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THE ROLE OF HUMAN FACTORS R&D IN WEAPONS SYSTEM DEVELOPMENT

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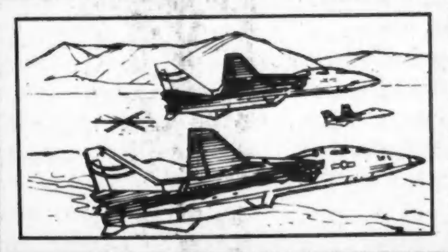

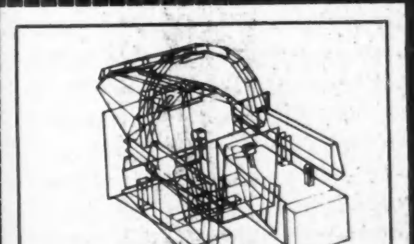

Why Human Factors R&D+ System Development= Improved National Defense

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The ultimate effectiveness of all Department of Defense weapon systems depends on the interaction of man, machines and missions. There are the approximately 2,100,000 uniformed military personnel who support, operate and maintain DoD weapons. These men and women are the first element of a Defense system. Machines are the weapon systems, and missions are the way the weapons are deployed or used. As the complexity of weapon systems has increased, the demands on operations and maintenance personnel, as well as on commanders of troops in the field, have increased. Human factors are the personnel-related part of the operation and maintenance of weapon systems. Proper attention to human factors considerations during the weapon system development process can have substantial impact on the operational effectiveness of the system.

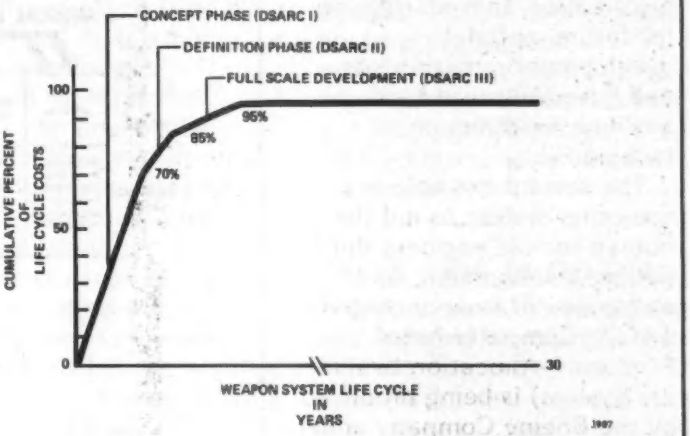
The life cycle of a major weapon system usually spans more than 30 years. This cycle begins with research and extends through the deployment and operation of the system. Crucial decisions are made during the 10-year period when the system is being acquired. A high level Defense committee, the Defense Systems Acquisition Review Council (DSARC), reviews major decisions made during this period. Major reviews are conducted and decisions are made at three points during the DSARC process, called DSARC milestones.

LIFE CYCLE COST

Figure 1 makes it clear that decisions made during the early phases of weapon system acquisition account for approximately 85 per cent of the system life cycle cost. About 70 per cent of the costs are determined during the conceptual phase, prior to the DSARC One milestone. Another 15 per cent of the life cycle costs occurs during the definition phase. Only 10 per cent of the life cycle costs are determined by decisions in the development, and 5 per cent during the production and operations phase. The decisions made during the concept and definition phases determine major components of the final system requirements and design. These decisions also, in a large part, determine personnel manning and skill levels and training requirements for the entire life of the system. Since personnel costs presently account for over 50 per cent of the DoD annual expenditures, human factors data demonstrating the impact of these early decisions on life cycle costs are needed. In the past, decisions have been made with minimum man-machine-mission interface information concerning system requirements and performance.

In addition to life cycle cost impacts, accidents

LTC Taylor



DECISION INFLUENCE ON LIFE CYCLE COSTS

Figure 1

associated with deficient crew station warning and display systems have resulted in a substantial number of weapon systems being destroyed, and many personnel being killed or injured. For example, an analysis of Naval Safety Center data for the period, mid-1969 through early 1974, indicates that 228 aircraft were destroyed and not available for operations. The analysis also indicates 249 human fatalities and 52 injuries. The economic impact of the aircraft loss is approximately $485 million and the personnel replacement costs about $90 million—a total cost of $575 million. These statistics dramatically emphasize the need for more effective use of human factors techniques and principles in weapon system design.

An outstanding example of early human factors involvement in the weapons system development process is the Tracked Optically, Wire-Guided (TOW) anti-tank weapon. The TOW is a highly accurate weapon with demonstrated combat effectiveness. Human factors engineering studies of the tracking precision needed to achieve the required kill probabilities resulted in the concept and design of a viscous-damped tracking mount for the TOW. This mount resulted in accurate tracking at less cost and lighter weight than other more complex rate-aided systems. The viscous-damped mount also required less complex maintenance and reduced training requirements.

HUMAN FACTORS R&D

Human factors research and development (R&D) bridges and helps integrate for system development two major areas of technology: the medical and life sciences area and the human resources area, as shown in Figure 2. R&D in each of these areas is concerned with the performance capabilities of man, the man-machine interface and system considerations (man-machine-mission interface).

Three examples of R&D programs from the human resources area will be discussed to illustrate how human factors R&D is useful in weapon system development and operations.

The first example describes a series of experiments dealing with problems in field artillery which were conducted by the Army

Materiel Command's Human Engineering Laboratory. The HELBAT (Human Engineering Laboratory Battalion Artillery Tests) studies have provided justification and information for future materiel development requirements and have improved field artillery fire direction techniques.

The second example is a computer system to aid the human factors engineer during design, development, and operations of weapon systems. CAFES (Computer Aided Function—Allocation Evaluation System) is being produced by the Boeing Company under contract to the Naval Air Systems Command and the Naval Air Development Center. CAFES models can be used to assist the human factors engineer in design or development activities during:

- New systems development.
- Modification of present systems.
- Resolution of operational problems.

The third example is a maintenance manpower simulation model developed by the Air Force System Command's Human Resources Laboratory. The simulation model is a more responsive method for estimating maintenance manpower requirements during the various stages in weapon system development. The model provides a means for estimating the impact on manpower requirements

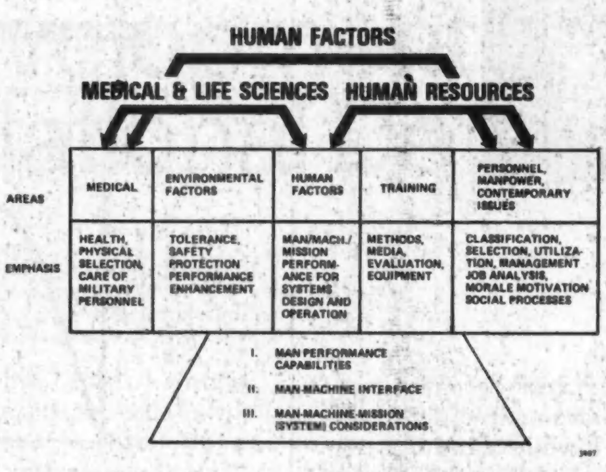


Figure 2

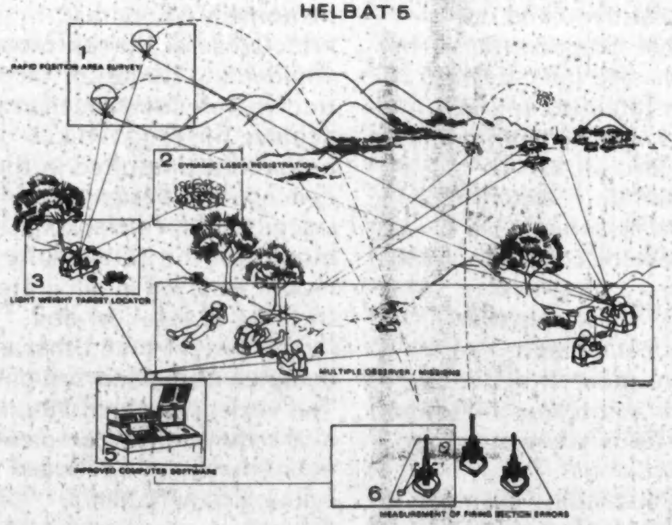


Figure 3

during design tradeoff analyses.

HELBAT EXPERIMENTS

A series of Army HELBAT experiments began in 1969 to determine and measure the source of error in field artillery systems during predicted fire missions. HELBAT I was concerned with measuring the error contributed by various system components and with total system error. Response time and accuracy of conventional fire against stationary targets were analyzed. The test results indicated that 53 per cent of the total system error was due to the forward observer's lack of ability to accurately locate himself and to locate the target on the ground in relation to his position.

As a result of these tests, new equipment and techniques were developed to reduce forward observer errors. In 1971, the laser rangefinder was used by the forward observer in the HELBAT II test. Using the rangefinder and new techniques, mean radial error of artillery rounds was reduced from 490 meters using conventional procedures and equipment to 21 meters. In addition, time and ammunition required to get adjusting rounds on target were reduced.

The ability of field artillery to engage moving targets was the subject of HELBAT III. New procedures were investigated, in which control of the mission was assigned to the fire direction center rather than the forward observer. The new procedure reduced target miss distance from 700 meters to 450 meters but time-lag from target acquisition to impact of rounds in the target area remained excessive—approximately 14 minutes. HELBAT IV, which was conducted during the latter part of 1974, tested the concept of using automatic data processing equipment in a fire control system that linked the forward observer to the howitzer firing section. Significant improvements were found in response time and firing accuracy.

HELBAT V, whose purpose was to investigate three levels of automation on the effectiveness of engaging moving targets, was conducted during the fourth quarter of fiscal 1975. Figure 3 illustrates this comprehensive field experiment of artillery automation concepts and procedures against both stationary and moving targets. While the data from HELBAT V are not completely analyzed, a number of direct hits were achieved against targets moving at 10 m.p.h. from distances of four to five kilometers.

The HELBAT efforts have systematically investigated various problems involved in the deployment of field artillery. The HELBAT series provides a system test bed for development of doctrine and procedures for present systems, and also provides the interface between field artillery studies and future development of materiel and doctrine. These field experiments are now a joint exercise between the Training and Doctrine Command (TRADOC) and Army Materiel Command.

CAFES AIDS ENGINEERS

CAFES, whose development was initiated by the Navy in FY 1971, is a system of interrelated data processing aids which provides assistance to the human factors engineer. The human factors engineer-computer interaction concept, which is the basis of the CAFES, is illustrated in Figure 4. Mission and system requirements drive the early phases of the system development process. During these early phases, human factors engineering information to be used in the decision trade-offs often involves routine data retrieval and manipulation.

Questions such as "What crew size is required?", "Can the crew handle the workload?", "How much automation is needed?", What kind of crew station will be used?", "What kind of controls and displays will be required?" need to be resolved.

Computer technology can be used to aid the human factors engineer and to enhance and expedite his analysis during decision tradeoffs. The engineer serves as the source of instruction to the computer, as a data reviewer and as the decision maker.

CAFES is composed of a set of submodels. The interface between the human factors engineer and the computer submodels is a Data Management System (DMS). DMS serves an executive function which allows independent access to each of the submodels and as a central data system which provides access to individual data items. The DMS also serves to integrate the information provided by the individual submodels during the system development process.

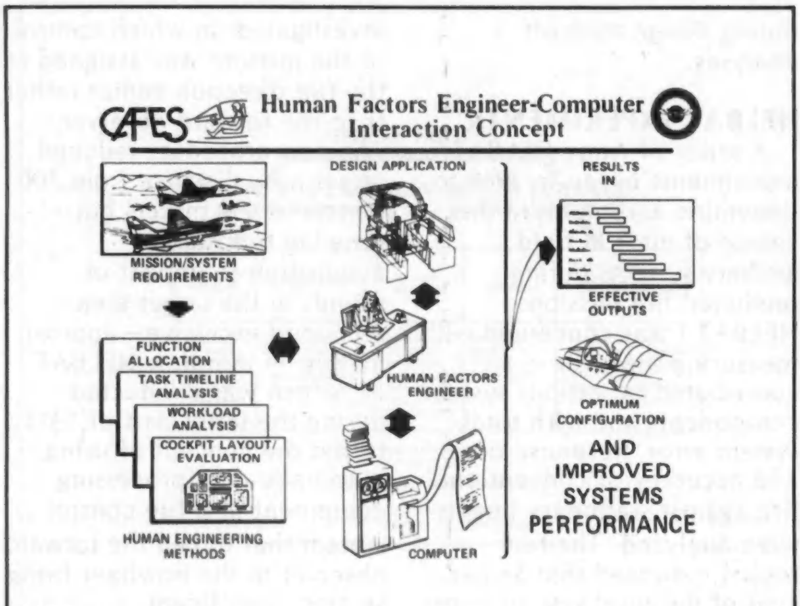


Figure 4

The first CAFES submodel developed was the Functional Allocation Model (FAM) which enables the engineer to develop and evaluate man/equipment trade-offs. Representative items evaluated by the FAM submodel are crew size, automation level, and optimum task allocation. The Workload Assessment Model (WAM) permits evaluation of the workload which results from the optimum function allocation alternatives generated by the FAM. The Computer Aided Design (CAD) model allows consideration of alternative crew station designs. The CAD interacts with outputs of the FAM, WAM and Crewstation Geometry Evaluation (CGE) models. Anthropometric data, lists of mission tasks and three-dimensional coordinates of the crew station configuration are inputs to the CGE submodel. The CGE evaluates if the crewstation design meets relevant military specifications and standards. The CGE submodel also checks physical or visual interferences and verifies the detailed configurations.

The Human Operator Simulation (HOS) replaces traditional man-in-the-loop simulation. The HOS provides estimates of human performance while considering behavioral factors, operating environments and operator characteristics. Use of the HOS submodel provides this evaluation at a significantly reduced cost and a significant time savings over traditional man-in-the-loop simulation.

Preliminary FAM, WAM, CAD and CGE submodels have been completed. The updated CGE and HOS models are currently being developed in the CAFES program. The integration of all models is also proceeding.

CAFES provides a comprehensive and timely human factors engineering effort in weapon system development, acquisition and operations. This is achieved by providing data for human factors trade-offs early in the weapon system development process. Improved man-system interfaces and improved crew performance during system operations will result from the application of CAFES.

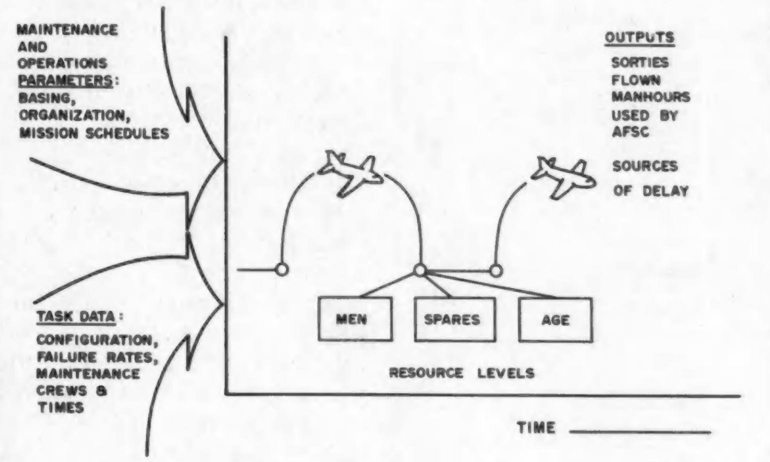


Figure 5

SIMULATION MODEL

The Air Force efforts to investigate the feasibility of using a simulation model to estimate maintenance manpower requirements during the early phases of weapon system development began during 1971. A Monte-Carlo simulation computer program called the Logistics Composite Model (LCOM) was selected. The LCOM processes data provided by the user according to established rules. The model is flexible enough and has enough capability to accommodate various weapon systems in differing environments.

Accurate data on various maintenance parameters, such as failure rates, maintenance tasks, numbers of maintenance crews and repair times are still basic to the prediction of maintenance manpower requirements. Collection of this data and the accuracy of the data sets limits on how early in the weapon development process manpower requirements can be predicted and on the accuracy of the predictions.

The AX Close Air Support Weapon System was selected as the test bed for the model simulation. At that time, the AX tactical aircraft was in the prototype development stage. The approach was to develop a simulation model of the maintenance and operation of an AX wing. Figure 5 illustrates the operation of the model.

The initial requirement is to define the desired operational performance requirements of the weapon system. Next, the following data served as input information to the model:

- Maintenance and operations parameters.
- Task data such as failure rates, maintenance crews, and repair items.
- The resource levels set in terms of maintenance personnel by AFSC, amount of aerospace ground equipment (AGE) and spare parts.

The simulation model process is shown in Figure 6. Based on the mission schedule and the available mission aircraft, sorties are flown and failure clocks are decremented (failure rates are the mean number of sorties between maintenance actions). When the sortie is completed, failure clocks are checked and maintenance tasks performed and resources (spares, manpower, AGE) are expended, if required. The interaction and resources and operations capability are outputs of the model.

The model must be run iteratively to determine manpower requirements for maintenance work centers. Detailed information about the level of operations achieved during a simulation run and the resources required to achieve that level is an important output necessary for successive iterations. The second output is the number of personnel required in a work center to meet the demand for maintenance. Minimum manning requirements for the operations level is determined and then missson flying

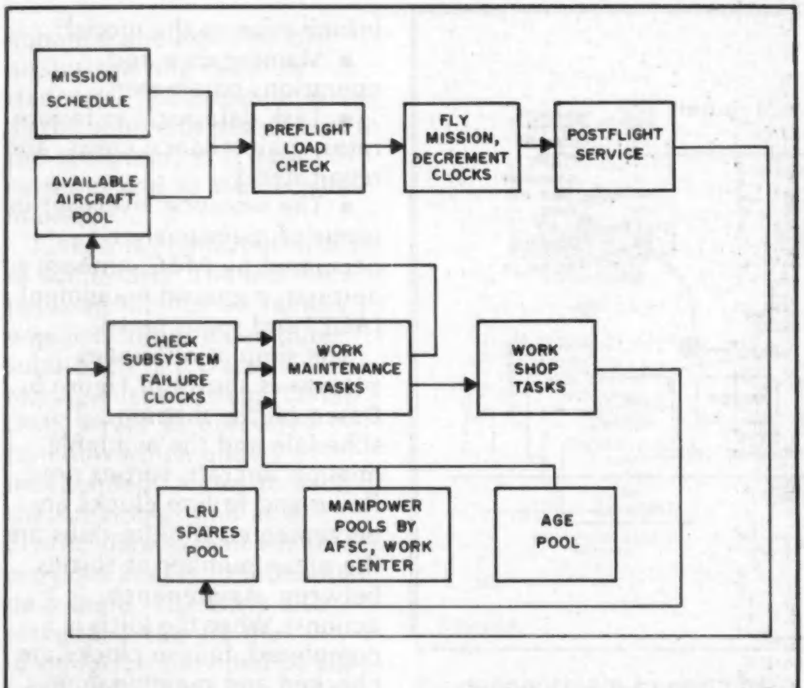


Figure 6

requirements are changed (increased or decreased) and a new set of manning requirements is established.

The specific objective to develop, test and employ a simulation model to effectively predict manpower requirements for new weapon systems was realized within the A-10 program, the aircraft system which was the winner of the AX prototype competition. The model was subsequently used to provide input to the competitive A-10/A7D fly-off. The LCOM model was transitioned to the A-10 System Program Office (SPO) and was subsequently used during trade-off decisions. Current plans envision use of the model by the Tactical Air Command to determine operational manpower requirements for the A-10. In addition, the F-16 SPO is currently using the demonstrated model technology during the F-16 development cycle.

The maintenance manpower prediction model was found to provide timely and useful maintenance data. The model provides the capability of determining the impact of system design, and support and operations alternatives upon maintenance manpower requirements. Work is currently underway by the Air Force to incorporate this methodology into a system for total logistic tradeoffs and life cycle costing.

EFFECTIVE INTEGRATION

The three human factors R&D examples discussed—HELBAT, CAFES and maintenance manpower simulation—have indicated that human factors considerations can be effectively integrated at all stages of weapon systems development. Further extensions of these and related technologies can assure that weapon systems developed, procured and operated by the military Services are designed compatible with human resources available for operations and maintenance functions. Broad scale implementation of these and other human factors R&D findings promises to have a substantial impact on the life cycle cost of weapon system ownership.

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