PATRIOT DISPLAY AND CONTROL SIMULATION

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SUMMARY

This paper presents a description of the US Army Human Engineering Laboratory (USAHEL) simulation and operator performance testing of the display and control subsystem of the PATRIOT Missile System.

INTRODUCTION: During the last 3 years an effort was undertaken by the HEL to develop a Command and Control Simulation Facility for the purpose of evaluating a variety of Display and Control (D&C) concepts and designs which are a vital part of today's complex military systems. The PATRIOT D&C subsystem is one of those systems currently being studied.

To begin with (Figure 1), I will give you an unclassified overview of the PATRIOT Missile System currently in development. Then I plan to talk about the PATRIOT's Display and Control Subsystem which HEL has simulated, the operator performance testing conducted for improving the D&C operator-machine interface design. Then I'll describe how we are currently using the PATRIOT simulator and some future tests that we plan to do.

PATRIOT System Overview:

The PATRIOT Missile System (Figure 2) is a new-generation Air Defense Weapon System now in development. The unique features of the system are a multifunction phased array radar, the track-via-missile guidance system and automated operation with human control.

In PATRIOT, a single multifunction radar performs all the tactical functions that, in present systems, require up to five separate radars; namely, airspace surveillance and detection, target tracking, identification, missile tracking and guidance and counter measures.

The track-via-missile guidance is the second major feature. It combines command guidance with homing guidance and, at the same time, provides for future adaptability to the changing threat by locating guidance processing in the ground equipment in software. This permits later changes, if necessary, to respond to threat changes without expensive hardware modifications to the missile. Automated operation is the third major feature which provides a basis for the system's firepower, effectiveness and reduced operating and maintenance costs. The central computer, monitored by operators, controls the operations of the complete PATRIOT Firing Platoon and monitors equipment status and locates faults for repair by replacement.

Finally, let's look at (Figure 3) the major equipment items comprising a PATRIOT Firing Platoon. The Firing Platoon consists of five major items: the radar set, the engagement control station and the electric power plant constitute the Fire Control Section, while five launching stations each including four missiles constitute the Launching Section. I should emphasize at this time that once the system is emplaced and operating, only the engagement control station is manned during air defense missions; all other items are remotely controlled and unattended.

Figure 4 shows a view of the engagement control station which is where human control is exercised. Stored computer programs, as modified by operator selections and instructions imputted on either of the two operator consoles, control the entire system operation.

Figure 5 shows the contractor's display and control consoles and Figure 6 shows one of the two consoles which have been simulated by the HEL. Since they are universal consoles, either console can be used by an operator to perform all functions or the functions can be divided between the two consoles in various ways; e.g., engagement control on one console and battalion interface and status monitoring on the other console.

HEL's PATRIOT D&C Simulation Overview

Briefly, the HEL simulation facility equipment consists of a Varian 620/f-100 minicomputer with 32K memory, a real-time clock and disc storage capability, plus an IDIIOM graphic-display system with up to four cathode ray tubes, function keyboards, light pens and tracking joysticks. Peripheral equipment includes a printer, teletype and card reader.

The computer programs are written in FORTRAN IV and are structured for making easy modifications to the basic console displays and control functions. The software programs developed for this simulation are divided into three categories (see Figure 7).

1. PATRIOT System overview.
2. HEL's PATRIOT Display and Control Simulation.
3. Operator Performance Testing.
4. Current use of the Display and Control Simulation and future testing.

Figure 1. Topics Presented

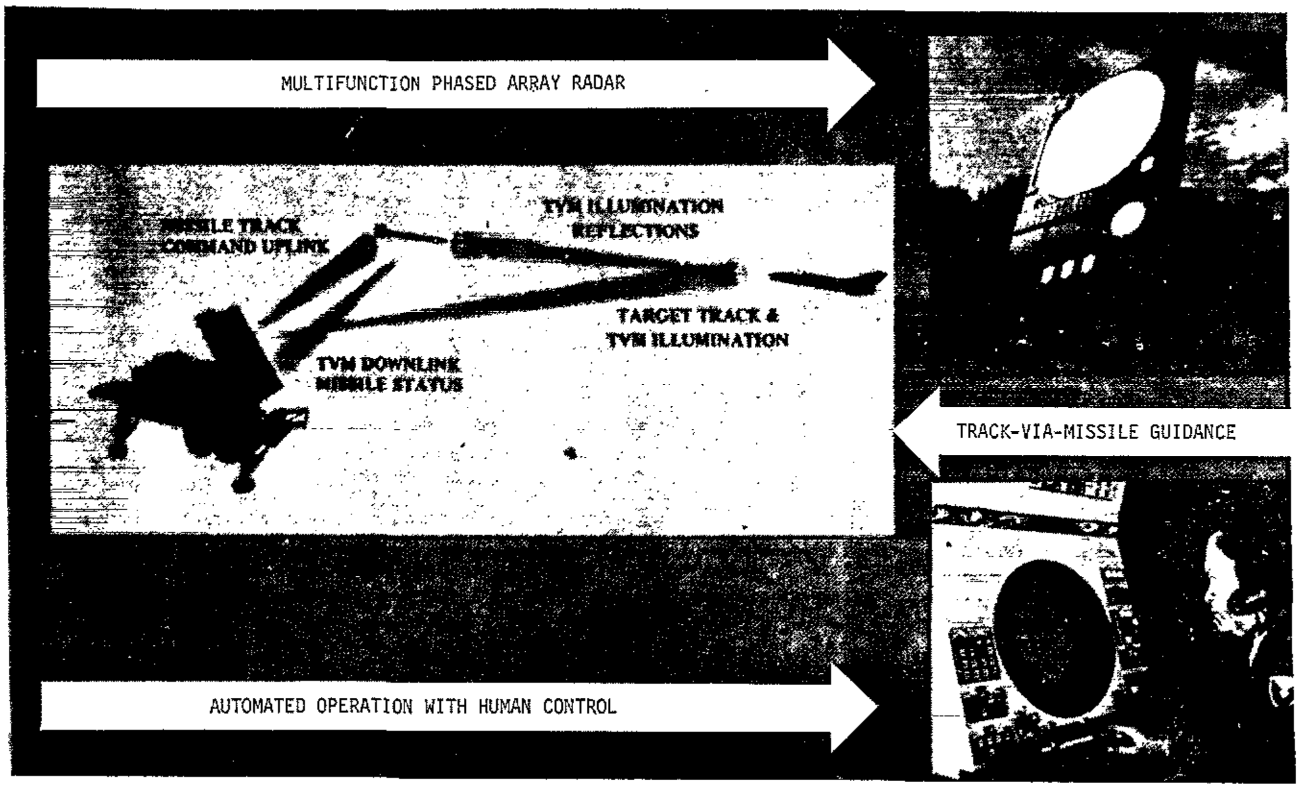


Figure 2. Essence of PATRIOT Missile System

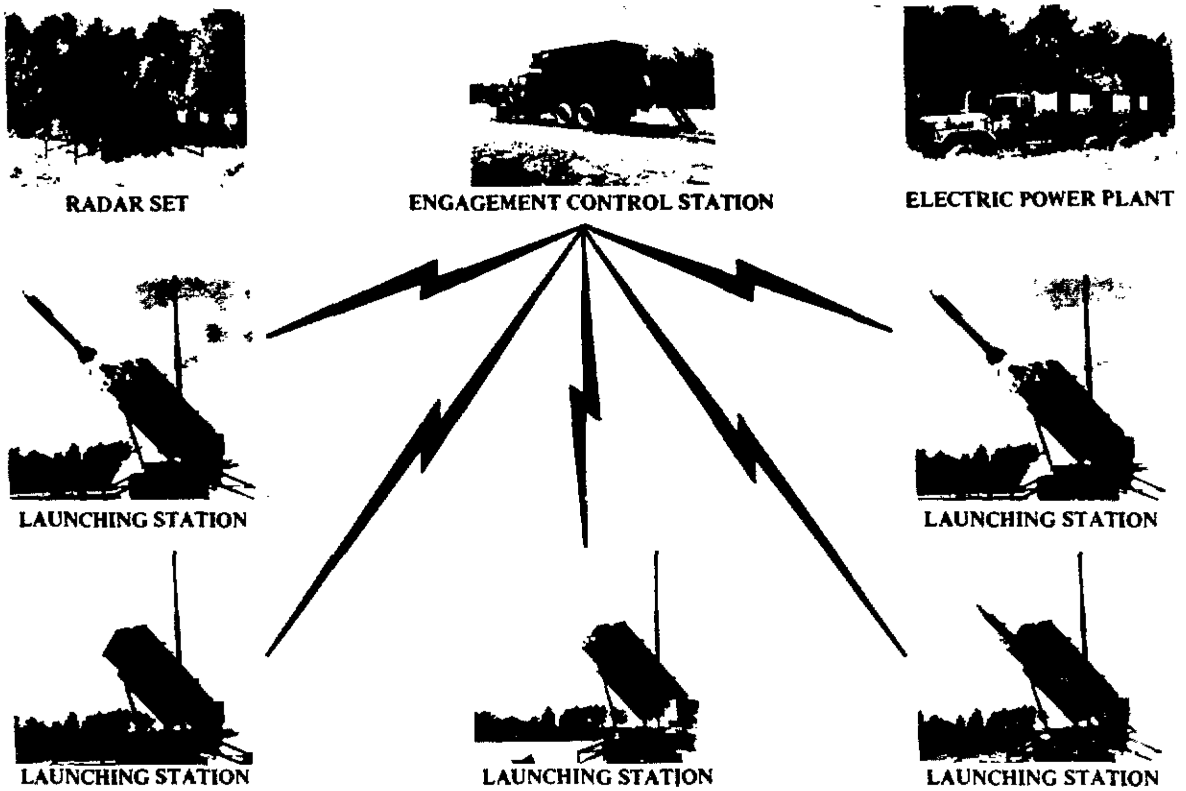


Figure 3. PATRIOT Firing Platoon

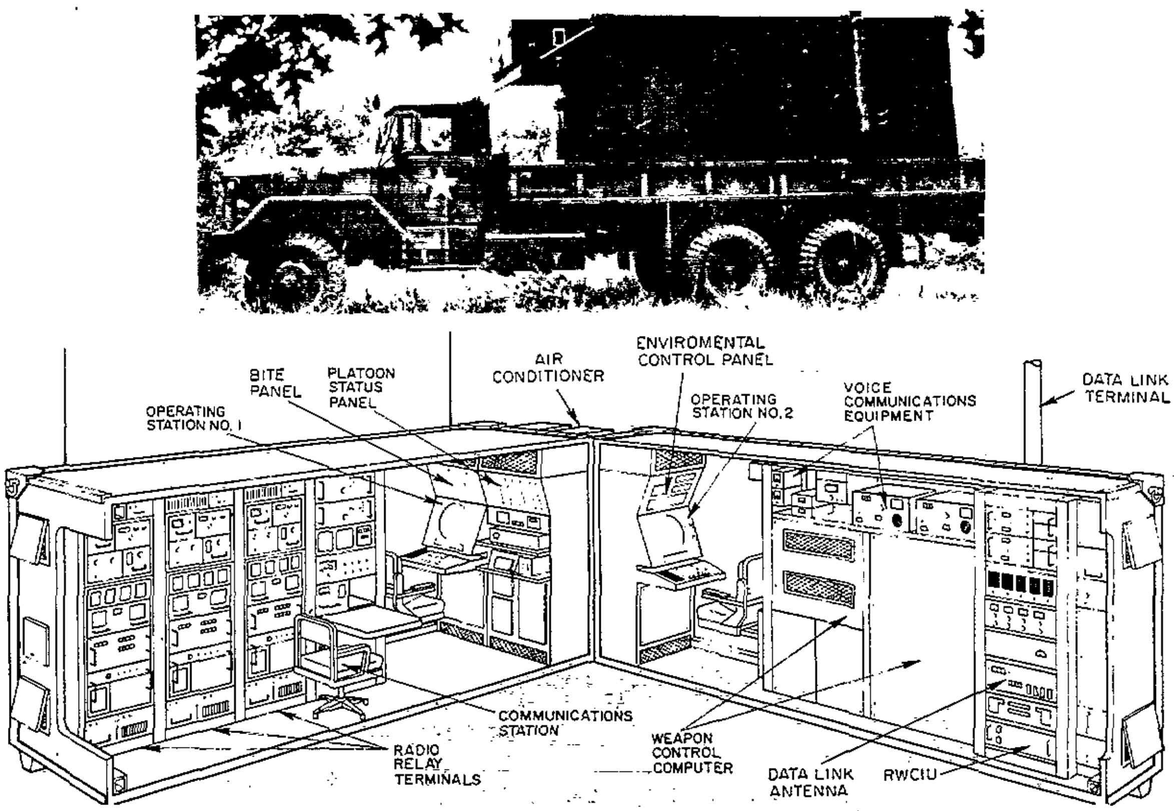


Figure 4. Engagement Control Station

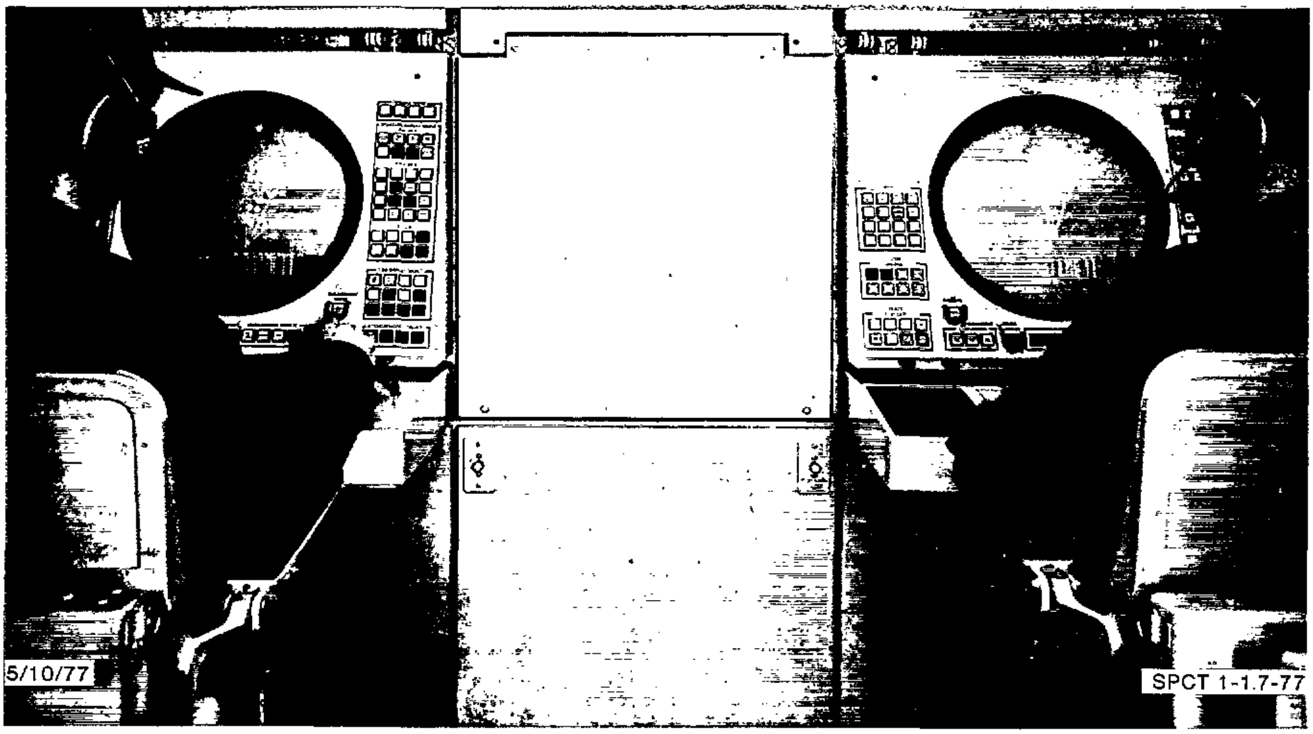


Figure 5. PATRIOT Display and Control Consoles

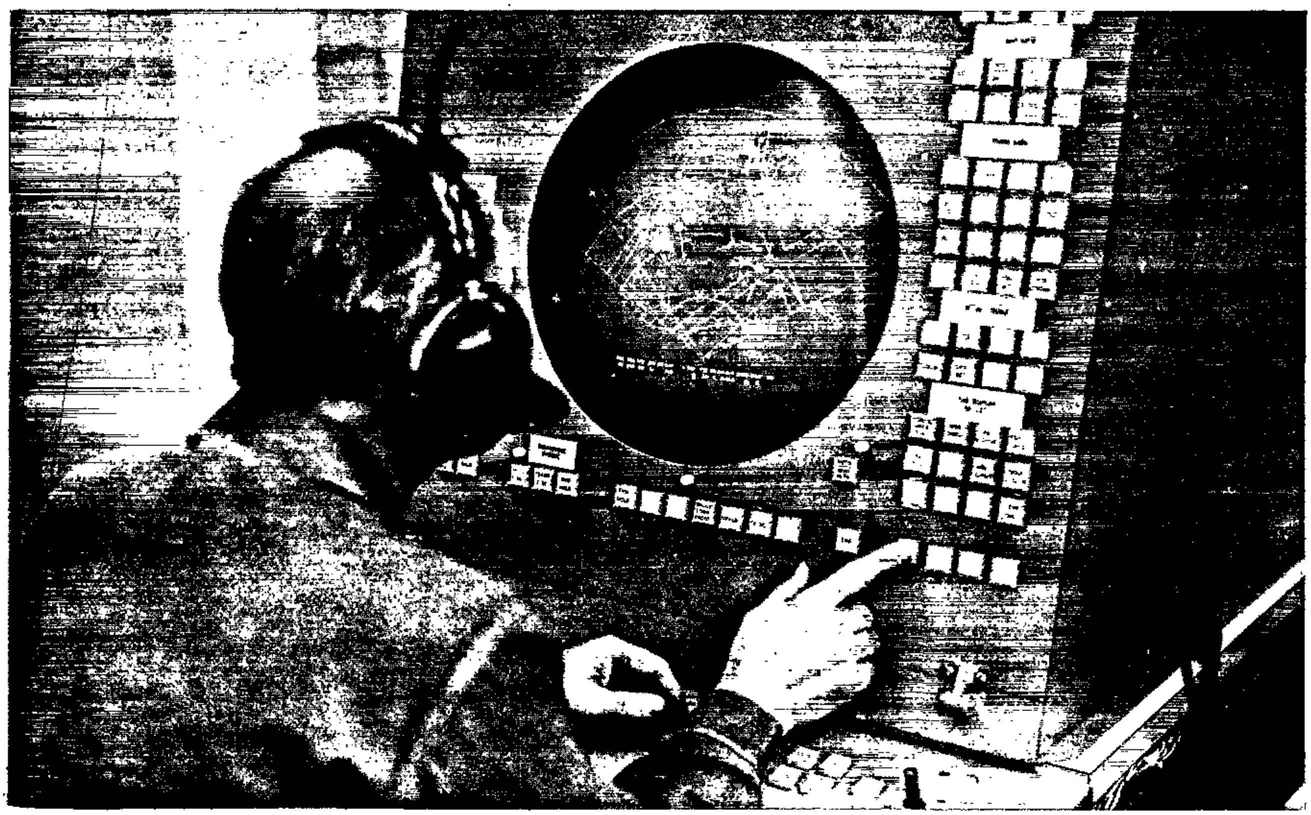


Figure 6. HEL's PATRIOT Display and Control Console Simulator

1. Preprocessing of target-scenario data.

2. Real-time radar display simulation.

3. Data analysis and operator-performance assessment.

Figure 7. Software Program Categories

The capability to preprocess target information relieves the computer of considerable arithmetic during program execution and permits preparing and checking a variety of scenarios prior to actual testing. For later access, preprocessed scenario data are stored on the disc. A scenario can contain up to 54 tracks plus a maximum of 45 target maneuvers.

The real-time simulation program uses the preprocessed scenario data to present a realistic display of aerial targets to the console operator. The target data interact with the operator's actions to simulate the total air-defense system. Operator actions and target events are recorded in real-time for later analysis.

Computer programs have been developed to aid in evaluating operator performance by isolating performance parameters and summarizing operator actions. There are also provisions for scenario replay with operator actions, individual target history, chronological event listing, target kill-assessment summary with intercept locations, asset boundary--penetration summary, and keyboard-action summary.

The PATRIOT Display and Control Simulation closely follows the actual system's current specifications for the displays, controls and fire control processes.

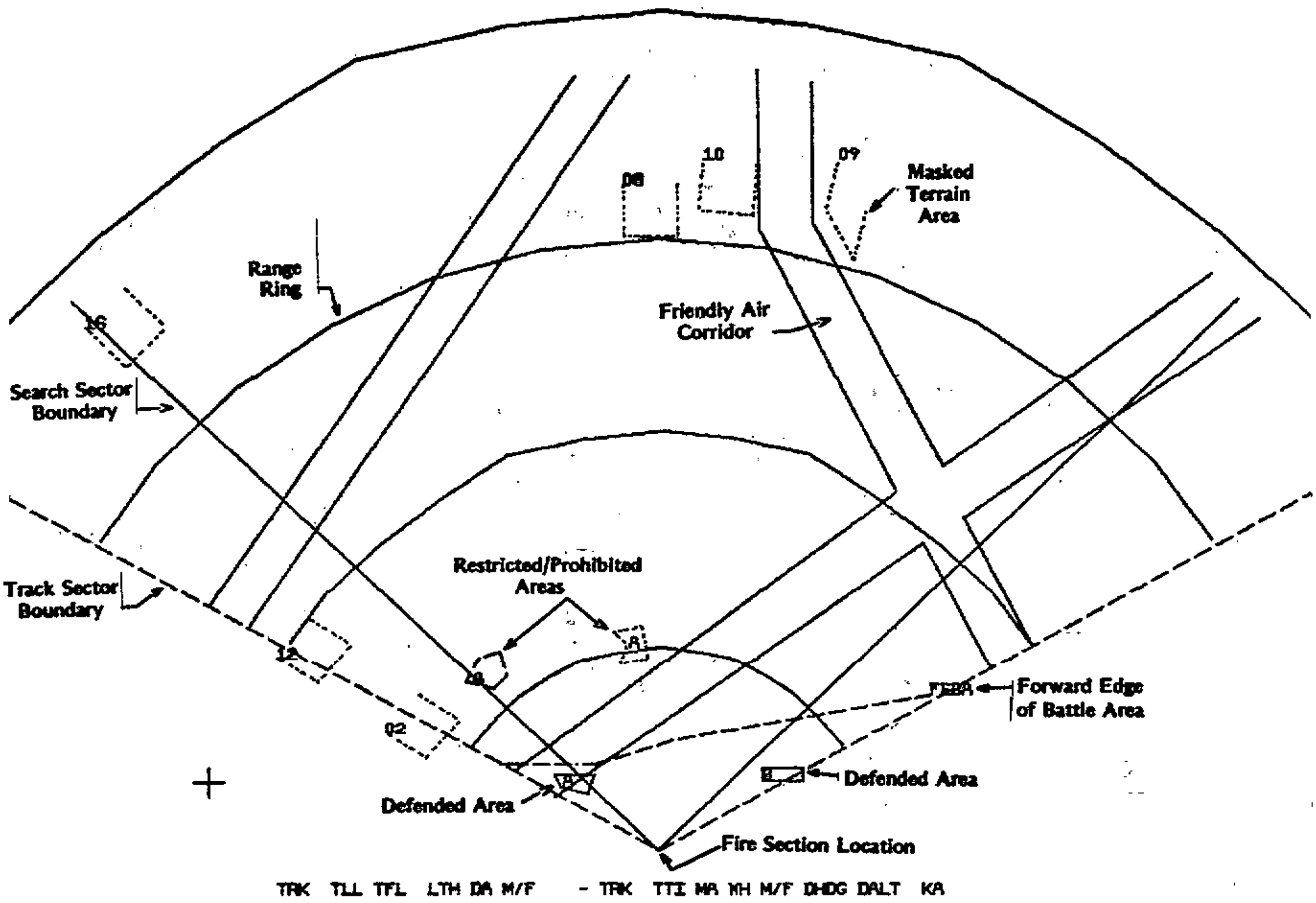
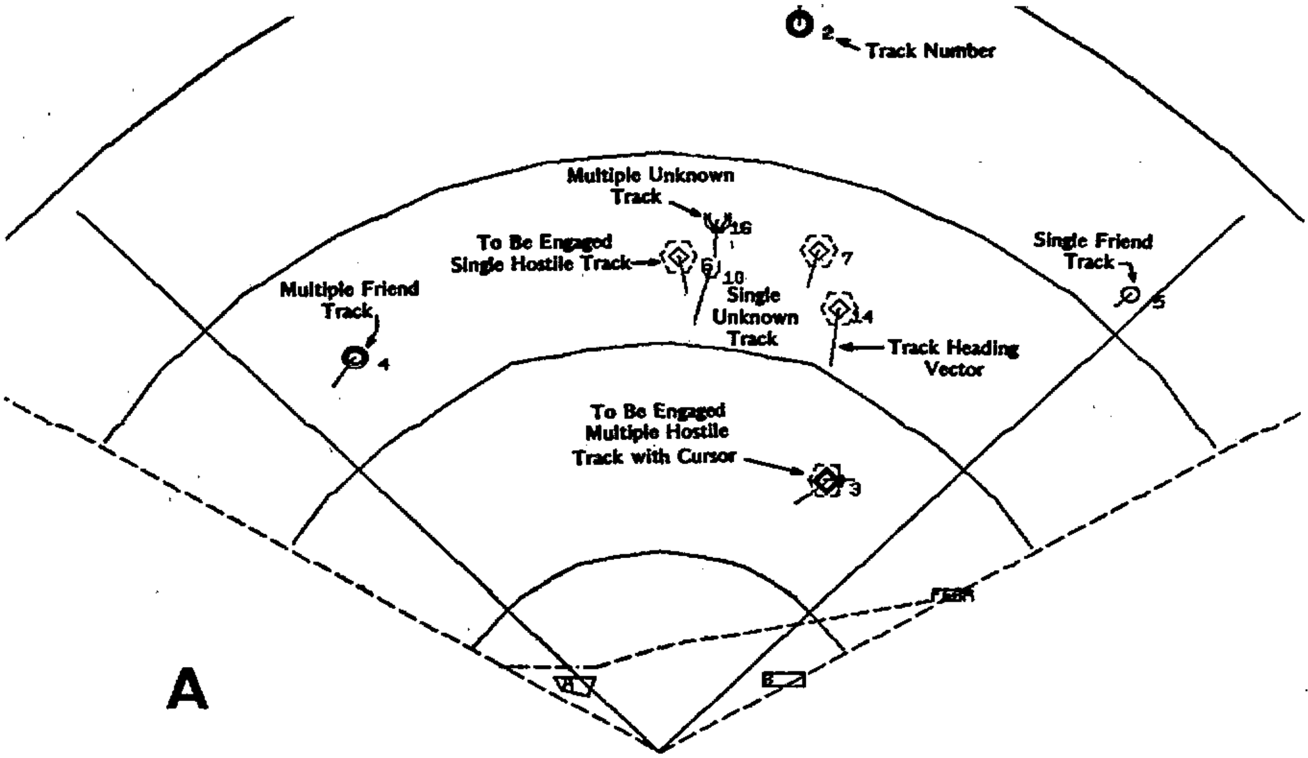
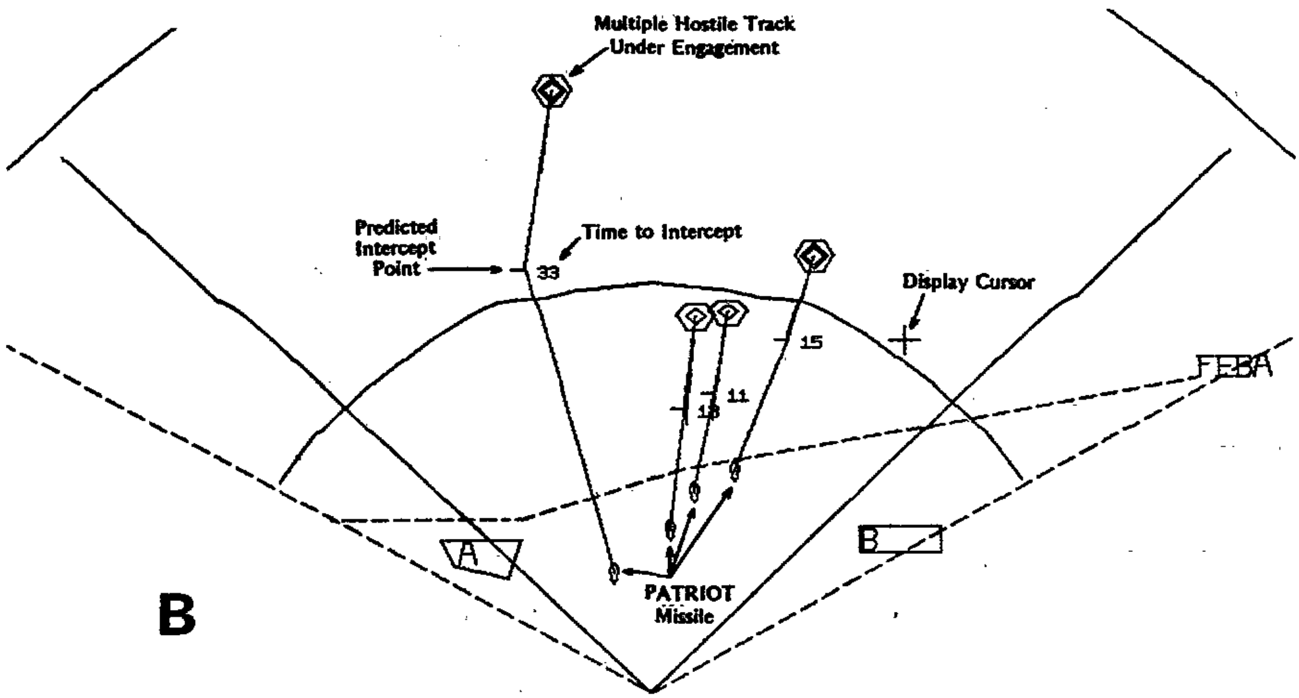


Figure 8. Typical PATRIOT Display



A

TRK	TLL	TFL	LTH	DA	M/F	- TRK	TTI	MA	MH	M/F	DHDG	DALT	KA
- 14	65	0	H		SLS								
3	105	0	H		SLS								
6	140	20	L		SLS								
7	205	25	L		SLS								



B

TRK	TLL	TFL	LTH	DA	M/F	- TRK	TTI	MA	MH	M/F	DHDG	DALT	KA
						10	11	I	H	SLS	0	0	
						8	13	I	H	SLS	0	0	
						12	15	I	H	SLS	0	0	
						3	33	I	H	SLS	0	0	

Figure 9. Dynamic Elements of the PATRIOT Display

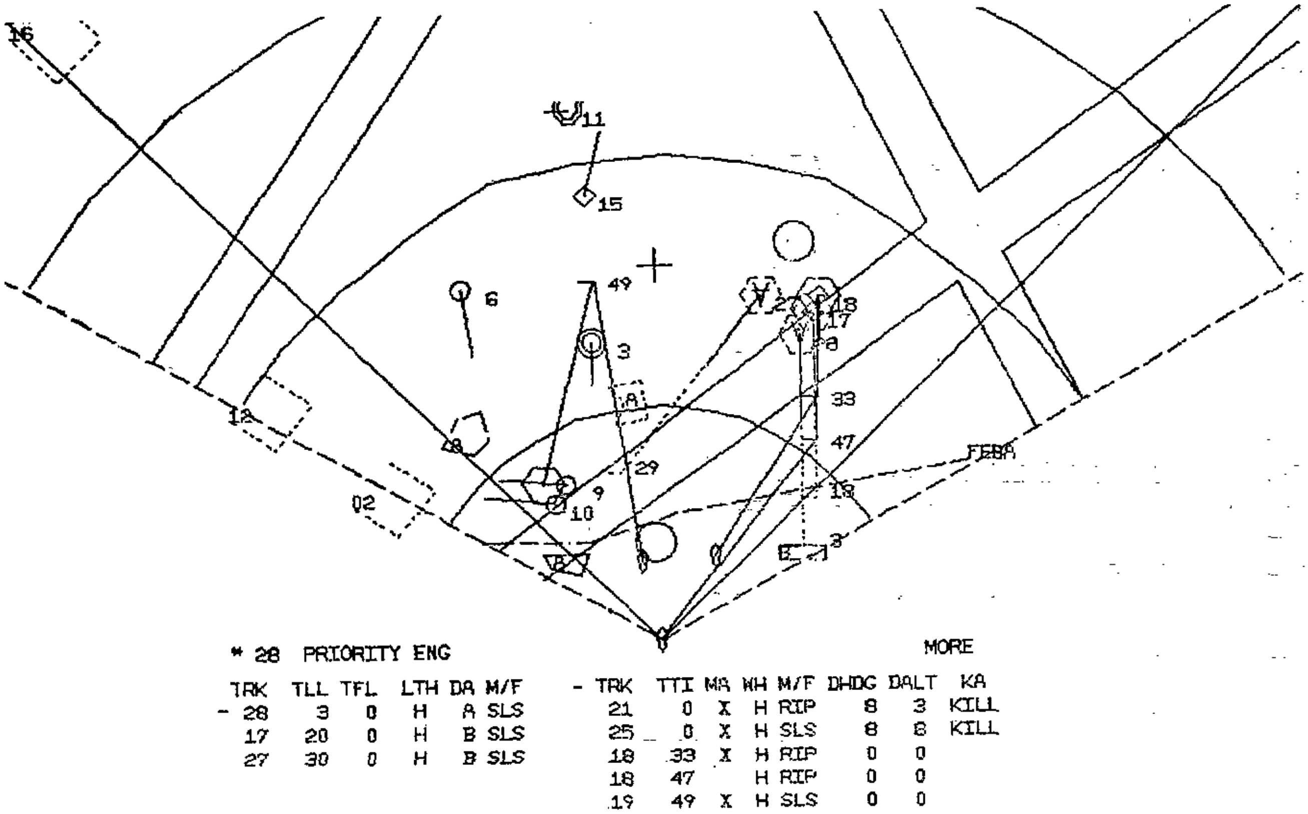
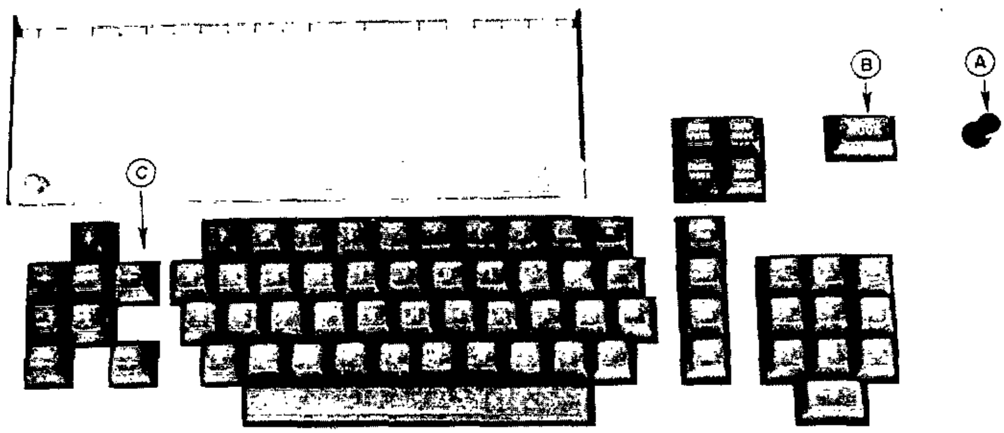


Figure 10. A Typical PATRIOT Display



A. Isometric Joystick

B. Manual Hook Key

C. Tabular Cursor Controls

Figure 11. PATRIOT Display and Control Console Shelf

Targets are identified and classified as they enter the radar-tracking sector, and are displayed as coded symbols. Each target is then subjected to various tests which determine its engagement eligibility and threat eligibility. If a target meets these criteria, further tests determine which asset it threatens. Then a launch-decision process ranks the target for engagement; this process is based on location of the predicted intercept, time urgency to protect an asset, and the initialized operator time requirements.

If the operator initiates an engagement, the weapon-assignment process selects a launcher and a missile, and begins launch action. When the engagement terminates in an interception, the program performs a target-kill assessment; the target is then either "destroyed," or considered for re-engagement.

I will now briefly describe the HEL-simulated PATRIOT Display and Controls.

The operator sees a basic picture like the one shown in Figure 8. This is a Plan Position Indicator (PPI) display which is on at all times. It shows the radar-boundary limits for searching and tracking targets, and range rings used as a guide for target distance. Through the operator's key actions, additional map data are available for display. These data include radar-masking terrain, air corridors, prohibited areas, restricted areas, defended areas, and the forward edge of battle area (FEBA). Dynamic elements shown in Figures 9A and 9B appear and are updated under program control. These elements include target symbol modifiers, track numbers, velocity vectors, defensive-missile symbols, launch-now-intercept lines, target-patch history, and predicted intercept points. The operator has the option of displaying or removing these elements by key action.

Tabular displays appear in an area directly below the PPI display. They consist of an alert-message line and three mutually-exclusive tabular displays: missile inventory, engagement data which is divided into to-be-engaged and engaged tracks and track-amplifying data.

Figure 10 shows a complete rather active display as an air-defense operator would typically see it.

The console contains 108 keys, of which 32 are under program control. Designated keys also contain a lamp which is under program control and which is used to indicate the status of the condition related to that key; i.e., function is active when lamp is on. Since keyboard functions are handled by a subroutine or set of subroutines, it is easy to add, delete, or alter keyboard functions as needed. This increases the simulation's flexibility and permits testing alternate key functions without affecting the remainder of the program. The keys are separated into functional groups on the console panel.

The console operator uses an isometric joystick to control a PPI-display cursor as a pointer to hook targets for further evaluation and/or engagement. The operator's performance, especially in time-critical situations, depends upon his ability to place and hold the display cursor close enough to a target for hooking.

The isometric joystick shown in Figure 11 is a pressure-sensitive stick with analog output. Unlike the other devices, the isometric joystick requires relative cursor positioning, since it returns to the center position when released. The rate of cursor movement is directly proportional to stick displacement. The transformation from digital output to raster units is selected by the experimenter, allowing great freedom in varying the cursor's movement rate as a function of the stick pressure.

The experimenter has complete control over the operator testing through his own monitor display, function keyboard and the teletype. The experimenter begins the test by entering "/SAM" on the teletype. This begins the execution of the simulation program, which causes the computer requests as shown in Figure 12.

Responses are entered on the teletype, and program execution continues. The experimenter's display duplicates the operator's display, and it also shown certain additional information only to the experimenter. This information includes elapsed time, scenario number, and other pertinent system data not displayed to the operator. Using his function keyboard, the experimenter can also "reload" the missile launchers when they are depleted. The experimenter can halt the display at any time, for discussion of critical situations during operator training, or to obtain a hard copy of the situation display shown on the console. Test termination is also controlled by the experimenter through the function keyboard. At termination, the test results are stored by test number.

Specific programs have been developed to assist in analyzing the test. These routines will display data on a CRT for viewing, or make a permanent record on the STATOS printer. Events can be listed chronologically or by track. Other routines summarize the operator's key actions, target-kill assessments and intercept locations, target-asset penetrations and operator hooking actions. A program has been developed that will replay the scenario and duplicate the operator's actions, so the experimenter can discuss and evaluate these actions with the operator. The playback is also valuable as a performance training aid for the operator.

Test results can be maintained on the disc indefinitely, and they are accessible for analysis at a later date.

Operator Performance Testing:

I will now describe the operator performance testing performed on HEL's PATRIOT Display and Control Simulator.

Since there was no test data available where PATRIOT operator performance could be compared, it was decided to obtain performance measures using the current D&C system design to establish a baseline of performance measures. Once this was done, software modifications were made to the design and tested to determine whether they improved operator performance over the baseline design.

Since time does not permit me to go into an explanation of the PATRIOT display and control features and capabilities, I will describe only a few of the modifications which significantly improved operator performance.

During our testing on the baseline system, we found that operators were having difficulty in performing the following tasks as stated in Figure 14.

To reduce or eliminate the above problems in hopes that operator performance would be significantly improved, the following software changes were made:

a. To improve performance on both detecting air-to-surface missiles (ASMS) and critical alert messages (problems a & e), ASMS which were originally not threat ordered were threat ordered in part; i.e., those ASMS which were targeted within a certain distance of the firing platoon were threat ordered in order to improve the self-defense posture of the firing platoon. Thus, the ASMS which were threat ordered were now put on the To-Be-Engaged section of the tabular display along with other aircraft threats. When one of these targets met a certain criteria, it initiated a blinking priority engagement visual alert message to the operator along with an audible alert. With this change, all the operator had to do was to acknowledge the alert and issue an engage command.

In the baseline system there was no audible alarm provided for critical threat ordered aircraft. At times the operator was not aware of the blinking alert message and he's had to depend strictly on his own surveillance capability to detect an ASM symbol on the PPI display. Once the ASM was detected, he had to use his joystick to manually hook the ASM track before he could issue an engage command. With the changes, the ASM track was automatically hooked when the priority engagement alert message was acknowledged.

b. To eliminate the operator task of moving the tabular cursor back to the first line of the TBE tabular display, all that was needed was a software change to prevent the cursor from moving down to the next line after a sequence hook action was taken by the operator. Apparently, when the sequence hook was designed, the contractor did not remember that the next logical action an operator would take after sequence hooking a track on the To-Be-Engaged display, would be an engage action. Once an engage action was taken, the track on the TBE display moved to the Engaged part of the display and all other tracks on the TBE display were reordered with the track on the first line having the highest priority; however, the tabular cursor was now on the second line and the operator had to move it back to the first line so that he could hook and engage the highest priority target. Remembering to do this task frustrated a number of subjects to a point where they completely refused to use the sequence hook function. I might add that once the change was made, the subjects found that this method of hooking was very effective, especially in times when there were many hostile tracks on the display and they preferred this hooking method over the manual/joystick hooking method.

c. To reduce the unknown identification time, a new tabular display was developed that listed all the hostile criteria for the unknown track. (See Figure 15.) All the operator had to do was count the number of hostile criteria exhibited by the track. If the number equaled or exceeded the TSOP number of criteria for an unknown track to be hostile, the operator designated the track hostile.

d. To eliminate the operator task of remembering to select the Ripple Method of fire on a multiple hostile track, the proper method would be automatically selected by the computer on a hooked target. I'm sure this short description of the problems and the modifications made to correct them leaves a lot of gaps, and if you want a more thorough understanding please feel free to talk to me later. The test results where our modifications showed a significant improvement in

Computer Output	Meaning
Scenario XX	Scenario Number
SAMS XX	SAM Missiles Available
TEST CONSOLE X	Test Console Number
TEST NO XX	Test Number (warns experimenter if number has already been used)
SUBJECT INFORMATION	Subject and Test Data

Figure 12. Computer Output Requesting More Data

1. To evaluate the current PATRIOT Display and Control (D&C) Design for performing air-defense missions in a benign environment.

2. To develop display and control modifications for improving the current display design.

3. To determine the effectiveness of these modifications on air-defense operator performance.

4. To assess the adequacy of an HEL developed Tactical Standing Operating Procedure for PATRIOT.

5. To examine operator performance under different target densitites.

Figure 13. Operator Performance Test Objectives

1. Detecting and engaging air-to-surface missiles within the short time period that these targets could be engaged and intercepted.

2. Remembering to move the tabular display cursor back to the first line of the To-Be-Engaged Tabular display after hooking a target on the first line.

3. Comparing TSOP Hostile criteria with an unknown track's paremeters for the purpose of declaring an unknown track as hostile.

4. Remembering to select Ripple Method of Fire on a multiple hostile track.

5. Detecting and rapidly responding to visual alert messages-even critical alert message.

Figure 14. Observed Problems on Baseline System

operator/machine/mission performance are shown in Figure 16. A total of 16 military air defense personnel having varying amounts of operator experience of the HAWK System served as subjects for this PATRIOT test. Based on our test results, we submitted a total of 10 recommendations to the PATRIOT PMO.

Upon completion of our formal testing and preparation of the report (HEL TM 15-77), it became rather obvious that our PATRIOT simulator could be used as a training device to provide some advance training of government personnel having responsibilities for DT/OT planning/testing and development of training devices. To date, over 30 personnel from the PATRIOT PMO, OTEA, TRADOC, TECOM, and AMSAA have taken our informal indoctrination training on the HEL Display and Control subsystem simulator.

The benefits which can be realized from this effort are shown in Figure 17.

Finally, in regards to our future tests planned for the PATRIOT simulators. The topics to be studied are shown in Figure 18.

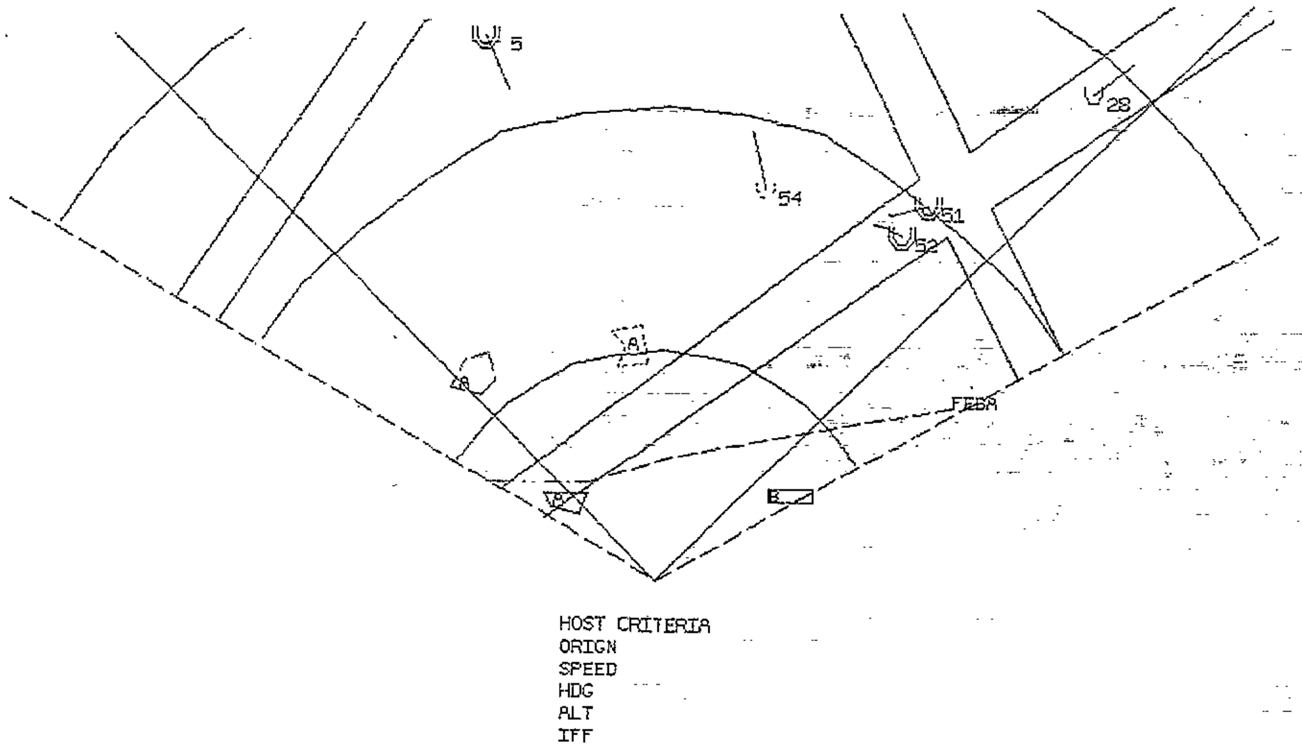


Figure 15. New Tabular Display for Identifying Unknown Tracks

Dependent Variables	Baseline System	Modified System
Unknown Track ID Time *(sec)	50.6	33.4
Priority Alert to Acknowledge Time **(sec)	5.0	2.5
Priority Alert to Engage Time *(sec)	6.0	4.2
Mean Time to engage FP directed ASMS*	15.0	10.0

*Significant at .05 confidence level using Tukey's Test of difference between the means.

**Significant at .01 confidence level.

Figure 16. PATRIOT Display and Control Evaluation Test Results

1. Reduces the need and costs of conducting special human engineering field tests on the actual system equipment.

2. Provides visibility on human engineering problems existent in the current system design. Detecting and correcting these problems now is less costly than when the system is fielded.

3. Provides a technical baptism to personnel in the test and training communities whereby they are better prepared for structuring their respective tests and defining their training requirements; i.e., when you know how a system is to perform, you are in a better position to prepare a test for measuring the required performance.

Figure 17. Training Benefits

1. Display study on operator capability in an ECM environment.

2. Task/workload divisions using two Display and Control consoles.

Figure 18. Future Tests Planned

ABOUT THE AUTHORS

MS. PATRICIA J. WILLIAMS has been employed at the Human Engineering Laboratory at Aberdeen Proving Ground, Maryland as an Engineering Psychologist since 1974. Publications include "Air Evaluation of Operator Performance on the PATRIOT Display and Control Console" and "Target Tagging Accuracy as a Function of Cursor Shape and Size." She received a B.A. degree in psychology from Towson State College in Baltimore.

MR. GARY L. KURTZ is a Human Factors Engineer at US Army Human Engineering Laboratory. He has 17 years of experience in the human engineering field and has made contributions to MAULER, SAFEGUARD, HAWK, and PATRIOT Missile Systems with primary effort on design of display and control concepts and human performance testing. He holds a B.S.E.E. degree.

MR. JAMES W. GOMBASH has been employed at the Human Engineering Laboratory at Aberdeen Proving Ground, Maryland as an Engineering Psychologist since 1976. Prior to that he was employed as an Engineering Technician at the U.S. Consumer Product Safety Commission in Bethesda, Maryland. Publications include "An Evaluation of Operator Performance on the PATRIOT Display and Control Console"and "Target Tagging Accuracy as a Function of Cursor Shape and Size." He received a B.S. degree in psychology from the University of Maryland.