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STUDY BY THE STAFF OF THE U.S.

General Accounting Office

Guidelines For Assessing Whether Human Factors Were Considered In The Weapon Systems Acquisition Process

Human factors should be an important consideration in the weapon systems acquisition process to assure that weapon systems can be operated and maintained by the people who must use them. GAO suggests general guidelines to use in determining the extent to which human factors were considered in this process.



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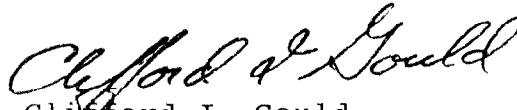
PREFACE

GAO has issued numerous reports over the years on individual weapon systems. Many problems discussed in these reports have a direct or indirect relationship to the human factors element and the acquisition process; that is "what assurances are there that weapon systems developed can be operated and maintained by the people who must use them."

The following pages contain general guidelines for auditors to use in evaluating what manpower implications were considered in the design of a weapon system. These guidelines do not necessarily include all of the questions that need answering. They do, however, provide a framework from which to begin and can be modified or expanded as experience in auditing a particular weapon system dictates.

We obtained informal comments on these guidelines from various officials in the Department of Defense who, because of their knowledge and interest in the human factors area, provided information used in developing these guidelines. We thank them for their comments and believe the guidelines have been greatly improved as a result of their input.

We encourage the use of these guidelines by those involved in the auditing profession and by those having day to day responsibility for the administration and management of any particular weapon system. Further suggestions for revising and improving the guide are welcome and should be addressed to me at the Federal Personnel and Compensation Division, U.S. General Accounting Office, 441 G. Street, NW., Washington, D.C. 20548.


Clifford I. Gould
Director

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ABBREVIATIONS

DCP	Decision Coordinating Paper
MAP	Manpower Analysis Paper
MENS	Mission Element Need Statement
OSD	Office of the Secretary of Defense

CHAPTER 1

INTRODUCTION

As highlighted in a recent GAO report (MASAD-81-26, May 14, 1981), GAO's work on weapon systems has culminated in 24 reports on 28 selected systems. Those reports, issued from September 1980 through April 1981, identified 81 issues in 14 categories that either have a direct bearing on the weapon systems' effectiveness or on the management of the acquisition program. One major issue concerns the manpower, training, and human factors engineering implications associated with the design of a weapon system: that is, what assurances can be made that (1) systems are designed to meet the capabilities of people, (2) adequate numbers of people with the right skills are available to operate and maintain the system, and (3) training needs are identified and met in order to provide for safe and effective operation and maintenance.

In another GAO report issued on January 29, 1981, (PSAD-81-17), manpower problems were identified as factors contributing to system failures. That report said:

"Limitations such as skill levels, proficiency, availability, environmental stress, and fatigue of the personnel who operate and maintain military systems contribute to human-induced system failures. Indications are that these types of failures are quite high. New policy emphasis on human limitations in the design of systems may have a very limited impact because:

- Human factor specifications, standards, and handbooks used in designing and developing systems and equipment do not adequately address human limitations.
- There are no common collective methodologies and data sources for use by system designers in forecasting skill and performance levels of future military personnel.
- DOD (Department of Defense) testing and evaluation policies and procedures do not tend to identify and resolve potential human-induced failures during the developmental stages of the acquisition process."

It has generally been the philosophy that technology will advance our capability to meet the mission needs and that man can adapt to the technology. Designers of weapon systems often do not consider the capabilities and performance requirements of the people who will operate and maintain the systems in the operational environment. It is therefore extremely important that weapon system reviews include an evaluation of the extent to which DOD considers manpower, personnel, and training needs and capabilities in the weapon system acquisition process.

Two different approaches to reviewing weapon systems can be used. The first, found in Chapter 1, involves a review of the manpower documentation required in the decisionmaking process. The second approach, found in Chapter 2, involves an analysis of various organizational functions as they relate to the weapon system acquisition process. Both contain general guidelines for auditors to use in evaluating what manpower, training, and human factors engineering implications were considered in the design of a weapon system. These guidelines address the question of whether such systems can be operated and maintained to achieve readiness requirements or design capabilities when they become available for use. Although these guidelines do not necessarily represent all of the questions that need answering, they do provide a framework which can be modified as experience in auditing a particular weapon system dictates.

CHAPTER 2

REVIEW OF REQUIRED DOCUMENTATION

GUIDELINES (APPROACH #1)

Final approval to proceed with the development and/or acquisition of individual weapon system programs rests with the Secretary of Defense or respective Service Secretaries. In 1969, the Defense Systems Acquisition Review Council was established to review such programs and provide the Secretary of Defense with recommendations concerning the status and readiness of individual weapon systems to enter or continue in the acquisition cycle. Basically the acquisition cycle is broken down into four phases which are (1) Milestone 0--Program Initiation, (2) Milestone I--Demonstration and Validation, (3) Milestone II--Full Scale Engineering Development, and (4) Milestone III--Production and Deployment. The Council plays an important role in the decisionmaking process in recommending whether to begin development of a new system or proceed from one stage to the next in its development.

The Mission Element Need Statement (MENS) is the document upon which the Milestone 0 decision is based. This document identifies and defines among other things (1) a specific deficiency or opportunity within a mission area, (2) the relative priority of the deficiency, and (3) the general magnitude of acquisition resources that the service is willing to invest to correct the deficiency. An August 1978 memorandum from the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) to the Secretaries of the military departments asks that manpower analysis and requirements information be submitted to the Office of the Secretary of Defense (OSD) to support the Secretary's review of system acquisitions. This memorandum requests that the manpower information be submitted to OSD in a separate Manpower Analysis Paper (MAP) or in existing documents if appropriate. The data should be submitted with the MENS or each Decision Coordinating Paper (DCP--document for use in Milestone I, II, and III decisions).

The following information presents guidelines to use during each of the program milestone review phases.

Milestone 0 - Program Initiation Phase

- (1) Review the MENS to determine if any manpower, training, and human factors engineering constraints or opportunities were used to justify the need for the weapon system.

- (2) Determine whether a MAP or other documents were submitted with the MENS for use in the decision process. If not, determine why.
- (3) If any of the above were submitted, determine what manpower data was included. The documents should provide an identification of any broad manpower constraints on the mission need, and a commitment to assess alternatives to reduce manpower requirements.

In connection with this, determine (during this phase or at least in Milestone I phase)

- (a) whether data was included that showed the peacetime and wartime manpower requirements compared against a projected supply of personnel, throughout the system's life span;
 - (b) whether the specific occupational specialties and, if possible, skill levels needed to operate, maintain, and support the weapons system throughout its life span were identified;
 - (c) whether estimated staffing levels per unit (squadron, battalion, ship, etc.) to meet wartime and peacetime requirements were developed and presented; and
 - (d) whether the lead times needed for training or obtaining the required number of people were presented.
- (4) During this phase, determine whether OSD or the services identified any manpower, training, or human factors engineering problems associated with previous similar systems (lessons learned). If so, determine what these problems were and if the information was used in the decision process to resolve similar problems or reduce the likelihood of human-induced system failures.
 - (5) Determine what procedures exist for insuring that needed training programs are developed and that training spaces are reserved for the numbers of people required to operate and maintain the system. Determine at what stage or stages the service training organizations are asked for input, and how the input affects the decision process. If this cannot be done in this phase, perform for Milestone I phase.

- (6) Obtain input from training organizations and determine if there were assurances that needed training programs could be developed. If not, determine what tradeoff recommendations were made. (Perform in Milestone I phase if unavailable in this phase.)
- (7) Determine if there were any lead times established in connection with the development of training programs. Determine in Milestone I phase if not done for this phase.
- (8) Determine if information regarding changes in estimates of people/skills/aptitudes, which may occur to varying degrees during any stage in the acquisition process, was provided to the training organization on a continuing basis. If so, assess any impact this may have on planned training. Determine in Milestone I phase if not done for this phase.
- (9) Determine if planning documents used in the Planning, Programing, Budgeting System address plans for new or improved weapon systems and the related impact on construction costs or possible training base expansion requirements.
- (10) Determine if the contractor selection process (Request for Proposal, Selection Panel, etc.) included manpower, training, and human factor engineering needs. Determine if the proposal evaluation criteria included as a specific reportable item throughout the contractual effort information concerning manpower, training, and human factors engineering.
- (11) Determine if the services provided baseline manpower, training, and human factors engineering data in their request for proposal.

Milestone 1 - Demonstration and Validation Phase

- (1) Determine whether a DCP was prepared and, if so, review it to determine whether it included estimates of unit and total program staffing levels for wartime and peacetime requirements. Obtain and evaluate supporting data that was or should have been attached to the DCP.
- (2) Determine whether a MAP was prepared and submitted. If so, determine what changes were made from any previous MAP and the rationale for the changes.
- (3) Review the MAP and determine whether it included information about optional manpower requirements and its effects on operational capability; i.e., options in

the number of personnel, skill (job proficiency) levels, and military occupational specialties. Determine what options were selected and whether a rationale for selection was presented. Obtain and evaluate supporting data that was or should have been attached to the MAP.

- (4) Determine what tests were planned for use in assessing the selected manpower alternatives in the MAP or other documents. Determine how the test results were used in deciding on a particular option.
- (5) Verify whether the MAP or any other document discussed alternative approaches to reducing manpower requirements or increasing productivity. An example of this would be a change in maintenance approach which affects the number of functions to be performed and number of personnel and skills required.
- (6) Determine what test and evaluation procedures were or are to be performed to assess the personnel skill requirements, human factors, or training implications of the total system (e.g., performance under stress or fatigue, visual or physical needs, workload, aptitude, and training required to operate and maintain). Real world scenarios should be used to identify people-related problems with the system.
- (7) Determine how the results of demonstration and validation will be used in the decision process.
- (8) Review respective requests for proposals or other similar documents to determine if the services included statements addressing manpower. Was service manpower/personnel/training information included as part of Government-furnished information in the contract package?
- (9) Determine if the source selection process included grading/evaluation criteria which address manpower and reward innovative approaches aimed at reducing manpower/training and/or personnel skill levels.

Milestone II - Full Scale Engineering Development Phase

- (1) During this phase, specific manpower estimates (minimum and maximum numbers) should be established. Determine whether the DCP, MAP, or other submitted documentation included this information. Obtain and review supporting documentation.
- (2) Assess the rationale for the estimates and identify whether any unique skills or specialties were estimated as being needed.

- (3) Determine whether revised estimates of manpower requirements were included and the basis for any revision; i.e., demonstrations from previous phase led to alterations of previous estimates.
- (4) Determine what tradeoffs among manpower demand, personnel supply, and training (quantity, skills, specialties) were made. Obtain supporting documentation and determine rationale used in making tradeoff decisions.
- (5) Determine whether requirements versus supply (available skills, particularly highly skilled technicians in specialized occupations) were considered in the decision. This should include consideration of turnover/attrition rates, specialized training required, and other factors affecting the availability of needed personnel.
- (6) Determine whether man-machine tradeoff criteria were used in the development of operation and maintenance work spaces, environmental control concepts, and control/display/software design concepts. Assess the extent to which developmental tests demonstrated (1) system conformance to human factors engineering design criteria, (2) adequacy of training approach, (3) acceptability of system-imposed operator workload, and (4) system safety.
- (7) Determine if plans were submitted which (1) outline procedures for acquiring personnel, including Reserves, to meet wartime and peacetime manpower requirements, (2) identify any staffing problems for any specialty, particularly those with shortages, and (3) evaluate the man-machine effectiveness during acceptance testing. If such plans were not submitted during this phase, determine if they were submitted during subsequent phase (Production and Deployment) and if not, determine why.
- (8) Determine if documentation identifies what training programs and training equipment are essential for each skill progression. If documents do not provide this information, determine if the information is included in subsequent phase (Production and Deployment) documentation. If not, determine why.
- (9) Determine what feedback process exists to provide information on manpower/personnel/and training shortcomings found during the various developmental and operational testing that should be considered in the development process. If process does exist, evaluate how effective the process is.

Milestone III - Production and Deployment Phase

- (1) Determine whether a DCP, MAP, or other document was prepared for this phase and review these for manpower data. Obtain supporting information.
- (2) Determine whether a staffing document was prepared showing total position requirements broken down by specialty and skill level required. Determine whether the document included an analysis of such things as high-demand workload, direct versus support work, supervisory assignments, etc.
- (3) Obtain and review the documentation concerning information on specialties to determine whether shortages of any required specialties have been a problem in the past, and assess what plans there are to overcome them.
- (4) Determine whether required training equipment is available so that individuals programmed for assignment to the weapon system will have had required training by time of deployment.

Questions for the Contractor/Subcontractor/ Program Manager

- (1) Determine whether the above were asked to give input (estimates) as to the number of people/skills/aptitudes it would take to operate and maintain the system when it became deployable. If not, why?
- (2) If so, during what stage (stages) was the input required? Determine whether this information was required within established time periods and, if so, was this requirement met?
- (3) Determine who was designated to receive this information and if it affected continuation to the next phase.
- (4) Determine whether OSD or the services provided any feedback to the contractor/subcontractor regarding submitted manpower, training, or human factors engineering data that would affect their estimates or design of the system. Determine if the feedback answered any questions raised by the contractor.
- (5) Determine whether the contractor was bound to any manpower, training, or human factors engineering constraints in designing and developing the weapon system.

- (6) Determine what dialogue took place between the contractor/subcontractor/program manager/service's manpower, training, and human factors engineering organizations and OSD decision-makers concerning these related factors.
- (7) Obtain contractor/subcontractor opinions as to effectiveness of the dialogue.
- (8) Determine whether the manpower, personnel, and training issues were considered for both the system/subsystem and the total operational environment in which it must operate, including hostile and fatigue-inducing environments.

ESTIMATED STAFF-DAYS FOR APPROACH #1

<u>Phase</u>	<u>Staff-days 1/</u>
Milestone 0 - Program Initiation	20
Milestone I - Demonstration and Validation	30
Milestone II - Full Scale Engineering Development	20
Milestone III - Production and Deployment	10
Contractor/Subcontractor/Program Manager	<u>10</u>
Total	<u>90</u>

1/Assumes all work outlined will be performed. These estimates are not precise and will vary depending upon such things as the auditor's (1) existing subject matter knowledge, (2) coverage on each of the individual guides, or (3) knowledge of organizations to visit to obtain needed information.

CHAPTER 3

REVIEW OF ORGANIZATIONAL FUNCTIONS

GUIDELINES (APPROACH #2)

This approach is an evaluation of the various functions that, from a manpower, training, and human factors engineering perspective, are important ingredients in the weapon system acquisition process. The audit work outlined in this chapter is not tailored to any specific phase or milestone and does not involve an evaluation of required documentation and supporting data. An auditor should bear in mind that within a service these functions may cross organizational lines. As a result, an auditor may be required to visit several locations.

The functions presented for review are

- manpower requirements (work demand created by weapon system),
- personnel inventory (supply of personnel to do the work),
- training,
- human factors engineering,
- staffing/assignment,
- testing/demonstration/validation, and
- research considerations.

Using this approach, an auditor should consider the following guidelines.

MANPOWER REQUIREMENTS VERSUS SUPPLY OF PERSONNEL

A criticism of the weapon system acquisition process has been that needed manpower is neither available in number or required skills to operate and maintain the system at the time the system becomes deployable, thereby contributing to system failures. The capability to predict the availability of people and their aptitudes and skills when the system becomes deployable could help alleviate or lessen the magnitude of human-induced failures. To address this issue:

- Determine what manpower analysis was conducted for input into the design/concept/program initiation phase.

- If manpower analysis was performed, determine whether requirements (both wartime and peacetime) were estimated for the life cycle of the system, and how these estimates were developed.
- Determine what staffing documents were developed that showed requirements (wartime and peacetime) by unit, squadron, ship, skill, occupation, etc.
- Review the staffing documents to determine if modifications to the documents were made and why. For example, during the demonstration and validation stage, testing results may dictate a change in maintenance procedures to correct a potential deficiency. This in turn may effect a change in staffing requirements. Such changes can be cross-checked to the original staffing document.
- Interview responsible officials to determine what assurance they had that the required personnel and skills, as estimated in the staffing documents, would be available at time of system deployment.
- Determine the extent to which the respective services' organizations for determining manpower requirements were asked to provide input to the weapon systems process before or during the design (concept/program initiation phase) and during subsequent phases.
- Determine the extent to which manpower factors are built into the contractual agreements with the company responsible for building the system and the extent to which the company is accountable for insuring the system is built with the user in mind.
- Determine if the program manager provides the services' manpower organizations the estimated manpower requirements needed to operate and maintain the system and seeks feedback on whether the number and skills will be available at time of system deployment. If not, why? If required numbers are available, determine what programs are developed to insure the retention of these personnel.
- Determine what procedures exist to insure continuous dialogue between program managers and personnel planning organizations throughout the weapon system's development. Such procedures would be necessary to insure that personnel planning organizations are aware of any changes to the weapon system which affect estimates on needed manpower availability.

- Determine if system manpower requirements are identified specifically by system so as to prevent loss of identity in the requirements decisionmaking process.
- Determine how the manpower requirements were derived. For example, were they extrapolated from a predecessor or reference system, simulation of hardware, or a complex research and development effort, etc. Determine how the requirements were characterized, i.e., by grade, years of experience, aptitude scores, etc.
- Determine if alternative system concepts and hardware configurations were explored to assess the impact on the supply of people by skill or aptitude level.

TRAINING

With adequate training or retraining, will man be better able to adapt to the designed weapon system? Are the human factor problems with operating and maintaining weapon systems the result of poor or inadequate training or poor quality of people entering the military? Will quality improve? If not, will training or retraining provide for correcting the problems? How can this training or retraining be planned for to insure that people are ready to operate and maintain the system when deployable? To determine the extent to which the services' training organizations and procedures affect the weapon system design, the following can be done.

- Determine and review what procedures exist to insure that the respective services' training organizations provide input on a continuous basis to the weapon system acquisition process.
- Determine and review what procedures exist to insure that training organizations are kept apprised, on a periodic basis, of changes in concept, design, etc., which may affect the development of training programs or training position requirements.
- Determine lead times needed for designing training programs for weapon systems and how classes will be scheduled to insure all needed training is received before system is deployed.
- Determine if tradeoff analyses were made concerning formal school course content versus on-the-job training effectiveness. Determine whether training device/simulator requirements were explicitly derived from such an analysis. Determine if manpower requirements were adjusted to provide people to conduct on-the-job training.

- Determine how the developers of the operations and maintenance manuals coordinate with the training organizations to insure that manuals are not too sophisticated for the estimated quality (e.g., reading ability) of people who will be trained.
- Determine length of time needed for developing operations and maintenance manuals and what input is needed from training organizations concerning future quality of people who will be using the manuals.
- Determine what documentation on training plans for operations and maintenance exists and review the documentation to insure it includes an evaluation of options concerning equipment choice and design, technical publications, formal vs. on-the-job training, unit training, individual training, and simulator training.

STAFFING/ASSIGNMENT

The development of a weapon system could have an impact on staffing, assignment, or classification procedures if part of a unit has to be retrained to operate and maintain a new or modified system. It is therefore important that those people involved in making assignments are kept apprised of weapon system development.

- Determine what procedures exist to insure continuous coordination between the weapon system acquisition process and the personnel skill classification and assignment process.
- Interview officials responsible for both functions to assess the impact weapon system development has on staffing/assignment procedures. Document potential problems.
- Review any documentation that shows how the information was requested, received, and fed back and its timeliness in the decisionmaking process.

TESTING/DEMONSTRATION/VALIDATION

Before the decision to enter full-scale engineering development is made, the system's usefulness should be thoroughly tested and evaluated so as to get an estimate of operational effectiveness and suitability, including logistic supportability. To insure operational effectiveness, human factors engineering considerations are also important to such estimates. To assess the extent to which human factors engineering considerations were included in the testing and evaluation of the system, the following can be done:

- Determine what manpower training or human factors engineering constraints or problems, surfaced from tests performed on the previous system, need consideration in the new or modified system. Determine if these constraints/problems were considered and tested for and what results were obtained.
- Determine if testing of the system included any consideration of aptitude levels, height, weight, stress, fatigue, performance, etc., that would affect system effectiveness. If so, determine how and when this information was communicated to decisionmakers and whether the communication had any impact on decisions.
- Determine whether these test results affected the estimated numbers or availability of personnel and skills, thereby effecting a needed change in manpower estimates contained in staffing documents. Determine if this information was communicated, its timeliness, and results.
- Determine whether testing results indicated the need for new or modified training documents, manuals, or programs. Assess results.
- Determine whether testing identified the level of personnel proficiency needed to meet mission objectives and whether this resulted in a plan for attaining and maintaining such personnel. Determine if this information was communicated to decisionmakers in time to affect decisions.

RESEARCH/HUMAN FACTORS
ENGINEERING CONSIDERATIONS

The services' human factors engineering laboratories, such as the Army's in Aberdeen, Maryland, play an important role in the weapon system acquisition process by researching and evaluating manpower considerations associated with designing, operating, and maintaining the system. The role they play is dependent upon the funding received and number of researchers available. Currently, the human engineering laboratories get involved in the acquisition cycle through industrial funding approved by interested program managers. Human engineering should be a significant factor in weapon system design and the auditor may wish to consult the following guidelines.

- Determine whether the funding methodology limits research on weapon systems and if it is more advantageous to conduct research through appropriated funds versus industrial funding.

- Interview responsible officials at the respective research laboratories to determine the extent to which they get involved in the acquisition process.
- Determine the extent to which human factors engineering regulatory documents and policies were employed during the acquisition process.
- Determine at what stage (program initiation, demonstration and validation, etc.) researchers get involved and assess whether they have time to affect the decisionmaking process.
- Determine the number of researchers involved and their average workload.
- Sample researchers to determine their perspective on the research performed, organizational difficulties, and suggestions for improvement.
- Determine the organizational alignment of the labs and the extent to which they provide input to the manpower and personnel organizations in the respective services.
- Determine the attrition/turnover rate of the researchers and their reasons for leaving as well as the average amount of experience the remaining researchers have.
- Determine why research is conducted only through industrial funding and how this affects the amount of research and type of research conducted.

ESTIMATED STAFF-DAYS FOR APPROACH #2

<u>Function/Organization</u>	<u>Staff-days 1/</u>
Manpower Requirements vs. Supply of Personnel	30
Training	23
Staffing/Assignment	8
Testing/Demonstration/Validation	17
Research/Human Factors Engineering Considerations	<u>22</u>
Total	<u>100</u>

1/Assumes all outlined work will be performed. These estimates are not precise and will vary depending upon such things as the auditor's (1) existing subject matter knowledge, (2) coverage on each of the individual guides, or (3) knowledge of organizations to visit to obtain needed information.

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