Research Product 89-11

Human Factors Design Criteria for Future Systems. Report No. 4: FAADS Design Criteria Evolving From the Sgt. York Follow-On Evaluation I

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Fort Hood Field Unit
Systems Research Laboratory

U.S. Army Research Institute for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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Fifty-one human factors design problems reported from the Sgt. York Follow-On Evaluation (FOE) I are examined with respect to the driver's station (20 problems) and the crew compartment housing the squad leader and gunner (31 problems). Each design problem is compared with human factors criteria from MIL-STD-1472C and MIL-HDBK-759A to determine the adequacy of currently available design criteria. Where existing design criteria were inadequate or nonexistent, proposed changes and additions are presented. The purpose of this work is to provide human factors design criteria for future Forward Area Air Defense System (FAADS) with respect to improved soldier-machine interfaces.

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Human Factors in Training and Operations

FOREWORD

In the process of participating in operational tests and evaluations, personnel from the U.S. Army Research Institute (ARI) for the Behavioral and Social Sciences isolate and identify human factors (MANPRINT) deficiencies in new, emerging Army systems. From this work come both positive recommendations for correcting the specific system problems and design criteria for improving future systems. This report, based on the Sgt. York Follow-On Evaluation (FOE) I, presents human factors design criteria for use in the design of future Forward Area Air Defense Systems (FAADS). This is the fourth in a series of reports that provide human factors design criteria for future weapons systems. Earlier reports present design criteria evolving from human factor evaluations of the M1 tank, the Fire Support Team Vehicle (FIST-V), and the Multiple Launch Rocket System (MLRS).

Results of these design criteria investigations were communicated to the Human Engineering Laboratory facility at Huntsville, Alabama, for integration into the Army's Human Engineering Design Handbook, MIL-HDBK-759A, and the DOD Standard, MIL-STD-1472C. Copies of the design criteria reports were also provided to Training and Doctrine Command system managers and Army Materiel Command program managers. Because it is concerned with forward area air defense, this report was also provided to the Air Defense School. This research was performed as a work unit subsumed under ARI Research Task 1.1.4, Air Defense Crew and Operator Performance.

This work was conducted in conjunction with the following agreements: (1) Letter of Agreement between U.S. Army Research Institute for the Behavioral and Social Sciences and U.S. Army Operational Test and Evaluation Agency, 15 June 1983; (2) Letter of Agreement between U.S. Army Research Institute for the Behavioral and Social Sciences and the U.S. Army Air Defense School, 20 November 1986.

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HUMAN FACTORS DESIGN CRITERIA FOR FUTURE SYSTEMS. REPORT NO. 4: FAADS DESIGN CRITERIA EVOLVING FROM THE SGT. YORK FOLLOW-ON EVALUATION I

EXECUTIVE SUMMARY

Requirement:

The objective of this analysis is to specify current design criteria related to human factors (HF) that are associated with Sgt. York deficiencies and to stipulate modified or new design criteria, where needed, to prevent a recurrence of these deficiencies in future Forward Area Air Defense Systems (FAADS).

Procedure:

During the Sgt. York Follow-On Evaluation (FOE) I, 51 human factors problems in safety and training were recorded. The procedure then involved comparing each of the 51 individual problems with pertinent design criteria statements in MIL-STD-1472C and MIL-HDBK-759A. These criteria were examined to determine if they provided adequate guidance for making informed design judgments. Where the criteria were judged to be inadequate or missing, revised or new criteria are proposed.

Findings:

The results were divided into two parts: (1) the driver's station and (2) the crew compartment housing the squad leader and the gunner. FOE I data clearly showed that the design of the driver's station was inadequate in such critical variables as workspace, seating, control design, environment, and visibility. Of the 20 problems identified, 15 could have been avoided if current design criteria had been complied with. Recommended design criteria that would reduce the probability of recurrence of the five remaining problems are provided.

In the crew station, 31 design problems were identified in such categories as inadequate workspace, poor seating, inadequate visibility, display and control deficiencies, and workload. Most important were mission performance deficiencies in the execution of the target engagement sequence, the principal purpose for which the system existed. Of the 31 problems, 18 were adequately covered by current design criteria; recommendations are given for handling the remaining 13.

Utilization of Findings:

The recommendations of this report are intended for use in improving and updating human factors design criteria for future self-propelled air defense systems. A major purpose is to prevent recurrence of the same and similar problems in future Forward Area Air Defense Systems.

HUMAN FACTORS DESIGN CRITERIA FOR FUTURE SYSTEMS. REPORT NO. 4: FAADS DESIGN CRITERIA EVOLVING FROM THE SGT. YORK FOLLOW-ON EVALUATION I

CONTENTS

LIST OF TABLES

HUMAN FACTORS DESIGN CRITERIA FOR FUTURE SYSTEMS. REPORT NO. 4:
FAADS DESIGN CRITERIA EVOLVING FROM THE SGT YORK FOLLOW-ON EVALUATION I

INTRODUCTION

HF Design Criteria for New Systems

The Fort Hood Field Unit of the Army Research Institute (ARI) has had an active program of human factors research concerned with improving the soldier-equipment interface for almost two decades. Based upon the assessment of soldier performance in a variety of systems employed in an operational test and evaluation environment, a series of design criteria reports have been produced as a result of evaluating three major Army weapon systems:

- The M1 Tank (Earl, 1984)
- The Multiple Launch Rocket System (MLRS) (Earl & Crumley, 1985)
- The Fire Support Team Vehicle (FIST-V) (Crumley & Earl, 1985)

The purpose of these reports was to provide the results of evaluations of existing design criteria, to propose modifications of existing design criteria where necessary, and to develop new design criteria where needed, with the expectation that more complete design criteria could be available for future systems in the class.

This report is the fourth in that series, and it deals with design criteria evolving from the Sgt York Follow-On Evaluation (FOE) I. It is intended for use in the design of future Forward Area Air Defense Systems (FAADS).

Purpose and Objective of this Report

Design criteria have been established as an aid and a guide to those individuals creating systems. There are two major documents that provide human factors design criteria for the soldier-machine-system interface:

- Military Standard: Human Engineering Design Criteria for Military Systems, Equipment and Facilities. Department of Defense, MIL-STD-1472C, 2 May 1981.

- Military Handbook: Human Factors Engineering Design for Army Materiel (METRIC). Department of the Army, MIL-HDBK-759A, 30 June 1981.

Considering the age of these documents and the rate of change of technology, several questions occur. One, to what extent are the present design criteria adequate? Two, to what extent are the present design criteria used? One way of answering both questions is to examine the human factors design problems identified during operational tests of actual equipment and systems.

Such problems can then be associated with: 1) an existing design criterion that was used, was overlooked or ignored; 2) with an existing design criterion that was not adequate and needs to be modified; 3) the absence of any pertinent design criteria. The case of missing criteria will reveal a need for additional criteria to cover problems not anticipated by current standards, handbooks, and specifications.

The recommendations of this report are based upon an examination of human factors design problems that emerged from a screening of data from the Sgt York FOE I. The report's objective is to provide design criteria for future FAADS. Fifty-one design problems have been identified in terms of their potential adverse impact on mission performance, safety, and crew performance. The problems result from poor human factors design. A separation has been made between the problems involving the driver's station and those involving the crew compartment housing the squad leader and the gunner. For each problem, the presence or adequacy of current design criteria is noted. Proposed changes or problem solutions are suggested as appropriate.

For more extensive analyses of the Sgt York FOE I data, three other documents are recommended: (1) Sgt York FOE I Human Factors Data (Babbitt, 1987); (2) Sgt York FOE I: Lessons Relearned (Seven, 1987); and (3) Sgt York Human Performance Data (Babbitt, Seven, & Muckler, 1987).

METHOD

Sgt York Follow-On Evaluation I

The DIVAD gun system (M247 Sgt York) was originally intended to provide all-weather, close-range air defense for forward area mobile tactical units against hostile fixed-wing aircraft, helicopters, and lightly armored vehicles. Sgt York was a self-propelled tracked vehicle with a crew of three (driver, squad leader, and gunner) and principal armament of dual 40 mm guns. Development of the system was initiated in 1976, with the eventual Follow-On Evaluation (FOE) I of the system in 1985, and cancellation of the system in 1985 (Seven, 1987, p. 6).

As is customary with weapon system development, a series of tests were conducted on the emerging system (Babbitt, 1988, p. 3). Prior to FOE I, the following tests were conducted:

- 1981: Division Air Defense Gun Developmental/Operational Combined Test;
- 1982: Developmental Test IIA;
- 1983: Developmental Test IIB;
- 1984: Sgt York Limited Test;
- 1985: AMSAA Independent Evaluation of the Sgt York Air Defense Gun Initial Production Test.

These tests revealed a number of human factors and safety deficiencies, and set the stage for the human factors and safety tests conducted as part of the FOE I, carried out during April, May, and June 1985 at Fort Hunter-Liggett, CA, and the White Sands Missile Range, NM (Babbitt, 1987, p. 5).

For the Force-On-Force phase of FOE I, a Sgt York platoon (four Sgt York fire units, each with a 3-man crew) and five Stinger companies were employed in support of an armor heavy battalion task force comprised of two tank companies and one mechanized infantry company. There were 52 validated record trials composed of 29 Sgt York trials, 12 Vulcan baseline trials, and 11 trials with Chaparral/Vulcan combined (alternate systems). Stinger was present on all trials, as were two Chaparral fire units deployed to the rear of the battalion task force. The battalion task force conducted a series of attack, delay, and tactical road march scenarios lasting about 20 minutes per trial against enemy ground vehicles and fixed- and rotary-wing aircraft. Trials were conducted under various electronic warfare conditions, under day and night conditions, and with and without nuclear, biological, and chemical (NBC) gear.

The Live Fire phase was conducted in the Red Rio area of White Sands Missile Range, NM, between 22 May and 15 June 1985. Five Sgt York fire units were used during this phase, with two Sgt York systems designated to fire during each aerial target scenario. Prior to each trial, the fire units completed a 52-mile road march with a full load of ammunition over unimproved dirt roads with the system fully operational in all modes. The basic scenario provided for two F-100 aircraft configured as drones and one UH-1 helicopter (drone) for each trial. Six of the F-100 drones and three helicopter drones were destroyed by Sgt York aerial fire in four trials. Sixty-one ground target engagements were conducted against stationary and moving M-114 and wheeled vehicle targets.

During FOE I, human factors, safety, and training data were collected by a team of specialists using five sources of information (Babbitt, 1988, pp. 11-14):

- Data from the 1553 data bus, recording many aspects of system and subsystem performance including in some cases crew performance, or at least selected aspects of crew performance
- Video and audio tapes of crew activities and communications
- Questionnaire responses from all player personnel after the test
- Structured interviews and observations from player personnel after each trial
- A review of data collected by the Reliability, Availability, and Maintainability (RAM) data collectors and a review of test conductor event logs

From these data sources, a large number of human factors and safety deficiencies were observed and recorded under 12 headings:

- Physical environment and workspace
- Workspace, anthropometrics, comfort
- Controls and displays
- Workload, division of labor
- Visibility
- Audio and visual alarms
- Target detection, acquisition, tracking
- Communications
- Travel and navigation
- Publication and documentation
- Safety
- Training

These data and reports are the basis for the human factors design problems discussed in this report.

HF Problem Selection Criteria

From all the data available from the Sgt York FOE I, fifty-one (51) specific human factors design problems were selected, twenty (20) for the driver's station and thirty-one (31) for the crew station housing the squad leader and the gunner. The following criteria were used in selecting these 51 problems:

- o The design problem was a clear violation of established human factors engineering design criteria: Department of the Army, 1981, MIL-HDBK-759A; Department of Defense, 1981, MIL-STD-1472C.

- o Safety evaluations from FOE I showed the possibility that the design problem could create a safety problem operationally, ranging from minor injury or minor system damage to catastrophic death or system loss. Part of this criterion concerned the probability estimates that a safety hazard might occur.

- o Seriousness of impact on mission performance was also a criterion for selecting the design deficiencies. The options were that the problem could prevent optimal mission performance, seriously degrade mission performance, or prevent mission performance.

- o In some cases, and particularly with respect to the target engagement sequence task, objective crew performance measurement was available and design problems were revealed through less than acceptable response times.

To be included, each design problem had to meet at least one of the four selection criteria. Several problems satisfied more than one.

Design Criteria Sources

As stated above, the first task of this report was to evaluate the human factors design problems against existing human factors design criteria, MIL-HDBK-759A and MIL-STD-1472C. These are the most widely used documents providing human factors design criteria for the development of military systems through the Department of Defense. The Sgt York contract specifications cited the prior versions that were in effect in 1976 (MIL-HDBK-759 and MIL-STD-1472B) as guidelines. They contained very similar criteria (Seven, 1987).

Our first step was to decide if any existing criteria in these two documents would have been applicable to the Sgt York design problem. If the applicable criteria were inadequate or incomplete, the second step was to suggest modified or new design criteria, or in some cases to make specific suggestions for solving the problem were it to occur in future FAADS design. Again, the purpose here is not to revisit the human factors issues in Sgt York but rather to enable avoidance of similar problems in future systems.

RESULTS

The Driver's Station

Table 1 shows the 20 major human factors design problems associated with the driver's station and current human factors design criteria that are applicable to each design problem. Where design criteria are inadequate or missing, proposed additions or changes to current criteria are presented. In some cases, design criteria are not needed; the problem can be solved presumably by procedures or equipment changes.

The driver's station will not accommodate 40% of the anticipated Army drivers. The driver requires an adequate seat, cushioning, seat belt, shoulder harness, and much better external visibility. There is no engineering reason why they cannot be provided.

Consequences of poor design were poor driving during the operational test trials, considerable slowing of the vehicle, and collisions with objects. Thus, battlefield mobility was seriously limited. Another consequence was that the squad leader spent much time "heads out" helping the driver travel and navigate. This is not what the squad leader is supposed to be doing.

The Sgt York driver's station was a part of the M48 chassis adopted for the York. The M48 chassis had a flawed design for the driver. It is customary for standard chassis to be adopted for air defense turrets apparently in the name of standardization and cost savings. Many of the presently proposed systems such as ADATS, Liberty, Shahine, and Paladin offer alternative standard chassis such as the M1A1 or the Bradley (Babbitt, Seven, & Muckler, 1987, page 11). It should be remembered that the M1 driver's station showed many of the same human factors deficiencies found in the M48 and the Sgt York, particularly with respect to inadequate workspace (Earl, 1984). It does not seem too wise to continue to perpetuate a poor soldier-machine interface when (1) it is not necessary and (2) there are more than sufficient data to show that the design has a negative impact on mission performance.

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
1. WORKSPACE. Workspace was inadequate for a large proportion of drivers, critically so with the hatch closed. Physical measurements of the w ·kspace area indicated inadequate room for those beyond the 60th percentile, based on known anthropometric measurements of Army driver population predicted for these vehicles. Drivers reported sore backs and cramped legs resulting in slow reaction time for braking.	Workspace design and sizing shall insure accommodation, compatibility, and operability by at least 90% of the predicted user population (S: 5.6.1.). Anthropometric data for design and sizing of workspaces are presented in Tables 50 and 51 (S: 5.12). For specific Army samples, workspace dimensions should follow data provided in Tables 2-6A, 2-6B, 2-6C, and 2-6D for U.S. Army Armor Crewman (H: 2-37).	None. (Comment: Selection criteria might be re-examined for drivers; criteria could include size limitations if the driver's station must be limited in its dimensions.)
2. HEAD CLEARANCE. There was a lack of clearance between the driver's head and the turret during "head-out" operation. Some drivers during FOE I were struck in the head as the turret slewed at some point during the test. When operating with the hatch closed and using the vision blocks, overhead clearance was inadequate. Less than 5% of the drivers (in regular or arctic clothing) could be accommodated without striking their heads on the rear of the turret hatch opening.	Seating for vehicle operators should follow the dimensions and clearances recommended in Figures 50 and 51 and Table XXVIII as applicable (S: 5.12.2.1). Minimum head clearance for the seated operator should be 550-610 mm (S: Figure 50).	None. (Comment: Problem to be corrected by procedures whereby the turret should be locked when the driver is in a "head-out" position. Conversely, the driver should be buttoned up when the turret is unlocked. However, a mechanical interlock system could be investigated as a design alternative.)

S = MIL-STD-1472C

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
3. VISION BLOCKS. Vision blocks did not allow adequate visibility for driver. There were 20° gaps between the vision blocks so horizontal vision was obstructed. Also, when buttoned up, driver could not see upwards or downwards. Vision blocks were not equipped with a cleaning device. Mud and dust on vision blocks obscured driver's view.	Vision blocks should be designed so that there is an overlap between fields of view (H: 7.5.8). Operator shall have forward visibility through a lateral field of at least 180° and preferably 220° (S: 5.12.5.2). Windshield wipers and washers shall be provided. Blades shall return to the stored position when turned off. Provision shall be made for manual operation in event of power failure (S: 5.12.5.8; H: 7.4.21).	Add "or vision block" following "Windshield."
4. NIGHT VISIBILITY. Incompatibility of cab lighting with night vision goggles made seeing difficult.	Adjustable illumination shall be provided for visual displays, including display, control, and panel labels and critical markings, that must be read at night or under darkened conditions (S: 5.1.1.5).	None. (Comment: Design studies of compatible lighting for driver's station and night vision goggles needed. Thermal sights for all crew members should be considered as an operational alternative.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
5. DRIVER'S SEAT. The seat was not adequate for 5th through 95th percentile operators, with the percentile accommodated varying from one dimension to another. Forward-rear adjustment was inadequate for knee clearance.	Seating for vehicle operations should follow the dimensions and clearances in MIL-STD references (S: Figures 40, 41, and Table XXIV). The driver's seat should accommodate 5th through 95th percentile operators in the full range of clothing in either closed or open hatch operation (approximately 380 mm to 435 mm deep and 380 mm to 510 mm wide) (See H: 7.5.12.2.1). Seats should adjust at least 150 mm (6 in) in the fore-aft direction (S: 15.12.2.3).	None.
6. CUSHIONING AND SUPPORT. The driver's seat had inadequate support and inadequate seat padding.	Seat padding should be kept to a minimum, but it should be resilient enough to keep operator's body from contacting the seat bottom during severe vibration. Seat padding made of foam-type material should be adequately ventilated (S: 5.12.2.6).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
7. LAP BELT AND SHOULDER HARNESS. Inadequate seat belts and shoulder harnesses were provided for the driver, making driving unnecessarily difficult over rough terrain and with vehicle vibration. The shoulder harnesses had too much slack and did not lock quickly enough. Once engaged, the harness latch was difficult to disengage and the harness sometimes had to be cut off.	All administrative type vehicles shall have safety seat belts. Seat belts should be installed on other type vehicles except when they interfere with operational requirements (S: 5.12.2.7).	S: 5.12.2.7 should read "All vehicles shall have safety seat belts. Seat belts shall be designed to minimize the extent to which they interfere with operational requirements." (Comment: Improved seat belts and quick disconnect harnesses should be considered for the driver's seat when cross-country and heavy vibration load driving is operationally required.)
8. INADEQUATE STORAGE. Insufficient storage space was provided for NBC (MOPP) clothing, necessary tools, and manuals.	Adequate and suitable space shall be provided on consoles or immediate workspace for the storage of manuals, worksheets, and other materials that are required for use by the operator or maintenance personnel (S: 5.7.1.3.4). Items of mission-critical nature should be stowed in a manner to permit rapid access by crew members (H: 5.2.1.(e)).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
9. USE OF MOPP GEAR. MOPP (NBC) gear is very hot. Also, wearing the MOPP face mask interfered with the use of the vision blocks.	When applicable, equipment shall be designed so that it can be removed, replaced, and repaired by personnel wearing personal and special purpose clothing and equipment including NBC protective clothing in an NBC-contaminated environment (S: 5.9.1.8). When special protective clothing is required and worn, a comfort microclimate between 20°C (68°F) and 35°C (95°F) is desirable and, where possible, shall be maintained by heat transfer systems (S: 5.8.1.6).	When applicable, equipment shall be designed so that it can be operated and maintained by personnel wearing personal and special purpose clothing and equipment, including NBC-protective clothing in an NBC-contaminated environment.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
10. INGRESS/EGRESS. Only one crew was successful in achieving emergency egress through the driver's emergency hatch. To enable the squad leader and gunner to egress through the driver's compartment required removal of the floor panel. The crew members had to lower themselves into the gun bay, and pass through the keyway into the driver's compartment. Egress through the gun bay was only possible when the turret was facing aft.	Emergency doors and exits shall be constructed so that they are simple to operate, readily accessible, unobstructed, simple to locate and operate in the dark, quick opening in 3 seconds or less, require 44 to 133 N (10 to 30 lb) of operating force to open, and do not themselves, or in operation, constitute a safety hazard (S: 5.13.4.2). Dimensions of whole body access openings shall follow those of Figure 37 (S: 5.7.8), varying with size of clothing. Escape hatches should be designed so they can be opened with one, single motion of the hand or foot. Escape-hatch dimensions should be based on three factors: (a) The work area personnel must escape from. (b) The equipment and clothing they will be wearing. (c) The environment they will enter (H: 2.9).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
11. BRAKING. If the driver is disabled with his foot on the accelerator, there is no way to stop the vehicle. If the accelerator lock is applied and the driver falls unconscious, neither the squad leader nor the gunner would be able to stop the vehicle quickly, and the vehicle would be out of control.	None.	None. (Comment: The feasibility of a main engine "kill" switch in the turret should be considered.)
12. BRAKE AND GAS PEDALS. The brake pedal is located above and to the left of the accelerator pedal. The steering column inhibited leg movement from the accelerator pedal to the brake pedal. Many drivers, especially those with longer legs, hit their legs on the steering column each time they depressed the brake pedals. In addition, there was a safety hazard in that the driver's foot sometimes slipped off the brake pedal and onto the accelerator pedal.	Pedal controls should be located so that the operator can reach them easily without extreme stretching or torso twisting, so that the operator can reach the maximally-displaced pedal within anthropometric and force capability of the operator (H: 1.1.9.4.2; S: 5.4.3.2.8).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
13. COMMUNICATION WITH SQUAD LEADER. During Force-on-Force trials, squad leaders spent 15.5% of trial time talking to drivers. Almost all of this time was spent directing the driver around nearby obstacles. Squad leaders spent more time talking to drivers than to gunners.	None.	None. (Comment: This problem is connected with poor design of the driver's station and tasks such as reduced visibility. An improved driver's station would reduce the requirement on the squad leader to be outside and reduce the time spent in assisting the driver.)
14. EXTERNAL COMMUNICATION. The exterior phone can only be turned on from within the driver's compartment. If the vehicle was powered up by the squad leader, it would have been dangerous for the driver or anyone else to climb aboard the vehicle without first informing the squad leader.	None.	None. (Comment: An exterior switch for the communication phone should be considered. If a phone is to be available for communicating from the outside of a vehicle to those inside, such a phone should be provided with an exterior switch.)

S = MIL-STD-1472C
H - MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
15. TRAVEL AND NAVIGATION. Drivers had a visibility problem under all weather conditions and in both daylight and darkness. Movement maneuvers have been slowed and there have been collisions and near collisions.	Vision blocks should be designed so that there is an overlap between fields of view (H: 7.5.8).	See Problems 3 and 4. (Comment: This was a collective problem resulting from poor driver's station design requiring improvement of vision blocks, better face protective gear (laser glasses and face masks) and improved night vision glasses. For night travel, thermal sights could be helpful.)

S - MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
16. AIR QUALITY. Air quality was a problem in the driver's station. During all trials, drivers complained of dust entering their compartment. Several drivers wore clothes over their faces to filter out some of the dust. Developmental test had indicated the possibility of toxic fumes, particularly in the gun bay.	Adequate ventilation shall be assured by introducing a minimum of 0.85 m^3 per minute per person into any personnel enclosure; approximately two-thirds should be outside air. air.... (S:5.8.1.2) Personnel shall not be exposed to the concentration of toxic substances in excess of the limits specified in either the DoD Occupational Safety & Health standards or specialized standards applicable to military unique equipment, systems or operations....(S: 15.13.7.4)	None.

S = MIL-STD-1472C
2H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
17. EXCESSIVE TEMPERATURES. Driver's compartment became excessively hot when operated with hatch closed. Wearing MOPP gear added to the heat problem.	An effective temperature range has been defined for a variety of military tasks (Figure 3-1, S: 3.2.2). The effective temperature within personnel enclosures utilized for detailed work during extended periods shall be maintained at or below 85°F (29°C) (S: 5.8.1.3). Operators should be protected from both heat from power-train and subsystem components as well as solar radiation (H: 3.4). Variables to be considered in temperature control, beyond heat level, include nature of work being performed, clothing, ventilation, and humidity (H: 5.8.1).	None.
18. NOISE. All crew compartments were noisy during tactical operations. Intermittent, damaging impulses and high, steady-state noise levels were recorded.	Personnel shall be provided an acoustical environment which will not cause personnel injury, cause fatigue, or in any way degrade overall system effectiveness (S: 5.8.3). Extensive criteria are available for allowable noise levels where the impact ranges from annoyance to physiological damage (H: Appendix B).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 1

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Driver's Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
19. FIRE ALARMS. There were no fire alarms in the gun bay or the main engine compartment, although there was one in the primary power unit.	A hazard-alerting device shall be provided to warn personnel of impending danger or existing hazards (e.g., fire, presence of combustible or asphyxiating gas, radiation, etc.) (S: 5.13.4.1).	None. (Comment: Based on a hazards analysis and the identification of potential fire hazards, design of an appropriate fire alarm system should be completed.)
20. FIRE EXTINGUISHERS. There is no fire extinguisher in the gun bay, and fires occurred in the gun bay during FOE.	Where fire hazards are known to exist, or may be created by the equipment, there must be portable, hand-operated fire extinguishers. These fire extinguishers should be located so that they are immediately and easily accessible (H: 6.3.3.1).	In particularly hazardous or inaccessible areas, where time and safety are of the essence, automatic fire extinguishers should be provided. (Comment: There should be automatic fire extinguishers in the gun bay similar to those provided in the primary power unit. This is important due to the possibility of live ammunition detonation.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

The Crew Station

Table 2 lists the 31 major human factors problems associated with the crew station which houses the squad leader and the gunner. As in Table 1, available design criteria are shown for the problem or proposed criteria changes are presented to solve the problem. Recommended additions to existing criteria are noted. In some cases, relatively simple engineering solutions are possible.

The basic workspace provided for the squad leader and the gunner in the crew compartment was inadequate. A significant proportion of the anticipated Army personnel that might have been in the vehicle would have found it cramped, uncomfortable, and difficult (if not dangerous) to use, as did most of the test subjects on FOE I. This situation in part is to be expected, since basic vehicle design profiles limit space available and there is a great deal of equipment that must be in the compartment. It is, therefore, all the more important that the space be properly apportioned on the basis of anthropometric dimensions of the anticipated users. Adequate support must be provided in terms of lap belts and shoulder harnesses so that crew members are not slammed into the equipment or into sharp surfaces by changes in speed or direction.

For task performance it was apparent that little attention was given to integrated control-display design; equipment modules were simply stacked around the two crew members (Babbitt, Seven, & Muckler, 1987, page 26). Crew station lighting received insufficient attention, for it produced an undesirable glare off display surfaces and made task performance at night difficult.

In all these parameters there are available adequate human factors design criteria and design data. The facts are reasonably known as to what is required for good soldier-machine interface design. It is to be hoped that future FAADS design of workspace, control-display design and integration, and crew station layout will be considerably improved.

Much more complicated is the design of the basic task to be performed in the crew station: the target engagement sequence. Successful execution of the target engagement sequence is the mission-critical task. It, indeed, is the reason for the existence of the system. Data from 271 Force-on-Force (non-live fire) engagement sequences produced a mean time to fire of 16.5 seconds, well over the system operational requirement (Babbitt, Seven, & Muckler, 1987, page 83). Clearly, this was unacceptable performance.

The tabular approach to design criteria problems may be too limited to cope with the general problem of tactical aircraft identification for the fire or hold-fire decision. Identifying aircraft as hostile or friendly is the single most important and difficult issue in the domain of air defense. Hostile aircraft must be identified at sufficient range so that they can be engaged before they have released their ordnance. Further, the identification must be highly valid and reliable. Friendly aircraft assets are of high value because they are high in cost, limited in number, and required highly trained and selected operators. Even a one percent fratricide rate imposed by each friendly air defense fire unit would eventually doom friendly air assets,, because there are so many fire units and because each friendly aircraft and pilot must overfly so many fire units so many times in carrying out even one day's mission. Thus, the central problem for air defense is how to be exceedingly accurate and timely in making the tactical identification decision. It seems a rather weak contribution to say that the identification function should output 80% correct calls and minimum false alarms - or to say that "automation and decision aiding is essential." It is beyond the scope of this report to provide a solution to the general issue of tactical aircraft identification.

In further speculation, part of the problem with the non-successful execution of the target engagement sequence may be in the complexity of the system operating modes and levels of automation. Only in the Radar Auto mode and the system preempt engagements was system performance within the time to fire requirements for a substantial proportion of the engagements. The other modes were simply too complicated for quick human response, despite the automation aiding provided. A message that may apply to all future FAADS soldier-computer interfaces for the target engagement sequence is: Keep the interface very simple if very short response times are required.

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
1. WORKSPACE. Squad leader and gunner workspace was inadequate to accommodate 5th to 95th percentile predicted crew members. Lack of head and foot room was especially constraining, resulting in bruises and leg cramps.	System workspace requirements should be based on size considerations for 5th and 95th percentile population wearing cold weather clothing (S: 5.6.1). Anthropometric data for design and sizing of workspaces are presented in Tables 50 and 51 (S: 5.12). For specific Army samples, workspace dimensions should follow data provided in Tables 2-6A, 2-6B, 2-6C, and 2-6D for U.S. Army Armor Crewman (H: 2-37).	None.
2. SHARP EDGES/SLIPPERY SURFACES. Sharp edges and slippery surfaces posed a danger to crewmen. The outside of the hull was slippery and lacked sufficient handholds. Hydraulic fluid leaks, mud, and water made the crew station areas treacherous. Rough and sharp edges on the squad leader's hatch were a hazard.	Where applicable, all exposed edges and corners shall be rounded to a minimum of .75 mm (.03 in) radius. Sharp edges and corners that present a personal safety hazard or potential damage to equipment during usage shall be suitably protected or rounded to a minimum radius of 13 mm (.5 in) (S: 5.13.5.4).	None. (Comment: Non-skid coating could be provided for slippery surfaces. The non-skid coating should be designed to facilitate rapid and effective decontamination.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
3. SEATING. The seat was not adequate for 5th through 95th percentile operators, with the percentile varying from one dimension to another. Body displacement in sideways directions needed to be controlled.	Seating for vehicle operations should follow dimensions and clearances in Figures 40, 41, and Table XXIV (S). The seat should accommodate 5th through 95th percentile operators in a full range of clothing in either closed or open hatch operation (approximately 380 mm to 435 mm deep and 380 mm to 510 mm wide) (H: 7.5.12.2.1). Seats should adjust at least 150 mm (6 in) in the fore-aft direction (S: 5.12.2.3).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
4. CUSHIONING AND SUPPORT. Squad leader and gunner commented frequently that seating in crew compartment was too hard and that frequent backaches developed due to inadequate padding in the lumbar area of the back. Squad leader and gunner had no back support when leaning forward to look through sights. Seat belt/harness was attached to the vehicle instead of the seat. Squad leader could not keep the shoulder straps from slipping from his shoulder. Backache and excessive fatigue reported from inadequate cushioning and support. The gunner's shoulder harness was attached to the hatch door in a way that, under some circumstances, might prevent the hatch from being opened. Shoulder harnesses had too much slack and sometimes did not provide the restraint necessary to prevent injury.	Seat padding should be kept to a minimum, but it should be resilient enough to keep operator's body from contacting the seat bottom during severe vibration. Seat padding made of foam-type material should be adequately ventilated (S: 5.12.2.6). A supporting backrest that reclines between 1745 and 2005 mrad (100 and 115 degrees) shall be provided. The backrest shall engage the lumbar and thoracic regions of the back, and shall support the torso in such a position that the operator's eye can be brought to the "eye line" with no more than 75 mm (3 in) of forward body movement (S: 5.7.3.4.3). All administrative type vehicles shall have safety seat belts. Seat belts should be installed on other type vehicles except when they interfere with operational requirements (S: 5.12.2.7).	S: 5.12.2.7 should read "All vehicles shall have safety seat belts. Seat belts shall be designed to minimize the extent to which they interfere with operational requirements."

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
5. INADEQUATE STORAGE. Insufficient storage space provided for NBC (MOPP) gear, required manuals, and tools.	Adequate and suitable space shall be provided on consoles or immediate workspace for the storage of manuals, worksheets, and other materials that are required for use by operator or maintenance personnel (S: 5.7.1.3.4). Items of mission-critical nature should be stowed in a manner to permit rapid access by crew members (H: 5.2.1(e)).	None.
6. EXCESSIVE TEMPERATURE. Crew compartment was excessively hot. Heat contributed to crew fatigue. Wearing MOPP clothing exacerbated the problem since only the MOPP face mask was cooled.	The effective temperature within personnel enclosures utilized for detailed work during extended period shall be maintained at or below 85°F (29°C) (S: 5.8.1.3). Operators should be protected from heat from both power-train and subsystem components as well as from solar radiation (H: 3.4). The optimum range of effective temperatures for accomplishing light work is (a) 21°-27°C (70°-80°F) in a warm climate or during summer, (b) 18°-24°C (64°-75°F) in a colder climate or during winter (H: 3.2.2.2).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
7. EXTERNAL VISIBILITY. The immediate field of view of the squad leader's periscope was inadequate. One result was that there were several instances of gun barrels swinging into trees and antennae hitting trees. When the squad leader had to assist the driver in travel and navigation, the squad leader was restricted in his vision through the periscope and had to spend too much time "heads out." Vision blocks were gapped, and there was no correlation with the periscope for fields of view. When buttoned up, upward and downward vision was restricted. View through squad leader's vision blocks was obstructed by top of turret.	External vision may require use of both vision blocks and periscopes which must be designed to provide overlapping and acceptable fields of view (H: 7.5.8.2). The operator shall have forward visibility through a lateral visual field of at least 180° and preferably 220°.	None.

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H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
8. NIGHT VISIBILITY. Night vision goggles were incompatible with crew compartment lighting. When combined with inadequate vision blocks and limited periscope field of view, the effect was to severely restrict operation. All of these poorly designed vision "aids" required that the squad leader spend too much time "heads out" rather than "buttoned up."	Adjustable illumination shall be provided for visual displays, including display, control, and panel labels and critical markings, that must be read at night or under darkened conditions (S: 5.1.1.5).	None. (Comment: Design studies of compatible lighting for crew compartment and night vision goggles needed. Thermal sights for all crew members should be considered as an operational alternative.)
9. DISPLAYS: GLARE. Glare on the plasma display interfered with the ability of the squad leader and gunner to read the display.	Reflected glare shall be minimized by proper placement of the scope or display relative to the light source, use of a hood or shield, or optical coating or filter control over the light source (S: 5.2.4.7). Other glare reduction techniques may be acceptable (H: 1.2.4.2.4), including, if necessary, special eyeglasses (H: 3.5.6.4).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
10. DISPLAYS: GUNSIGHT AND PERISCOPE. The squad leaders and gunners found it difficult to keep their faces to the gunsight and periscope due to inadequate brow pads and MOPP face shields.	The functions of a brow pad are to stabilize the observer's eye within the exit pupil of the sight or viewing device and to absorb energy which would otherwise be absorbed by the human head, with resulting damage to its internal organs, bone structure, or external tissue. Brow pads should be compatible with eyeglasses, protective mask, and the CVC helmet (H: 7.5.7; 7.7.5.5).	None.
11. DISPLAYS: TARGET ALARMS. The engageable target alarm, activated frequently, was too loud and interfered with internal communications. The reset button was located on the squad leader's control panel making it difficult for the gunner to turn alarm off if the squad leader was "heads out." If either squad leader or gunner had to reset the alarm, he had to remove his hand from the control grip which could delay the engagement sequence.	Signals with high alerting capability shall not be so startling as to preclude appropriate responses or interfere with other functions by insistently holding attention away from other critical signals (S: 5.3.4.2.1).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
12. DISPLAYS: LABELS. Some of the display labels were either confusing or incorrect. For example, the M239 label was misleading.	Labels, legends, placards, signs, or markings, or a combination of these shall be provided whenever it is necessary for personnel to identify, follow procedures, or avoid hazards, except where it is obvious to the observer what an item is and what he or she is to do with it. Label characteristics shall be consistent with such factors as: accuracy of identification required, time available for recognition or other responses, distance at which labels must be read, illuminant level and color, criticality of function labeled, consistency of label design within and between systems (S: 5.5, 5.5.1; H: Section 4).	None. (Comment: The M239 firing button label should have read "Salvo 1" and "Salvo 2" and not "left" and "right.")

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
13. CONTROLS: HEADSET. For headset control, squad leader had to remove his hand from the control grip interrupting performance of engagement tasks.	When normal working conditions will permit the operator to remain seated at the working position and access to "talk-listen" or "send-receive," control switches are required for normal operation; or if console operation requires the use of both hands, foot-operated controls shall be provided (H: 5.3.10.3). Operator microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions (S: 5.3.9.2).	None.
14. CONTROLS: GRIPS. The removable control grip for the squad leader was difficult to operate without support when the squad leader was "heads out."	None.	None. (Comment: A mount for the control grip could be placed outside the squad leader's hatch.)

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H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
15. CONTROLS: GRIP PLACEMENT. The placement of the control grips was fixed and too high for easy and comfortable use by the squad leader and gunner. Fatigue and reduced accuracy could be expected with longer periods of operator use.	All controls mounted on a vertical surface and used in normal equipment operation shall be located between 860 mm and 1780 mm (34 in and 70 in) above the standing surface (S: 5.7.2.4).	None.
16. CONTROLS: COORDINATION. The gunner's hand grip controls were disabled except for pointer on switch thumb tracker cursor control when squad leader used slave designate. This interrupted gunner task performance in modes independent of the squad leader.	None.	None. (Comment: Operation of the gunner's control should not be made dependent upon the actions of squad leader except where clear override by the squad leader is essential.
17. CONTROLS: MODES OF OPERATION. Specific mode switches for the acquisition and non-acquisition modes were not clearly defined and were not located in conjunction with each other for optimum use.	None.	None. (Comment: A redesign of the primary mode control switches would have been required to insure that appropriate switching functions and their controls were co-located.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
18. COMMUNICATIONS. Interference between internal and external communications caused increased workload for the squad leader. The squad leader was required to monitor too many nets which resulted in internal/external communications interference, higher than necessary workload, and interruption of tactical tasks.	Where communication channels are to be continuously monitored, each channel shall be provided with a signal activated switching device to suppress channel noise during no signal periods. A manually operated on-off switch to deactivate the device when receiving weak signals should be provided (H: 1.2.7.3.3.2.6). When there could be a possibility of simultaneous presentation of automatically initiated messages, a message priority system should be provided, such that the most critical message overrides for initial presentation any messages occurring lower on the priority list (H: 1.2.7.3.1.6).	None.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
19. CREW COMMUNICATION ACTIVITY. Field test data suggested that internal communication among the three crew members was not appropriate to primary mission and task performance. For example, the squad leaders spent more time communicating with the driver than with the gunner. Further, an inordinate amount of time was spent by the squad leader in external communication with regard to position information and maintenance of the preplanned operational order. Greater time should have been available for communication between the platoon leader and the squad leader on Red Force activity.	None.	During design, a careful analysis shall be made of simulated crew communication activities to insure appropriate communication workload and direct support to mission and task activities.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
20. WORKLOAD: SQUAD LEADER. The squad leader was "heads out" for excessive amounts of time because he had to provide directions to the driver for travel and navigation. The combination of excessive communications demands, time given to the driver, and performance of operational tasks overloaded the squad leader at several points and reduced the tactical interaction between squad leader and gunner. This in turn increased the workload on the gunner.	Design shall be such that operator workload, accuracy, time constraint, mental processing and communication requirements do not exceed operator capabilities. (S:4.1) Design shall reflect allocat of functions to obtain req sensitivity, precision, tim safety; reliability; minimum & quality of req personnel. (S:4.3) Design shall reflect human engineering, life support & biomedical factors that affect human performance. (S:4.4)	

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
21. EMERGENCY EGRESS. Emergency egress was tested at the completion of FOE I. Crew members were able to get out of the fire unit by their normal exits in less than 5 seconds, regardless of normal or MOPP clothing. However, only one crew of three was able to use the underside gun bay and emergency hatch. This path led through the driver's station and required removal of the floor panel.	Emergency doors and exits shall be constructed so that they are simple to operate, readily accessible, unobstructed, simple to locate and operate in the dark, quick opening in 3 seconds or less, require 44 to 133 N (10 to 30 lb) of operating force to open, and do not themselves, or in operation, constitute a safety hazard (S: 5.13.4.2). Dimensions of whole body access openings shall follow those of Figure 37 (S: 5.7.8), varying with size of clothing. Escape hatches should be designed so they can be opened with one, single motion of the hand or foot. Escape-hatch dimensions should be based on three factors: (a) The work area personnel must escape from. (b) The equipment and clothing they will be wearing. (c) The environment they will enter (H: 2.9).	None. (Comment: Empirical tests with crew members are required to assure that planned emergency egress is indeed possible.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
22. USE OF MOPP GEAR. MOPP (NBC) gear is very hot for the users. Wearing the MOPP face mask created visual problems and interfered with the use of laser goggles, periscopes, and the vision blocks. Wearing MOPP gear worsened an already difficult workspace fit. MOPP gear could be torn easily by the many sharp surfaces in the crew station. Finally, inadequate storage space was provided in the crew station for MOPP gear.	When applicable, equipment shall be designed so that it can be removed, replaced, and repaired by personnel wearing personal and special purpose clothing and equipment, including NBC-protective clothing in an NBC-contaminated environment (S: 5.9.1.8). When special protective clothing is required and worn, a comfort microclimate between 20°C (68°F) and 35°C (95°F) is desirable and, where possible, shall be maintained by heat transfer systems (S: 5.8.1.6).	When applicable, equipment shall be designed so that it can be operated and maintained by personnel wearing personal and special purpose clothing and equipment, including NBC-protective clothing in an NBC-contaminated environment. (for S: 5.9.1.8).
23. TURRET SLEW. Under automatic modes of operations, rates of turret slew were potentially dangerous to crew members physically and/or could initiate nausea and an incapacity to perform mission tasks.	A hazard alerting device shall be provided to warn personnel of impending danger or existing hazards (S: 5.13.4.1).	Add: Provisions shall be supplied and procedures established so that when high rates of turret slew are generated, appropriate warning devices and crew support gear, such as harnesses and seat belts, are available.

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
24. MACHINE GUN EJECTION HAZARD. Hot brass cases and clips could strike the gunner's right arm and hand. Cases and clips entering the crew station could damage console equipment.	Casing ejection should not endanger personnel or equipment. Space should be provided to store expended casings within the fighting compartment or a means should be incorporated into the design to allow disposal of these casings by another method (H: 7.2.1.3). Expended brass should be caught by a spent brass container (H: 7.2.2.5.2).	None. (Comment: Brass catch bags should be furnished and required to be used.)
25. RELOAD. Loading ammunition at night, squad leader could not hold a flashlight with one hand and load a four-round clip of 40 mm shells with the other. Also, the squad leader's intercom cord interfered with reload.	For efficient performance of the various tasks which vehicle fighting compartment crews must perform, certain minimum amounts of light are required. To provide a basis for designing the interior lighting system of a vehicle fighting compartment, the tasks of each member of the crew should be carefully appraised to determine how much illumination they require (H: 3.5.3.1 and Tables 3-1 and 3-2).	None. (Comment: Careful design attention must be given to night crew tasks and appropriate lighting for those tasks. A longer intercom cord would have eliminated reload interference.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
26. TARGET DETECTION. Visual problems in target detection, acquisition, and tracking involve effects of smoke and dust as well as sighting problems on the move.	Dust skirts are of great value in reducing the dust raised around a vehicle and should be provided (H: 3.10.2). Mud and water are analogous to dust in that the same aspects of design affect them. As with dust, it may be impractical to eliminate them as problems, but vehicle design should minimize the problem (H: 3.11.1).	None.
27. TARGET IDENTIFICATION. The procedures for, and the feedback displays for, target identification, friend or foe (IFF), were ambiguous. Four out of five squad leaders said that aircraft had been misidentified with automated IFF. Some aircraft gave alternating friend-hostile-friend signals. Friendly flight vehicles were engaged.	The design of military systems, equipment and facilities shall reflect human engineering, life support, and biomedical factors that affect human performance, including, when applicable: compatibility of control /display interfaces and procedures with human information processing capability, decision making effectiveness, & the limits of short-term, long-term memory & computation skill. (S:4.4)	

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
28. LASER OPERATION. There was no laser warning system. Without a warning system, all personnel working within the safety range of the laser (approximately 3 km) would be required to wear laser eye protection. This could be a significant operational limitation.	A hazard alerting device shall be provided to warn personnel of impending danger or existing hazards (S: 5.13.4.1).	
29. FIRE CONTROL DECISIONS. Time required for automated fire control computation exceeded the maximum time allowed for the entire target engagement sequence.	None.	To be determined. (Comment: Additional design consideration and prototype checkout are necessary for such systems to insure that correct fire control data can be provided to achieve required operational system response times.)

S = MIL-STD-1472C
H = MIL-HDBK-759A

Table 2

Comparison of Major HF Design Problems in the Sgt York FOE I with Current and Proposed Design Criteria: The Crew Station (Cont'd.)

HF Design Problem	Current HF Design Criteria	Proposed Change (Addition) to Criteria
30. DECISION TO FIRE. Very limited response times were available to the squad leader to initiate or confirm the decision to fire, with little feedback provided as to the correctness of the decision. Insufficient design attention was given to the display feedback data supporting the squad leader's decision.	The design of military systems, equipment and facilities shall reflect human engineering, life support, and biomedical factors that affect human performance, including, when applicable: q. compatibility of control display interfaces and procedures with human information processing capability, decision making effectiveness, & the limits of short- & long-term memory and computation skill. (S: 4.4)	
31. CREW SIZE. Operational test experience and fire unit deployment procedures, as well as crew performance, coordination, and integration suggest that three may not be the optimal crew size for this type of tracked air defense vehicle.	Design shall reflect allocation of functions to personnel, equipment and personnel-equipment combinations to achieve: required sensitivity, precision, time, & safety; required reliability of system performance; minimum number & level of skills of personnel; required performance in a cost-effective manner. (S: 4.3)	

S = MIL-STD-1472C
H = MIL-HDBK-759A

SUMMARY AND CONCLUSIONS

It seems apparent that the Sgt York design was relatively uninfluenced by existing human factors design criteria and design data. While MIL-STD-1472B and MIL-HDBK-759 (current in 1976) were contract reference documents, there is little evidence that they were used. The Army's Required Operational Capability (ROC) document stated that crew station design should be "based on good human engineering design principles," but it was not (Seven, 1987, pages 12-15). The majority of the 51 human factors design problems listed here in Tables 1 and 2 would have been avoided had existing design criteria been followed.

It would appear that many of the functions of the Sgt York needed more thorough examination. The most serious is the frequently unsuccessful (by mission required response times) target engagement sequence performed jointly by the squad leader or the gunner and the computer subsystem. FOE I performance data indicated that, the greater the operator's involvement in the target engagement sequence, the longer the system's Time to Fire.

Another issue that should be closely examined in future FAADS design is crew size. Looked at from the limited aspect of the FOE, one might question whether three crew members are needed to perform the FAADS mission tasks. However, if one considers the Operational Mode Summary/Mission Profile, the crew size of three will be taxed when continuous, sustained operations are required. Detailed simulation tests and design studies (not to exclude the OMS/MP noted) are all needed to produce a credible estimate of the required crew size. The attractiveness of reducing crew size is understandable, for the reduction of a single crew member would have enormous impact on workspace, workload, task performance and all MANPRINT domains.

Reference has already been made to the common practice of using a standard tracked or wheeled vehicle chassis upon which to mount the air defense turret. In the case of the Sgt York, the chassis was the M48 which had to be modified to handle the primary power unit as it was. It is unfortunate that some modification could not also have been made to the driver's station. Other Chassis improvement seems much needed. The M1 chassis also has many limitations affecting driver and squad leader (Earl, 1984). Unless the factors of standardization and lessened chassis cost lose importance relative to improved driver, crewmen, and squad leader performance, the expectation of a high performance future FAADS vehicle is not very optimistic.

These human factors evaluations always raise a question as to what extent the soldier-machine problems make a difference in mission and system performance. Clearly, here there were at least two operational test examples. First, poor driver performance because of poor driver station design did impact mission performance during FOE I. Second, although it is difficult to assign blame directly, the operation of many of the engagement modes of the Sgt York's soldier-computer interface did not allow the target engagement sequence to be performed with desired swiftness. The data suggest that using a simplified system of target acquisition and engagement modes would have produced performance that was more often within the required time limits.

With other design criteria, it is not so easy to correlate soldier-machine problems with system performance. Some 10 items were identified as potential safety hazards (Babbitt, 1988), including, for example, inadequate shoulder harnesses for the crew members.

During FOE I, the rough terrain resulted in many sudden stops, with crews being thrown forward. This was a severe problem for gunners who were thrown against the inadequately padded gunsights. Another example illustrates the predicted performance problem. The MOPP gear was very hot and uncomfortable for the crew members. Yet no effect on performance was shown during FOE I (Babbitt, Seven, & Muckler, 1987, pages 117-119). The actual durations of wearing MOPP gear during FOE I were too short to show performance degradation; crew members will adapt and adjust, up to a point.

Another problem associated with all design criteria and notably with human factors design criteria is the possible specification of performance requirements (cf. Kaplan & Crooks, 1980). It has been proposed that performance requirements be substituted for design criteria, but current and predicted practice seems to be continued use of design criteria, supplemented, where possible, by performance requirements. In the present case, supplementary performance requirements can be provided for the target engagement sequence task, and performance standards can be devised for this task. They would, however, be contingent upon the sensor, signal processing, and fire control computer equipments.

On the other hand, the performance impact of inadequate workspace is difficult to specify. One performance impact might be that some soldiers of larger size wearing full MOPP gear may simply not be able to get into the station. Another impact might be that the larger soldier with full MOPP gear might have great difficulty or fail to conduct an emergency egress.

In FOE I, and in most operational tests, judgments from subject matter experts (SME) were solicited regarding the potential impact of design problems on mission performance. Indeed, these judgments were one of the criteria used in selecting the problems. The extent to which these judgments are valid predictors of mission performance or degradation is not known. For example, one stated problem was that,

> "The crew compartments are crowded, hot, dirty, and noisy during tactical operations."

The subject matter experts judged that this would eventually seriously degrade mission performance and nearly always degrade target engagement operator functions.

The consideration of human factors in the design of weapons systems has been institutionally present in the Department of Defense for over 40 years and has been involved in system design since World War II. A very substantial body of applicable design data has been generated and packaged in specifications, standards, hand books, and technical reports. It would appear that there remains a continuing problem of getting human factors design concepts, criteria, and data into some system designs. It would appear, for example, based on the four reports in this series, that human factors considerations have not had a significant impact on tracked vehicle design.

For future FAADS, it is to be hoped that this trend will change and that future FAADS man-machine interfaces can be radically improved. Such improvement will result in greater soldier user acceptance and better system performance on the battlefield.

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