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MANPOWER, PERSONNEL, TRAINING, AND SAFETY GUIDANCE AND CONTROL FOR WEAPON SYSTEM ACQUISITIONS

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The need for manpower, personnel, training, and safety (MPT&S) guidelines and constraints can originate at both the specific weapon system and aggregate system levels - whereas the typical Government acquisition team specializes only in information at the first (weapon system design) level. The amount of organizational support provided them is also not adequate to their task. In order to help integrate MPT&S factors during weapon system acquisitions, the Government needs: (a) enhanced analytic capabilities to analyze total system tradeoffs between man and machine in the performance, maintenance, and support of system tasks; (b) interactive communications with experts in system utilization policy and aggregate system constraints; (c) MPT&S-oriented incentive systems for Government, as well as for contractor personnel; and (d) a strong centralized headquarters advocate for MPT&S factors with the authority to establish policies and procedures for acceptable MPT&S guidance and control. Specific control guidance is also needed by Government acquisition teams and teams of contractor personnel. For this purpose, recent case studies of Government guidance and control were analyzed, and two lists of "do's" and "don'ts" were developed.

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TABLE OF CONTENTS

LIST OF TABLES

MANPOWER, PERSONNEL, TRAINING, AND SAFETY GUIDANCE AND CONTROL FOR WEAPON SYSTEM ACQUISITION[a]

I. INTRODUCTION

It is difficult to get manpower, personnel, training, and safety (MPT&S) issues considered at an early stage during weapon system design. Government acquisition teams sometimes provide very little guidance about MPT&S issues because of uncertainty about the kind of guidance they should provide and reluctance to interfere with contractor operations. Contractors are almost forced to dictate MPT&S requirements under such circumstances. One of the reasons that this situation occurs is that the Government acquisition team does not have enough information to provide all the guidance that is needed.

On the assumption that experience is the best basis for facilitating MPT&S decisions, experience-based recommendations were collected from the literature as well as from experts in the field, and documented as recommendations in the paper that follows. Information alone, however, will not solve the problem. Organizational systems changes (improved analysis capabilities, improved communication and incentive systems, and new organizational structures) are also needed. The paper is thus intended for consideration by policy and decision makers as well as by Government and contractor personnel who work on the development of new weapon systems.

II. THE ISSUES INVOLVED IN GOVERNMENT GUIDANCE AND CONSTRAINTS

In weapon system design, the most important priority is that the system perform as required. Other considerations, such as MPT&S requirements, are of secondary importance. There is a lot of merit in these priorities, since it would be very wasteful to develop a comprehensive MPT&S plan for each strawman version of a weapon system as it goes through the early concept exploration stages. One could conceivably develop 30 MPT&S plans, none of which would ever be used because the 30 strawman weapon systems for which the MPT&S plans were designed will never, in fact, be developed. It is only the approved weapon system design that will actually need MPT&S plans, and these plans will probably go through several iterations before they settle down.

There is, however, another side to this story. Assuming that the MPT&S plans are not taken seriously until the 31st iteration, problems are likely to occur. In the first place, the hardware system that "works" may not, in fact, perform as required if MPT&S factors are considered to be of secondary importance during the early stages. Assuming that the system does indeed meet expectations, the Government may find itself forced to accept a plan that is not realistic in terms of the available resources, or the Government could find that there is not enough time or money to develop the MPT&S systems (e.g., expensive simulators) that are needed before the system is scheduled to become operational. So, the Government, rightly or wrongly, encourages contractors to develop MPT&S plans early in the weapon system acquisition process (WSAP).

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[a]The opinions expressed in the paper are those of the authors and do not necessarily reflect an official position of the Department of Defense or the United States Air Force.

The amount of control that should be exercised is controversial. Too much Government control becomes excessive interference that can stifle the contractor's creativity or force the contractor to design a system in one particular way. It is always possible that the contractor might have used a different approach that could have saved the Government millions of dollars or been several times more effective if fewer restrictions had been imposed. At the other extreme, lack of Government constraints can become equally deplorable, since the contractor could waste millions of dollars designing something that is prohibitively expensive or cannot be used because the needed MPT&S systems are not available.

III. RECENT DEVELOPMENTS IN CONTROLS OVER MPT&S DECISIONS

Need for Early MPT&S Decisions. Several years ago, a number of advisory groups, including the General Accounting Office [1] and the Defense Science Board [2] urged the Government to consider MPT&S factors at an earlier point in the WSAP. In response, the military services made a number of efforts to change their procedures, but the initial results were not always fully satisfactory [3, 4]. Many problems can occur when MPT&S decisions are not made early in the WSAP, and the challenge of MPT&S integration was addressed in many different ways [5].

A good example of the need for early decisions is in the area of job aids. The ready availability of microcomputers makes it possible to modify MPT&S requirements extensively by using job aids and expert systems. Job aids can decrease the number of maintainers who are required, change high skill level jobs to low skill level jobs, decrease or change the training requirements, and convert unsafe conditions into safe ones. As pointed out by Lineberry [6], "...guidance with job aids should always be the choice, unless key factors contra-indicate, because job aids generally cost less to develop than instruction, are easier to revise when performance requirements change, reduce the time to achieve on-the-job performance, and are not subject to forgetting" (p. 15). Booher [7] has provided a nine-step selection algorithm for identifying the most appropriate job-performance-aid/training combination. These decisions must be made early, since the job aids and expert systems could be built-in and become part of the equipment.

Control Through Procedural Guidelines. All three services have developed procedural guidelines for controlling MPT&S decisions during the various stages of the WSAP. The Navy developed a system called HARDMAN [8, 9] (for Hardware and Manpower Integration), which was originally based upon some early Air Force work in this area [10, 11, 12, 13]. The Army has adopted similar techniques based upon an early version of the Navy system [14], and has recently expanded this approach to include even more areas of responsibility as part of a program called MANPRINT (for Manpower and Personnel Integration) [15]. Recent evaluations indicate that these procedural guidelines are working reasonably well [16, 17, 18], although there were a number of initial problems in getting the systems implemented.

Control Through Data Item Descriptions (DIDs). Another approach to control is the use of standardized Data Item Descriptions (DIDs) which contain detailed descriptions of the kind of MPT&S plans that are to be provided by the contractor [19, 20, 21]. The DID needs vary from one stage of the WSAP to another. For example, the Navy [21] has one MPT concept DID, a separate MPT resource requirements DID, and a third MPT data report DID. Although revisions to these DIDs are not permitted, portions of the DIDs can be deleted to meet the needs of a specific weapon system. The advance thinking in these DIDs about what the Government should require at various WSAP checkpoints can be very useful, even when the original DID cannot be used.

IV. SPECIFIC WEAPON AND AGGREGATE SYSTEMS GUIDANCE

Guidance and control are needed at the specific weapon system design and aggregate system levels.

At the specific weapon system design level, the major issues and concerns are ways of influencing the design of a weapon system and facilitating cost-effective performance of the personnel assigned to it. Qualitative and quantitative MPT&S requirements, key design characteristics for manning, job aiding, system maintenance, supporting job structures, and training - all of these must be evaluated with respect to optimum MPT&S performance for a specific weapon system. These analyses must be closely coordinated with human factors engineering specialists. Logistics support guidance is especially important, since it deals with how, where, and when the new weapon system will be operated, maintained, and supported. Examples of important logistics guidance decisions are: dispersed basing; maintenance concepts and the number of different levels of maintenance; operational temperatures; and the use of dedicated crew chiefs. Another important issue at the weapon system design level is the need to establish an MPT&S baseline for determining the impact of proposed design changes.

Aggregate MPT&S systems combine information from several different weapon systems and jobs and examine MPT&S policy issues from an organizational unit, major command, and/or military department point of view. In aggregate systems, the major issues are the availability and affordability of MPT&S options in the context of the total force structure and all of the external demands that are made upon it. The important objectives are to avoid disconnects and unexpected consequences for MPT&S subsystems in future years [5]. Other issues at the aggregate systems level are cross-utilization of information, reduced overhead requirements, and policy decisions to redesign or restructure occupational specialties. These analyses at the higher command level need to be continuously transmitted to specific product divisions for further planning and implementation.

V. WEAPON SYSTEM DESIGN GUIDANCE

MPT&S Guidance on the Way that Tasks are Assigned. One major MPT&S impact of weapon system design guidance is the way in which tasks and duties are assigned to the total (operator, maintenance, and support; civilian, military, and contractor support) man-machine system in order to make the weapon system operational. The constraints (e.g., operator maintainability, limits on mean time between failures) have important implications for the assignment of tasks to humans or machines, the cost effectiveness of the manned equipment system, the effectiveness of the multipurpose work group to which the individuals belong, and the extent to which that particular job assignment makes an individual more useful in future assignments.

One of the key issues in MPT&S system design is the amount and kind of specialization in jobs. On those occasions when a single weapon system will utilize all the time of the responsible personnel, the job design considerations are relatively straightforward [2,]. What usually happens, however, is that many personnel are involved in each weapon system on a part-time basis. It is possible to design these part-time jobs such that personnel are specialized by function; to establish multifunction jobs in which personnel act as generalists; and/or to use computer software and job aids to minimize knowledge requirements.

Implications for Skill and Grade Progression Plans. The way in which tasks are assigned has important implications for skill and grade progression plans. Suppose that half the jobs in a particular occupational specialty involved assignments to generalist jobs and half the jobs involved assignments to specialist jobs. What would this do to career progression plans in that occupational specialty? Could technicians move back and forth between specialist and generalist

assignments? Probably not, since the technicians would not be qualified for many of the tasks that they would be expected to perform in either case. The situation is complicated by the fact that overspecialized and underspecialized occupational specialties already exist. According to Edenfield [23], "Today's AF personnel specialty classification system, as it has evolved with advances in weapon system technology, has resulted in over-specialization/job fragmentation in some disciplines and very broad-based, generic skills in other disciplines. These phenomena have resulted in a lack of work force stability and experience, inefficient use of manpower resources, poor job satisfaction and declining retention, and, possibly, an overstatement of manpower requirements" [23, p. vii]. These problems in Air Force Specialty Codes (AFSCs) are a direct result of the way in which tasks were assigned to personnel when weapon systems were designed in previous years.

The Impact of System Utilization Policy Constraints on Job Design. Several kinds of system utilization policy constraints could be imposed on the jobs that are performed by operations, maintenance, and support personnel. One possibility is to require that several functions be performed by the same person. For example, operators could be required to maintain their equipment to some degree (this is quite common in Army and Navy). It is also possible to require that the operators be assisted by job aids and computers. Another possibility is to impose limitations on the number of personnel that can be used when many different functions must be performed. This will usually force the contractor and/or the involved Government agencies to design generalist jobs that cut across traditional job specialties. Another option is to put limits on the amount of training that can be required or to put limits on the aptitude or skill levels of the incumbents. If the limits are restrictive, the contractor could be forced to design a system with lots of job aids, computer-assisted expert systems, "black boxes," etc. These tradeoffs should be analyzed early in the development cycle before resources are invested in options that will not be utilized.

VI. MPT&S DECISIONS AT THE AGGREGATE SYSTEM LEVEL

Aggregate Data Bases and Information Systems. Each Service has a variety of limited purpose and aggregate information systems for MPT&S. The major function of these data bases and information systems is to ensure that there are no disconnects or unexpected consequences of decisions at the subsystem level among the organizations that are responsible for different parts of the MPT&S system. For example, if a new weapon system is going to require 1,000 additional fighter pilots and 10,000 maintenance and support personnel during a particular period of time, it is important that the manpower experts know that the slots are needed and distribute them to the right organizations, that the personnel experts set up assignment systems that will get people to the right places at the right times, that the training experts schedule the appropriate number of trainees into the appropriate training pipelines, and that the safety experts certify that the system is safe and make sure that the necessary safety regulations are issued and enforced in a timely fashion. Aggregate data bases and information systems are needed in order to do these things [24] - and they are needed years in advance. Aggregate data bases are also used by top-level decision makers when choosing among competing systems for inclusion in the future force structure.

The aggregate data bases could have important input-output relationships with job design and weapon system design decisions. These aggregate data bases provide: informed inputs regarding the total system consequences of specific weapon system designs; information about the MPT&S constraints that should be imposed upon weapon system design; and long-range MPT&S planning inputs to aggregate system plans for future years.

Manpower, Aptitude and Skill Level Constraints. The most likely constraints to be imposed by decision makers at the aggregate level are constraints on the total number of personnel at each

aptitude or skill level. As weapon systems have become more and more complex and technical, aptitude requirements - especially in the electronics specialties - have increased from year to year. Yet the labor market is not expected to change dramatically during the next few years and we will probably have approximately the same number (or less) of high aptitude people in 1995 as we have today. When skills are scarce, who will decide which weapon systems are really entitled to higher aptitude and/or skill level personnel, and which are not?

Each group of weapon system designers tends to think that their weapon system should be given priority over other weapon systems for the small number of military personnel who qualify for higher aptitude jobs. Yet we obviously cannot have job requirement profiles that do not correspond with the realities of the available military personnel populations from which those requirements must be met. It seems logical, then, to impose constraints on the system designers. For example, system designers can be prevented from requiring that their weapon systems be manned with nothing but engineering officers and E-7 technicians. If the long-range forecasters are expecting to have shortages in these categories - or, if the jobs that would prepare a person for E-7 skills do not exist (which prevents personnel from gaining the experience needed for higher level jobs) - the weapon system can be designed (using job aids, computer software, black box replacements, etc.) so that people with less skill, education, and aptitude can do what needs to be done. Moreover, we need to be certain that these forecasts will remain valid as systems go through development and are fielded for 10 years or more.

It is clear that the requirements for higher and higher aptitudes cannot continue indefinitely. The Army, which has historically been most affected by skill shortages, is taking an aggressive stand in this area with its MANPRINT program [15]. The other Services will be watching the Army's progress very carefully as it develops new systems and procedures for imposing manpower and skill level constraints on weapon system contractors.

Training Budget Constraints. It has become commonplace in recent years to require that the contractor provide crew maintenance and support training for a certain number of years after the new weapon system becomes operational. This has the effect of imposing training budget constraints that are likely to be tight if the original procurement was competitive. By establishing a financial cost if the contractor develops inadequate training systems, the Government hopes to receive better quality training systems in a more timely fashion.

VII. RECENT STUDIES OF GOVERNMENT GUIDANCE AND CONTROL

Studies of Government guidance and control have been conducted in all three Services [25, 26, 27, 28, 29, 30]. Recommendations regarding guidance and control have also been provided as a result of conferences with industry [31]. The consensus is that the new MPT&S management systems (e.g., HARDMAN, MANPRINT) are being used and are having a beneficial effect.

Most of the problems that have occurred can be attributed to less-than-adequate, biased, or excessive control by the Government. The following statements summarize expert opinions regarding the "direct causes" of the human factors and MPT problems that have occurred.

Undercontrol

There was ambiguity and/or lack of precision in describing required system objectives.

System description was incomplete.

Task and skill analyses and man-machine tradeoff studies were not required early enough to affect basic systems parameters.

Many of the proposed MPT&S measures could not be verified or enforced.

There was laxity in following up and verifying human factors and MPT&S supportability goals.

Test and evaluation plans did not emphasize maintenance support requirements in operational environments.

Inadequate guidance and unmeasurable criteria were contained in requirements documents.

MPT&S decision points and evaluations for new systems were programmed without adequate test or evaluation.

Design requirements for training equipment were very general and incomplete.

No penalties were established for failure to perform MPT&S planning.

Overcontrol

Some systems requirements were specified exactly when they should have been determined by tradeoff analysis studies.

Status Quo Approach

MPT&S approaches that had worked for previous systems were accepted uncritically without proper examination of the unique circumstances of the system currently under development.

Personnel characteristics of previous systems were assumed to be valid for new systems, without adequate test or evaluation.

Maintenance requirements were assumed to be met with routine and standard maintenance procedures when other options should have been explored.

Manning was by policy rather than by requirements.

Hardware Bias

There was a tendency to overlook personnel-oriented performance measures and man-machine tradeoff studies in favor of equipment development.

In performance specifications there was too much concentration on hardware rather than man-machine performance.

There was a tendency to overlook human performance measures in favor of hardware-oriented performance measures.

The general attitude was, "Let's worry about the equipment first; we can always get the people later."

VIII. RECOMMENDED GUIDANCE FOR WEAPON SYSTEM DESIGN

Based upon our analysis of the case studies reported in the literature and conversations with experts in the field, a slightly different approach seems to be needed at each stage of the WSAP (see Table 1).

Table 1. Recommended Approach for Weapon System Design

WSAP phase	Present approach to MPT&S requirements	Recommended approach to MPT&S requirements
Pre-Concept	Consensus of responsible organizations that are primarily responsible for the status quo	Creative analytic studies of MPT&S constraint alternatives, goals, and issues
Concept Evaluation	Engineering-oriented trade studies	Total-system-oriented trade studies (including MPT&S alternatives) for both operators and maintainers
Demonstration-Validation	Budget is usually adequate only for engineering system improvements	Adequate budgets for total system improvements and alternate system analysis
Full-Scale Development	Quick fixes for inadequate or underdeveloped MPT&S systems	Evolutionary changes only, since MPT&S system needs are already anticipated
Production and Deployment	Gradual evolution of MPT&S system improvements	Minor changes only, since MPT&S system needs are already anticipated

Pre-Concept. During the pre-concept phase, the Government needs some way of specifying constraints without telling the contractor how to design the weapon system. These constraints are required because of the circumstances under which the weapon system would be used. For example, limitations on maintenance manpower could be created because of dispersed basing requirements. Even though these constraints are imposed by system utilization policies, it is still possible to give the contractor enough freedom to come up with a range of personnel mixes in support of the type of weapon system desired. The contractor can be required to conduct broad-brushed total system trade studies before recommendations are made regarding the design of specific MPT&S subsystems.

Contractors do not want to be perceived as "non-responsive." They will usually give the Government what it says is wanted, unless there are strong reasons to do otherwise. So the Government acquisition team must be very careful about what the Government "says" is wanted. On the other hand, the performance of work costs money - and the contractors will not perform work that is "implied" or "seems to be" a logical requirement unless there is an explicit requirement that they do so. This is especially true of tradeoff and sensitivity studies for MPT&S alternatives. It is important that the requirement for such studies be explicitly stated in the Request for Proposal (RFP) when it is issued. It is also important that the tradeoff-thinking implicit in such a requirement not be negated by other requirements in the RFP. The Government should not ask the contractor to plan and conduct manning tradeoff studies, for example, while simultaneously requiring that the weapon system be operated by a two-person crew. Another important point to remember here is that good MPT&S systems will not be free. If the Government wants high quality MPT&S systems, it must pay for quality.

Too often, the pre-concept constraints are decided upon by contacting the headquarters organizations with responsibility for each relevant area of expertise, and arriving at a consensus. The time available for studying these issues at these headquarters organizations is rarely adequate for a comprehensive study of constraint alternatives. The headquarters organizations cannot always be as future-oriented as they should be, since they are very busy trying to keep track of the status quo; nor do they usually have available the kind of long-range-oriented analytic capabilities that are needed; and the aggregate data bases that are needed to justify constraints are not always available.

Concept Evaluation. The typical concept evaluation trade study at the present time is engineering-oriented. What is needed instead are total-system-oriented MPT&S trade studies (including both operator, maintainer, and support personnel) in which man-machine tradeoffs are considered. These tradeoff studies cannot be permitted to become "pencil-whipping" exercises in which evaluations are based upon superficial analyses of alternatives that are not really competitive. In-house Government expertise and independent quality control checks are needed in order to make certain that the concept evaluation trade studies are well conducted and taken seriously.

Demonstration-Validation. A common conclusion after competitive procurements are awarded is that the demonstration-validation budgets are adequate only for engineering system improvements; MPT&S plans (and possibly logistics and maintenance plans as well) are often curtailed because the engineering budgets were underestimated. It may be hard for the Government to do this at times, but someone needs to step in, evaluate the plans, recognize that the budget is inadequate, and take whatever steps are needed to ensure either that the budget is increased or that the work plans are modified to redefine the system. This may be difficult to do when the company has a fixed price contract and there are already cost overruns and schedule slippages - but someone must do it if MPT&S factors are to be given the weight that they deserve.

Full-Scale Development. The typical approach during full-scale development is that of quick fixes to resolve MPT&S oversights. Evolutionary changes are to be expected; however, very few quick fixes should be needed if the MPT&S requirements are properly anticipated (and given realistic budgets) during earlier WSAP phases. The MPT&S efforts during full-scale development should be devoted to refining the MPT products developed earlier (numbers, skill levels, tasks, and training analyses). Test/evaluat and validation of these MPT&S projections need to be programmed. In addition, evaluation of training development, training media and materials (formative and summative) will be a major activity.

Production and Deployment. When the new weapon system is actually deployed, there may still be a need for some quick fixes, but one thing is certain: If the MPT&S requirements were not understood before, they are about to become understood in a hurry. For obvious reasons, operational personnel are active proponents of improvements that would make the system more effective and cost-efficient. MPT&S systems will consequently improve during production and deployment in an evolutionary way as fast as circumstances will permit. There is nothing wrong with this process, and nothing wrong with the importance attributed to MPT&S factors (at long last). Ideally, however, the MPT&S needs would have been adequately anticipated in previous stages, and little change should be needed during the production and deployment stages.

IX. CONSTRAINTS ON THE MPT&S PROCESS

Weapon System Design Constraints. Almost everyone is willing to agree that MPT&S utilization policy and task assignment constraints should be developed and imposed during the pre-concept and concept evaluation phases. Unfortunately, the Government personnel responsible for developing a weapon system usually do not have a clear-cut idea as to what these constraints should be.

System utilization policy, skill level, and task assignment constraints are hard to specify when the exact nature of the equipment is unknown and the equipment developers and the MPT&S experts are in separate organizations. They are, however, no more difficult to specify than the equipment options under consideration. The most important impact of system utilization constraints is on the assignment of functions to man or machine. New and improved total system analysis techniques are needed to evaluate the pros and cons of assigning tasks to human personnel, to machines, to human personnel equipped with job aids, to specialists, to generalists, etc. Logistics system constraints are especially important. Examples are: dispersed base locations; maintenance levels; dedicated crew chiefs; requirements for operator maintainability; limitations on the number of maintenance personnel available to support a system; and requirements for the consideration of machine-assisted alternatives that would limit crew size. Clearly, the MPT&S developers need to work closely with human factors engineers in order to deal with these constraints.

Aggregate System Constraints. Aggregate system constraints usually derive from the projected availability of personnel at particular skill levels, the feasibility of establishing new occupational specialties to support a particular weapon system, acceptable training times, etc. It is important that this guidance be provided in a flexible format that permits tradeoff studies. It is also possible to be more directive. One Army general recently directed, for example, that the Army establish a Design for Discard (DFD) program. The emphasis in DFD was to be "innovative design to reduce the cost of discard" rather than repair cost analysis or classical engineering approaches [32]. The general decided on this approach because of manpower projections that fewer people with higher skills would be available when needed and excessive "tooth to tail" (i.e., combat to logistics support) ratios. Ideally, however, aggregate data bases would be used to provide guidance without ruling out viable alternatives when new weapon systems are designed.

X. THE NEED FOR ENHANCED ANALYTIC CAPABILITIES WITHIN GOVERNMENT

It is easy to tell Government representatives that they should provide more information about system constraints. It is not easy to tell them how to do it. Nor is it really clear who should conduct the quality control checks and provide the weapon system designers with the kind of guidance that is needed.

Many analytic procedures already exist to justify constraints at the weapon system design level. This is not as true of constraints that logically originate at the aggregate system level. Neither the Government contract monitors nor the weapon system contractors are likely to have the expertise that is needed to say what these constraints should be. They rarely have access to long-range forecasts and long-range plans; they rarely have the "big picture"; and they are not supposed to establish policy.

Each military department has "studies and analysis" groups that conduct constraint-oriented studies of the type that is needed - but they are rarely available to study specific weapon system constraints on short notice. New data bases, analytic methods, and study groups seem to be needed in order to help expedite this process. Important tools and guidelines needed by MPT&S study groups are: ways of stating MPT&S requirements in terms of criteria that can easily be measured; ways of dealing with the interfaces between subsystem data bases; and ways of forecasting the impact of weapon system design decisions on MPT&S criteria at early stages during the design process. The data bases and methods should be a computerized system that would include systems characteristics, logistics, MPT&S factors, warfighting capability, and costs. The new data bases and analytic methods should assist and interact with the MPT&S analyst in a "decision support" mode [33], and help get his or her inputs considered during relevant facets of the weapon system design process, hopefully including an interface with the computer-assisted

design (CAD) process. The system should be capable of simulating wartime scenarios given various inputs (reliability rates, numbers of people, etc.). The system should also permit various levels of analysis - top level as well as more specific options.

The new guidelines and decision aids are needed to make it easier to model a new system in terms of its complexity, types of components, and MPT&S requirements. Analytic methods that are capable of evaluating tradeoff decision options and identifying the best options for further exploration are also needed. Given these decision aids and data bases, early budgeting and MPT&S requirements could be based on historical records and growth/cost curves. These early MPT&S estimates could then be refined (possibly using computer-assisted update systems) as more specifics are learned during the design and developmental processes.

Unified data bases [34] seem to be logical prerequisites for these MPT&S decision support systems - but a lot of work still needs to be done, in spite of the many procedural guidelines that already exist. We are a long way from the system described in the preceding paragraphs.

XI. THE NEED FOR INCENTIVES

To make the MPT&S system work, it is possible to use the same incentives approach that was used with the Air Force Reliability and Maintainability (R&M 2000) program that was signed into action on 1 February 1985 [35, 36]. This would require: clear statements of MPT&S needs in official requirements documents throughout the entire WSAP; quantitatively stated requirements to select MPT&S systems that are systems-effective and cost-efficient; improved source selection procedures that would give more weight to the past MPT&S record of the companies that are being evaluated; the documentation of "lessons learned" regarding MPT&S system tradeoffs and their dissemination to all involved contractor organizations and Government agencies; contract incentives and warranties that would guarantee satisfactory MPT&S systems for a given number of years after the system becomes operational; contract evaluation points that are timed to correspond with the satisfactory development of MPT&S systems; specific requirements for timeliness and ready accessibility of needed MPT&S products; specific requirements for field evaluations of MPT&S systems before the implementation phase is reached; and a DOD-wide coordinating group that would ensure that new ideas for improved MPT&S systems are put to work in an expeditious fashion.

A similar set of incentives is needed to avoid disconnects and unexpected consequences within Government organizations. For the contractors, money is the best incentive. For Government MPT&S managers, the best incentive is to provide prompt cost-effectiveness feedback to the managers of those who make the planning decisions. Qualified evaluators and enhanced study analysis capabilities are needed to provide the kind of feedback that is needed. General officer support is needed to make certain that the evaluations are taken seriously.

XII. THE NEED FOR CENTRALIZED HEADQUARTERS COORDINATION GROUPS

Although all three Services have established headquarters focal points for MPT&S systems, the authority and the resources allocated to these headquarters groups have not always been adequate. The current headquarters staff groups in the Air Force do not have enough influence or resources to insist upon or support analytic studies of system utilization policies and aggregate system constraints, for example.

Since all three Services are working this problem area using similar policies and procedures, it may be desirable to set up a DOD-wide Headquarters Coordination Group for MPT&S systems. An organization along these lines already exists in the training area - the Training and Performance

Data Center (TPDC) [37]. It is possible that TPDC could be modified to give it a broader perspective so that it could accept more responsibilities in the MPT&S area.

Even if the TPDC role is broadened, however, a strong headquarters focal point for MPT&S factors is needed within each military department. It is very important that headquarters coordinators have the authority to direct that MPT&S policies and aggregate systems guidance be followed by lower echelons. The need for such a group in the Air Force was recognized in the recent Akman Associates report [21] on the design of Air Force systems for Readiness Achieved through Manpower Personnel, Requisite Training, and Safety (RAMPARTS). An important proposal in their report was that a strong, centralized office be established within the Air Force.

One of the most important objectives for new organizational structures is improved communications between weapon systems designers, data base designers, and experts at the aggregate systems level. People need to talk to people - to ask questions, get expert advice, and let the experts know how well their recommendations worked out; and these communications need to take place quickly. Designing communication systems of this type is an important challenge for those who would establish new organizations to facilitate the MPT&S planning process.

XIII. "DO'S AND DON'TS"

We prepared two lists of "Do's" and "Don'ts": one for Government acquisition teams (Table 2) and one for teams of contractor personnel (Table 3). We then sent preliminary drafts of Tables 2 and 3 for review by approximately 20 experts in the field. As a result of their comments, some additional items were added to the lists, and some of the original items were revised or deleted. The editorial decisions are ours, however; so the two lists do not represent a consensus.

XIV. CONCLUSIONS

Existing Government guidelines and constraints for those responsible for MPT&S factors in Government acquisition teams are not working well. There are many instances of: undercontrol; overcontrol; too much use of a status quo approach; and a strong hardware bias. Providing experience-based guidance to Government and industrial personnel will go a long way towards improving the situation, but it is not enough.

Satisfactory guidance and control are not likely to be forthcoming unless the following steps are taken: the development of enhanced analytic capabilities that can analyze system utilization policies and make tradeoffs between man and machine in performance of system tasks; the establishment of interactive communication channels between experts in weapon system design and aggregate system constraints; the establishment of incentive systems that will reward both Government and contractor personnel for giving greater priority to MPT&S factors in weapon system design; and the establishment of a strong, directive headquarters group that can act as an advocate of total-system-oriented MPT&S plans within each military department.

Table 2. "Do's" and "Don'ts" for Government Acquisition Teams

Most relevant WSAP phase	Do	Don't
Pre-Concept	Specify what the weapon system must do within constraints without telling the contractor how to design the MPT&S systems for it.	Don't tell the contractor how to design the MPT&S systems for a specific weapon system.
	Focus on total system performance, including all of the human performance aspects.	Don't focus on operational system performance requirements and neglect MPT&S requirements.
	Specify MPT&S system objectives completely and unambiguously.	Don't use ambiguous or incomplete descriptions of MPT&S system objectives.
	State the implications of future military demographics for MPT&S system design in the context of total force commitments when the system will be fielded and continue to operate.	Don't design the system for present populations or populations that have infinite skills and abilities; and don't under-estimate the intelligence, and desire to be proud of job accomplishment, of future military personnel.
	Provide supporting literature and documentation to the contractor in a timely manner.	Don't force the contractor to waste resources on unnecessary red tape for getting access to needed information.
	Consider requiring that the contractor use validated MPT&S analysis methods (e.g., the Logistics Composite Model (LCOM)) for manpower modeling.	Don't allow the contractor free rein in selecting non-standard or unvalidated MPT&S analysis techniques.
	Tell the contractor what the most important problems are on comparable systems and request that the prime contractor design these problems out of the new system; develop MPT&S lessons learned and provide them to the contractor.	Don't assume that the contractor will understand MPT&S problems found in other weapon systems and design the system accordingly without special guidance on your part.

Table 2. (Continued)

Most relevant WSAP phase	Do	Don't
Concept Exploration	Be sure that requirements for MPT&S sensitivity and tradeoff analysis studies are explicitly stated in the initial request for proposals.	Don't assume that logically "implied" tasks will be performed when there is no explicit requirement that the contractor perform them.
	State MPT&S constraints, goals, and issues to be examined in such a way that a reasonable range of tradeoff decisions is permitted.	Don't impose constraints that eliminate viable MPT&S tradeoff decisions.
	Weigh MPT&S factors heavily in the procurement and hold the winning contractor to promised performance.	Dont' permit MPT&S factors to be assigned a low priority when budget and authority decisions are made.
	Evaluate contractors on past as well as promised performance. Let them know that their track records in MPT&S are to be considered in future procurements.	Don't permit past performance in MPT&S system to be overlooked when procurement decisions are made.
	Include MPT&S experts on source selection review panels and on design review teams. Use outside consultants where Government personnel are weak.	Don't assemble selection panels or design review teams that do not contain the kind of MPT&S systems expertise that is needed.
	When developing the human factors plan, ensure that attention is paid to the maintainer as well as the operator, since lack of system availability due to poor maintainability can lose the war.	Don't concentrate most human factors efforts on the operator, leaving maintenance human factoring for engineering change proposals after the system is fielded. This can cause expensive fixes, critical delays in maintenance turnaround, and unrealistic demands on the resource requirements for future MPT&S systems.

Table 2. (Continued)

Most relevant WSAP phase	Do	Don't
	Consider effects of wartime environmental factors on MPT&S (e.g. chemical-biological, aircraft battle damage).	Don't base supportability analyses only on peacetime requirements.
	Prioritize the MPT&S analyses that are needed; be prepared to justify their value and show how you will use the information.	Don't request nice-to-have data that no pressing need requires or request data that will be received too late to be used effectively.
	Enforce MPT&S, human factors, reliability and maintainability (R&M), and other supportability design criteria from MIL STDs in your program.	Don't waive supportability MIL STD requirements applicable to your program, since they could affect life cycle costs, have severe MPT consequences, and/or affect force readiness.
	Permit and encourage tradeoffs between M, P, T, and S factors on a variety of cost, performance, and other supportability criteria.	Don't assume that one kind of tradeoff study is all that is needed.
	Tell the offerer how MPT&S and human factors engineering (HFE) factors will be evaluated and the relative weight that will be given to supportability.	Don't fail to provide information about the weight assigned to MPT&S/HFE evaluation factors.
	Have the prime contractor model the consequences for MPT&S supportability and indicate design changes that could improve it.	Don't overlook modeling of MPT&S supportability issues as a technique for analyzing interactions within the system.
	Develop objective source selection criteria that will differentiate among proposals that have MPT&S supportable systems and those that may have problems.	Don't use subjective or incomplete proposal selection criteria that will permit MPT&S problems to go unnoticed.

Table 2. (Continued)

Most relevant WSAP phase	Do	Don't
	Require that important training environment conditions be considered in the design of MPT&S systems.	Don't permit contractors to design training systems that can be used only under uncontaminated conditions at large bases and/or at well-equipped training centers.
	Be sure that each MPT&S task has a product, and that the products are required deliverables.	Don't assume that mere recitation of the goals of the weapon system means that the contractor will spend adequate time and money on MPT&S tasks.
	Use a DOD Form 1423 to require delivery of MPT&S products to the Government.	Don't assume that if the Statement of Work (SOW) contains MPT&S tasks, the products will automatically show up on your desk.
	Be sure that the MPT&S performance requirements are clearly defined, quantifiable, and testable.	Don't specify MPT&S objectives in terms of criteria that cannot be measured.
	Require that the contractor consider alternative MPT&S concepts that would control, avoid, or reduce safety and health hazard risks.	Don't accept safety and health hazard risks because they are considered basic to a particular technical concept.
Demonstration Validation	Make sure that plans for MPT&S systems remain up to date as plans for the weapon system evolve.	Don't allow MPT&S plans to lose concurrency with plans for engineering design changes.
	Schedule MPT&S contract reviews concurrent with other system evaluations.	Don't permit MPT&S factors to be overlooked during engineering system evaluations.
	Require cost-effectiveness and cost-benefit evaluations of the most important MPT&S alternatives.	Don't accept MPT&S justifications of important systems that do not contain adequate cost-effectiveness and cost-benefit evaluations.

Table 2. (Continued)

Most relevant WSAP phase	Do	Don't
	Subject the prime contractor's MPT&S models to close scrutiny by asking Government support contractors to conduct an independent evaluation using an independent systems manpower model (e.g. LCOM). (NOTE: Independent life-cycle cost (LCC) analysis is required by legislation, and manpower is a major cost element of LCC.)	Don't assume that the prime contractor will understand the full MPT&S implications of the developing system.
	Select appropriate Logistics Systems Analysis DID requirements and specify timely delivery in appropriate formats of all data needed for MPT&S.	Don't assume that all participants are planning to jointly use common data items; if coordinated data are not required, some data needed for later decisions may not be placed on contract, or you may pay for essentially the same data twice.
	Require analytic support of MPT&S requirements for new system proposals.	Don't assume that past practices are an acceptable model for new systems without analytic support.
	Make sure that the funding priority of MPT&S factors is protected during changes and perturbations in the WSAP.	Don't permit MPT&S budgets to be cut in order to provide additional funds for other purposes.
	Require MPT&S managers to sign off on all design drawings and design changes.	Don't assume that engineering changes will have little or no effect on MPT&S performance.
Full Scale Development	Require that the contractor have qualified MPT&S personnel and adequate MPT&S budgets.	Don't assume that qualified personnel and adequate budgets will be provided when needed.
	Qualitatively and quantitatively verify that MPT&S factors have been adequately considered.	Don't approve plans without qualitative and quantitative verification of MPT&S systems by the Government.

Table 2. (Concluded)

Most relevant WSAP phase	Do	Don't
	Consider beginning training development contracting early enough to allow development and delivery of training systems concurrently with first weapon system delivery.	Don't assume that training development can play "catch up" to system production using compressed scheduling without allowing for prohibitive costs. It usually ends up as expensive interim contractor support with very little, if any, scheduled relief.
	Require that the contractor consider meaningful alternatives to the proposed MPT&S plans.	Don't accept the recommended MPT&S plans without requiring consideration of alternatives that are viable and competitive.
	Test and evaluate the adequacy of MPT&S numbers and skill requirements.	Don't assume that the contractor's estimates will be acceptable without some kind of verification.
	Ensure that test and evaluation is conducted using realistic tests of MPT&S support systems using "average" personnel of the type expected to operate, maintain, and support the system.	Don't allow tests to be conducted using only "superhuman" personnel who can make anything work.
	Continue to monitor the impact of MPT&S criteria in the design of the weapon system by participating in regularly scheduled conferences and reviews.	Don't assume that your job is done just because the system has reached the full-scale development stage without any major problems.
Production and Deployment	Require that adequate MPT&S resources be allocated for cost and risk reduction studies during redesign and retrofit.	Don't expect cost and risk reduction studies to be conducted without adequate resources to support them
	Be alert to the possible impact of procurement changes (e.g., an accelerated schedule) on the design of MPT&S systems.	Don't assume that changes in procurement will have negligible effects on MPT&S plans.
	Document MPT&S lessons learned so others can benefit from this experience.	Don't assume that MPT&S problem histories won't be repeated.

Table 3. "Do's" and "Don'ts" for Teams of Contractors

Most relevant MSAP phase	Do	Don't
Pre-Concept	Start MPT&S p' ning early and focus on performance of the total system (operator, maintainer, and support).	Don't focus on hardware and defer consideration of operator, maintainer, and support functions until later.
	Conduct task and skill analyses early enough to let your findings influence the design.	Don't defer task and skill analyses until hardware requirements are firmly established.
	Consider the costs and benefits of substituting technology for labor.	Don't assume that traditional assignments of tasks to labor will be cost effective for the new system.
Concept Evaluation	Address MPT&S factors for all system components, conditions, and major scenarios.	Don't limit MPT&S studies for budget reasons.
	Plan MPT&S support for the entire life of the system.	Don't limit your MPT&S plans to the first few years.
	Allocate sufficient protected budget and authority to MPT&S contractor personnel/ organizations so that they have the means to perform.	Don't undermine efforts by glossing over or ignoring MPT&S problems that will affect schedule or budget.
	Provide accurate estimates of the total system manpower, skill, and aptitude requirements for all circumstances under which system operation is expected.	Don't underestimate or overestimate the total system manpower, skill, and aptitude requirements.
	Plan for concurrent and coordinated development of training systems (operator, maintenance, and support).	Don't postpone training planning until later acquisition phases.

Table 3. (Continued)

Most relevant MSAP phase	Do	Don't
	Consider the occupational specialty and career field implications of the system being developed (overspecialization, aptitude requirements, new skills).	Don't assume that existing military occupational structures and resources will provide the kind of personnel that are needed.
	Make sure that the individual MPT&S area managers continuously coordinate developments in their areas with the other area managers.	Don't assume that a development or change in one "people" area will have no effect on other "people" areas.
Demonstration Validation	Use human performance measures and standards to help influence and evaluate system performance and supportability, since they will affect performance.	Don't use engineering performance studies alone to evaluate system performance.
	Develop plans for dealing with potential safety and health hazard impacts in all environments in which the system will be used.	Don't limit safety and health hazard studies to the most likely environments in order to reduce costs.
	Plan for methods to reduce "skill decay" (resulting from lack of frequent practice) through cost-effective changes in training system design.	Don't focus on initial skills acquisition without giving adequate attention to problems resulting from lack of frequent practice.
	Conduct human-machine tradeoff studies that optimize maintenance and support of the total system as well as consider machine tradeoffs.	Don't limit human-machine tradeoff studies to operators and equipment.
	Conduct human-machine tradeoff studies early enough to influence the design of the equipment.	Don't defer human-machine tradeoff studies until equipment characteristics are relatively well established.

Table 3. (Concluded)

Most relevant WSAP phase	Do	Don't
	Require MPT&S managers to sign off on all design drawings and design changes.	Don't assume that engineering changes will have little or no effect upon human performance.
Full Scale Development	Analyze and develop total system training requirements (equipment, spares, technical manuals) for all personnel.	Don't assume that technical training for operators alone will fully support the system.
	Evaluate the wartime and peacetime system impacts of proposed changes in weapon system design to ensure supportability from an MPT&S point of view.	Don't evaluate proposed systems changes without considering both wartime and peacetime impacts.
Production and Deployment	Allow adequate time and resources for evaluating MPT&S systems before operational use is required.	Don't delay development of MPT&S systems so long that there is not enough time or money to support adequate testing before operational use.
	Make sure that training equipment is available when new systems are fielded.	Don't field new systems without needed training equipment.

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