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DEFENSE SYSTEMS MANAGEMENT COLLEGE

PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

HUMAN FACTORS ENGINEERING
IN AIR FORCE WEAPON SYSTEMS ACQUISITION

Study Project Report
PMC 77-1

Bronislaw P. Prokuski, Jr.
Major USAF

FORT BELVOIR, VIRGINIA 22060

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IN AIR FORCE WEAPON SYSTEMS ACQUISITION

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TABLE OF CONTENTS

EXECUTIVE SUMMARY ii

SECTION

I. INTRODUCTION 1

Purpose of the Study Project 2
Specific Goals of the Study Project 2
Limitations of the Study Project 5
Human Factors Engineering Defined 5
Human Factors Objectives 9
Policy and Directive Guidance 10
Relation to Other System Engineering Disciplines 12

II. HUMAN FACTORS ENGINEERING MANAGEMENT IN THE ACQUISITION PROCESS 17

Human Factors Engineering in the Conceptual Phase 18
Human Factors Engineering in the Validation Phase 22
Human Factors Engineering in the Full-Scale Engineering Development Phase 23

III. HUMAN FACTORS ENGINEERING APPLICATIONS TO ACQUISITION PROGRAMS 26

IV. CONCLUSIONS AND RECOMMENDATIONS 31

REFERENCES

EXECUTIVE SUMMARY

The application of human factors engineering to system acquisition programs has often been hampered by an unclear understanding, on the part of program management personnel, of its definition, role, and scope. An awareness by program management personnel of human factors engineering and early consideration of its elements in the acquisition cycle, particularly in the conceptual phase, are, however, key to achieving an optimum man-machine interface in the design of weapon systems. Failure to consider the man-machine interface early may result in deficiencies which limit the system's performance and effectiveness and are costly to correct.

Section I of this report describes the purpose and goals of this study project, defines "human factors engineering," reviews policy guidance and provides some insight into the relationship of human factors engineering to other system engineering disciplines.

Section II describes the conceptual, validation, and full-scale engineering development phases of Air Force system acquisition with emphasis on the key documentation required. Human factors engineering activities appropriate to these acquisition phases and the interrelationship with other system development activities are also identified and discussed.

Section III discusses the need for program management support of an effective human factors engineering program and some applications to acquisition programs. Emphasis is given to the practical and wide-ranging scope of human factors engineering efforts through discussion of some aspects of the F-15 and F-16 programs.

Section IV concludes that the success of human factors engineering is directly related to the management emphasis and priority given it and

provides some general recommendations concerning improvement for the implementation of human factors engineering to system acquisition programs.

SECTION I

INTRODUCTION

Man, though we often forget him, is the key element for success in Air Force missions. The Air Force must have men to operate, maintain, control and support every system in its current operational inventory. Even with increased reliance on automation, the current and programmed complex and sophisticated military systems without the human resource would lack functional utility. Coupled with the impact of the accelerating state of technology is the increasing awareness of Air Force manpower limitations in terms of numbers and skills. The consequence is that the human resource must be treated on an equal basis with hardware in order to have systems that are capable of accomplishing intended missions in the most effective and efficient manner possible.

In achieving that effectiveness and efficiency in the development of Air Force systems, the man-machine relationship must be given proper consideration. The role given to Human Factors Engineering in Air Force program management can be the key to that success. Too often human factors has been thought of as just the identification and selection of individuals required to operate, maintain, and control the system hardware. System developers and particularly program management personnel have taken the attitude that if hardware systems or subsystems can be made to operate, somehow personnel with the proper skills and proficiencies will be found to operate, maintain and control them. Often the human factors requirements have been eliminated because of cost effective considerations. Cost effectiveness, however, means more than getting the most equipment for the least dollars; it also means operational effectiveness for the optimum cost. As is illustrated in Figure 1, the value of human factors is most beneficial early in the system life-cycle when changes to design can be made at minimum cost. (26:16). It is in this light that human factors should properly be considered - that of providing cost effective solutions and providing the user with efficient tools both in a hardware and human element sense to perform the required mission.

As is illustrated in Figure 2, consideration of human factors engineering in the development and acquisition of systems can result in improved performance through major contributions to the reliability of the man-machine combination. (26:10). In addition, training costs can be reduced, manpower utilization can be improved, and losses through accidents or misuse can be reduced through proper application of human factors engineering principles in the early design of system hardware.

PURPOSE OF THE STUDY PROJECT

It is the purpose of this study project to provide a general understanding of human factors engineering in Air Force program management for the consideration of program management personnel in the implementation to future acquisition programs.

SPECIFIC GOALS OF THE STUDY PROJECT

In order to accomplish the purpose of this study project, the following specific goals will be achieved: (1) definition of human factors engineering in the Air Force context; (2) review of Air Force human factors engineering policies; (3) outline of major human factors engineering functions to be accomplished in the acquisition process; (4) identification of some applications of human factors engineering; and (5) identification of trends and problem areas based upon personal observation of human factors

VALUE/COST OF HUMAN FACTORS CONSIDERATIONS

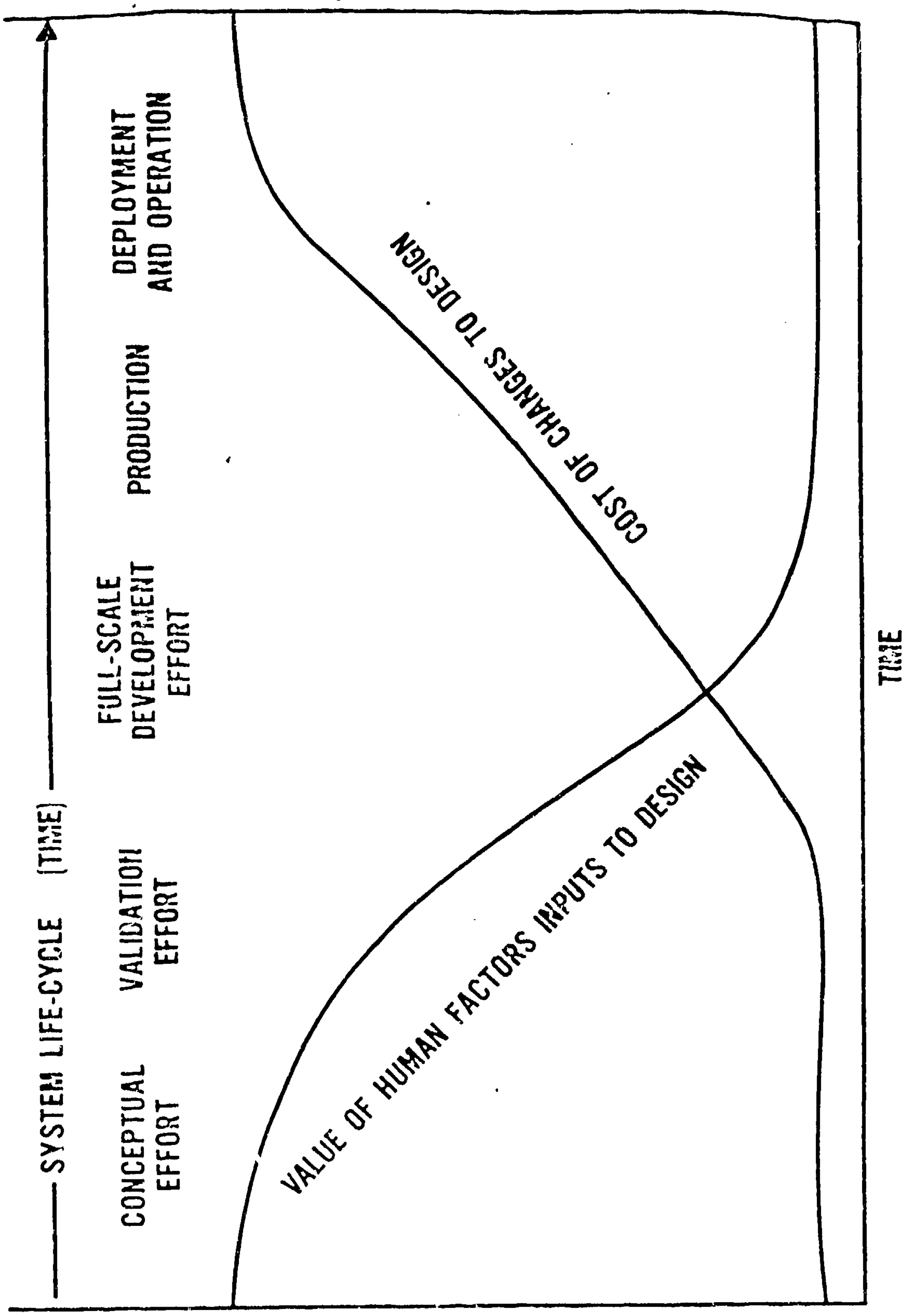

Figure 1

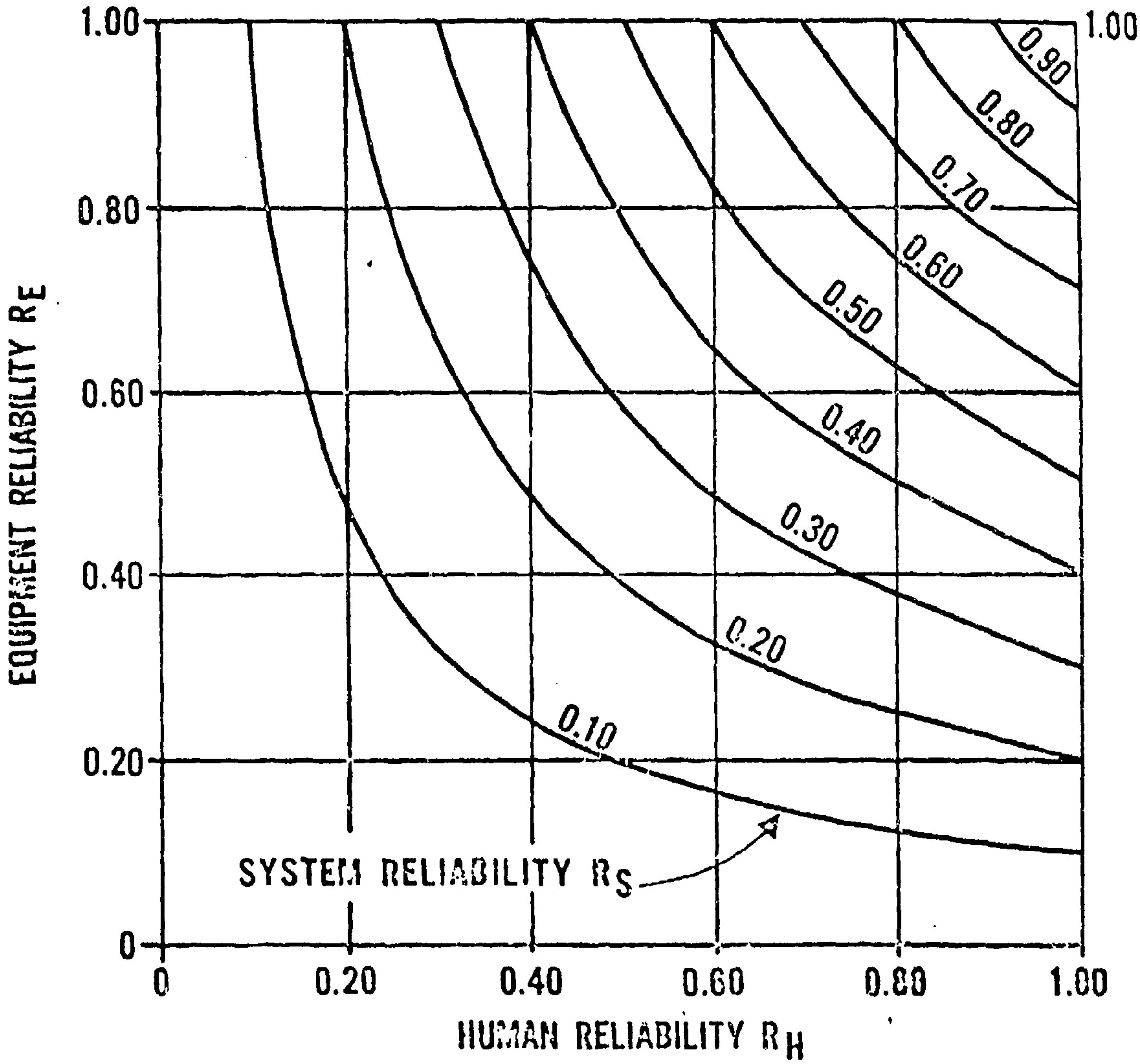
1.00
0.80
0.60
0.40
0.20
0
EQUIPMENT RELIABILITY R_E
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
SYSTEM RELIABILITY R_S
0
0.20
0.40
0.60
0.80
1.00
HUMAN RELIABILITY R_H

Figure 2

efforts.

LIMITATIONS OF THE STUDY PROJECT

Because of time limitations and the extensive nature of human factors engineering, the general discussion will focus on aircraft systems. This report is directed at program management personnel who are uninitiated to human factors efforts and provides a perceptual framework for the future consideration and application of human factors to their acquisition programs.

Research material was generally limited to that available through the Defense Systems Management College library and the Headquarters, Air Force Systems Command Technical Library. A primary source of information was personal observations gathered during a year and a half as a systems engineering policy monitor in Headquarters, Air Force Systems Command. Another source was personal discussions with human factors personnel during that time period. A final source was a series of written replies that responded to a letter that inquired about human factors career field management. (24:).

HUMAN FACTORS ENGINEERING DEFINED

Often, program managers and other key acquisition management personnel have been unfamiliar with the definition, scope and objectives of human factors engineering, or they have been misled by the previously used Air Force term "Personnel Subsystem" into thinking of the actual personnel assigned to man the system. As a result, a definition is required before discussing the role of human factors engineering in the development and acquisition process. In broad terms, human factors engineering can be thought of as a concept that consists of a "systematic and integrated approach to providing timely products and processes necessary for optimizing the man-machine relationship." In the Air Force, it is the current term employed for the management of the development, integration, and test of human factors elements in systems acquisition. (2:1) (5:2). It is part of the mainstream engineering effort throughout the system life cycle and is concerned with those engineering and management tasks required to provide for effective human performance (both operations and maintenance). It consists of various elements which encompass all aspects of human performance and are considered an integral part of the total system performance. The following elements as listed in AFR 800-15 are interdependent, developed concurrently, and include functions to be performed, the activities of which require proper management and controlling.

. Human Engineering Element. Human engineering is the application of knowledge about human capabilities and limitations to system or equipment design or development to achieve maximum system performance through the most effective use of man's capabilities and limitations. Applied human engineering insures that the system or equipment design and development, the human tasks, and the work environment are compatible with the sensory, perceptual, mental, and physical attributes of the personnel who will operate, maintain, control, and support the system or equipment.

. Biomedical Element. The biomedical element includes every area that requires provisions for the promotion of health and safety including the protection, sustenance, escape, survival and recovery of personnel employed in the total system environment under normal and emergency conditions.

. Manpower and Personnel Requirements Element. The manpower and personnel requirements element identifies the number of trained personnel required to operate, maintain, control, and support the system equipment in its operational environment. Information generated by this element serves as a basis for manpower and personnel planning and programming decisions.

. Training Element. This element includes all training provided by the Air Training Command, the using command(s) and the training support, equipment, facilities and data. This element has five subelements which are:

(1) System Trained Personnel Requirements (STPR). The STPR identifies the personnel positions (officer, airman, civil service civilian and contract technical services personnel) and the number of personnel for each position that will require system-peculiar training. The STPR, the training plan, and the training programs (maintenance and operations) are all based on the manning requirements identified in the Manpower and Personnel Requirements Element.

(2) Training Plan. The training plan is an evolutionary document that is initially written during the conceptual phase of systems development and is updated periodically to identify system information that comes-to-light as the system is developed. It includes such items as system training objectives, personnel and training concepts, Air Training Command individual training plans, training planning information, training equipment planning information, using command operational readiness training plans, the Integrated Logistics

Support plan and the milestone dates for the start and completion of all system training.

(3) Training Equipment Development. This subelement includes defining, programming, budgeting, contracting, developing, producing, acquiring and supporting the system training equipment package.

(4) Training Facilities. The training facilities subelement includes identification of the facilities (buildings, building modifications, electricity and other utility requirements) required and the planning for (military construction program) and the cost of construction or modification of existing facilities to house the maintenance and operational training equipment.

(5) Training Support Data. This subelement includes such data as contractor prepared drawings, in-house documents, commercial manuals, procedural support data, development program manuals, job performance aids. preliminary or hard copy technical orders, transparencies, films, computer programs or analysis data that are identified and obtained for the Air Training Command and the operating command training purposes.

. Human Factors Test and Evaluation Element (HFT&E). This element is part of the system test and is conducted in accordance with Air Force Test and Evaluation procedures contained in AFR 80-14. The HFT&E test plan is concerned with determining whether Air Force personnel with system training and system peculiar tools can operate, maintain, control and support the system in its intended operational environment.

The elements can be summarized as follows:

Human Engineering - System and Hardware

Biomedical Support - Environmental

Manpower and Personnel Requirements - Skills and Numbers

Training Element - Numbers, Facilities, Tech Manuals, Films, etc.

Human Factors Test and Evaluation - Measuring Operational Suitability

HUMAN FACTORS OBJECTIVES

In accomplishing the human factors objectives of designing and developing systems or equipment to make the best use of resources and man's capability, the management of a system program requires the active participation and continuous coordination between human factors specialists and consideration of the following:

- Man's Role: Has man's role in the system been defined to make best use of his limitations and capabilities.

- Analysis and Trade Studies: Man-machine analysis and trade studies must be an inherent part of the system life cycle. Studies should consider life cycle costs, system performance requirements, complexity and availability of capable manpower to perform the intended functions.

- Operating and Workplace Environment: The operating and workplace environment has been planned for and optimized in consideration of man's contribution to the system and mission performance.

- Biomedical: When appropriate the biomedical analysis and design support includes all environmental protection necessary to promote personnel health and safety and the capability for safe operation and maintenance of the system or equipment item.

- Training Requirements: Identify the type of training course, its length, and course outline necessary to support the system or equipment.

- Training Program: Assure that the training program that supports the system includes training requirements, training equipment, training facilities, training support data and the quantity of people to be trained.

- Test and Evaluation: Test and evaluation includes testing of all the human factors elements to verify that the system or equipment can be safely and effectively operated, maintained, controlled, and supported in its intended operational environment.

POLICY AND DIRECTIVE GUIDANCE

Basic policy guidance on the incorporation of human factors engineering in system acquisition is contained in the latest revision of DoD Directive 5000.1, Major Systems Acquisition.

> The number and skill levels of personnel required and human engineering factors shall be included as constraints in system design. The integration of the human element and system shall start with initial concept studies and refined as the system program progresses to form the basis for personnel selection and training, training devices, simulators and planning related to human factors.

This guidance which was not previously included in this document underscores the increasing awareness and impact of the man-machine relationship.

In implementing this guidance, AFR 800-2 (Program Management), and AFR 800-3 (Engineering for Defense Systems) serve to outline, respectively, the program management concept and the policy and principles for the management of the totally integrated engineering effort under this concept. Under the guidance provided in AFR 800-3 the engineering management task of the Program Manager is to assure:

> ...that the technical functions in the program office are properly planned and implemented, and that the technical functions performed under contract are tailored, monitored, and controlled to best meet the needs of the system or program.

One of these technical functions is human factors engineering. Specific guidance on incorporating its elements into the mainstream engineering and program management effort of all acquisition programs and conceptual studies is contained in AFR 800-15, Human Factors Engineering and Management. In essence the policy calls for the following:

1. Application and appropriate adaptation of human factors engineering to all projects, programs, equipment procurements, modifications, and test and evaluation programs where the intended end product has human performance as an integral part.

2. Incorporation of human factors engineering responsibilities in each system management, planning, programming, or contractual document and transfer along with the system in inter-command transfer agreements.

3. Appropriate definition, tailoring, and implementation of each human factors engineering element to best meet the needs of the system or program.

4. Coordination of the human factors elements with Integrated Logistic Support to assure proper planning for man's role in relation to operational and maintenance concepts.

5. Inclusion of human factors test objectives in system test plans for systems conducted in accordance with AFR 80-14, Test and Evaluation.

In further clarification of the application of human factors engineering in weapons system acquisition, the Air Force Systems Command supplement to AFR 800-15 requires that the Product Divisions (those field commands having responsibility for the development and acquisition of electronic, space, aeronautical and armament systems) establish a focal point to ensure that adequate and uniform human factors engineering policies, procedures and programs are followed and that efforts are coordinated with other disciplines to attain overall system effectiveness. Further, the program offices are to ensure that appropriate human factors engineering effort is planned for and implemented by assigning a part or full-time human factors engineering manager upon formulation of the program office cadre. Preferred for these assignments are individuals with the appropriate human factors background and training such as those individuals possessing Air Force Specialty Code 2675.

Other primary guidance on human factors for incorporation into statements of work and system specifications can be found in MIL-STD-1472B which established general human factors engineering criteria for development of military systems, equipment, and facilities and MIL-H-46855A which establishes and defines the general requirements for applying the principles and criteria of human factors engineering in the development and acquisition process. Additional design guidance such as anthropometric data is contained in AFSC Design Handbook 1-3, Human Factors Engineering.

RELATION TO OTHER SYSTEMS ENGINEERING DISCIPLINES

As was previously discussed, human factors engineering should be thought of as a concept since its elements as shown in Figure 3 cut across

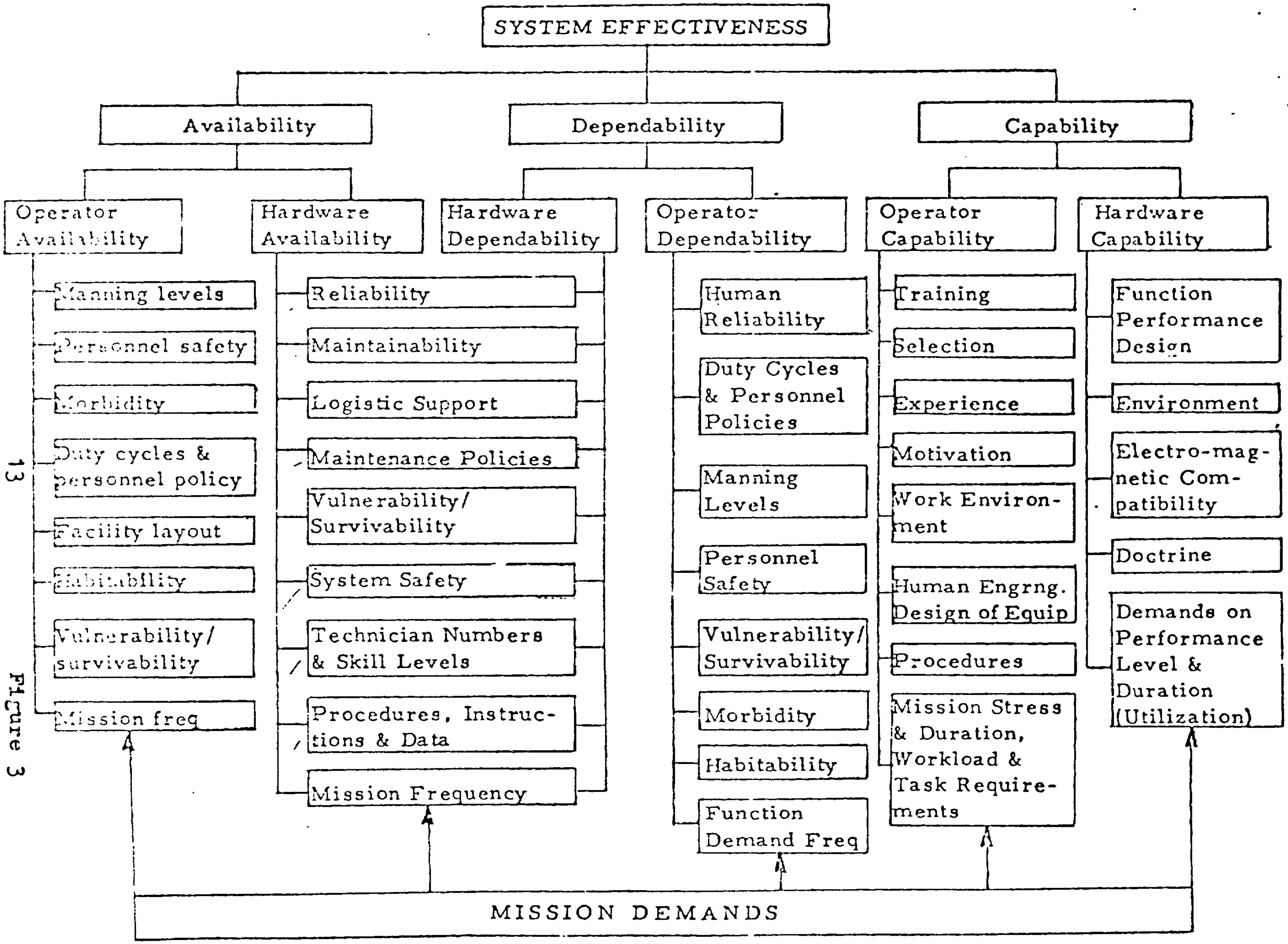
SYSTEM EFFECTIVENESS
Availability
Dependability
Capability
Operator Availability
Hardware Availability
Hardware Dependability
Operator Dependability
Operator Capability
Hardware Capability
Manning levels
Personnel safety
Morbidity
Duty cycles & personnel policy
Facility layout
Habitability
Vulnerability/ survivability
Mission freq
Reliability
Maintainability
Logistic Support
Maintenance Policies
Vulnerability/ Survivability
System Safety
Technician Numbers & Skill Levels
Procedures, Instructions & Data
Mission Frequency
Human Reliability
Duty Cycles & Personnel Policies
Manning Levels
Personnel Safety
Vulnerability/ Survivability
Morbidity
Habitability
Function Demand Freq
Training
Selection
Experience
Motivation
Work Environment
Human Engrng. Design of Equip
Procedures
Mission Stress & Duration, Workload & Task Requirements
Function Performance Design
Environment
Electro-magnetic Compatibility
Doctrine
Demands on Performance Level & Duration (Utilization)
MISSION DEMANDS

Figure 3

and interact with other systems engineering disciplines to achieve system effectiveness. (27:2). In practice, however, human factors engineering tends to be most closely linked with the systems engineering disciplines of reliability and maintainability, although it is complimentary to safety and Integrated Logistics Support. However, the objectives of reliability and maintainability should not be confused with those of human factors engineering. For example, in a flight test program, reliability and maintainability engineers would be gathering data to predict maintenance manhours per flight hours and to identify subsystems of high maintenance manhour consumption and low reliability. The human factors engineer, in contrast, would be evaluating the human engineering of the maintenance equipment and tools, adequacy of technical manuals, the individual functions which are being performed to determine if the task could be performed more efficiently in terms of ease of removal, replacement or repair, or if there is a potential for personal hazard, equipment damage or error. In essence, for this example, the human factors specialist is concerned with the total picture of the aircraft deployment and the utilization of personnel. He looks at the total task involvement such as aircraft turnaround, pre-flight and post-flight activities, and addresses the skill level, use of support equipment, and allocation of personnel in performing the tasks. Thus, in relation to the other systems engineering disciplines the major emphasis of human factors is early-on assistance to other design engineers to recommend changes that would facilitate human performance. As another example consider the case of avionics equipment reliability. (25:26). As is shown in Figure 4, the large "other causes" category includes failures resulting from errors during design, production, operation and

AVIONICS EQUIPMENT FAILURE CAUSES

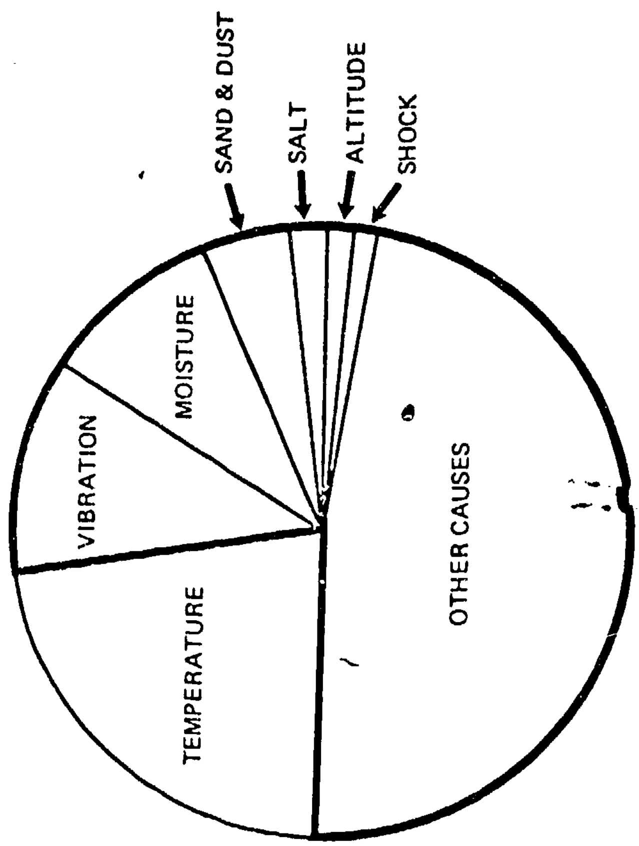

Figure 4

maintenance. Theoretical reliability predictions ignore this human induced failure category and these "other cause" failures that occur during reliability testing are considered irrelevant. From an operational point of view though, all failures are relevant and must be fixed. Therefore, in improving the accuracy of reliability predictions, the potential for human error must be considered during design and continually evaluated or eliminated during the development test program. Delaying treatment of the human-induced causes, only serves to cause a chain reaction that can effect numerous components and subsystems.

SECTION II

HUMAN FACTORS ENGINEERING MANAGEMENT IN THE ACQUISITION PROCESS

As was indicated in the previous section, human factors engineering is not only a concept complimentary to other systems engineering disciplines, but tends in application to cut across the other functional disciplines. However, it must be managed as a package so its development, documentation, test and evaluation are integrated with the procedures that govern the development of the hardware portions of the system. To accomplish this integration, the management responsibility for human factors engineering is assigned to the program manager. However, since all the human factors elements are not developed solely by resources directly available to him, the program manager should appoint a human factors manager as directed in AFR 800-15 to integrate the efforts of representatives from each command or agency that has a functional association with any of the human factors elements. In essence, the implementation of human factors engineering is an interdisciplinary team approach.

To acquaint management personnel with the development and management of human factors engineering, the purpose of this section will be to briefly discuss the first three phases of the acquisition process, conceptual, validation and full-scale engineering development and in the opinion of the author some of the more important functions that are appropriate to each. Only the first three phases are discussed because as was indicated previously the effective impact of human factors considerations and changes tends to decrease as a system moves through development and because, from a program management viewpoint, management transfer of a program is usually effected between the developing and supporting command early in the production phase in accordance with Program Management Responsibility Transfer agreements.

HUMAN FACTORS ENGINEERING IN THE CONCEPTUAL PHASE

The Conceptual Phase extends from the validation of the mission need, Program Initiation Decision, to the program decision that authorizes accomplishment of the Validation Phase. This phase defines and selects the systems concepts which warrant further development. (14:2-1). During this phase, the primary human factors effort is concerned with the preparation of the Request for Proposal to which potential contractors will respond by submitting proposals to accomplish the contractual requirements of the next phase, the Validation Phase. However, if the technological know-how required to satisfy the mission need is not readily available or if continued technological advances are to be pursued, then exploratory development programs or projects are initiated to provide the required knowledge. On these programs, human factors engineering management personnel are primarily interested in the impact which human performance may have upon the program's feasibility and practicability. Generally, a task is included in the exploratory development statement of work or plan to require the contractor or in-house laboratories to consider the role and impact of man upon the hardware, as well as the impact of the hardware contemplated upon the human performance requirements and personnel resources, i.e., man-machine tradeoff studies.

If the advanced development approach is selected to reduce the technical risk by developing experimental subsystems or components for operational demonstration, then the human factors engineering is again similar to that in the exploratory development approach. However, in addition to trade studies, a description of the basic manning concept that is recommended for the operation/maintenance of the system or equipment should it become operational should be required. This information then provides the basis to measure the impact on support personnel skill levels and numbers, training requirements, and logistics support. These data are basic to all other efforts which are accomplished during this period, e.g., risk assessment, cost studies, and utility analysis. The results of these assessments determine to a great degree the final system performance.

Once a program office has been established, human factors considerations should be aligned to directing and coordinating system engineering efforts for the preparation of the Program Management Plan (PMP), establishing the functional baseline (program requirements baseline) and statement of work sections of the Request for Proposal, and initiating preparation of the Test and Evaluation Master Plan and the Test and Evaluation Objectives Annex.

In the PMP, which contains the program manager's objectives and methods he intends to apply in order to complete the program through the Validation Phase and other appropriate phases, human factors engineering requirements should be considered an integrating function in determining and defining organizational relationships, system engineering approaches, critical issues and area of risk as related to test objectives, operational and maintenance concepts, personnel, training and training equipment requirements, and logistics support. Human factors specialists must assure that appropriate human factors considerations are given each of these areas.

In addition to assuring that all the requirements needed to execute and support the program's human factors engineering development effort are planned for, the human factors specialist should devote particular attention to the requirements for Human Factors Test and Evaluation support from other Air Force or contractor test facilities as this critical element is often overlooked.

The functional baseline which is established by the end of the Conceptual Phase includes broad system performance objectives, an operational concept, a logistics concept and cost estimates. The system specification defines the technical portion of the program requirements baseline. (14: 2-8). System functions and subfunctions should be identified in consideration of the man-machine interrelationship for once system definition progresses to more detailed levels it is extremely difficult, time consuming, complicated and costly to reverse the initial decisions and the benefits of human factors integration may be seriously diminished.

As was previously mentioned, the prime human factors effort is involved with the preparation of the RFP. The RFP sets the pace for the entire program and the human factors requirements in the preplanning documentation serve as the foundation upon which the entire human factors effort is built.

Accurate and realistic inputs must be provided in the RFP in order to have a truly cost effective baseline. During RFP preparation, the program manager must make every effort to have a qualified team of human factors specialists "on board," for without them the human factors baseline (integration of other functional disciplines) will be put together in an incomplete and haphazard manner and will lack cohesiveness in thought and organization.

The program manager should place a positive premium in the RFP/ Proposal Evaluation/Source Selection activities in achieving simplicity in cost, concept, and design. These activities should ensure an absolute minimum of sophistication by measuring each function against the minimum criteria of accomplishing the mission and providing the operational capability. (14:2-10). Data requirements listed on the Contract Data Requirements List should be those of value and tailored from those listed in the DoD Authorized Data List (TD-3) under Category H.

One of the final tasks facing the human factors specialists is preparation of the Source Selection Plan which provides the process to be used for assessing and evaluating proposals and awarding contracts for the Validation Phase. In addition, the plan outlines and relates the important performance characteristics to operational effectiveness. In determining the evaluation criteria, specific attention should be given to the elements discussed in Section I in preparing descriptions and standards for each element upon which to evaluate each offeror's proposal. The tasks the offeror must accomplish, the technical constraints imposed upon these tasks, and the relationship with other tasks and requirements should be identified. The criteria should be written with clear lines of demarcation to evaluate duplication and overlap in the evaluation process. Thus, the descriptions should be clearly written to provide an idea of the specific human factors facets that will be scrutinized with the standards indicating the quality and quantity of performance expected from each offeror in satisfying the human factors engineering elements.

In preparing the Test and Evaluation Master Plan, primary emphasis, in this phase, should be to assure that the roles of test agencies and contractors are clearly delineated as to the satisfaction of human factors test requirements. In addition, the criteria section of the Test and Evaluation Objectives Annex is a key document in outlining the critical questions to be answered in development and operational test and evaluation. In arriving at the criteria, specific attention must be given to the human interfaces in the demonstration and evaluation of operational suitability. Specific attention must also be given to the maintenance concept and tasks to be performed, not only to begin evaluating the impact on personnel and training requirements, but to provide a basis for determination of support equipment and technical order requirements necessary for logistic support planning.

HUMAN FACTORS ENGINEERING IN THE VALIDATION PHASE

At the end of the Conceptual Phase the Secretary of Defense reviews (for major programs) the program's Decision Coordinating Paper and Defense System Acquisition Review Council's recommendations and makes a decision to proceed to the next phase (Validation Phase) or to terminate the program effort. If program continuation is decided, Headquarters, Air Force Systems Command will reaffirm the priority of the program and furnish the program office with guidance and implementing directives. During the Validation Phase, the program characteristics (performance, cost, and schedule) are validated and refined through extensive study and analysis, hardware development, or prototype testing. (14:3-1).

In this phase, primary emphasis from the human factors standpoint will be on evaluation of validation phase results, preparation of the full-scale engineering development phase RFP requirements, and evaluation of proposals arising from the RFP.

If the prototyping concept is used in this phase, prototypes will be available for testing. This will allow sufficient information to be obtained on the proposed designs to support a detailed human factors analysis with the subsequent incorporation of changes at a time when the design is still flexible. In addition, since the allocated baseline (design requirement) specifications are being developed during this phase to serve as the basis for detailed development and design of the system by the contractors in the full-scale engineering development phase, human factors inputs should concentrate on the human performance requirements in relation to the mission, and operations and maintenance scenarios. Particular attention should be paid to known problem areas or comparison with other similar systems. Of primary importance is the tentative identification, allocation and sequencing of operator and maintainer tasks so that training concepts can be delineated and the need for training devices, job performance aids, and other special training requirements can be identified. In addition, human engineering investigation should be conducted to determine control/display requirements, crew/work station arrangements, job performance aids requirements, and workload and performance evaluations.

In preparing the design specifications and the RFP for the full-scale engineering development phase, human factors analysis should concentrate on tradeoff studies to optimize operational performance against engineering design and cost. Particular attention should be paid to integrating the other systems engineering disciplines and obtaining user inputs to assure that optimum decisions are made.

HUMAN FACTORS ENGINEERING IN THE FULL-SCALE ENGINEERING DEVELOPMENT PHASE

The specific events that occur within the full-scale engineering development phase vary, depending upon the program in question, but in general the system, including all support items, is designed, fabricated and tested during this phase. The human factors engineering specialists shall be concerned with system design integration, interface control, design reviews, design/optimization, effectiveness analysis and known potential problem areas.

Of primary importance to human factors engineering management is the test and evaluation conducted by the contractor and the Air Force to assess the adequacy of the pre-production system and resolve engineering problems within stated operational requirements and cost guidelines. Human factors test plans should be prepared as an integral part of development test plans and procedures to eliminate duplication of effort and reduce cost. The human factors test plan should describe how it fits into the overall test picture because unless it is an integral part of other test procedures, the tendency will be to eliminate the tests for expediency. The primary output from these tests should be an evaluation of operation and maintenance task sequences, determination of skill and training requirements and consequent organizational manning implications, and recommendations concerning equipment design deficiencies related to the man/machine/mission performance limitations and requirements.

During the Preliminary Design Reviews human factors requirements must be properly identified in the Part I Design Specification for the various configuration items with each requirement verified by a specific test or combination of tests to satisfy design/performance requirements. Specific attention should be given to the Critical Design Reviews, which serve to ensure that the recommended detail designs adequately satisfy the requirements contained in the Part I Detail Specifications and provide an effective interface between the configuration item and the personnel, facilities, other configuration items and procedural publications. All human factors requirements must be properly identified and described, otherwise the human factors requirements that are overlooked will have very little chance of being placed in the Part II configuration item specifications after the Critical Design Review, unless a major impact on the program would occur that would justify the time and cost associated with implementing the change.

As the development tests are completed, the Functional Configuration Audit is conducted with human factors personnel involved to verify that the configuration item has achieved the performance specified in its functional or allocated configuration baseline based upon formal review of the test data.

SECTION III

HUMAN FACTORS ENGINEERING APPLICATIONS TO ACQUISITION PROGRAMS

In the application of human factors engineering, there have been many positive and significant inputs made to many weapon systems. However, the degree to which human factors has been brought to bear in the development and testing of systems has generally been directly related to the support given by the program manager for the early involvement of experienced human factors personnel in the development phase. If a formally stated and budgeted human factors program is included as part of the development contract, the program manager is interested in the human factors analyses, and human factors engineering support is provided in a timely and effective manner. Then, the application of human factors can be a highly successful venture. Without the above ingredients, however, the human factors engineering efforts have suffered. Inattention to human factors is particularly serious when one considers, for example, that as a result of inadequate attention to the human/machine interface 70 percent of the aircraft incidents and accidents and 56 percent of the deficiencies reported to the program offices on new weapon systems by the Joint Test Force cadres at the Air Force Flight Test Center are human factors related. Recognition of this fact, the costs, and resultant mission degradation should provide ample evidence of the need for human factors engineering involvement in the acquisition effort.

However, as discussed in Section I, a mystique does surround the human factors engineering efforts and outputs and, as a result, many of the deficiencies reported above become subsumed as engine problems, flight control problems, or problems in other major system areas. Thus, human factors engineering often fails to gain the priority, attention or appreciation it should. In order to provide some perspective on the type of efforts human factors engineering has involved, a brief discussion will follow on some applications to aircraft systems.

One of the first areas one may think about in the application of human factors to aircraft systems is in the cockpit. For example, the F-15 cockpit with its large bubble canopy provides the opportunity for excellent visibility. However, if the pilot is restricted in his seat with short parachute risers and cannot rotate his shoulders in order to look behind him, he loses 180 degrees of his field of view. During human factors evaluation, it was found that by lengthening the shoulder straps another three inches the necessary mobility could be provided the pilot. In addition, it was found that when pilots attempted to track an overhead target, the size of the headrest caused pressure against the back of the helmet, to the extent that the headrest interfered with target tracking. It was found that the headrest size had been determined by U.S. Navy requirements to adequately support the pilot's head during catapult launches. Subsequent modification for Air Force use provided a way of minimizing the visual tracking problem. Other areas where human factors was concerned in the F-15 cockpit evaluation were the displays, the head-up display, readability and visibility of display information, adequacy of interior lighting, control placement layout, cockpit noise and vibration, seat geometry and so on. (23:34).

In the biomedical area, human factors is involved in the taking of various measurements concerning man's working environment. Parameters such as noise, toxicity, radiation, and temperature are measured to accurately describe the working environment and to identify hazards that affect man's ability to get the job done or which could cause permanent physical damage. For example, tests were conducted on the F-16 to determine the thermal radiant load caused by its large bubble canopy and the adequacy of the heating and cooling systems in relation to acceptable pilot temperature levels. (22:20). Unsatisfactory design of these systems could have resulted in lower "g" tolerance, decreased performance, and reduced system effectiveness. In addition, climatic tests are conducted to assess the capability of man to perform various functions and tasks as required in various climatic conditions such as extreme cold or heat. This allows a selection of tasks which would be better performed in shelters, etc., to reduce error and safety hazards, provide better time consumption, or ease of operation.

Human factors engineering was also involved in recommending the formation lights configuration for the F-15. This involved identifying what cues the pilot was using, which involved both looking at the formation lights that were available and talking with pilots that had flown night formation flights with the aircraft. (23:55). In addition, models of the aircraft were used to explore a variety of configurations using day glow material as a representation of the electro illuminescense strips. Movies and slides using black lighting were taken of these configurations and, through the use of pilot evaluations, the configuration that provided the least occurrence of error in identifying aircraft attitude was selected and flight tested.

Human factors engineering is also involved in maintenance evaluations. Here the tasks involve evaluating the human engineering of the maintenance equipment and tools, the individual functions which are being performed to determine if the task can be performed more efficiently or if there is a potential for personnel hazard, equipment damage or error. For example, if access to a hydraulic line is limited and visual access is poor, then there is a good chance that a problem will be encountered during servicing and that a leak is likely to occur. In the F-16 prototype human factors evaluation, unsatisfactory access was found to the normal and lateral accelerometers. Removal and replacement of the accelerometers only took 15 minutes, but the removal and replacement of two pieces of equipment before the maintenance man could get to the accelerometers required 16 hours, plus an additional 6 hours for their servicing and checkout, upon reinstallation. (22:69).

Another area where human factors is involved is in addressing the adequacy of job performance aids such as checklists, flight manuals, technical orders and so on to determine if the job can be completed using the tools and tech orders available without possibility of error or hazard. All areas such as training, technical orders, tools, and support equipment are addressed during these assessments to ascertain the positive and negative aspects of each. For example, in the F-15 development tests, maintenance evaluations were conducted at Edwards AFB and human factors personnel were involved in looking at the tear down and assembly of the engine. This test demonstration, which was accomplished approximately 2 years before these tasks would have been performed by the Air Force in the field, allowed consideration of the corrective action needed to address and evaluate the training that Air Force people had received, the adequacy of the tech orders, and the tools provided by the contractor for use in assembly and tear down.

A final area of major human factors involvement is in the provision of personnel planning information. Here, the total concept of how the aircraft and its equipment are expected to be operated and maintained is addressed, as well as the impact on the utilization of personnel. To do this, the tasks which are performed repeatedly on the flight lines, as well as other total tasks involved, such as aircraft turnaround, pre-flight and post-flight activities, are examined to determine the skill levels of the personnel required, the use of support equipment and the allocation of personnel in performing these tasks. This task information then provides the basis for the determination of manning and training requirements in providing operationally ready hardware.

Other programs have also benefited from human factors engineering involvement such as: the EF-111 cockpit design and evaluation, various RPV programs, Simulation SPO programs, High Acceleration Cockpit designs, the MX missile system design, and the A-10A in evaluation of the head-up display, cockpit noise, ejection seat, and cockpit layout.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

In summary, human factors engineering does not tend to be a clear-cut discipline due to its many facets and wide ranging interface with many other functional specialties. This complicates its understanding and thus it is generally more appropriate to view it as a concept that considers the optimization of the man-machine interface.

The secret of success in its application to acquisition programs appears to be directly related to the management emphasis and priority given it, the availability and technical competency of the human factors engineering specialists, and the acceptance of human factors engineering as something other than just another "ility." The trend appears to be an increasing concern for the man-machine interface with human factors being regarded as an approach to cost, complexity, and modification savings. However, there is need for continued improvement of the human factors engineering involvement. Program managers must continue to plan for, budget for, and use the benefits of human factors efforts, while the human factors specialists must continue to educate others on the benefits of the human factors approach, obtain the required design and testing data, suggest realistic, cost-effective design alternatives, and work in concert with other engineering disciplines towards acquiring useable systems.

Although Air Force and Air Force Systems Command policy guidance does provide a strong emphasis on the implementation of human factors engineering to acquisition programs, there are several areas that appear to be limiting that implementation. First there is no human factors qualified focal point at either Headquarters USAF or Headquarters AFSC. In fact, at HQ AFSC the human factors engineering effort is fragmented and dispersed across the systems applications effort, the biomedical effort, and the laboratory effort. This tends to limit the impetus that can be given to human factors in program directives. As an intermediate step toward correcting this organizational weakness, AFSC has formed a Human Factors Engineering Steering Group of both Headquarters and field personnel to provide a channel for problem discussion and policy guidance. However, to provide the appropriate priority and emphasis and not "lip service," the management of the human factors engineering effort could be strengthened by having qualified human factors personnel as the focal points at both HQ USAF and at HQ AFSC as delineated in AFR 800-15.

The second area of concern is the continued decline in a viable cadre of human factors personnel at the Product Divisions. This worsening situation does definitely limit the role that human factors can play in the acquisition cycle. At the present, only three of the four Product Divisions have experienced human factors personnel assigned to their engineering staffs. There is generally a small number of people, namely two to three, with the exception of the Aeronautical Systems Division at Wright-Patterson AFB, Ohio with its larger central core of civilian human factors personnel and its proximity to several of the laboratories that have human factors expertise. Action, in terms of improved training and strengthening the career field to make it more attractive and rewarding, will be necessary if a viable cadre of personnel is to be retained and built upon to furnish the ever increasingly important human factors engineering integration interface.

REFERENCES

1. Dept of Defense, DOD Instruction 5000.1, "Major Systems Acquisition," 18 January 1977.

2. Dept of Air Force, AF Regulation 800-15, "Human Factors Engineering and Management," 1 October 1974, with CH-1, 15 September 1976

3. Dept of Air Force, HQ AFSC, AFSC Sup 1, AFR 800-15, "Human Factors Engineering and Management," 4 June 1976.

4. Dept of Air Force, AF Regulation 800-2, "Program Management," 16 March 1972.

5. Dept of Air Force, AF Regulation 800-3, "Engineering for Defense Systems," 1 June 1976.

6. Dept of Defense, Military Standard 721C, "Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety," draft 1 October 1976.

7. Dept of Air Force, "Military Specification, MIL-H-XXX, Human Factors Test and Evaluation Plan," draft 5 July 1976.

8. Dept of Air Force, Military Standard 499A (USAF), "Engineering Management," 1 May 1974.

9. Dept of Defense, "Military Specification, MIL-H-46855A, Human Engineering Requirements for Military Systems, Equipment and Facilities," 2 May 1972.

10. __________, "Military Standard 1472B, Human Engineering Design Criteria for Military Systems, Equipment and Facilities," 31 December 1974, with Notice 1, 10 May 1976.

11. Taylor, Henry L., "The Role of Human Factors R&D in Weapons System Development," Commanders Digest, Vol 18, No. 22, 27 November 1975.

12. Fujii, Donald S., "Human Factors Engineering - A Potential Personnel Management Tool," Air University Review, Vol 22, No. 4, May-Jun 1971.

13. Dept of Air Force, AF Regulation 80-14, "Test and Evaluation," 19 July 1976.

14. Dept of Air Force, AFSC Pamphlet 800-3, "A Guide for Program Management," 9 April 1976.

15. Dept of Army, Army Regulation 602-1, "Human Factors Engineering Program," 15 July 1976.

16. Merriman, Stephen C., "Human Factors Programs in Navy Systems Acquisition," DSMC Study Project Report PMC 76-2, November 1976.

17. Dept of Air Force, Aeronautical Systems Division Pamphlet ASDP 375-5, "Development of a Personnel Subsystem for System/Equipment Programs," 25 August 1969.

18. Dept of Air Force, Headquarters, Space and Missile Systems Organization (AFSC) Manual 375-1, "Personnel Subsystem Management of Air Force Space and Missile Systems," 5 June 1969.

19. Jordan, Nehemiah, "Human Factors Aspects in Maintainability," RAND Corp. Report, October 1961.

20. Dept of Navy, Pacific Missile Test Center Report No. TP-75-15, "Human Factors Engineering Policy and Procedures for Test and Evaluation of Navy Systems," 15 July 1975.

21. Dept of Navy, Pacific Missile Test Center Report No. TP-75-58, "Translation of DSARC Milestones into Human Factors Engineering Requirements," 30 September 1975.

22. Dept of Air Force, Air Force Flight Test Center Report No. TR-75-5, "Human Factors Evaluation of the XF-16 Prototype Aircraft," May 1975.

23. Dept of Air Force, Air Force Flight Test Center Report No. TR-75-47, "Air Force Development Test and Evaluation of F/TR-15A Cockpit Human Factors," December 1975.

24. Dept of Air Force, Headquarters Air Force Systems Command, SDD Ltr, "Human Factors Career Field Management," and responses thereto, 9 February 1977.

25. Marsh, Robert T. Lt. Gen., "Avionics Equipment Reliability: An Elusive Objective," Defense Management Journal, Vol. 12, No. 2, April 1976.

26. Conrad, Ronald G., "Human Factors Engineering and Management," Presentation to Air Force Armament Development and Test Center System Program Management Workshop, July 1976.

27. Chasko, G. J., Schmidt, W. J., and Arcieri, J. D., "Reliability, Availability and Maintainability," Systems Engineering Logistics Management Course Handout, Defense Systems Management College, March 1977.