Research Report 1388

Human Factors Evaluation of the M1 Combat Tank in Operational Test III

William K. Earl

ARI Field Unit at Fort Hood, Texas
Systems Research Laboratory

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

December 1984

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

Technical review by

Donald Kristiansen
James A. Bynum

NOTICES

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Report 1388	2. GOVT ACCESSION NO. ADA164538	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HUMAN FACTORS ANALYSIS OF THE M1 COMBAT TANK IN OPERATIONAL TEST III		5. TYPE OF REPORT & PERIOD COVERED --
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) William K. Earl		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263739A793
11. CONTROLLING OFFICE NAME AND ADDRESS TRADOC Combined Arms Test Activity Fort Hood, TX 76544		12. REPORT DATE December 1984
		13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) —		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

This research paper and questionnaires used in the study are published as a section of OTEA Report IER-OT-58, Independent Evaluation of the M1 Main Battle Tank, November 1981.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Crew station design
Fighting vehicle systems
Human factors engineering design
M1 combat tank
Operational test and evaluation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An analysis of the human factors engineering design considerations of the M1 Combat Tank was conducted in conjunction with the XM1 Operational Test III. The methods used to obtain the human factors data are described and summarized data and analyses are presented. Results of the evaluation are discussed and their implications are considered. The most important design problems identified were concerned with inadequacies in weapons controls and seating. This report provides the Army with data that identify needed design (Continued)

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ARI Research Report 1388

20. (Continued)

changes in future production models of the M1 Tank. The data also impact on the design of future tank systems.

Research Report 1388

Human Factors Evaluation of the M1 Combat Tank in Operational Test III

William K. Earl

Submitted by
George M. Gividen, Chief
ARI Field Unit at Fort Hood, Texas

Approved as technically adequate
and submitted for publication by
Jerrold M. Levine, Director
Systems Research Laboratory

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

December 1984

Army Project Number
2Q263739A793

Human Factors in Training &
Operational Effectiveness

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

This report presents the results of research regarding human factors (man/machine interface) aspects of the Army's new M1 Abrams Tank. The research was conducted in conjunction with the Army's main Battle Tank Operational Test III (XM1 OT III). The Army Research Institute's Fort Hood Field Unit performed the effort in support of the Training and Doctrine Command's Combined Arms Test Activity (TCATA), the test agency for XM1 OT III. The test was conducted at Fort Hood, TX. This analysis is part of an ongoing ARI program of research on human factors and training aspects of Army combat vehicle systems, with emphasis on system development and system evaluation. ARI developed the research design, data collection and analysis plans, and test materials in coordination with TCATA. The report presents the results of interviews, questionnaires, and performance tests administered to the tank crew participants in XM1 OT III. The main purpose of the report is to identify problems in the human engineering design of initial production M1 tanks. The findings provide information to correct the problems on future production series tanks, and as input to the design of future vehicles.

This project is responsive to requirements of Army Project 2Q263739A793 and to special requirements of U.S. Army TCATA, Fort Hood, TX.

EDGAR M. JOHNSON
Technical Director

HUMAN FACTORS ANALYSIS OF THE M1 COMBAT TANK IN OPERATIONAL TEST III

EXECUTIVE SUMMARY

Requirement:

The human factors analysis of the XM1 tank was conducted in conjunction with OT III for the Army's new XM1 tank (now M1). This OT was designed to provide information on the capabilities of initial production tanks in an operational environment. The data were needed as input to the decision process to determine whether or not to place the tank into full scale production and deployment. The ARI Field Unit-Fort Hood was tasked by the test agency (TCATA) to perform the human factors test objective. The scope included assessing the functional effectiveness of the commander's weapon station; collecting crewmen evaluations of human factors design considerations; collecting performance data on the loader's ability to load and transfer main-gun ammunition; conducting analyses of the resulting data; making recommendations for improving the man/machine interface of future production models of the M1 Tank; and providing design criteria for future tank systems.

Procedure:

The data collection methods used were crewstation interviews, elapsed time measures of ammunition loading and transfer performance, and end-of-test questionnaires. Structured interviews were administered to individual crewmen at their crewstations in the tank after they had completed the live firing and field exercises of OT III. The sample consisted of 10 tank commanders, 10 gunners, 10 loaders, and 10 drivers. During the live firing exercises 10 loaders were tested under different combinations of uniform type (NBC or fatigues) and tank motion (stationary or moving) during which their ammunition loading and transfer speed was measured. After OT III was completed, end-of-test questionnaires were administered to 175 crewmen and mechanics.

Findings:

Results from the crewstation interviews and end-of-test questionnaires indicated a total of 94 probable or confirmed human engineering design inadequacies, of which 31 items were judged to be serious enough to induce significant reductions in operational effectiveness. There were main design problems with weapons controls and seating, e.g., the commander's power control is located too low in the turret to reach when needed during the target acquisition task; the controls for the commander's weapon are poorly designed, and the majority of commanders feel they could not use them effectively; the driver's seat is inadequately designed and produced neck and upper back pain in the majority of drivers; there is no seating for commanders in open hatch modes.

Examples of other problems were that overall stowage space is seriously inadequate; protective masks do not interface properly with gun sights; the external gun sight gets dirty easily and often cannot be used when the tank is in muddy or dusty terrain; the thermal night sight shuts down and cannot be used when the gun is pointed forward, because its power unit is located next to the heater vent which causes it to overheat.

Utilization of Findings:

The results of this report were incorporated as part of TCATA test report New Army Battle Tank (XM1) Operational Test III (OT 58), TCATA Test Report OT 058A, TRADOC Combined Arms Test Activity, August 1981 (C), and included as a section of OTEA test report Independent Evaluation of the M1 Main Battle Tank, OTEA Report: IER-OT-058, U.S. Army Operational Test and Evaluation Agency, November 1981 (C). The ARI findings were presented to the CY 81 ASARC/DSARC IIIa to assess the suitability of the M1 Tank for full-scale production and fielding, and to clarify needed modifications for future production M1 Tanks. These findings have subsequently been used as the basis for design changes which have been incorporated into later production models of the M1 tank system, and as the basis for the ARI Research Product 84-05, March 1984, Human Factors Engineering Design Criteria for Future Systems, Report No. 1: Tank Design Criteria Evolving from the M1 Tank Operational Test III.

HUMAN FACTORS ANALYSIS OF THE M1 COMBAT TANK IN OPERATIONAL TEST III

CONTENTS

APPENDIX: All references in this report to appendixes refer to OTEA Report IER-OT-58, Independent Evaluation of the M1 Main Battle Tank, November 1981.

LIST OF TABLES

HUMAN FACTORS ANALYSIS OF THE M1 COMBAT TANK IN OPERATIONAL TEST III

INTRODUCTION

The New Army Battle Tank Operational Test III (XM1 OT III) was conducted at Fort Hood, TX from September 1980 through May 1981. It was a comprehensive test of low rate initial production (LRIP) M1 tanks operated by members of a standard Army tank battalion in live-firing and non-firing field exercises. The test was designed to provide data and analyses of the capabilities of LRIP M1 tanks in an operational environment. The results were for use in the decision of whether or not to place the M1 tank system into full-scale production and fielding.

The test agent for XM1 OT III was the United States Army Training and Doctrine Command's Combined Arms Test Activity (TCATA). The Army Research Institute Field Unit at Fort Hood agreed to a request by TCATA to provide technical support and perform the human factors objective of the test. The overall XM1 OT III included many objectives. Examples are reliability, availability, maintainability, logistic supportability, and fire power performance. All the objectives are discussed in the TCATA report of the OT III (August 1981), and the OTEA Report of the OT III (November, 1981). This report is limited to considering only the human factors objective. It presents a more thorough treatment of the objective than the summary given given in the TCATA report. This report is designed as a supplement to the TCATA report providing additional information, analyses, and discussion.

Purpose and Objective

The purpose of the human factors test objective was to provide data to determine if problems observed previously during XM1 OT II (March 1979) on prototype tanks had been corrected on the LRIP tanks and to identify additional needed modifications. The scope of the effort was to include the following activities: assess the ability of the tank commander to function in the M1's commander's weapon station; administer questionnaires to all crew members to obtain data on human factors engineering design considerations; collect performance data on the times required to accomplish loader's tasks involving loading and transferring main-gun ammunition.

The objective was defined into a set of data requirements. Individual items were to be addressed during various phases of the test. Table 1 presents a tabulation of the requirements which were defined for the OT III human factors evaluation.

TABLE 1

DATA REQUIREMENTS FOR THE HUMAN FACTORS OBJECTIVE IN XM1 OT III
(From Test Design Plan for XM1 OT III)

1. Opinions on crew stations.

2. Opinions on operating and servicing all weapons systems.

3. Opinions on adequacy of provision for stowage and accessibility of all prescribed equipment, material, supplies and clothing.

4. Observed hazardous conditions.

5. Opinions on problem areas observed during OT II.

6. Time to load from ready-rack.

7. Time to load from semiready-rack (bustle & turret floor).

8. Time to transfer rounds from hull ammunition stowage to ready or semiready-racks.

9. Opinions of crews on ammunition basic load stowage with respect to accessibility for firing.

10. Identification of difficulties with firing, by crew members, including tank commander.

11. Identification of difficulties during loading; by weapons system.

12. Opinions on duty performance while in an NBC Mission Oriented Protective Posture (MOPP).

13. Opinions of drivers and tank commanders on driving performance.

14. Crew opinions on ride dynamics.

15. Opinions of crews on ability to observe, by crew station.

16. Opinions of crews on ability to communicate, by crew station.

17. Observed vision obstructions in Commander's station.

18. Observed difficulties in operation of Commander's station control handles.

Description of the M1 Tank System

The M1 combat (main battle) tank is a fully tracked armored-fighting vehicle powered by a 1500 horsepower turbine engine and operated by a crew of four. Presently, the primary armament is a 105mm, rifled tube, M68 high-pressure gun. The turret is designed, however, to mount a 120mm smooth- bore gun without structural modification to the vehicle. The secondary armament includes a caliber .50 M2HB machine gun for the tank commander and two 7.62mm M240 machine guns; one is mounted coaxially with the main gun, the other on a stake mount outside the loader's hatch. The M1 has smoke generation capability produced by an engine mounted device, and by two six-tube smoke grenade launchers. The tank incorporates a combination of armor materials and design features that provide ballistic protection against kinetic and chemical energy munitions. Survivability is further enhanced by ammunition and fuel compartmentalization and by increased mobility. The mission of the M1 tank is to attack and destroy enemy tanks, equipment, and forces. It achieves its mission by using high speed, maneuverability, and firepower, while its armor envelope and smoke generators provide protection for the crew.

METHOD

The data requirements specified collection of different types of data. They ranged from operator opinion of crew station and vehicle design to performance measures of main gun ammunition loading and transfer tasks. To meet these dissimilar demands, an assortment of data collection methods were used.

Subjects

The test personnel were regular troops from the 2d Battalion, 5th Cavalry, 1st Cavalry Division, Ft. Hood, TX. All tank crewmen were qualified M1 operators (MOS 19K) and all organizational mechanics were qualified M1 mechanics (MOS 45E or 63E). The crewmen operated in their usual crew positions. Individuals were assigned to one position within one crew for the duration of the test. Personnel turbulence was controlled throughout the test, hence, personnel turnover and reassignments were kept to a minimum.

Instruments and Procedures

Data collection methods used in this test were crew station interviews, crew station temperature comfort judgments, performance measures of main gun ammunition loading and transfer performance, and end-of-test questionnaires. The data obtained from these instruments comprise the data base of the report.

Crew station Interviews. Structured individual interviews were administered to random samples of crewmen for each crew position after they had completed the live firing exercises and field training exercises of OT III. The samples consisted of 40 crewmen: 10 tank commanders (TC's), 10 gunners, 10 loaders, and 10 drivers. The interviews took place at the battalion motor pool inside the tanks at the appropriate crew stations. During each interview, a crewman sat in his seat in his crew station and the interviewer sat near him at normal distance for conversation. Duration of the interviews ranged from one and a half to two hours.

A human factors evaluation checklist of system deficiencies was used to structure these interviews. Each checklist item introduced a specific system component for discussion, but did not restrict the form or direction the interviewers response would take. It was developed from deficiencies reported in previous tests on the M1: Development Test II, Desert Phase, (January 1979); FSED Reliability Test, (September 1979); Operational Test II, (March 1979); Prototype Qualification Test, (February 1979). The checklist was composed of seven sections. Sections one through four covered each of the crew stations; section five covered safety hazards; section six covered exterior items; and section seven covered operator maintenance and storage.

All crewmen were interviewed on the section pertaining to their crew station and on section five (Safety Hazards). The TC's and drivers were also interviewed on sections six and seven, as they were the crewmen who had the greatest responsibility for those areas.

Checklist items were directed towards obtaining operator opinion concerning the human factors engineering design of the crew stations and vehicle. This involved considering such factors as the location and arrangement of equipment, direction and force to operate controls, operating conditions, clearance, visibility, safety, operability, and maintainability. Individual items were written in the form of questions requiring a two-choice response. Crewmen were asked to judge whether the component under evaluation was either adequate or inadequate in terms of human factors design considerations. Opinion data was obtained from individual crewmen on the human engineering design of his crew station; on operation and servicing of weapons; on stowage and accessability of materials, equipment and ammunition; on operator performance in the full nuclear, biological, chemical (NBC) protective uniform; on his ability to observe, communicate, and acquire targets; and on the driving performance and riding dynamics of the M1.

The checklist was given a pretest to detect any overlooked problems or faults with the construction and validity of individual items. Two qualified M1 crews and four mechanics from the Ft. Knox OT III Test Team were interviewed. The problems identified in the pretest were corrected and the corrections were included in the test version.

Two types of data were gathered: classification responses such as yes or no and good or bad, and noteworthy comments discussing specific design features contributing to the problem. The data were processed and summarized by checklist item. Classification responses were tabulated and summed. Comments were paraphrased, grouped according to similarity of meaning, and summed.

The data were analyzed by classifying items according to the proportion of negative judgement they received indicating a human engineering design inadequacy. Since military systems are designed to insure accommodation of 90 percent of the user population, this value was used as the expected proportion for positive judgements. The Binomial Test was used to determine if the observed proportions of positive judgements differed from the expected proportions at statistically significant levels of probability. Checklist items were classified into one of three categories depending upon the size of the difference between the expected and observed proportions. If 50 percent or more of the responses rated the item to be inadequate, differing significantly from the expected proportion at the 99 percent confidence level, it was classified as a probable inadequacy. If 30 to 40 percent of the responses to an item were negative, differing significantly at the 95 percent confidence level, it was classified as a possible inadequacy. If zero to 20 percent of the responses rated the item to be inadequate it was classified as adequate.

The Human Factors Evaluation Checklist of System Deficiencies and a tabulation of responses is presented in Appendix A.

Crew station Temperature Comfort Judgements. Individual ratings of crew station temperature comfort were made daily by crewmen operating under different crew station modes during the live firing exercises which took place during the Winter season. Judgement data were collected from individual crew members of the three tank companies tested; a total of 164 crewmen. These judgements were recorded on score sheets by the crewmen during debriefings or rest periods following completion of test activities.

There were 16 crew station modes based on combinations of hatch position (open or closed), heater status (on or off), blower fan status (on or off), and tank mobility (stationary or moving). The judgements were made by selecting alternatives from a five-point scale: very cold, cold, comfortable, hot, and very hot. Each judgement was labeled with the date and time of day and correlated with the effective ambient temperature calculated from meteorological data provided by the post weather detachment.

The data for each crew station were analyzed separately. They were combined by crew station mode and temperature interval. Mean scores were then calculated for each combination. The following criterion was used to identify conditions producing satisfactory or unsatisfactory crew station temperatures. If the mean rating was comfortable, then crew station temperature was considered to be satisfactory; if hot or cold, then it was considered to be unsatisfactory. Detailed mean score and frequency data are presented in Appendix B.

Main Gun Ammunition Loading and Tranfer Test. During the live firing exercises of OT III, a test was run to measure the effects of two variables on the ability of a sample of ten loaders to load and transfer main gun (105mm) ammunition. The two variables were type of uniform and tank mode. There were three loading tasks and two transfer tasks. The three loading tasks consisted of loading from the ready rack, loading from the semi-ready rack, and loading from the turret floor rack. The two transfer tasks consisted of transferring rounds from the hull storage compartment to the ready rack and transferring rounds from the semi-ready rack to the ready rack. The two tank modes were stationary and moving (approximately 12 miles per hour). The two types of field uniforms were fatigues and the full NBC protective uniform that included protective mask, two-piece overgarment, rubber boots, and gloves. Four rounds were loaded or transferred during each task except for loading from the turret floor rack as only three rounds can be stowed in the turret floor.

The tasks of loading from the ready rack and turret floor were performed under both moving and stationary mode conditions. The other tasks--loading from the semi-ready rack and transferring rounds from the semi-ready rack and hull storage--were performed while the tank was in a stationary mode only, because it is impractical and hazardous to perform these tasks when the tank is moving.

Each of the three loading tasks required the loader to use different procedures to load the rounds. To load from the ready rack, the loader had to hit the door switch with his knee to open the door and then remove the rounds. To load from the semi-ready rack, the TC had to remove the safety panel in front of the semi-ready rack door, unlock and manually open the door, and then hand the rounds to the loader. To load from the turret floor rack, the loader had to get out of his seat, reach down between his feet and slide the round out, and then insert the round into the breech.

To perform the transfer tasks the loader had to use the following procedures. To transfer rounds from the semi-ready rack, the TC had to first remove the safety panel, manually open the door, withdraw the rounds and hand them to the loader who placed the rounds on the turret floor. The TC closed the semi-ready rack door, and the loader opened the ready rack door and in serted the rounds. To transfer rounds from the hull storage compartment, the TC first alined the turret opening with the door of the storage compart- ment; the loader then opened the door, removed the rounds, and placed them on the turret floor. He then changed position, opened the ready rack door, and inserted the rounds.

A loading trial consisted of loading one round, and a transfer trial consisted of transferring four rounds. Performance was measured by a stopwatch in terms of elapsed time (tenths of seconds) required to execute the task. The data were analyzed by analysis of variance to determine the effects of the independent variables on loading and transfer performance. Summaries of the analyses of variance are presented in Appendix C.

End-of-Test Questionnaires. After OT III was completed, end-of-test questionnaires were administered to 175 crewmen and organizational mechanics of the test battalion. The sample group consisted of 26 TC's, 31 gunners, 39 loaders, 29 drivers, 12 turret mechanics, and 38 track vehicle mechanics. The questionnaires were based on ones developed in OT II. They were modified with revisions and additions to meet the requirements of OT III. The questionnaires for the different crewmen were essentially similar varying only with respect to the differences in crew station tasks and equipment. They consisted of four sections covering crew station tasks, general duties, crew station conditions, and NBC operations. In contrast, the questionnaires for the mechanics contained only two sections: maintenance tasks, and NBC operations.

The questionnaires contained three types of questions. There were rating scale items, multiple choice items, and time estimate items. The rating scale items used one of two attribute scales. In the first section on crew station or maintenance tasks a six-point scale was used which rated task difficulty. It ranged from -3 (extremely difficult) to +3 (extremely easy). In the last section on NBC operations an 11-point scale was used which rated performance effectiveness while wearing the full NBC protective uniform. It ranged from 0 (cannot do the task) to 10 (as good as when wearing fatigues). Multiple-choice items were used in all sections of the questionnaires except the first one covering operator and maintenance tasks. The alternatives ranged from two to seven choices for various items; the majority of items presented five-choice response alternatives. Time estimation items were used in the last section on NBC operations. These items asked for estimations of the duration personnel can operate effectively when wearing the normal field uniform or the NBC protective uniform.

The questionnaires were also pretested with the qualified M1 crew and mechanic personnel from the Ft. Knox OT III Test Team. The problems that emerged from the pretest were corrected and the corrections were included in the test versions of the questionnaires.

The data from the questionnaire items were analyzed by calculating descriptive statistics; these included frequencies, modes, medians, means, and standard deviations. The following criteria were used to identify items given negative ratings or judgements. Multiple choice items were classified as probably adequate or inadequate according to whether the modal response fell within an interval indicating either some level of adequacy or inadequacy. Rating scale items were classified into the same two categories depending where the mean score was located in relation to the midpoint on the scale. It was classified as adequate if it fell in the positive or upper half of the scale and inadequate if in the negative or bottom half. Time estimate items concerning the duration crewmen can operate effectively when wearing the NBC protective uniform were classified as adequate if the mean response was four hours or more and inadequate if less than four hours. Copies of the questionnaires containing the individual items, plus response data and descriptive statistics for each item, are presented in Appendix D.

RESULTS

Examination of the data collected from the crew station interviews and end-of-test questionnaires indicated a total of 92 probable human engineering design inadequacies. Thirty-one of them were judged to be serious enough to probably induce significant reductions in the operational effectiveness of the M1. These critical problems are summarized in the following sections.

Tank Commander's Station

The rating data from the interview and questionnaire on the critical problems in the tank commander's station are summarized in Table 2. The results indicate that the main design problems uncovered were concerned with weapons controls and seating arrangements. Other important inadequacies included operation of the automatic engine shutoff function, hazardous safety conditions presented by the design of control mounts, and interface incompatibility between the eyepiece of the gunner's primary sight extension and the lens of the NBC protective mask.

Commander's Power Control.

This problem is considered to be the mostserious one hindering the M1's potential tank-fighting capability. Comments from the tank commanders, presented in Table 2, point out that the power control handle is positioned too low inside the turret. Most commanders cannot reach it when standing upright and operating in the open or protected-open hatch modes. They cannot maintain uninterrupted visual contact with targets during acquisition and handoff to the gunner because they must duck their heads down into the turret to reach the power control. This needlessly complicates the target handoff task. It increases target acquisition time by increasing the time required by the commander to make the initial lay of the gun. After estimating the amount of traverse needed to bring the main gun to bear on the target, he must drop down into the turret and perform the alignment on the basis of his short-term memory of the spatial relation. Obviously, performing the task in this "half-blind" manner is slower and less accurate than doing it while maintaining continuous visual contact with the target. The problem directly reduces the capability of the M1 to effectively engage multiple targets; a task it was, presumably, designed to contend with. The preponderance of threat armor forces will probably require committing the M1 into battle situations where it will be frequently outnumbered. Under these circumstances the capability to engage multiple targets quickly and effectively will be a crucial one for mission success and overall system effectiveness.

Commander's Weapon Controls. All tank commanders interviewed pointed out that their weapon could not be operated effectively (see Table 2). They reported that the elevation, traverse, and trigger controls are difficult to operate in a coordinated manner, the way they are used when tracking and engaging targets.

Commander's Seat. The seat cannot be used by the commander when he is operating in the two open hatch modes that are used most often for operating the tank (see Table 2). This situation compels tank commanders to stand for long periods of time. They become fatigued after relatively short periods of operation, especially on road marches.

Automatic Engine-Shutdown Function. The engine incorporates an automatic shutoff function that shuts down the engine whenever engine oil pressure becomes too low. This could present a serious problem if it occurred during critical moments of desperate combat engagements. Tank commanders indicate (Table 2) that a manual override control should be installed in their station to provide the means of withdrawing from combat and avoiding total loss of the system. Their opinion is that it is better to save the tank by sacrificing the engine than to protect it and by so doing lose both the tank and crew.

Mounts for the Commander's Weapon Station Control Handle. The two upper mounts for the control handle have pointed ends that are in close proximity to the tank commander's head. Tank commanders feel (Table 2) that the mounts are safety hazards presenting the risk of head injury.

NBC Protective Mask M25A1. Tank commanders indicate (Table 2) there is an incompatible interface between the lenses of the protective mask and the eye- piece of the gunners primary sight extension. This prevents the tank commander from obtaining an adequate sight picture.

TABLE 2

Ratings and Opinions of Probable Human Engineering Design Problems in the Tank Commander's Station

Probable Inadequacy	Response Measures Yes	Response Measures No	Data Source
	Mean		
1. Power Control Handle			
(1) Location is poor	8	2	C1-33[2]
(2) Position needs to be raised	8	2	C1-35
(3) Difficult to operate	6	4	C1-79
(4) Difficult to see out of turret while operating control	-0.27[3]		Q1-1-7
2. Commander's Weapon Controls			
(1) Elevation, traverse, and trigger controls are difficult to coordinate and operate	10	0	C1-45
(2) It's difficult to acquire and track targets	10	0	C1-46
(3) Traverse control has poor force/			
(4) The present combination of powered and manual controls is unsatisfactory	10	0	C1-64
(5) Tracking targets is difficult	-1.23		Q1-1-11
(6) Firing the weapon is difficult	-1.16		Q1-1-23
(7) Operating trigger controls is difficult	-1.24		Q1-1-46
(8) Operating the traverse control is difficult	-0.36		Q1-1-47
3. Commander's Seat			
(1) Cannot sit with head above hatch	10	0	C1-28
(2) Seating adjustments are inadequate for full open hatch operation			

TABLE 2 (Cont'd)

Ratings and Opinions of Probable Human Engineering Design Problems in the Tank Commander's Station

Probable Inadequacy	Response Measures Yes Mean	No	Data Source
(3) An autobahn seat is needed for the traveling mode	8	2	C1-31
4. <u>Automatic Engine-Shutdown Function</u>			
(1) There is the need to add a master override switch to keep the tank operating	9	1	C1-80
5. <u>Mounts for the Commander's Weapon Station Control Handle</u>			
(1) The control-handle mounts are safety hazards endangering the TC	9	0	C1-6
6. <u>NBC Protective Mask</u>			
(1) Tank commanders are unable to acquire adequate sight pictures when wearing the protective mask	8	2	C1-106
(2) The mask tends to fog up blocking vision	7	3	C1-105

NOTES:

[1]Only those items indicating a problem have been entered into this table and the following tables on human engineering design problems. Items judged to have adequate human engineering design are not included.

[2]The codes in the Data Source column indicate the item in the specific check- list or questionnaire from which the accompanying data was derived. Code prefixes designate particular checklists (c) or questionnaires (Q). Cl identi- fies the Commander's Checklist and Ql the Commander's Questionnaire. Code suffixes identify the section and item number; for example, Ql-1-7 indicates Commander's Questionnaire, Section 1, Item 7. Checklist codes contain item numbers only, no section numbers.

2The mean rating values presented were derived from rating samples using the following scale: -3 = Extremely difficult; -2 = Very difficult; -1 = Difficult; 1 = Easy, 2 = Very easy; 3 = Extremely easy.

Loader's Station

The rating data from the interview and questionnaire for the critical problems in the loader's station are summarized in Table 3. The results indicate that the major design problems are inadequate workspace and poor location of the radio amplifier unit.

Workspace. The majority of loaders interviewed feel (Table 3) that work- space is minimal. They are constrained when withdrawing, turning, and rotating main gun rounds during the loading task. It is especially difficult to load HEAT rounds in the confined workspace because they are longer in length. Head room, body room, and leg room were all rated to be inadequate for performing some tasks; those that require considerable stooping, reaching or bending.

AM 1780/VRC Radio Amplifier. Both loaders and tank commanders feel that the 1780 is located in an unsafe position (Table 3). It sits in an exposed position on the left side of the turret directly underneath the loaders hatch. This location exposes it to rain and moisture dripping on it, crewmen stepping on it, objects falling on it, and main gun rounds striking it during the loading task.

TABLE 3

Ratings and Opinions of Probable Human Engineering Design Problems in the Loader's Station

Probable Inadequacy	Response Measures Yes Mean	Response Measures No Mean	Data Source
1. Workspace			
(1) Workspace for loading is cramped	7	3	C2-30-f1
(2) It is difficult to load HEAT ammo in the confined workspace	3	0	C2-3d
(3) Headroom is inadequate for some tasks	24	14	Q2-3-142
(4) Bodyroom is inadequate for some tasks	27	12	Q2-3-15
(5) Legroom is inadequate for some tasks	22	17	Q2-3-16
2. AM 1780/VRC Radio Amplifier			
(1) The 1780 is exposed to damage	17	3	C1-98 C2-84

NOTES:

1C2 designates the Loader's Checklist.
2Q2 designates the Loader's Questionnaire.

Gunner's Station

The data for the critical problems in the gunner's station are summarized in Table 4. The results indicate that the items judged to have major design problems are the primary sight, the NBC protective mask and the thermal imaging system.

Gunner's Primary Sight. Gunners indicate that the large external lens of the sight gets dirty quickly when the tank travels over dusty or muddy terrain. To clean the lens, a crewman (the loader most likely) must leave his station, move outside onto the turret roof, and manually wipe it off. This activity temporarily removes the tank from full operational status; unavoidably, one crew station has been left unmanned. Furthermore, it puts the displaced crew- man into a highly exposed position, making him vulnerable to all types of threats.

There is another problem at the other end of the sight. The interface between the lens of the NBC protective mask (M25A1) and the eyepiece of the sight is incompatible. The lenses are poorly designed for viewing through the eyepiece. Gunners report that they must press the curved mask lens flat against the eyepiece to reduce distortion and obtain recognizable sight pictures. Obviously, this is an improvisation which achieves questionable improvement and, probably, misuses and damages the equipment.

Thermal Imaging System. The gunners pointed out that operating the heater causes the Thermal Imaging System to malfunction and shutdown, leaving the fire control system without night vision capability. The problem results from the location of the turret heater vent. When the turret is pointed foward over the front of the hull, the vent blows heat directly onto the General Power Unit. The unit overheats and then malfunctions. This, in turn, causes the Thermal Imaging System to malfunction and shutdown. To avoid the problem, the crew must refrain from using the heater on cold nights. They suffer intense discomfort and an accompanying loss in operational effectiveness.

TABLE 4

Ratings and Opinions of Probable Human Engineering Design Problems in the Gunner's Station

Probable Inadequacy	Response Measures Yes Mean	No	Data Source
1. Gunner's Primary Sight (GPS)			
(1) There is need for a device to clean the GPS lens	8	2	C3-241
2. NBC Protective Mask			
(1) The GPS eyepiece and NBC mask are incompatible	8	2	C3-63
3. Thermal Imaging System (TIS)			
(1) The TIS shuts down when the turret heater is used	8	2	C3-33

NOTE:

1C3 designates the Gunner's Checklist.

Driver's Station

The data for the critical problems in the driver's station are summarized in Table 5. The results show that the items judged to have serious design problems include: The workspace, the seat, the wiper/washer unit, the periscope arrangement, and the lock on the steering column.

Workspace. Driver opinion was that in the open-hatch mode legroom and head clearance are inadequate for a large proportion of drivers. In the closed-hatch mode legroom is also felt to be insufficient for taller drivers. The source of the problem seems to be the position of the seat pan. In the open-hatch mode it is too high and too far forward, forcing some drivers to sit in a hunched-over, prenatal posture. In the closed-hatch mode it is too far forward, taking away needed legroom.

Driver's Seat. The majority of drivers feel that the seat does not provide adequate support. They report that they suffer discomfort and pain after sitting in it for more than two hours. The problem is centered in the neck and upper back area. Several drivers reported to the post physical therapy clinic complaining of neck pain induced by sitting in the seat. [1]

Wiper/Washer Unit. The center periscope in the driver's hatch is equipped with a manually powered wiper/washer device. Drivers indicate that it is difficult to operate while driving; it requires one hand to move the wiper. Also, it is not effective in cleaning water and mud off the lens.

Periscope Alignment. A majority of the drivers interviewed report that the three periscopes in the driver's hatch are out of alignment. The misalignment produces a noticeable image shift upward when the driver switches his view from the center periscope to either of the side periscopes. They complain that it causes disorientation and reduces their visual comprehension of the field of view.

Position-Adjustment Pin. The position-adjustment pin on the steering control column is difficult to use and cannot be relied on to lock the control in place. This is a serious safety hazard. The driver can lose control of the tank if the pin vibrates loose during travel, allowing the steering control to telescope back and forth freely.

TABLE 5

Ratings and Opinions of Probable Human Engineering Design Problems in the Driver's Station

Probable Inadequacy	Response Measures Yes	Response Measures No	Data Source
		Mean	
1. Workspace			
(1) Legroom is insufficient	6	4	C4-681
(2) Driver's knees hit the hydraulic pump	5	5	C4-69
(3) Driver's knees hit the brake release	7	3	C4-70
(4) Headroom inadequate for some tasks	0.41		Q4-3-142

(Rating Scale: 1 = Adequate, 0 = Inadequate for some duties, -1 = Completely inadequate for all duties.)

1 Letter: From D. A. Kersey, LTC, AMSC Chief, Physical Therapy Clinic, US Army Medical Department Activity, Ft. Hood, TX, to Commander, TCATA. Subject: Driver's Headrest Support System. 19 March 1981.

TABLE 5 (Cont'd)

Ratings and Opinions of Probable Human Engineering Design Problems in the Driver's Station

Probable Inadequacy	Response Measures Yes	No	Data Source
	Mean		
2. Driver's Seat			
(1) Better seat positions are needed in closed and open hatch modes	5	5	C4-61-62
(2) Seat needs to be adjustable for taller drivers	9	1	C4-63
(3) Amount of pain suffered from sitting in seat for 2 hours or more	1.66		Q4-3-21
(Rating Scale: 0 = None, 1 = Some, 2 = Quite a bit, 3 = Very much.)			
3. Center Periscope Wiper/Washer Unit.			
(1) Wipers are difficult to operate and ineffective	6	4	C4-55
4. Alignment of Periscope			
(1) Vision blocks are out of alignment and cause disorientation	7	3	C4-79
5. Steering Control Adjustment Pin			
(1) The pin is difficult to lock, remove, and adjust	6	4	C4-50

NOTES:

1C4 designates the Driver's Checklist.
2Q4 designates the Driver's Questionnaire.

NBC Protective Uniform

Crewmen and mechanics ratings on performing essential operational tasks while wearing the NBC protective uniform are summarized in Tables 6 and 7. The results indicate that performance quality and endurance are reduced substantially.

Performance Quality. When wearing the protective uniform, effectiveness for performing essential tasks was estimated as ranging from 40 to 60 percent of that attained when wearing fatigues.

TABLE 6

Estimates of the Effectiveness of Performing Critical Tasks When Wearing the NBC Protective Uniform

Probable Inadequacy	Percent Effectiveness When Wearing NBC Uniform	Data Source
Performance Quality		
(1) Performing Tank Cmd'rs critical tasks	54%	Q1-4-18-23[1]
(2) Performing Loader's critical tasks	55%	Q2-4-12-15
(3) Performing Gunner's critical tasks	62%	Q3-4-18-22
(4) Performing Driver's critical tasks	58%	Q4-4-13-17
(5) Performing Turret Mechanic's critical tasks	49%	Q5-2-10-17
(6) Performing Vehicle Mechanic's critical tasks	41%	Q6-2-10-21

NOTE:

[1]The statistics were derived from the designated items in Section 4 of the respective Crewmen's Questionnaires and Section 2 of the Mechanic's Questionnaires.

Performance Duration. When wearing the protective uniform on hot and warm days, crewmen and mechanics estimate they can operate effectively for only two to four hours before becoming fatigued.

TABLE 7

Mean Estimates of the Number of Hours Crewmen Can Operate Effectively When Wearing the NBC Protective Uniform

Position	Hot Day (96-115F)	Warm Day (86-95F)	Data Source
Performance Duration			
(1) Tank Cmdr	3.42 hrs	4.73	Q1-4-25,27[1]
(2) Loader	2.87	4.08	Q2-4-17,19
(3) Gunner	1.90	2.87	Q3-4-24,26
(4) Driver	1.35	2.10	Q4-4-19,21
(5) Turret Mechanic	2.00	2.50	Q5-2-19,21
(6) Vehicle Mechanic	1.84	2.53	Q6-2-23,25

NOTE:

1The statistics were derived from the designated items in Section 4 of the respective Crewmen's Questionnaires and Section 2 of the Mechanic's Questionnaires.

Tank Exterior

Table 8 summarizes the crewmen's ratings of items located on the outside of the tank that were judged to have serious design problems. They include: walking and standing surfaces, front fuel filler caps, locking pins for the skirt panels, sponson boxes, and the rear skirt panels and fenders.

Walking and Standing Surfaces. A preponderant majority of crewmen interviewed felt that the exterior walking and standing surfaces become slippery when wet or muddy. Many expressed concern about the problem which creates a safety hazard that cannot be avoided when executing routine operating tasks.

Front Fuel Filler Caps. These two caps are located on the front of the hull area over which the turret front projects. The overhang blocks the vertical clearance necessary for opening them; the turret must be traversed to gain the needed clearance. The crewmen feel that the problem makes an otherwise simple task unnecessarily time consuming.

Skirt Pins. The side skirt panels are secured by latch pins. Many crewmen interviewed indicated that they have had latch pins vibrate loose during travel. This allows the skirt to swing freely on its hinges, creating a safety hazard.

Sponson Boxes. Turret overhang limits vertical clearance for the sponson boxe The box lids can be opened only part way thus restricting free access to the equipment stored inside. Many crewmen are of the opinion that there is not enough access space available to easily remove and stow equipment in these boxes.

Rear Skirt Panels and Fenders. A number of crewmen pointed out that mud collects under the rear skirts and around the rear sprocket wheel when the tank travels over wet ground. The accumulation soon reaches a point where it damages the skirts and reduces automotive performance. Also, it is a serious maintenance problem because removing the mud frequently requires up to two or three man hours of effort by the crew.

TABLE 8

Ratings and Opinions of Probable Human Engineering Design Problems Related to Exterior Items

Probable Inadequacy	Response Measures Yes Mean	No	Data Source
1. Exterior standing surfaces are slippery when wet	31	9	C5-141
2. Front fuel filler caps are inaccessible	17	3	C6-12
3. Skirt pins vibrate loose unlatching skirts	14	6	C6-30-35
4. Sponson boxes are inaccessible	15	5	C6-38
5. Mud builds up under the rear skirts and fenders	11	9	C6-25

NOTES:

1C5 refers to the Checklist on Environmental Hazards.
2C6 refers to the Checklist on Exterior Item Deficiencies.

Storage Space and Maintenance

The data for problems in the areas of storage space and maintenance are summarized in Table 9. The results indicate that the items judged to have major design problems are inadequate stowage space for personal clothing and equip- ment, food rations, oil and lubricants, and basic issue items. In the area of maintenance, crewmen indicated that no heat resistant gloves and blankets have been provided to enable the crew to work on and near the hot engine. They also feel that the crew should be assigned responsibility for performing the more simple maintenance tasks now assigned to the organizational level mechanics.

Storage Space. The crewmen indicate the tank contains inadequate storage space for many items essential for effective crew performance. Space is especially scarce for personal equipment: uniforms, duffle bags, sleeping bags, carrying cases, and the like. During OT III it was observed that these bags were stowed on the rear area of the turret roof behind the two hatches. This is an unacceptable location from a tactical point of view, because the bags block the commander's and loader's fields of view to the rear of the tank; it thus makes the tank vulnerable to surprise attack from a rearward direction. Unfor- tunately, there is no other place to stow this equipment on the LRIP tanks. Many commanders suggest that a bustle rack similar to the one mounted on the M60 series tanks, should be installed on the back of the turret to provide additional stowage space.

Maintenance. The commanders were of the opinion that the crews are not being assigned appropriate responsibility for maintenance of the tank at the operational level. Many of the more simple tasks that could be performed by the crew are now assigned to the organizational mechanics. Crewmen feel that the present arrangement is inefficient and tends to increase the incidence of maintenance problems, thereby reducing system reliability, availability, and maintainability.

TABLE 9

Ratings and Opinions of Probable Human Engineering Design Problems Related to Storage Space and Operational Maintenance

Probable Inadequacy	Response Measures Yes	Response Measures No	Data Source
	Mean		
1. Storage Space			
A. Storage Space is Inadequate For:			
(1) Duffle bags	17	3	C7-541
(2) Personal equipment	18	2	C7-55
(3) Food rations	12	8	C7-53
(4) CVC helmets	19	1	C7-50
(5) NBC protective masks	6	4	C7-46
(6) Basic issue items	6	4	C7-46
(7) Oil and lubricants	13	7	C7-56
(8) A bustle rack should be installed to increase stowage space	9	1	C6-44
B. Storage Difficulty			
(1) Storage of TA-50 field uniform	-1.44		Q1-4-2-10
(2) Storage of personal equipment	-0.79		Q1-4-2-11
(3) Following loading plan for basic issue items	-0.12		Q1-4-2-11

(Rating Scale: 3 = Extremely easy, 2 = Very easy, 1 = Easy, -1 = Difficult, -2 = Very difficult, -3 = Extremely difficult.)

Probable Inadequacy	Yes	No	Data Source
2. Maintenance			
(1) Crews, rather than mechanics, should perform simple organizational tasks	12	8	C7-38

TABLE 9 (Cont'd)

Ratings and Opinions of Probable Human Engineering Design Problems
Related to Storage Space and Operational Maintenance

Probable Inadequacy	Response Measures Yes Mean	No	Data Source
(2) Heat resistant gloves and blankets are not provided for engine work	20	0	C6-17

NOTE:

1C7 refers to the Checklist on Maintenance and Storage.

Other Probable Inadequacies

The other 61 probable human engineering design inadequacies were judged as having a less detrimental effect on system effectiveness than the critical problems. In this latter group, the severity of effect appears to vary widely from one deficiency to another. Nevertheless, the crewmen judged all of them to be problems that should be corrected. The problems and their data sources are listed in Table 10.

TABLE 10

Ratings of Other Human Engineering Design Problems
Classified as Probable Inadequacies

Probable Inadequacy	Response Measures Yes Mean	No	Data Source
1. Commander's Station			
(1) The hatch frame is not padded to protect commander	8	2	C1-21
(2) The light level in the gunner's primary sight extension is too low	6	4	C1-40

TABLE 10 (Cont'd)

Ratings of Other Human Engineering Design Problems
Classified as Probable Inadequacies

Probable Inadequacy	Response Measures Yes	No	Data Source
3. The Commander's weapon sight cannot be aligned	6	4	C1-44, 47
	Mean -0.65		Q1-1-43
4. The charging cable on the Commander's weapon breaks easily	8	2	C1-48, 74
5. The elevation lock on the Commander's weapon mount vibrates loose	7	3	C1-70, 71
6. The arrangement of the manual traverse ring and Commander's weapon sight is a safety hazard	6	4	C1-73
7. Commanders are exposed to flying surface debris	7	3	C1-75
8. The Commander's master power switch can improperly shut down engine	10	0	C1-80
9. Station storage space is inadequate	6	4	C1-104
<u>Loader's Station</u>			
1. The knee guard does not provide adequate protection	7	3	C2-29
2. The loaders hatch leaks and has other problems	6	4	C2-20-23
3. The station needs another support handle	6	4	C2-26
4. The spentcase ejection guard is a safety hazard	5	5	C2-37
5. It is difficult to load from the floor racks	6	4	C2-52
6. The coax ammo box is too deep	6	4	C2-59-60

TABLE 10 (Cont'd)

Ratings of Other Human Engineering Design Problems Classified as Probable Inadequacies

Probable Inadequacy	Response Measures Yes	Mean No	Data Source
7. The spentcase can on loader's MG is too small	6	2	C2-66
8. The view through the loader's periscope is poor	6	2	C2-73-76
9. The turret blower is noisy and drafty	7	3	C2-79
10. Access to loader's intercom box is difficult	5	5	C2-85
11. The lenses in the NBC protective mask fog up	7	3	C2-86
<u>Gunner's Station</u>			
1. The main gun manual elevation crank is located in a poor position	8	2	C3-13,38
2. The location of the thermal magnification switch is poor	5	5	C3-2
3. Vibration in the gunner's station is intense at slow speeds	6	4	C3-9
4. There is concern that the external sight is poorly protected	6	4	C3-26
5. The muzzle reference reticle is hard to see under nightlight conditions	6	3	C3-36
6. The cord on the manual elevation crank-handle gets entangled when cranking	5	5	C3-39
7. The gunner's intercom box is in a poor location	8	2	C3-56
8. Storage space at gunner's station is inadequate	7	3	C3-59

TABLE 10 (Cont'd)

Ratings of Other Human Engineering Design Problems
Classified as Probable Inadequacies

Probable Inadequacy	Response Measures Yes	No	Data Source
	Mean		
9. Heat distribution in the gunner's station is poor causing discomfort	6	4	C5-4
10. It is difficult to understand communications when blower is running	-0.16		Q3-1-25
11. It is difficult getting in and out of gunner's seat	-0.16		Q3-2-22
<u>Driver's Station</u>			
1. The driver's hatch leaks during rainy weather	7	3	C4-22
2. Hatch frame padding protection is inadequate	5	5	C4-27
3. The driver's master power switch can improperly shut down engine	10	0	C4-41
4. Transferring fuel from front to rear tanks is too slow	6	4	C4-59
5. Storage space in driver's station is inadequate	10	0	C4-75
6. The heater overheats and distribution is poor causing discomfort	5	5	C4-85-86
7. Difficult to understand communications when blower is running	5	5	C4-91
8. Driver's intercom box is in a poor location	6	4	C4-94
9. Drivers should have capability to use the radio	7	4	C1-99 C4-95

TABLE 10 (Cont'd)

Ratings of Other Human Engineering Design Problems
Classified as Probable Inadequacies

Probable Inadequacy	Response Measures Yes	Mean No	Data Source
10. The NBC mask lenses fog up reducing vision	8	2	C4-98
11. The front fenders don't protect driver from flying debris	6	4	C4-100
<u>Tank Exterior</u>			
1. Both sets of front tow hooks should be redesigned	10	0	C6-12
2. The rear grille doors are too fragile	9	1	C6-19,22
3. Roadwheel hub plugs leak when washed down	8	2	C6-28
4. The main gun muzzle cover does not fit properly	7	3	C6-45
5. The windsensor is exposed to damage	9	1	C6-47
6. The transmission needs an excess oil drain plug	7	3	C7-5
<u>Storage Space and Maintenance</u>			
1. Need to install mounts for stowing spare track sections on turret	7	3	C6-48
2. The bracket holding the firing circuit cable obstructs maintenance of main gun	8	2	C7-15
3. The quart scale on the engine oil dipstick has minus (-) symbols missing causing confusion		(Personal Observation)	
4. Many pre-op maintenance tasks are assigned as post-op	6	4	C7-37

TABLE 10 (Cont'd)

Ratings of Other Human Engineering Design Problems
Classified as Probable Inadequacies

Probable Inadequacy	Response Measures Yes	Response Measures No	Data Source
	Mean		
5. An oil spout is needed for oiling road wheels	8	2	C7-6
6. A high-pressure grease gun is needed	8	2	C7-7
7. Two ratchets are required to tighten track connectors	7	3	C7-22
8. A tool set is needed to do field maintenance on suspension	6	4	C7-23
9. A special screwdriver is needed for radios on command tanks	6	4	C7-25
10. Tool bags need to be made more durable	7	3	C7-26
11. A 1-1/2" socket is required	6	4	C7-30
12. A wedge-bolt tool is required	7	3	C7-32
13. An auxiliary engine is required for producing electrical power	8	2	C1-102

Possible Inadequacies

There were also 68 checklist items which over 30 percent of the crewmen judged to be inadequate. This range is greater than the 10 percent one would expect for items presumably designed to accommodate military personnel falling between the fifth and ninety-fifth percentiles. The response distributions indicate that for various reasons some of these items may be marginally inadequate designs that the majority can adapt to and tolerate, but the defects do cause problems for a minority of crewmen; other items may contain latent deficiencies that may emerge as serious problems only under the stress of combat operations; other items may not have significant problems at all. In any case, they need to be investigated further to determine the presence and extent of the deficiencies and whether corrective action is required.

Crew station Temperature Comfort Judgements

Results from the crewmen's comfort judgements are presented in Appendix B. The judgements were made under ambient temperatures ranging from -20o to 20o centigrade. The mean judgements made in both above-zero and below-zero ambient temperatures disclose that the crewmen were relatively comfortable under most tank mode conditions. There are no systematic changes in the mean judgements to indicate that crew comfort was reduced significantly.

Ammunition Loading and Transfer Test

The mean loading performance times were compared in an analysis of variance. A summary of the analysis is given in Table C-1 in Appendix C. The analysis revealed three important effects. The first was that the factor of mobility did not reduce mean loading speed significantly. Loaders loaded as quickly when the tank was moving (at approximately 12 mph) as when it was stationary.

The second effect was a statistically significant interaction between loading task x round loaded, $F(6,54) = 159.35$, $p < .001$. The treatment means and results of multiple comparisons tests for the interaction are presented in Table 11. The mean differences show that loading the first round from the semi-ready rack is much slower than loading from either the ready rack or turret floor rack. This is because the safety panel in front of the semi-ready rack door has to be removed and then the door itself has to be unlocked and opened manually before the first round can be withdrawn. On the other hand, loading subsequent rounds from the semi-ready rack (with the aid of the TC) is virtually as fast as loading from the ready rack. The second relation is that loading speed from the ready rack and semi-ready rack, except for the first round, is approximately twice as fast as loading from the turret floor rack.

Table 11

Table of Mean Loading Times (Seconds)
for the Loading Task x Round Loaded Interaction

	Loading Task (Load from)		
Round Loaded	Ready Rack	Semi-Ready Rack	Turret Floor Rack
First	5.06	29.57	9.94
Second	5.30	5.59 [1]	10.51
Third	5.33	5.42	12.76
Fourth	5.31	5.45	--- [2]

1 Means underscored by the same line are not significantly different
2 Only three rounds are stowed in the turret floor racks

NOTE:

Scheffe critical value for mean differences = 1.37, $p < .01$

The third effect was a statistically significant interaction between loading task x crew uniform, $F(2,18) = 16.05$, $p < .001$. The treatment means and results of multiple comparisons tests for the interaction are presented in Table 12. The mean differences show speed of loading performance when wearing the fatigue uniform compared to loading performance when wearing the NBC protective uniform (protective mask, two-piece overgarment, rubber boots and gloves).

Table 12

Table of Mean Loading Times (Seconds) for the Loading Task x Crew Uniform Interaction

	Uniform	
Loading Task	Fatigues	NBC
Load from Ready Rack	5.26	5.24 1
Load from Semi-Ready Rack	9.97	13.05
Load from Turret Floor Racks	9.22	12.52

1 Means underscored by the same line are not significantly different

NOTE:

Scheffe critical value for mean differences = 1.20, $p < .01$

The comparisons show that when wearing the NBC Uniform loading speed is reduced significantly when loading from either the semi-ready rack or turret floor rack. However, there is no decrease in loading speed when loading from the ready rack. These results are assumed to be due to differences in task difficulty. It is easier to load from the ready rack than the other racks. There is much less bending, turning, lifting and moving involved. Therefore, the NBC uniform is less of a hinderance than it is when loading from the semi-ready rack and turret floor rack.

The results from the analysis of variance of ammunition transfer performance data in Appendix C, Table C-2, showed that the main effect of crew uniform had no influence on performance while the main effect of transfer task was statistically significant, $F(1,9)=16.63$, $p<.003$. The first result indicates that the NBC protective uniform does not reduce performance effectiveness when executing ammunition transfer tasks. Loaders are able to maintain transfer speed in spite of its restrictive characteristics.

The performance differences produced by the effect of transfer task are shown in Table 13. The means show that ammunition can be transferred faster to the ready rack from the hull storage compartment than from the semi-ready rack. The reason for the difference appears to be due to the need

Table 13

Table of Mean Main Gun Ammunition Transfer Times (Seconds) for the Transfer Task Main Effect

Transferring Four Rounds From:	
Hull Storage to Ready Rack	Semi-Ready Rack to Ready Rack
53.76 seconds	78.61 seconds

to open and close the ballistic doors when transferring rounds from the semi- ready rack. The procedure is rather complicated. First, the safety panel in front of the semi-ready rack door has to be removed. Then the semi-ready rack door has to be opened manually while the ready rack door remains closed. The rounds can then be withdrawn and placed on the turret floor. Next, the semi- ready rack door must be closed manually and the ready rack door opened. Finally, the rounds can be inserted in the ready rack.

SUMMARY AND IMPLICATIONS

This research identified a substantial number of human factors problems on the LRIP M1 Tanks during OT III. Many of these have important implications for future development of the M1 system as it continues to evolve throughout its life cycle.

Several probable inadequacies were identified that inhibit operator performance to the extent that they may reduce system capability to achieve mission ojectives. Ultimately, these problems will have to be solved before the system can attain its full potential.

Tank Commander's Station

The most important function of the tank commander in combat is to detect targets and perform the initial phase of the target acquisition process. He frequently makes the initial lay of the main gun bringing the target into the gunner's sight picture. It is crucial to the outcome of tank duels that this task is executed as quickly and accurately as possible; the goal is to shoot first and hit with the first round. The tank that can acquire and shoot the fastest will probably win. Furthermore, the Army will find it necessary to employ the M1 against superior numbers of enemy tanks. This situation requires engaging multiple targets in rapid succession which puts even greater emphasis on fast target acquisition speed. Yet in the LRIP M1 the devices used to perform the target acquisition task have been poorly positioned. In their present arrangement they needlessly complicate the task and seriously inhibit performance speed and accuracy. Mission success may be jeopardized by this poor design configuration. Also, the controls for the commanders weapon have been designed poorly and many commanders feel they are unable to use them effectively. This inadequate design significantly reduces the firepower of the secondary armament. It makes the tank more vulnerable to attack from dismounted infantry, lightly armored vehicles, and helicopters at ranges between 1 and 2 kilometers.

Loader's Station

Lack of workspace is a fundamental design problem in the loaders station. In the M1 series turret which mounts the M68 105mm gun workspace is barely adequate to accommodate loading 105mm ammunition. The problem will be increased when the 120mm gun is mounted in the M1E1 series turret. Presumably, the ammunition for the larger gun will also be larger requiring even more workspace for the loading task than is presently available. If the breech of the 120mm gun is larger than the one for the 105mm gun, workspace will actually be reduced from its present volume, further exacerbating the problem.

Driver's Station

Inadequate design of the driver's seat and misalignment of the driver's periscopes are two problems whose compound effects work to inhibit driver performance. They reduce the capability of the M1 to operate safely and effectively for extended periods during continuous operations.

Stowage Space

Exterior stowage space is inadequate. As a result, clothing and equipment is stowed in areas where they interfere with the conduct of tasks essential to the security and effectiveness of the tank.

Safety Hazards

The commanders, loaders, and gunners stations include design arrangements that can cause injury to the operators, producing reductions in system effectiveness. Specific problems were identified and discussed previously in the crewstation sections in the Results chapter.

Human Engineering Design

Human engineering design configurations for the crew stations can be described as basically acceptable for the gunners, loaders and drivers stations, although they contain problems with individual components as noted, but basically deficient for the commander's station. Corrections here will probably require a total redesign of the commander's weapon station and main gun controls and displays.

REFERENCES

Development Test II (PQT-G), Desert Phase of XM1 Tank System (U). YPG Report 363, US Army Test and Evaluation Command, January 1979.

FSED Reliability Test: User Concerns, Logistics and HFE Comments. Test and Analysis Division, Armor-Engineer Board, Fort Knox, KY. 13 September 1979.

Independent Evaluation of the M1 Main Battle Tank (U). Report: IER-OT-058, US Army Operational Test and Evaluation Agency, November 1981 (C).

New Army Battle Tank Operational Test II Test Report (U) (FTR for XM1 OT II [U]). Report: FTR-OT-049, US Army Operational Test and Evaluation Agency, March 1979.

New Army Battle Tank (XM1) Operational Test III (OT 058 [U]). Test Report OT 058A (C), TRADOC Combined Arms Test Activity, August 1981.

Prototype Qualification Test - Government (PQT-G) of XM1 Tank System (Temperate Climate Phase) (U), Volume 1, Partial Report TECOM Porject No. 1-VC-080-001-023, US Army Test and Evaluation Command, February 1979.