).

    ° Training device performance and supportability requirements criteria.

    ° NOTE: These criteria should be closely related or identical to specifications/constraints in FSED RFP to ensure communication and accountability/audit trail.

  . Test Objectives, Plans for OT II (Tests: OTEA).

    ° Documentation (TM) validation plans and criteria.

° Operator and maintainer training adequacy/performance criteria.

° Personnel requirements criteria.

° RAM criteria.

° ILS criteria.

° Training planning (ICTP) validation plans and criteria.

° NOTE: Those criteria should also be closely tied to RFP requirements/constraints.

- Parallel Development in Support of OT/DT II: (PM Coordination).

  . Contract development of SPA, TMs, etc. for FSED system (may be prime contractor or separate contract).

  . Training device development (may be prime or separate contract).

  . In both these areas, decisions regarding specifications, front-end analysis requirements and cross-feed with FSED prime contractor are critical to the development of appropriate, complete, usable, and timely support items for evaluation.

Following OT/DT II, logistic support and training planning are again updated, this time on the basis of data from the FSED effort and DT/OT II. This is a critical point in verification of whether design and development constraints that impact MPT issues have been understood and implemented. During these updates, decisions are made about the adequacy of developments and resolutions of issues which will affect manpower requirements, training, and system/subsystem supportability.

- Logistic Support Planning Update (ODCSLOG/PM/MRSA).

  . Validation of LSA Data via teardown of prototype equipment. Determines whether maintenance task/skill requirements have been identified, and identifies operator/maintainer-system interface issues yet to be resolved/addressed.

  . Determine Adequacy of Projected Maintenance Manpower Requirements (AMMH) from OT II test results to determine if personnel requirements projections are accurate and adequate.

- Training Planning Update (TSM/Proponent School).

  . Validate Previous Personnel Requirements Raised on Logistic (LSA) Data - Determine whether operator, maintainer projections accurate in light of obtained DT/OT II results; modify plans if projections inaccurate.

  . Update Training Plans (SPA, FM, TM, etc.) and develop preparation/implementation plans to support system IOC.

- Prepare Updated QQPRI (PM cognizance) and BOIP.

  . Acquire FSED LSAR data and update operator, maintenance skill, task, MOS, and force structure requirements data.

- Prepare Final MOS Decisions and Determinations (MILPERCEN).

  . Based on updated QQPRI.

Revised training and logistics plans, updated QQPRI and MOS decisions are documented in an updated Program Management Plan (PMP) which contains (among other things):

° Production RAM requirements (using military personnel).

° Identification of unresolved logistic support issues.

° Revised BOIP.

° Revised personnel and training plans and requirements.

° Updated QQPRI and MOS decisions.

° Updated resident and unit training plans (ICTP).

° DT/OT III test plans.

. As at earlier stages, the PMP feeds into the DCP. Upon ASARC/DSARC approval, low-rate production can begin.

APPENDIX C

LIST OF ACRONYMS AND

ABBREVIATIONS USED IN THIS REPORT

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AMMH	Annual Maintenance Manhours
AMSAA	Army Materiel Systems Analysis Activity
ARTEP	Army Training and Evaluation Process (Plan)
ASARC	Army Systems Acquisition Review Council
BOIP	Basis of Issue Plan
BTA	Best Technical Approach
CD	Combat Developments (Developer[s])
CFP	Concept Formulation Package
COEA	Cost and Operational Effectiveness Analysis
CTEA	Cost and Training Effectiveness Analysis
DARCOM	U.S. Army Material Development and Readiness Command
DCD	Department of Combat Developments
DCP	Decision Coordinating Paper
DCSLOG	Deputy Chief of Staff for Logistics
DSARC	Defense Systems Acquisition Review Council
DT	Development Test(ing)
DTD	Department of Training Developments
FEA	Front-End Analysis
FSED	Full-Scale Engineering Development
HFE	Human Factors Engineering
ICTP	Individual and Collective Training Plan
ILS	Integrated Logistic Support
IOC	Initial Operational Capability
IPS	Integrated Program Summary
ISD	Instructional Systems Development
JWG	Joint Working Group
LCSMM	Life Cycle System Management Model
LOA	Letter of Agreement
LSAR	Logistic Support Analysis Record

MENS	Mission Element Needs Statement
MILPERCEN	Military Personnel Center
MOS	Military Occupational Specialty
MPT	Manpower, Personnel, and Training
MRSA	Material Readiness Support Activity
NET	New Equipment Training
ODCSOPS	Office of the Deputy Chief of Staff for Operations
OICTP	Outline Individual and Collective Training Plan
O&O	Organizational and Operational (Concept)
OT	Operational Test(ing)
OTEA	Operational Test and Evaluation Agency
PFC	Private First Class
PM	Program Manager
PMP	Program Management Plan
QQPRI	Qualitative and Quantitative Personnel Requirements Information
RAM	Reliability, Availability, and Maintainability (Analysis)
RDT&E	Research, Development, Test, and Evaluation
RFP	Request for Proposal
ROC	Required Operational Capability
SAP	Systems Acquisition Process
SOW	Statement of Work
SM	Soldier's Manual
SPA	Skill Performance Aids
SQT	Skill Qualification Test
SSG	Special Study Group
STF	Special Task Force
TDR	Training Device(s) Requirement
TEC	Training Extension Course(s)
TECOM	Test and Evaluation Command
TM	Technical Manual
TOA	Tradeoff Analysis
TOD	Tradeoff Determination
TOE	Tables of Organization and Equipment
TQQPRI	Tentative Qualitative and Quantitative Personnel Requirements Information
TRADOC	U.S. Army Training and Doctrine Command
TSM	TRADOC System Manager