

Research Report 1335

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HUMAN FACTORS EVALUATION OF THE PATRIOT AIR DEFENSE MISSILE SYSTEM DURING OPERATIONAL TEST II

Richard J. Carter and John M. Lockhart

ARI FIELD UNIT AT FORT BLISS, TEXAS

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Each subsystem/component had human factors problems. The primary concerns, however, dealt with software, troop proficiency trainer programs, draft equipment publications, missile reload, the environment within the engagement control station and the information and coordination central, and maintenance.

The results of the evaluation were used by the Army Systems Acquisition Review Council and the Defense Systems Acquisition Review Council as part of the information on which the decision for the PATRIOT system to enter production was based.

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**HUMAN FACTORS EVALUATION OF THE PATRIOT
AIR DEFENSE MISSILE SYSTEM
DURING OPERATIONAL TEST II**

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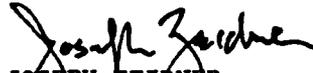
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FOREWORD

The Fort Bliss Field Unit of the Army Research Institute for the Behavioral and Social Sciences executes human performance research under Army Project 2Q162722A791 and provides technical advisory service to agencies in support of air defense systems. This report is responsive to a request by the Army Operational Test and Evaluation Agency for technical assistance during operational test II of the PATRIOT air defense missile system.

The objective of the research was to determine whether the human operator/repairman, support, and other personnel can perform all of the tasks which are required to accomplish the mission objectives of PATRIOT system and to identify man-machine interfaces which might impair performance.


JOSEPH ZEIDNER
Technical Director



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HUMAN FACTORS EVALUATION OF THE PATRIOT
AIR DEFENSE MISSILE SYSTEM DURING OPERATIONAL TEST II

BRIEF

Requirement:

To evaluate the PATRIOT air defense missile system during operational test II for human factors considerations.

Procedure:

Three questionnaires addressing specific test issues were completed by eighty-five male service members. Thirteen checklists, covering procedures for missile reload, march order, and emplacement, were completed by eight data collectors. Two interviews were held with selected test participants. The objective of one interview was to determine whether problems existed with the troop proficiency trainer programs. The objective of the second interview was to identify potential human factors concerns with maintenance operations and procedures.

Findings:

Each subsystem/component had human factors problems. The primary concerns, however, dealt with software, troop proficiency trainer programs, draft equipment publications, missile reload, the environment within the engagement control station and the information and coordination central, and maintenance.

Utilization of Findings:

The findings from the human factors evaluation were incorporated into the operational test report and utilized in the independent evaluation of the PATRIOT system prepared by the Army Operational Test and Evaluation Agency. The findings were used by the Army Systems Acquisition Review Council and the Defense Systems Acquisition Review Council as part of the information on which the production decision for the PATRIOT was based.

HUMAN FACTORS EVALUATION OF THE PARTIOT AIR DEFENSE
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HUMAN FACTORS EVALUATION OF THE PATRIOT AIR
DEFENSE MISSILE SYSTEM DURING OPERATIONAL TEST II

INTRODUCTION

PATRIOT Air Defense Missile System

A new air defense missile system, PATRIOT, is being developed by the US Army under contract to Raytheon Company. It will replace the Nike-Hercules system and some Improved HAWK missions. The PATRIOT consists of three major subsystems, namely, fire units (FU), an information and coordination central (ICC), and communications relay sets (CRS). Each fire unit is composed of five specific components. They are:

1. Engagement control station (ECS).
2. Radar set (RS).
3. Electrical power plant (EPP).
4. Launching station (LS).
5. Guided missile (GM).

Communications between FUs, the ICC, and CRSs are enhanced by antenna mast sets (AMS).

The ECS is the operational control center of the PATRIOT platoon. It provides the equipment and facilities to accomplish data processing, display and control, and communication functions and is mounted on an M814 five-ton truck.

The PATRIOT RS is a multifunction phased array radar set on an XM860 trailer and towed by an M818 tractor. It supports the functions of: search, missile acquisition, track, and guidance, electronic countermeasures (ECM) sensing, target illumination and tracking, and identification friend or foe (IFF).

The EPP provides the power for the operation of all the RS and ECS equipment. It consists of two 150kw gas turbine generators and ancillary equipment arranged on an M814 five-ton truck.

The LS is mounted on an XM860 semitrailer which is towed by an M818 tractor. It serves as the transporter and launch platform for up to four ready missiles. The LS points the missiles with its azimuth and elevation systems. It is remotely operated and controlled by the ECS using digital data link.

The PATRIOT GM consists of a missile assembled within a canister that serves as both a shipping and storage container and a launch tube. It is propelled by a single stage, solid propellant, nonseparable booster rocket motor. The warhead is a blast fragmentation sidespray type.

The ICC is the PATRIOT battalion control center for the performance of the assigned air defense mission. It monitors the communications networks

and exercises direct control and supervision of the air battle. The ICC provides the interface between the battalion and higher echelons.

The CRS is a communications equipment entity that enables non-line-of-sight deployment between the ICC and ECS. It extends the operating range and permits performance by the data and voice radio circuits under conditions where distance, terrain, or countermeasures environment require their use.

Field manual 44-15 (1979) furnishes a more detailed description of the missile system and its deployment.

Operational Test II

An operational test was conducted on the PATRIOT air defense system by the US Army Operational Test and Evaluation Agency (OTEA). It was performed during the period October 1979 to January 1980 at White Sands Missile Range, New Mexico and Ft Bliss, Texas and was divided into four phases: (1) tactical effectiveness evaluation (TEE), (2) nonfire search/track, (3) nonfire maneuver, and (4) live fire.

The test evaluated:

1. The capability of the PATRIOT battalion to engage and destroy hostile targets in an operational environment.
2. The interoperability of PATRIOT with the AN/TSQ-73 group operations center.
3. The survivability of the PATRIOT system.
4. The capability of the PATRIOT FU and ICC to march order, road march, and emplace under operational conditions.
5. The proposed personnel training package to include the troop proficiency trainer (TPT) programs.
6. The proposed organization to support the PATRIOT battalion during 24 hour operations.
7. The reliability, availability, and maintainability under tactical operational conditions.
8. The proposed logistical support concept.

The test was conducted under: (1) two visibility conditions: day and night; (2) two environments: normal and nuclear, biological, and chemical (NBC); (3) two engagement modes: automatic and semi-automatic; and (4) four methods of control: centralized, decentralized, independent, and autonomous. A complete test plan is provided by Arnold (1979).

The Army Research Institute for the Behavioral and Social Sciences (ARI) was requested by OTEA to conduct a human factors evaluation of the PATRIOT system during the operational test. The purpose of the evaluation was to determine whether the human operator/repairman, support, and other personnel can perform all required tasks to accomplish the mission objectives of the PATRIOT system and to identify areas within the man-machine interface which might impair performance.

METHOD

Subjects

Eighty-five male service members (71 E2-E6, 12 O1-O3, and 2 W01-W02) stationed at Ft Bliss, Texas and White Sands Missile Range, New Mexico participated in the operational test. They were from both the 4th Battalion (Nike-Hercules), 62nd Air Defense Artillery and the US Army Material Test and Evaluation Directorate. The personnel were assigned either to one of two fire units (FU4 and FU5), the ICC, three AMSs, or a maintenance team. Eighteen crew members, 8 lieutenants and 10 enlisted, were allotted to the two ESCs. The two LSs and two EPPs had 12 and 8 enlisted personnel respectively. Eighteen service members, 4 captains and 14 enlisted, were assigned to the ICC, while the AMSs had three enlisted personnel each. The maintenance team consisted of 20 crew members, 2 warrant officers and 18 enlisted.

Prior to the test, each participant received new equipment training (NET) from the missile system contractor. The training included: launcher and fire control operations, crew actions, air defense mission, initialization, and operator and organization maintenance procedures.

Apparatus

Three questionnaires were used during the evaluation. Each contained both open and closed-ended items (Dyer, Matthews, Wright, and Yudowitch, 1976) and addressed specific test issues. Table 1 shows the issues covered in each questionnaire. Questionnaire #1 also incorporated questions concerning the TPT programs and equipment design and physical comfort, while questionnaire #3 also had items oriented towards obtaining overall PATRIOT comparison ratings.

Thirteen checklists were utilized in the human factors evaluation. They were composed of lists of march order, emplacement, and missile reload procedures, as detailed in the 1979 draft equipment publications (DEP) for the display and control group, ECS, LS, RS, and digital data communications set. Each procedure was followed by five criteria, namely, done poorly, not done, done fast, done adequately, and done slow, and by space for comments. A page from one of the checklists is displayed in Figure 1. The checklists were tried out during a two-week pretest which took place just prior to the start of the operational test.

Two interviews were conducted during the test. The first had the objective of determining whether problems existed with the TPT tapes; the other was directed at identifying potential human factors concerns with maintenance operations and procedures. Both interviews were semi-structured, using key questions as initiators, and took form as they proceeded.

Meister's human factors manual (1978) was used as a guideline in the construction of the test plan, questionnaires, checklists, and interviews.

Table 1
Test Issues in the Questionnaires

| Test Issue | Questionnaires | | |
|---|----------------|---|---|
| | 1 | 2 | 3 |
| Track Initiation/Maintenance | | X | |
| Identification | X | X | X |
| Eligibility for Engagement | X | X | |
| Missile Round Interface | | | X |
| ECM | | X | |
| Interface of the ECS with the LS, RS, Power Sources, and Communications | | X | X |
| ICC-FU Interface | | X | X |
| Operator Interface/Employment Doctrine/Firing Doctrine/Tactical Standard Operating Procedures | X | X | X |
| Reinitialization, Saturation Alleviation, Sector Reorientation | X | X | X |
| Interface of PATRIOT ICC with the AN/TSQ-73 | | | X |
| Self-Defense | X | X | |
| Battlefield Signature | | | X |
| Nuclear, Biological, and Chemical | | | X |
| March Order | | | X |
| Road March | | | X |
| Emplacement | | | X |
| Organization | | | X |
| Adequacy of the Maintenance Aids to Support the Maintenance Concept | | | X |
| Impact of the Maintenance Concept on Personnel Requirements | | | X |

Note. X means that the test issue was addressed in the questionnaire.

| DATE | TIME | WEATHER CONDITIONS | DATA COLLECTOR | | | | COMMENTS | |
|------|------|--|----------------|----------|------|------|----------|------|
| | | | POORLY | NOT DONE | FAST | ADEQ | | SLOW |
| | | MISSILE RELOAD PROCEDURES | | | | | | |
| | | CREWMAN # 2 CONTD | | | | | | |
| | | 10. ASSIST CREWMAN #1 IN ALIGNING AND LOADING CANISTER ON LAUNCHER | | | | | | |
| | | 11. CONNECT GROUND CABLES AND TORQUE INSIDE TIE-DOWNS | | | | | | |
| | | 12. ASSIST CREWMAN #1 IN REMOVING SLING | | | | | | |
| | | 13. REPEAT UNTIL ALL FOUR CANISTERS ARE LOADED ONTO LAUNCHER | | | | | | |
| | | 14. REMOVE MRCTS AND TEST ALL FOUR CANISTERS | | | | | | |
| | | 15. TIGHTEN AND TORQUE REMAINING CANISTER TIE-DOWNS | | | | | | |
| | | 16. ASSIST IN LOADING OFF-LOADED CANISTERS ONTO GMT | | | | | | |
| | | 17. TIGHTEN AND TORQUE TIE-DOWNS ON GMT | | | | | | |
| | | 18. RAISE AND STOW WRECKER ROADSIDE OUTRIGGERS | | | | | | |

Figure 1. A page from one of the checklists.

Procedure

The questionnaires were administered to all service members during three sessions of approximately one-hour each. Questionnaire #1 was completed at the end of the TEE (Phase 1). The participants received questionnaire #2 at the conclusion of the nonfire search/track phase (2). Questionnaire #3 items were answered at the termination of the live fire part of the test (Phase 4). Instructions that were provided to the service members during each session are included in the Appendix.

The thirteen checklists were used during the entire maneuver phase. They were filled in by two teams of four data collectors each. One team monitored the day operations; the other the night. Each team observed either two or three components during a specific march order or emplacement. The data collectors were responsible for evaluating two crew members each during the selected maneuvers. They marked one of the five criteria and made comments, as appropriate, as each procedure was accomplished. Table 2 details the number of checklists which were completed.

There were eight data collectors. Two were researchers from the ARI Ft Bliss Field Unit. The remaining six were service members from the 4th Battalion, 62nd Air defense Artillery, had received NET, and were PATRIOT LS crewmen for six-months during developmental testing. They were assigned to ARI for a period of nine-months, part of which was spent becoming familiar with human factors engineering and systems evaluation.

The interviews were semi-structured and individualized. The interview dealing with the TPT programs took place after the TEE was concluded; the maintenance interview was conducted at the end of the operational test. One second-lieutenant was queried about the ECS TPT tapes, while one captain was asked about the ICC TPT programs. The maintenance interviews were held with the two warrant officers. Each interview session lasted approximately one-half hour. The service member's responses were recorded by an interviewer (one of the two researchers).

Table 2
The Number of Checklists Completed

| Checklist | Total | Fire Units | |
|-----------------|-------|------------|----|
| | | 4 | 5 |
| Missile Reload | 11 | 5 | 6 |
| ECS March Order | 17 | 7 | 10 |
| ECS Emplacement | 19 | 7 | 12 |
| RS March Order | 17 | 7 | 10 |
| RS Emplacement | 19 | 7 | 12 |
| LS March Order | 15 | 6 | 9 |
| LS Emplacement | 16 | 6 | 10 |
| EPP March Order | 1 | 0 | 1 |
| EPP Emplacement | 2 | 0 | 2 |
| AMS March Order | 1 | | |
| AMS Emplacement | 1 | | |
| ICC March Order | 5 | | |
| ICC Emplacement | 7 | | |

RESULTS

Tactical Effectiveness Evaluation

Questionnaire

Closed-ended questions. Means and standard deviations were calculated for the closed-ended items in questionnaire #1. Findings from the data provided by the ECS and ICC personnel are presented below.

Table 3 shows the computed values for the test issue questions. Only one of the items, (Sensitivity or Effectiveness of Current Threshold Values in the Automatic Identification Mode Relating to Hostile Aircraft Still Designated "Unknown" at the Ordnance Release Point), was rated below 1.5 (Fair). It received the rating from the ICC crewmen.

Table 4 exhibits the means and standard deviations for the equipment design and physical comfort questions. ECS members rated the item, "Extent to Which You Are Bothered or Irritated by the Overall Noise in the Van", between 0.0 and 1.5 (Poor to fair).

Mean and standard deviation values for the four TPT software programs closed-ended questions are displayed in Table 5. All of the items were rated poor to fair by the ICC personnel. "How You Feel About the TPT Tape" was also rated below fair by the ECS crewmen.

Open-ended questions. Answers and comments from the ECS and ICC personnel to the open-ended questions in questionnaire #1 were evaluated, summarized, and then grouped by category. The categories were TPT tapes, display and control console, control keyboard assembly, and internal environment.

The TPT tapes were not programmed correctly. Many errors and problems were identified. They included the signaling of wrong targets as being hooked, alert messages remaining on the screen, and slow presentation of pop-up targets. The tapes developed for use with the ICC could only be used in the automatic mode, while the ECS tapes could be used only in semi-automatic mode. Crewmen stated that the tapes could not be utilized for training console operators and as an evaluative or diagnostic tool. They also reported that the firing doctrine had not been correctly incorporated into the TPT tapes. The service members were not provided with guidelines regarding the use and function of the tapes and taught how to use them for training.

Most of the buttons on the ICC display and control console did not function properly. Specifically the IFF, track amplitude data, and send tab controls were non-operational. The IFF push button on the ECS console also did not work correctly. ECS crewmen said that the send pointer, sequential hook, numerical hook, and cancel hook buttons were positioned too close together.

The service members reported that the keyboard assemblies on both the ICC and ECS consoles were too sensitive and very inaccurate. They also stated that the keyboard lettering was very hard to read.

The environments within the ECS and ICC were less than desirable. The

Table 3

Means and Standard Deviations for
Test Issue Questions From Questionnaire #1

| Question | Subsystems | | | |
|---|------------|--------------------|------|--------------------|
| | ECS | | ICC | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Usefulness and Adequacy of "Operator Delay Time" During the Automatic Mode of Engagement | 2.6 | 0.84 | 1.6 | 1.70 |
| Sensitivity or Effectiveness of Current Threshold Values in the Automatic Identification Mode Relating to Hostile Aircraft Still Designated "Unknown" at the Ordnance Release Point | 2.3 | 1.25 | 1.2 | 0.91 |
| Effectiveness of "Friendly Protect" Features of PATRIOT | 3.2 | 0.69 | 2.4 | 1.11 |
| Effectiveness of the Rules for Engagement of Targets as Specified in the Tactical Standard Operating Procedures | 3.1 | 0.81 | 2.4 | 1.31 |
| Quality of the Coordination/Interface Between the Two Operators at the ECS and ICC | 2.7 | 0.97 | 3.0 | 1.53 |
| How Well the Crew Performed the Required Antiradiation Missile Alerts/Attacks Actions Specified in the Tactical Standard Operating Procedures | 2.1 | 1.37 | 2.1 | 1.36 |
| Effectiveness of Saturation Alleviation Procedures on the Engagement Capability of PATRIOT | 2.8 | 1.13 | 1.6 | 1.72 |

Note: For Means:
4.5 = Excellent
3.0 = Good
1.5 = Fair
0.0 = Poor

Table 4

Means and Standard Deviations for
Equipment Design and Physical Comfort Questions

| Question | Subsystems | | | |
|---|------------|--------------------|------|--------------------|
| | ECS | | ICC | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Quality of the Indicators on the Display Console | 3.4 | 0.89 | 3.1 | 0.84 |
| Ease of Use of the Controls on the Control Console | 3.6 | 0.78 | 3.5 | 0.56 |
| Symbol to Background Contrast | 3.5 | 0.68 | 3.4 | 0.42 |
| Distinctly Different Symbols | 3.6 | 0.58 | 3.5 | 0.46 |
| Symbols Discriminable When Overlaid or Bunched | 2.2 | 0.62 | 1.7 | 1.37 |
| Symbols Large and Easily Seen | 3.3 | 0.51 | 3.3 | 0.52 |
| Velocity Vectors Readily Interpretable | 3.0 | 0.96 | 2.2 | 1.40 |
| Symbol Meaning Not Confused with Other System Symbols | 3.5 | 0.61 | 3.3 | 0.74 |
| Track Numbers Discriminable | 2.9 | 1.00 | 2.6 | 1.21 |
| Accessibility of the Keys on the Keyboard | 3.2 | 0.78 | 3.6 | 0.46 |
| Quality of Your Working Environment | 2.5 | 1.08 | 2.4 | 1.08 |
| Extent to Which You Are Bothered or Irritated by the Overall Noise in the Van | 1.3 | 0.97 | 1.8 | 0.85 |
| All Things Considered, How Were Your Working Conditions in the Van | 2.5 | 1.12 | 2.9 | 0.66 |

Note: For Means:

- 4.5 = Excellent
- 3.0 = Good
- 1.5 = Fair
- 0.0 = Poor

Table 5
Means and Standard Deviations for
Troop Proficiency Trainer Questions

| Question | Subsystems | | | |
|--|------------|--------------------|------|--------------------|
| | ECS | | ICC | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Value of the TPT in Maintaining Operator Efficiency | 2.7 | 1.18 | 1.5 | 0.93 |
| Realism of the TPT Tape | 2.4 | 1.04 | 1.5 | 0.93 |
| Value of the TPT Tape to You in Practicing the Making of Air Defense Decisions | 2.4 | 1.11 | 1.4 | 0.70 |
| How You Feel About the TPT Tape | 2.2 | 1.13 | 1.4 | 0.97 |

Note: For Means:
5.0 = Excellent
3.6 = Good
2.3 = Fair
1.0 = Poor

temperature could not be regulated because the heaters were incorrectly positioned. The crewmen would like to see the vent to the right of man-station (MS) #1 removed. There is not enough room for the stowage of personnel and field gear. The space provided for writing was too small.

Interview

ECS crewman. The second-lieutenant said that the TPT tapes became boring with repeated use. He indicated that the tapes lacked realism in that: (1) there was no ECM; (2) none of the hostiles had either air-to-surface or antiradiation missiles; and (3) there were no indications of successful enemy attacks on the FU or assets. The scoring of the TPT tapes was judged as confusing. Operators were able also to obtain high scores by doing other than the desired procedures. It was also not clear to the interviewee as to whether a high score necessarily reflected good performance every time. He reported that the TPT tapes "bombed" quite a lot. The crewman believed that there were difficulties with IFF against hostiles.

ICC crewman. The captain stated that the tape ran for 43 minutes and appeared to have only one heavy-load of targets. He said that there was no FU communication, no audio, and no integration simulated on the tape. The interviewee reported that, after he had hooked and pressed the track amplitude data (TAD) button, the TAD file was empty except for one row of seemingly irrelevant data at the top. He said that there were never any data in the "to be engaged queue" (TBEQ). The interviewee judged the TPT tape to have no intermediate level training value.

Nonfire Search/Track

Questionnaire

Closed-ended questions. Means and standard deviations were derived for the closed-ended items in questionnaire #2. Results from the ECS and ICC personnel are presented in Table 6.

Open-ended questions. Answers and comments to the open-ended questions in questionnaire #2 were oriented toward problems identified with either the ECS or ICC. The information provided by the ECS and ICC personnel are summarized below.

The data in the TBEQ at both the ECS and ICC were not accurate. Too many of the targets presented on the cathode ray tubes (CRT) were false targets. ECS and ICC crewmen reported that the automatic identification and IFF functions did not work properly. Many times unknowns and friendlies were not changed to hostile symbols after the aircraft had committed hostile acts. Personnel from both the ECS and ICC stated that the tactical standard operating procedures were not well defined. They were quite general in nature and did not provide guidance to cover the entire PATRIOT system.

MS#3 panels in the ICC were nonoperational. The battalion status panel was only partially operational. Indicators for the status of the firing platoon, missile rounds, missile count, and defense readiness condition did not function properly. The automatic mode of engagement was also nonoperational. ICC crewmen reported that the communications and equipment lights did not always reflect the situations at the FUs, and the targets on the CRT were not always the same as shown at the ECSs. The jammer correlation tab did not work, and the information presented in track amplitude data was erroneous.

The routing logic/radio interface unit (RL/RIU) at the ECSs was unreliable and worked only about 10% of the time. Incorrect missile data were presented at the ECSs. ECS personnel stated that a high level of target information on the CRT caused the display to disappear. They reported that their headsets hindered communication between operators.

Table 6

Means and Standard Deviations for Questions From Questionnaire #2

| Question | Subsystems | | | |
|--|------------|--------------------|------|--------------------|
| | ECS | | ICC | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Level of Difficulties Encountered in Conducting the Air Battle When Deceptive Jammers Were Employed | 3.4 | 0.75 | 3.1 | 1.58 |
| Disruptive Effect on Operational Effectiveness of the PATRIOT Battalion and the Interface with the AN/TSQ-73 of Making Communication Key Changes to the KG-27, KY-57, KY-30, and TPX-46 Security Devices | 3.1 | 1.26 | 2.9 | 1.54 |
| Usefulness and Adequacy of "Operator Delay Time" During the Automatic Mode of Engagement | 2.4 | 1.00 | 2.5 | 1.04 |
| Sensitivity or Effectiveness of Current Threshold Values in the Automatic Identification Mode Relating to Hostile Aircraft Still Designated "Unknown" at the Ordnance Release Point | 2.3 | 0.75 | 1.7 | 1.04 |
| Effectiveness of "Friendly Protect" Features of PATRIOT | 3.1 | 0.85 | 2.2 | 1.49 |
| Number of Instances Where Operators Were Required to Assist the System in Resolving Range on Nondeceptive Jammers | 2.8 | 1.24 | 3.8 | 1.52 |
| Level of Difficulty in Conducting the Air Battle When Chaff Was Employed | 3.7 | 0.87 | 3.5 | 1.13 |
| Level of Difficulty in Maintaining the Tracks When Chaff Was Employed | 3.6 | 1.02 | 3.8 | 0.94 |

Table 6(Continued)

Means and Standard Deviations for Questions From Questionnaire #2

| Question | Subsystems | | | |
|--|------------|--------------------|------|--------------------|
| | ECS | | ICC | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Effect of Jamming the VHF Data Links on the Conduct of the Air Battle | 3.8 | 0.59 | 3.9 | 0.66 |
| Seriousness of System Operational Problems Associated with the Use of Communications Equipment Particularly When the Operator Is Heavily Loaded | 2.6 | 1.20 | 2.0 | 1.76 |
| Level of Difficulty Encountered by the ICC Operator in Maintaining Ground Situation Data | | | 3.5 | 1.18 |
| Level of Difficulty Encountered by the ICC Operator in Maintaining Battalion Status Data | | | 3.3 | 1.52 |
| How Frequently the ICC Operator Had Problems in Threat Evaluation and Ordering of Targets on a Battalion Wide Basis Using FU Data, But with Different FU Evaluations and Orderings | | | 3.2 | 1.06 |
| How Successful Do You Think the Current Employment Doctrine Is for PATRIOT | 2.0 | 0.82 | 1.7 | 1.24 |
| Effectiveness of the Rules for Engagement of Targets as Specified in the Tactical Standard Operating Procedures | 2.5 | 0.86 | 2.0 | 1.34 |
| Quality of the Coordination/Interface Between the Two Operators at the FU and ICC | 2.7 | 0.99 | 2.6 | 1.39 |

Table 6(Continued)

Means and Standard Deviations for Questions From Questionnaire #2

| Question | Subsystems | | | |
|---|------------|--------------------|------|--------------------|
| | ECS | | ICC | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| How Well the Crew Performed the Required Antiradiation Alerts/Attacks Actions Specified in the Tactical Standard Operating Procedures | 3.2 | 1.03 | 3.0 | 0.72 |
| Effectiveness of Saturation Alleviation Procedures on the Engagement Capability of PATRIOT | 2.6 | 1.02 | 1.8 | 1.41 |

Note: For Means:
 4.5 = Excellent
 3.0 = Good
 1.5 = Fair
 0.0 = Poor

Nonfire Manuever

Checklists

Human factors concerns identified during the maneuver phase by the eight data collectors are detailed below by subsystem/component/procedure.

Engagement control station. The data link terminal (DLT) antenna latch knob and ground strap were hard to unscrew and attach with gloved hands. The DLT antenna smaller tube became easily stuck, especially when wet, within the larger tube when it was being extended. Many difficulties were encountered when the DLT antenna was being aligned with the red markings after it had been telescoped. Personnel did not know when to stop depressing the retract/extend switch when they were raising the DLT antenna. Also the switch was labeled incorrectly in relationship to the action taken by the mast.

The EPP power control and prime power cable connectors were hard to connect to and disconnect from the ECS. Also the connectors on the ECS shelter for the AMS cables were poorly placed and were too close together. Problems were encountered with the removal of the tailgate hooks. The pins at the bottom of the DLT antenna platform were hard to connect.

The safety chains on the front curbside platform were too low. The shelter air vent covers would not stay open. As a result, foreign objects were used to keep them open. The rear door could not be fully closed because field wire was in the way. The strings on the whip antennas were too short and could not be secured when the antennas were extended.

The door handles on the inside of the ECS were difficult and slow to operate due to the design of the latches. The chairs at MS#1 and MS#3 could not be stowed because the latches were stripped. There were too many fasteners on the voice commo equipment door, DLT access equipment covers, and panels underneath MS#1 and MS#3 that needed to be tightened or removed in order to gain access to or stowage of equipment. There was not enough stowage room within the ECS for NBC/field gear and manuals.

Information and control central. The prime power cable was stowed in the front of the truck bed. Since no reel was provided, the cable became quite easily tangled and hard to unstow. The prime power cable connectors were hard to connect and to disconnect from the ICC.

The same problems as identified with the engagement control station were encountered with the ICC in regard to the connectors for the AMS cables, tailgate hooks, shelter air vents, chairs at MS#1 and MS#3, stowage room for NBC/field gear and manuals, inside door handles, and fasteners on the voice commo equipment door and on the panels underneath MS#1 and MS#3.

Radar set. At night, the driver could not see the king pin of the shelter when he was backing the tractor to the RS because of poor illumination and blockage by the spare tire. The fifth wheel lock plunger lever at the tractor rear platform was hard to swing forward when crewmen tried to release the king pin. A pipe extension had to be used. Two people were needed to install

the cover over the king pin access hole.

Opening of the environment cover vent on the front curbside while wearing gloves was hard to almost impossible. The front curbside utility bay door had nothing to hold it open.

The ECS power cable connectors were hard to connect to and disconnect from the RS. The slave cable from the RS to the tractor was also extremely hard to connect and disconnect. Problems were encountered with the threading of the dust cover caps to the power and control cable. The ground wire was hard to connect due to the bad location of the receptacle (under the van on the chassis) and poor design. A wrench had to be used to perform the task.

The whole front of the shelter had to be opened in order to gain access to the circuit breakers. The status control lights could not be read when direct sunlight hit them. Use of the M-2 aiming circle was difficult and slow at best. Under night blackout conditions it was impossible. The procedures to change tires in the field were difficult and hazardous. It was difficult to do the outrigger leveling task at night while wearing the NBC mask.

The same problems as identified with the engagement control station were encountered with the RS in regard to the EPP prime power cable connectors and the shelter air vents.

Launching station. It was extremely hard to connect the launcher electronics module grounding cable to the upper mast connector while wearing gloves. There were too many fasteners on the data link terminal module (DLTM) access panel that needed to be removed in order to obtain access to the code cards. The locking pin on the DLTM was also hard to insert. The latch on the roadside fender work platform was hard to operate because of its location. The light emitting diode displays on the launcher control unit display could not be read when direct sunlight hit them.

The same problems as identified with the radar set were encountered with the LS in regard to the king pin, fifth wheel lock plunger lever, the king pin access hole cover, slave cable, M-2 aiming circle, and the procedures to change tires.

Electrical power plant. It was hard to connect the fuel trailer hoses to the EPP. The grounding cables could not be connected without the use of tools. A ratchet wrench was used. Insertion of the lock pins on the inside of the front rack assembly and of the rear retaining pins was difficult. The EPP curbside platforms at times became binded when they were raised and secured.

Antenna mast set. The guy and antenna control cables became tangled easily. The truck bed did not have enough room for the crewmen to work, and was quite cluttered. The antenna disc was oriented by pushing a button inside either the ICC or ECS. This was a blind task because the individual could not see the disc move. The antenna mast had many protruding bolts. An individual's clothing often got caught on them.

Missile reload. The tie-down bolts were easily stripped and as a result could not be tightened or torqued. The canisters were difficult to steady

with the tag line procedures. They were extremely difficult to align and load on the launcher and the guided missile transporter (GMT). The handles on the back of the canisters were too small and poorly positioned for safe use. The shackle bolt on the hoist beam was hard to remove when changing from the load to empty position. It was difficult to stow the hoist beam on the GMT due to the lack of work space.

Questionnaire

Closed-ended questions. Means and standard deviations were computed for the closed-ended items in questionnaire #3 which pertained to the nonfire maneuver phase of the test.

Table 7 shows the calculated values for the nonfire maneuver questions. The means and standard deviations for two LS reload items were based on the ratings provided by those personnel who had participated in missile reload. The values for the question, "Quality of the Data Which Was Used to Initialize the FU," were derived from the data generated by the ECS service members only. One of the items, "Level of Difficulty of LS Reload with NBC Protective Gear," was rated between poor and fair. It was assigned the rating by the officers.

Open-ended questions. Comments and answers to the nonfire maneuver closed-ended items in questionnaire #3 were abridged. They fell into three areas, namely: NBC environment, safety hazards, and initialization and integration.

The LS crewmen reported that missile reload was more unwieldy and time consuming while NBC gear was worn. They stated that the mask reduced their visibility. They said that it was hard to see the ground guide from the wrecker's position and problems were encountered while climbing on and off the missile canisters. The missile reload personnel reported that the NBC gloves made many tasks cumbersome. They said that it was difficult to unfasten the tie-down bolts and hard to align the guidepins on the missile round canisters and connect the hoisting beam to the canisters. The LS crewmen stated that they had problems communicating and a tanker style gas mask was needed for the wrecker operator when missile reload took place in an NBC environment.

Other tasks that were difficult to almost impossible to perform while wearing NBC gear included:

1. Turning knobs and setting dials.
2. Using the M-2 aiming circle.
3. Attaching the dust covers on the LS DLTM.
4. Raising the DLT antenna.
5. Pounding ground stakes.
6. Attaching power cables.

The maintenance personnel said that the RS slipped and fell off its van

Table 7

Means and Standard Deviations for Nonfire Maneuver Questions

| Question | Crewmen | | | |
|---|----------|--------------------|----------|--------------------|
| | Officers | | Enlisted | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| How Successful You Think the Current Employment Doctrine Is for PATRIOT | 2.5 | 0.99 | 2.7 | 0.81 |
| Level of Difficulty of LS Reload without NBC Protective Gear | 2.6 | 1.66 | 3.9 | 0.77 |
| Level of Difficulty of LS Reload with NBC Protective Gear | 1.3 | 1.59 | 2.1 | 1.07 |
| Level of Difficulty in Initializing the ICC and ECS | 3.8 | 0.76 | 3.8 | 0.88 |
| Formal Training You Received on Initialization Procedures | 2.5 | 1.69 | 2.8 | 1.04 |
| Collective Training You Received on Initialization Procedures | 2.6 | 1.35 | 2.9 | 1.10 |
| On-Job Training You Received on Initialization Procedures | 3.6 | 1.02 | 3.5 | 0.76 |
| Quality of the Data Which Was Used to Initialize the FU | 2.5 | 1.49 | 2.7 | 0.86 |
| Formal Training You Received on PATRIOT | 2.0 | 1.00 | 2.7 | 0.93 |
| Collective Training You Received On PATRIOT | 1.8 | 0.67 | 2.8 | 0.96 |
| On-Job Training You Received on PATRIOT | 3.4 | 1.06 | 3.4 | 0.65 |

Note: For Means:

4.5 = Excellent

3.0 = Good

1.5 = Fair

0.0 = Poor

during road march. They felt that this was due to the march order procedures not being correct in the DEP. They also reported that procedures in the RS and LS DEPs did not include checking the tractor coupling before raising the outriggers. The maintenance personnel stated that the fifth wheel on the RS and LS tractors did not always engage. They said that the EPP, power, and ground cables were too short.

The ECS and ICC personnel stated that correlation problems occurred between the ICC and both FUs. They reported that targets were displayed at the ICC which were not in evidence at either fire unit and vice versa. They also said that sometimes the targets that were displayed would vary greatly in location from the ICC to the FUs. The ECS crewman reported that they had problems entering map data. They felt that this was due to the keyboard being too sensitive. The LS and maintenance personnel stated that the DEP procedures for obtaining location data when line of sight did not exist between the LS and RS were vague. They said that the obtained data were not accurate and at night operators just made educated guesses.

Live Fire

Questionnaire

Closed-ended questions. Means and standard deviations were calculated for the closed-ended items in questionnaire #3 which dealt with the live fire phase of the test.

Table 8 details the derived values for the test issue questions. The means and standard deviations for items 6-11 were based on the ratings provided by only the ECS and ICC crewmen. The values for questions 7 and 8 were computed on the data generated by the ICC members. "Adequacy of Existing Emergency Procedures for the ICC and ECS Vans" was rated poor to fair by both the officers and enlisted personnel. The officers also rated "Current PATRIOT DEPs" below fair.

Table 9 displays the means and standard deviations for the overall PATRIOT comparison ratings questions.

Open-ended questions. One of the open-ended items in questionnaire #3 requested that recommendations be provided for the number, rank, and military occupational specialty (MOS) of personnel at each of the major pieces of equipment in a tactical PATRIOT battalion. For each position, the operational test participants were asked to rate the criticality of the position and to list suggested rank, transition MOS, and the number of crews/24 hours. Table 10 presents the consensus of the eighty-five service members.

Comments and answers to rest of the live fire open-ended questions were oriented towards recommendations for improvements, modifications, and additions to the PATRIOT missile system. The suggestions are delineated below by subsystem/component/procedure.

The ECS crewmen would like to have totally reliable software. They recommended that the firing platoon status panel be repositioned and the engagement lamps redesigned so that they can be more easily read. The computer boot/reset switches need to be relocated and the computer control panel needs to be exposed for easier access. The ECS service members suggested that the inside door fasteners be replaced because they are too difficult to use. They indicated that they would like to have chairs which were more comfortable and could be adjusted horizontally. The van needs to be modified so that it has an escape hatch and more space for storage and writing. The ECS personnel proposed that a warning horn button be mounted on the MS#3 console and the push button on MS#1 be lower. They said that the headphones/microphones should be easier to work while typing and mentioned that there should be a way that the ECS members can communicate via the head set without having to reposition the net selector switch. A rack should be provided near MS#1 and 3 so that the headsets are not on the floor.

The ECS crew members advised that the DLT antenna and the shelter air vents should be redesigned. They stated that the DLT cable connectors should be spaced farther apart, and the prime power cable connector needs to be relocated for easier access. A ring to guide the ultra high frequency antenna

Table 8

Means and Standard Deviations for
Test Issue Questions From Questionnaire #3

| Question | Crewmen | | | |
|--|---------|--------------------|-------|--------------------|
| | 01-03 | | E2-E6 | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Value of the Operator/Maintainer Concept for PATRIOT | 3.5 | 0.72 | 3.6 | 0.78 |
| Concept of a Single Military Occupational Specialty | 2.3 | 1.69 | 2.9 | 1.32 |
| Current PATRIOT DEPs | 1.4 | 1.16 | 2.3 | 0.92 |
| Number, Types and Availability and Adequacy of Tools and Equipment at Operator and Organizational Level | 1.5 | 1.41 | 2.6 | 0.70 |
| Number, Types and Availability and Adequacy of Test Equipment at Operator and Organizational Level | 1.8 | 1.44 | 2.7 | 0.82 |
| Adequacy of Existing Emergency Procedures for the ICC and ECS Vans | 0.4 | 0.54 | 0.6 | 0.75 |
| Importance of Having an Escape Hatch at Man-Station #3 for the ICC and ECS Vans | 3.4 | 1.38 | 3.9 | 0.85 |
| Quality of Displays and Indications Present for Kill Assessment When the Missile Round Intercepts the Target | 2.0 | 1.90 | 3.1 | 0.91 |
| Level of Difficulty in Returning a Selected Launcher to a Standby Status | 2.8 | 1.81 | 3.7 | 1.02 |

Table 8 (Continued)

Means and Standard Deviations for
Test Issue Questions From Questionnaire #3

| Question | Crewmen | | | |
|--|---------|--------------------|-------|--------------------|
| | 01-03 | | E2-E6 | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Quality of System Safeguards Available to Prevent Accidental Launch of Live Missile Rounds | 2.3 | 1.75 | 2.6 | 1.28 |
| Disruptive Effect on Operational Effectiveness of the PATRIOT Battalion and the Interface with the AN/TSQ-73 of Making Communication Key Changes to the KG-27, KY-57, KY-30, and TPX-46 Security Devices | 2.5 | 1.84 | 2.7 | 1.31 |
| Level of Difficulty Encountered by the ICC Operator in Maintaining Ground Situation | 3.2 | 0.80 | 3.3 | 0.94 |
| Level of Difficulty Encountered by the ICC Operator in Maintaining Battalion Status Data | 2.8 | 1.85 | 3.5 | 0.90 |
| Effectiveness of the Rules of Engagement of Targets as Specified in the Tactical Standard Operating Procedures | 2.9 | 0.73 | 2.6 | 0.94 |
| Smoke/Blast Signature of the PATRIOT Missile Compared to that of the Improved HAWK. | 3.1 | 1.10 | 1.9 | 1.20 |
| Smoke/Blast Signature of the PATRIOT Missile Compared to that of the Nike Hercules | 2.8 | 0.92 | 3.2 | 0.70 |
| Level of Effect that the EPP Noise Level Had on You | 2.1 | 1.33 | 3.0 | 1.21 |

Note. For Means:

- 4.5 = Excellent
- 3.0 = Good
- 1.5 = Fair
- 0.0 = Poor

Table 9

Means and Standard Deviations for
Overall PATRIOT Comparison Ratings Questions

| Question | Crewmen | | | |
|--|-----------|--------------------|----------------|--------------------|
| | ICC / ECS | | Maintenance/LS | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| PATRIOT as an Air Defense System Compared to the Nike Hercules | 3.1 | 1.02 | 3.2 | 0.89 |
| PATRIOT as an Air Defense System Compared to the Improved HAWK | 3.5 | 0.87 | 2.5 | 0.77 |
| Ease of Operation of PATRIOT Compared to Nike Hercules | 3.4 | 0.50 | 3.7 | 0.75 |
| Ease of Operation of PATRIOT Compared to Improved HAWK | 3.8 | 0.60 | 3.2 | 0.30 |
| Mobility of PATRIOT Compared to Nike Hercules | 4.0 | 0.58 | 4.2 | 0.45 |
| Mobility of PATRIOT Compared to Improved HAWK | 3.0 | 1.49 | 3.9 | 1.04 |
| Reliability of PATRIOT Compared to Nike Hercules | 2.5 | 0.70 | 2.3 | 0.78 |
| Reliability of PATRIOT Compared to Improved HAWK | 2.2 | 0.80 | 2.4 | 0.75 |
| Command and Control of PATRIOT Compared to Nike Hercules | 3.0 | 0.68 | 3.1 | 0.82 |
| Command and Control of PATRIOT Compared to Improved HAWK | 3.6 | 0.54 | 3.0 | 0.13 |
| Safety of Operation of PATRIOT Compared to Nike Hercules | 3.2 | 0.54 | 3.0 | 0.70 |
| Safety of Operation of PATRIOT Compared to Improved HAWK | 3.5 | 0.73 | 3.2 | 0.44 |
| Engagement Parameters of PATRIOT Compared to Nike Hercules | 3.0 | 0.53 | 2.7 | 0.76 |

Table 9 (Continued)

Means and Standard Deviations for
Overall PATRIOT Comparison Ratings Questions

| Question | Crewmen | | | |
|---|-----------|--------------------|----------------|--------------------|
| | ICC / ECS | | Maintenance/LS | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Engagement Parameters of PATRIOT Compared to Improved HAWK | 3.9 | 0.57 | 3.4 | 0.90 |
| Rate of Fire of PATRIOT Compared to Nike Hercules | 3.8 | 0.73 | 4.1 | 0.47 |
| Rate of Fire of PATRIOT Compared to Improved HAWK | 3.8 | 0.90 | 3.6 | 0.83 |
| PATRIOT in an ECM Environment Compared to the Nike Hercules | 3.2 | 0.84 | 3.5 | 0.72 |
| PATRIOT in an ECM Environment Compared to the Improved HAWK | 3.8 | 0.90 | 3.6 | 0.80 |
| PATRIOT in an Identification Mode Compared to the Nike Hercules | 3.4 | 0.75 | 3.4 | 0.75 |
| PATRIOT in an Identification Mode Compared to the Improved HAWK | 3.6 | 0.82 | 3.7 | 0.91 |
| Effectiveness of PATRIOT as an Air Defense System Compared to the Nike Hercules | 3.0 | 0.73 | 3.4 | 0.64 |
| Effectiveness of PATRIOT as an Air Defense System Compared to the Improved HAWK | 3.8 | 0.41 | 2.7 | 0.91 |

Note. For Means:
4.5 = Excellent
3.0 = Good
1.5 = Fair
0.0 = Poor

Table 10

Tactical PATRIOT Battalion Manning

| Piece of Equipment/ Function/Personnel | Characteristics | | | |
|--|---------------------|-------------|---|---------------------------------|
| | Recommended Rank | Criticality | Transition Military Occupational Specialty | Number of Crews/ 24 Hours |
| Tactical Operations Center | | | | |
| Battalion Commander | O5 | 3.3 | 14D | 1 |
| Command Sergeant Major | E9 | 2.5 | 16Z | 1 |
| Assistant | O4 | 3.0 | 14D | 1 |
| Crewman/Driver | E4 | 2.1 | 16H | 2 |
| Other | E3 | 2.1 | 16C | 1 |
| Information and Control Central | | | | |
| Tactical Director | O3 | 3.5 | 14D | 3 |
| MS #1 | E6 | 3.4 | 16H | 3 |
| MS #3 | E6 | 3.2 | 16H | 3 |
| Other | E5 | 2.5 | 16H | 3 |
| Commo Chief | E6 | 3.4 | 31M | 1 |
| ICC Commo Operator | E5 | 3.2 | 31M | 2 |
| AMS Commo Operator | E4 | 2.8 | 31M | 3 |
| Other | E4 | 2.1 | 31M | 3 |
| Electrical Power Unit | | | | |
| Generator Operator/ Mechanic | E5 | 3.3 | 63B | 2 |
| Other | E4 | 2.1 | 52C | 3 |
| Maintenance | | | | |
| Maintenance Chief | WO | 3.5 | 222C | 1 |
| Mechanic | E6 | 3.2 | 24Q | 2 |
| Other | E6 | 2.6 | 24Q | 3 |
| Firing Unit | | | | |
| Battery Commander | O3 | 3.2 | 14D | 1 |
| Platoon Leader | O2 | 3.0 | 14D | 1 |
| Noncommissioned Officer- In-Charge | E7 | 3.0 | 16C | 1 |
| Other | E6 | 2.7 | 16C | 3 |

Table 10 (Continued)

Tactical PATRIOT Battalion Manning

| Piece of Equipment/ Function/Personnel | Characteristics | | | |
|---|---------------------|-------------|---|---------------------------------|
| | Recommended Rank | Criticality | Transition Military Occupational Specialty | Number of Crews/ 24 Hours |
| Engagement Control Station | | | | |
| Tactical Director | O2 | 3.5 | 14D | 2 |
| MS #1 | E6 | 3.5 | 16E | 3 |
| MS #3 | E5 | 3.3 | 16C | 3 |
| Other | E4 | 2.5 | 31M | 3 |
| Commo Chief | E6 | 3.2 | 31M | 1 |
| ECS Commo Operator | E5 | 3.3 | 31M | 2 |
| AMS Commo Operator | E4 | 3.0 | 31M | 2 |
| Other | E5 | 2.3 | 16C | 3 |
| Electrical Power Plant | | | | |
| Generator Chief | E6 | 3.3 | 63B | 1 |
| Generator Operator/ Mechanic | E5 | 3.3 | 63B | 2 |
| Other | E4 | 2.1 | 52D | 1 |
| Radar Set | | | | |
| Crewman #1 | E5 | 3.2 | 16C | 3 |
| Crewman #2/Driver | E5 | 3.1 | 16C | 3 |
| Launching Station | | | | |
| Launcher Chief | E6 | 3.6 | 16B | 1 |
| Wrecker Operator | E5 | 3.3 | 63F | 2 |
| Crewman #1 | E4 | 3.2 | 16B | 2 |
| Crewman #2 | E4 | 3.2 | 16B | 2 |
| Other | E4 | 3.2 | 16B | 3 |
| Maintenance Chief | W0 | 3.8 | 222B | 1 |
| Assistant Chief | E7 | 3.2 | 24Q | 1 |
| Mechanic | E5 | 3.4 | 24Q | 2 |
| Mechanic | E5 | 3.2 | 24Q | 2 |
| Other | E5 | 2.8 | 24Q | 2 |

Note. For Criticality:
0.0 = Detracts from mission
1.0 = Not critical
2.0 = Somewhat critical
3.0 = Critical
4.0 = Very critical

ropes and hooks for wires need to be added to the outside of the van. The ECS personnel said that the ultra and very high frequency (VHF) equipment and the voice patch panel should be updated to better handle the multi-routing requirements. They proposed that the IFF systems be totally transistorized and the IFF air filters and interlocks improved. The ECS should be redesigned so that the computers and communications equipment can be maintained while the system is functioning..

The LS members reported that there should be a secondary means of electrically raising the outriggers since so many problems were encountered with the 28 volt power cable. They suggested that the area where the crypto code is inputted be lowered since people under six-feet had a hard time reaching it. The trailer junction box is too fragile for tactical operations. After short periods of use, the plugs and wires became loose and worn. The LS crewman recommended that the rubber brace which is currently used to secure the circuit cards be replaced with some other kind of retainer. They stated that the small switches on both DLTs are too small and easily bent. The tractor mirrors are inadequate. They need to be extended a minimum of 6 inches on each side.

The maintenance personnel felt that the RS "crashed" too often. They would like to have a permanent light mounted on the rear of the van to show when the system is radiating. The outside indicator lamps need to be shielded so that they can be seen in sunlight. The maintenance personnel recommended that the cable connectors be replaced and better insulated since the present ones bind and wear too easily. They proposed that some system other than aiming circles for orientation should be devised. The rear-view mirrors are not long enough, and the hook-up for the trailer lights is very poor.

The maintenance crewmen suggested that the DEPs be improved. They mentioned that the DEPs did not provide an adequate explanation of how the PATRIOT system operates and interfaces with the Government furnished equipment. The DEPs are also far too misleading, inaccurate, and complicated. The maintenance personnel stated the DEPs are particularly weak in that they reflect a lot of theory that is not needed or applicable. There are no set parameters established as to which DEP should be used at what time, and there is no cross reference from DEP to DEP. Repair parts cannot properly be ordered due to the inaccuracy of the DEPs. The maintenance crew members suggested that the parts manuals be laid out with diagrams showing detailed configurations, identifying common parts needed, and parts itemized. They advised that the parts should have greater reliability than the current 50%. The battery replacement unit (BRU) lists and the diagnostics for isolating faults need to be more precise and complete. The maintenance service members recommended that one tool box of small tools be provided per van. They would like to have more detailed schematics and easier access to components.

The PATRIOT personnel indicated that a faster method of missile reload, a better way of grounding the system, and improved training tapes should be developed. They believed that facilities for heating food, relaxing, sleeping, and storage of personnel equipment, rifles, and ammunition should be provided. Vans should be supplied for a battery level command post and for support personnel. A majority of the PATRIOT crewmen proposed that a security platoon should conduct perimeter ground and air defense. They recommended that

PATRIOT should be tested further before the decision to field PATRIOT is made.

Interview

Both interviewees said that the maintenance procedures were poorly written and very unclear. They reported that no guidelines were provided for conducting preventive maintenance checks and diagnostics. One of the maintenance personnel stated that many of the components on which corrective maintenance was performed were not easily accessible.

One interviewee said that the ECS DLT antenna drive unit had to be replaced many times during the test. He believed that this might be due to the fact that the micro-switches for extending and retracting the antenna did not work. He reported that he had to climb onto the truck in order to replace the unit.

One of the warrant officers stated that 45 screws had to be loosened in order to remove the input air filter from under MS#1 and MS#3 in the ECS. He said that the ECS air intake and exhaust vents need to be ruggedized. The other warrant officer reported that the ECS was not protected for an NBC environment. He stated that: outside air leaked through the VHF radios; a direct outlet from the computer power unit to the outside existed; and the NBC shielding on the doors was worn.

One interviewee felt that the communication patch panel inside the ECS was useless since he was unable to run external wire into it. He said that 23 watts were inputted, but only 5 were outputted. The warrant officer also reported that the acoustic padding in the ECS doors was worn and did not withstand normal wear and tear. The other interviewee stated that he could not communicate with the ECS personnel from outside the van.

One of the maintenance personnel reported that fewer than 100 of the 5000 elements within the RS radar antenna were connected to the built-in test equipment test. He felt that this sample was too small because he had to continually replace faulty elements by guess alone. The interviewee also said that the radar antenna azimuth drive unit had to be replaced between 8 and 10 times during the test and it took two men to complete the replacement task. He stated that the transmitter maintenance lights on the outside of the RS were not visible under daylight conditions without shielding.

The warrant officers said that it was cramped inside the RS. One stated that there were too many screws on the card panel doors that had to be loosened in order to access cards. He reported that the azimuth stow lock on the floor of the RS was hard to move (a crowbar had to be used). The interviewee stated that some of his checks required interaction with the operator, but that he could not communicate with personnel outside while he was inside the RS. The other warrant officer said that he would like a location chart mounted inside the van.

Both interviewees reported that not all of the necessary test equipment and tools required to do their jobs were available. They felt that more tool boxes per fire unit were needed, and said that there was no back-up test

equipment during the test. One of the maintenance personnel believed that at least four volt meters should have been provided. He reported that the Government furnished equipment was not always appropriate.

The warrant officers said that the software diagnostics were less than 30% reliable. One stated that the repair parts, which were supposedly certified, had a failure rate of more than 50%. He reported that the repair parts manuals were not accurate. He also stated that the diagnostics provided incorrect part numbers. The other interviewee felt that a lot of work was needed on the BRU lists.

The maintenance personnel reported that the DEPs were inadequate. They said that the flowcharts should indicate input and output ports and a picture of what they should look like. One said that the DEPs did not provide part reliabilities, location, and numbers. He stated that it was not possible to follow signal flows through the units and more detailed checks and adjustments for BRUs are needed. The other wanted items in the drawings to be defined and acronyms listed in the glossary.

One of the warrant officers stated that, as a result of the DEP, diagnostics, repair part manuals, and repair part reliability problems, the PATRIOT missile system could not be maintained by Army air defense personnel. He said that improvements have to be made before the system is fielded.

DISCUSSION AND CONCLUSIONS

The first goal of the human factors evaluation was to determine whether the operator/repairman, support, and other personnel can perform all required tasks to accomplish the mission objectives of the PATRIOT system. Results obtained through the questionnaires, interviews, and checklists point to the fact that this goal can not be met by the current PATRIOT configuration.

The other aim of the evaluation was to identify man-machine interfaces impairing performance. Human factors problems were identified with practically every subsystem/component/procedure. Major problem areas associated with the ECS and ICC included the software, TPT tapes, display and control consoles, control keyboard assemblies, DLT antennas, communication equipment, and internal environment, i.e., temperature, noise, escape hatch, and space for storage and writing. Difficulties encountered with the LS and RS were related to the king pins, cable connectors, door fasteners, and alignment using the M-2 aiming circle. The EPP had problems with the fuel hose and grounding cables, while the AMS requires a redesign for the truck bed and guy antenna control cables. Missile reload took too long to perform. The DEPs, repair parts, and BRUs were determined to be totally inadequate. Safety hazards and problems in the simulated NBC environment were identified. The man-machine interfaces were so inadequate that the majority of the operational test participants recommended that the PATRIOT system not be fielded until the human factors deficiencies are corrected. There was also consensus that the decision to field PATRIOT should not be made until further testing is conducted.

The weapon system developer cannot, however, be faulted for all of the human factors problems since some of the deficiencies were caused by and/or are related to existing Army hardware and software. The vans for the ECS, ICC, and RS, tractors for the RS and LS, communication equipment, TPT tapes, M-2 aiming circle, and AMS were supplied as Government furnished material. The Government does not immediately need to be concerned with the human factors problems identified in regard to the TPT tapes, M-2 aiming circle, and AMS since these items were provided for the operational test to fill voids created by the contractor when his equipment was not ready for evaluation. The Government should, however, rethink its decision to require the weapon system developer to package ECS, ICC, and RS hardware inside the Government furnished vans. The Government also needs to make the required modifications to the tractors and employ state-of-the-art communication equipment.

The findings from the human factors evaluation were utilized by OTEA in the independent evaluation of the PATRIOT system. They were used by the Army Systems Acquisition Review Council and Defense Systems Acquisition Review Council as part of the information of which the decision for PATRIOT to enter production was based.

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APPENDIX

The instructions given to the service members prior to a questionnaire session are shown in this appendix. They accompanied questionnaires 1 through 3 respectively.

Questionnaire #1 Instructions

The following questionnaire is designed to obtain your opinion and recommendation concerning the operation of the PATRIOT system. It is important that when the system is fielded, future procedures and equipment design will assist you, not hinder you in the operation of PATRIOT. The questionnaire is in three sections. The first section deals with operational procedures. The second section deals with equipment design and physical comfort. The third section deals with the TPT software tapes. Throughout the questionnaire you will be asked to rate different characteristics. In order to rate a given characteristic, place a vertical line anywhere on the scale appropriate to your rating.

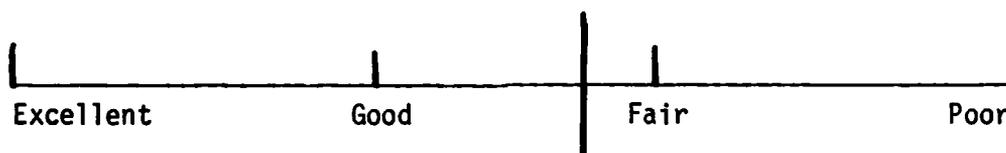
For example, the rating below is just a little better than fair.



Questionnaire #2 Instructions

The following questionnaire is designed to obtain your opinion and recommendation concerning the operation of the PATRIOT system. It is important that when the system is fielded, future procedures and equipment design will assist you, not hinder you in the operation of PATRIOT. Throughout the questionnaire you will be asked to rate different characteristics. In order to rate a given characteristic, place a vertical line anywhere on the scale appropriate to your rating.

For example, the rating below is just a little better than fair.



Questionnaire #3 Instructions

The following questionnaire is designed to obtain your opinion and recommendations concerning the organizational factors and operation of the PATRIOT system. This questionnaire represents an opportunity for your comments and recommendations to become an official part of the OT II record. The questionnaire is in four sections. Please attempt to answer every question. It is anticipated that you will be able to answer most of the questions in the first two sections. If there are questions in the third and fourth section that you are unable to answer, just respond to those questions with N/A.

Throughout the questionnaire you will be asked to rate different characteristics. In order to rate a given characteristic, place a vertical line anywhere on the scale appropriate to your rating.

For example, if you were asked to rate apple pie, the mark below would indicate a rating of a little better than fair.

