Improving Instructor Operator Stations To Enhance Electronic Warfare Training

Robert T. Nullmeyer and **Glenn D. Cicero**
Warfighter Training Research Division
Air Force Research Laboratory
Mesa, Arizona

V. Alan Spiker
Anacapa Sciences, Inc.
Santa Barbara, California

Steven J. Tourville and **Jerry S. Thompson**
Raytheon Systems Company
Albuquerque, New Mexico

Advances in modeling and simulation technology are rapidly increasing the fidelity of tactical training for aircrews, especially in the electronic warfare (EW) arena. Unfortunately, the tools that allow instructors to monitor and manipulate these complex training environments have failed to evolve accordingly. Sixteen experienced instructors and engineers were interviewed to identify problems with the Instructor Operator Station (IOS) used to control simulation-based training environments at the 58th Special Operations Wing (58 SOW). Thirty-four problem areas were identified, and then rank ordered. Three areas emerged as most problematic: lack of sufficient information about the mission environment (terrain, cultural features, planned waypoints, etc.); excessive levels of effort required to modify the EW environment (e.g., up to 25 steps to manipulate a threat); and a "Spaceball" that is difficult to operate and unreliable. Instructors reported that training effectiveness can be enhanced substantially by manipulating the simulated EW environment. However, the procedures were so complex and time-consuming that it is unrealistic to make these changes while instructing students. To improve instructor control and situational awareness, several IOS display enhancements were examined on a "proof of concept" basis: (1) a digitized JOG chart was added, (2) the entire display was re-hosted using a X-windows and Motif format, and (3) the touch-screen and "Spaceball" interfaces were replaced with a user-friendly Trackball. Termed the Enhanced-IOS (E-IOS), these changes were implemented in a stand-alone workstation emulation and subjected to controlled testing using twelve instructors. The E-IOS led to significantly faster threat manipulations, lower difficulty ratings by instructors, and more accurate range and bearing estimates between ownship and other objects of interest. On the basis of these results, it is anticipated the E-IOS changes will be implemented on 58 SOW simulators, at which time impacts on training will be assessed.

ABOUT THE AUTHORS

Robert T. Nullmeyer is a research psychologist with the Warfighter Training Research Division of the Air Force Research Laboratory at Mesa, AZ (AFRL/HEA), where he has been since 1981. He has conducted research on training system evaluation, and simulator training effectiveness. He earned a Ph.D. in Experimental Psychology from the University of New Mexico.

Glenn D. Cicero is an engineer with AFRL/HEA. He has conducted investigations on the electronic warfare portion of training system designs, covering basic procedures training up to tactical mission training. He earned a B.S. Electrical Engineering Degree from the University of Colorado and has accumulated over 1000 flying hours in various aircraft to become familiar with the electronic warfare systems installed.

V. Alan Spiker is a principal scientist at Anacapa Sciences, Inc., Santa Barbara, CA. He is responsible for human factors research associated with advanced technology and has conducted field studies on mission planning and command and control systems for all branches of service. He has a Ph.D. in Experimental Psychology from the University of New Mexico and has been with Anacapa Sciences since 1982.

Steven J. Tourville is a senior training analyst and operations manager with Raytheon Systems Company, Albuquerque, NM. He is experienced as a USAF Joint Special Operations mission planner, an instructor navigator, and a training manager in the MC-130P Aircrew Training System. He is responsible for managing aircrew team performance and training evaluation research for combat mission training and mission rehearsal. He is currently an Ed.D. candidate in Adult Education at Nova Southeastern University.

Jerry Sue Thompson is a principal research scientist at Raytheon Systems Company, Albuquerque, NM. She is responsible for human factors research, training requirements analysis, training system design and evaluation, and human factors operational testing and evaluation. She received her Ph.D. in Experimental Cognitive Psychology from New Mexico State University in 1985, and has been active in human factors, training, and evaluation for military systems since 1984.

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INTRODUCTION

The 58th Special Operations Wing (58 SOW), Kirtland AFB, NM provides initial qualification training, combat mission training, and refresher training for UH-1N, MH-53J and MH-60G helicopter crews, and for MC-130H and MC-130P/N fixed-wing crews. Training is conducted using a variety of media including high-fidelity Weapon System Trainers (WSTs). A fully integrated electronic warfare (EW) environment is provided that interacts with every aspect of tactical aircrew training for these weapon systems. (The MC-130H WST is not yet fully operational and a UH-1N trainer is under development).

Advanced simulation technology at the 58 SOW now provide the capability for greater interaction between simulation models and the training environment, resulting in much more realistic performance characteristics in threat models (Reed, 1993). As a result, EW training has evolved from simple signal recognition and procedures training to realistic tactical training against high-fidelity threats. The Instructor Operator Stations (IOSs) that control the simulations, however, have not kept pace with the complexities present in the newer tactical training environments. The typical strategy used to modify the instructor interface for controlling these newer tactical environments has been to design for compatibility with the older IOSs. Due to limitations inherent in the older architectures, procedures to manipulate the advanced EW environment have become very complex and convoluted.

Many instructors report that controlling the environment using the Current-IOS (C-IOS) interface diverts so much time and attention from their primary instructional activities that they would be ill-advised to modify the EW simulation during training. The majority of simulator instruction at 58 SOW is thus delivered using “canned” scenarios that provide common timelines, event sequences, and parameter settings (e.g., weather, threats, winds, etc.). A recent review of 95 simulator sessions revealed that instructors modified the threat environment in only five instances. On the other hand, instructors indicate that a more user-friendly ability to tailor the scripted environment could substantially increase training effectiveness.

Instructors also cite a lack of sufficient situational awareness (SA) when using the C-IOS to monitor tactical environments. Given the complexity and composition of the EW environment, these critiques are not surprising. The environment consists of radio frequency emissions, the presence of chaff and flares, terrain clutter (radar signature of the ground), infrared background radiation and generally, anything that affects the operation and performance of sensors and weapons. In addition, modern environmental models use grazing angles, slant ranges, and emitter beam position to affect threat radar performance. High fidelity EW training demands threat radar models that reflect dynamic projections over time rather than performance at discrete points. For example, the amount of interference presented to a threat radar by the environment (i.e. clutter) should affect how long the system operates in any mode and whether it can transition to lethal target tracking and engagement modes. This fidelity is necessary to model realistic threat radar performance in the tactical environment. The C-IOS provides little insight into this realm.

To improve the instructor/simulator interface, the Air Force Research Laboratory and the 58 SOW formed a project team to develop an Enhanced-IOS (E-IOS). The MH-53J WST was chosen for evaluation of the E-IOS prototype. In this paper, we summarize the C-IOS problems that were identified and describe the major changes that were made to create the E-IOS. We then describe a controlled experiment that assessed the usability gains afforded by the new system. Finally, we present results and implications regarding how these changes affect instructor SA and ability to manipulate the simulation-based training environment.

PROBLEM IDENTIFICATION AND SOLUTION SPECIFICATION

The project team began the problem analysis by operating a standalone IOS workstation and holding informal discussions with experienced simulator instructors and engineers. A number of trouble spots were immediately apparent. These included the large number of line-entry selects and key strokes required to manipulate threats, the inherent difficulty in manipulating moving models due to a non-intuitive entry device (the "Spaceball"), the complexity of changing environmental parameters during a scenario, and the frequent loss of SA by instructors during simulator instruction. The latter problem was attributed in part to the austere C-IOS ground-track map.

To build on the information gleaned from these activities, formal interviews were conducted with eight highly-experienced simulator instructors and engineers. Questions addressed student training needs, IOS operator training, tailoring scenarios, maintaining SA, IOS instructional support features, conducting mission debriefs and monitoring student performance, networked training, and human factors issues.

Table 1: C-IOS Problems Identified by Instructors and Simulator Engineers

Problem Category	Problem Statements
Lack of Instructor familiarity with the IOS	**1. *Even experienced instructors do not know how specific features of the IOS function and are often unaware of engineering changes that impact their procedures.*** 2. Less experienced instructors need help from engineering for setting up.
Lack of Instructor SA	**1. *The ground track map is insufficient to help instructors maintain SA throughout the mission. 2. The IOS does not provide sufficient information for simulator instructors to maintain SA during key mission events.***
Unfriendly Organization of IOS Information	1. Instructors must sift through many pages and lines that are irrelevant to that scenario. 2. Instructors must access both a status page and a control page to make changes to the scenario. 3. Instructors presently have trouble accessing IOS pages in a timely fashion. 4. The current text-based system slows instructors interpretation of the Dynamic Parameters Display Area.
IOS Complications Involving Networked Scenarios	1. Instructors are reluctant to modify the scenario environment when it is shared with other IOSs. 2. Valuable training is lost because the MC-130P is not vulnerable to threats in tanker mode. ***3. Instructors have difficulty in performing select IOS tasks due to peculiarities associated with the master/slave relationship.*** 4. Instructors presently lack information concerning the status of other participants on the net. 5. There are some missing links in the communication chain involving the netted WSTs and the Training Observation Center (TOC).
EW Instruction is too Labor Intensive	**1. *Adding, moving, or deleting threats requires too much effort. 2. Instructor SA is challenged because it takes two screens to completely describe the EW environment. 3. Instructors have poor SA regarding the status of threats or ownship vulnerability. 4. The Master Electronic Warfare Environment status pages are awkward to use because the threats become unsorted and the instructor is forced to hunt for entries.***
An Unfriendly Human Computer Interface	**1. *The Spaceball is hard to use and intensely disliked.*** 2. IOS Display pages are hard to read at night and from a distance. ***3. The touch-screen is not always responsive and lacks consistent tactile feedback.*** 4. Instructors have difficulty remembering which parameters they have changed when modifying a scenario. 5. It is difficult to visually track from the line select number to the corresponding text. ***6. Instructors are prone to make key entry errors.***
IOS is under-used to Debrief and Monitor Performance	1. Instructors do not have access to an acceptable set of performance indices to support their debriefs. 2. Video recording capability is not used for debriefing.
Infrequently used Instructional Support Features of the IOS	1. The use of snapshots, record/replay, and selecting moving models are valuable in principle but unused in practice; they often cause system crashes. 2. The instructional capability of the IOS is underutilized because instructors cannot easily reconstitute scenario parameters to support repeated practice of key tasks.
Malfunctions suffer Multiple Problems	1. Most malfunctions are presently inserted manually because it is difficult to use the precondition capability of the IOS. 2. Instructors use only a subset of the total malfunction capability of the IOS. 3. The interactions among malfunctions do not create a realistic cascading effect during a mission. 4. Instructors do not fully understand the status nor function of many of the malfunctions in the IOS.
Difficulties Using Environmental Features	1. Wind environmental controls are overly detailed and require too many instructor selections. 2. Instructors must enter awkward text-based information for icing, precipitation, moon/star sky, and runway conditions. 3. Weather data on the IOS are not formatted in a manner consistent with traditional aviator weather briefings.

The IOS experts generated 83 problem statements. The project team reduced this to a smaller list by combining similar problem statements and eliminating infrequently encountered problems. Table 1 illustrates the resulting 34 problem statements, organized into ten categories. The most salient problems with IOS were then identified through a second set of interviews. A five-point scale was developed to rate the impact of each problem on training effectiveness (“Very Low”, “Low”, “Middle”, “High”, or “Very High”).

IOS experts were then asked to evenly distribute the problems across these five categories. For example, the “very high” category should reflect the 20% of problems with the greatest potential impact. Although the experts generally thought that all 34 problems were important and that solutions for any of them would be valuable, there was considerable agreement concerning rank orders among the problems.

Eleven problems were consistently rated as having relatively low impact. Median ratings for 12 other problems were “middle.” The potential impact of the remaining 11 problem statements was rated either “high” or “very high” (shown in ***bold italics*** in Table 1). The three problem statements that are also underlined in Table 1 were consistently rated as having the most impact. The top 11 problems were not evenly distributed across problem categories. Rather, they were confined to five of the ten categories. Further, nine of the 11 high impact problems were in just three categories-- instructor SA, EW instruction, and unfriendly human-computer interface.

The next step was to identify solutions for these problems. Through iterative reviews by the project team, eight solution packages were identified and linked to the problem statements. These are listed in Table 2 along with the primary factors that were considered during the selection process and the recommended disposition of the package. The solution packages and recommendations were reviewed by a working group consisting of instructors, engineers, and project team members. The goal was to select the total solution set that maximized potential gain while also being executable within program resources.

Table 2: Summary of Solution Selection Considerations

Solution Package	Selection Considerations and Recommendations
1. Integrated Instructor Training	Economical development; Rated “very high” by IOS experts; Impacts 2 problems (1 High, 1 Medium); Eliminate since it has less impact than other solutions
2. *Image Map*	Its development will likely consume entire programming budget; Rated “very high” by IOS experts; Impacts a large number of important problems (7 High, 2 Med., 7 Low); ***Retain*** for final solution since it has high-impact individual capabilities
3. Reorganization of Existing IOS System	Economical development; Moderate rating by IOS experts; Impacts 15 problems, one highly important (1 High, 7 Med., 7 Low); Eliminate since selection of other feasible enhancements will limit its overall impact
4. Input/Output Modifications	Its development will likely consume entire programming budget; Moderate rating by IOS experts; Impacts two problems (2 Hi); Eliminate since it represents weak cost-benefit tradeoff
5. *Graphic Improvements*	Economical development; Low/moderate rating; Impacts 13 problems, in combination with other solutions (5 Hi, 4 Med, 4 Low); ***Retain*** for final solution since it can be combined with other solutions
6. IOS in Training Observation Center	Development is costly, hardware-driven, and high technical risk; Moderately rated by IOS experts; impacts a select number of problems (1 Hi, 3 Med, 1 Low); Eliminate due to high technical/fiscal risk for this project
7. Performance Monitoring	Development will consume entire programming budget, but is doable; Rated low by IOS experts; Impacts only two low- rated problems (2 Low) Eliminate in 1st round due to low impact potential
8. *X-Windows Implementation*	Time-consuming and costly for complete implementation; Moderately rated by experts; Impacts problems in combination with other solutions (3 Hi, 2 Med, 5 Low) ***Retain*** for final solution since it has high-impact individual capabilities

E-IOS FUNCTIONAL SPECIFICATION

The highest payoff item was determined to be a new map display and associated functions. The map solution shown in Figure 1 was entitled the *Threat Map Display* (TMD) and it combined all three of the selected solution packages--an Image Map, Graphic Improvements, and X-Windows Implementation. TMD features included: (a) a Trackball input device that would be easier to use and could improve instructors' ability to set up and manipulate scenarios, and (b) threat icons that can be directly manipulated by instructors in order to quickly alter threat positions and modes. The main elements of the final E-IOS specifications were:

- Cartographic map with Joint Operational Graphic (JOG) chart resolution
- Flight route and modified waypoints
- Threat icon tool bar
- Pop-up object annotation
- Trackball input device
- Scenario set-up page
- Embedded help functionality for the TMD
- Re-formatted Current Conditions window
- X-Windows click and drag interface
- Iconic representation of threats
- Color-coded indication of threat status

Instructors designed a revised format for organizing information in the Current Conditions window. They also organized this status field into six areas corresponding to: flight information (e.g., airspeed, heading), latitude/ longitude, time, weather (e.g., temperature wind,), radio frequencies, and weights (fuel, gross weight). A three-button Trackball was selected to replace the Spaceball (which had been reported by participants as very difficult to use). This iterative design process provided maximum input from the end-users concerning the final product.

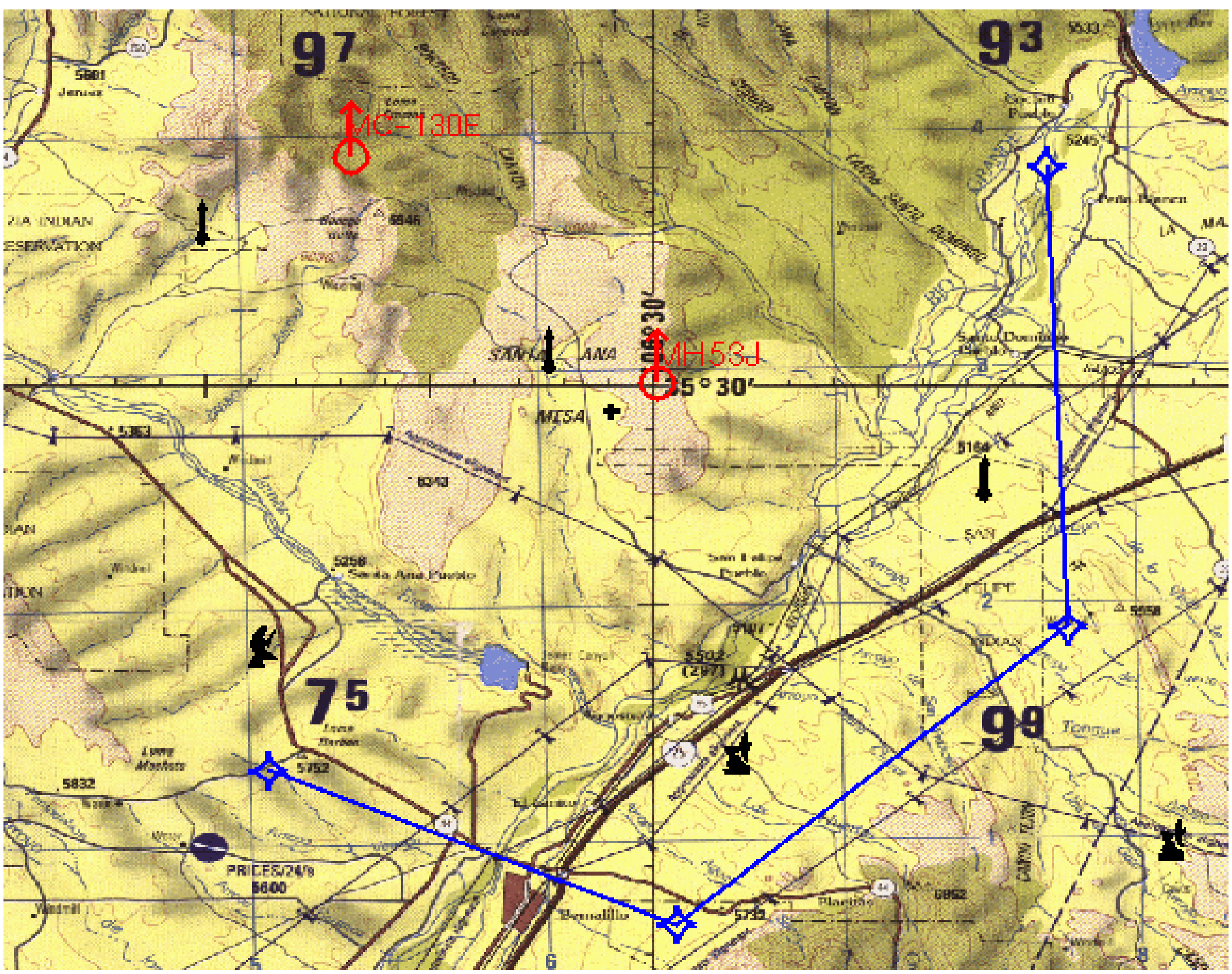

Figure 1: The E-IOS Threat Map Display (TMD)

The TMD replaces the austere C-IOS ground-track map which uses alphanumeric symbology to represent cities (i.e., "C's"), mountains (i.e., "M's"), valleys (i.e., "V's"), etc. The TMD, conversely, uses an object-oriented visual format within an X-Windows/Motif based environment. Areas include a Menu Bar for opening and closing windows; a map area for displaying topographic, physical, and cultural features; an iconic toolbar for controlling the appearance of threat emitters of various types and classes; as well as fields below the map area for displaying current conditions, system status, and messages. Major categories of entities that were represented in the TMD as icons were Surface to Air Missiles (SAMs), Anti-Aircraft Artillery (AAA), Radar, and Navigation Aids.

E-IOS IMPACTS ON INSTRUCTOR PERFORMANCE

Method

Participants. Seven MH-53J Pilot and five MH-53J Flight Engineer simulator instructors were observed as they accomplished a variety of tasks in both the C-IOS and E-IOS. These subjects comprise the entire population of MH-53J simulator instructors at the 58 SOW. Four instructors were active-duty USAF flight instructors and eight were contractor simulator instructors.

Test Apparatus and Mission Script. The study was performed using two side-by-side Silicon Graphics Indigo[2] microcomputer systems with 21-inch monitors and multi-function Trackball subsystems. These systems were networked via ethernet -- one system was used to emulate the IOS's touch-screen keyboard layout, while the other was used to emulate either the ground-track map from C-IOS or the threat-map display from the E-IOS.

Two mission scripts with fourteen embedded tasks were developed for the study, one for the C-IOS condition, and the other for the E-IOS condition. Both were designed to operate on the stand-alone test apparatus and closely approximate typical MH-53J missions that instructors may perform in the WST. Scripts were also designed to present a similar degree of difficulty and scope, yet minimize the amount of subject recall between scenarios by eliciting different responses. Both scripts depicted low-level routes in New Mexico, and included ten electronic threats distributed near the flight path.

Data Structure and Analysis. The experimental design was completely within-subjects—all subjects performed each task under both IOS conditions. Data from the first and last of the fourteen tasks were combined into an overall assessment of the C-IOS or E-IOS. The remaining twelve tasks involved activities normally accomplished by instructors. For analyses of statistical significance, these tasks were grouped into three categories based on *a priori* considerations of the activities involved. We combined four tasks that involved interpreting information concerning *Current Conditions*. Then we aggregated three tasks requiring subjects to estimate heading/bearing and range/distance from the display, reflecting *Spatial Interpretation*. Five tasks involving moving, enabling, and changing the mode of threats were combined into a category we refer to as *Threat Manipulation*.

For each of the twelve performance tasks, three dependent measures were recorded: (1) the time required to complete each task, obtained by having a researcher operate a stop watch as each trial started and ended; (2) subjects' ratings of task difficulty based on the following 5-point scale – "Very Easy", "Easy", '"Average", "Hard", or "Very Hard;" and (3) a binary assessment (Yes/No) of whether the subject needed coaching to accomplish the task. In addition, distance estimation errors were recorded, but only for the spatial estimation tasks. Finally, supplemental instructor comments were also recorded.

A multivariate analysis of variance (MANOVA) was used test the significance of IOS condition main effects (C-IOS or E-IOS), task main effects (Current Condition, Spatial Interpretation, or Threat Manipulation) and the IOS by task interaction based on response time, difficulty rating, and coaching required. This approach was taken to control for Type I error inflation (Harris, 1975).

Distance estimation error and overall assessment data were analyzed separately because they were not fully crossed with task type. Distance estimation was not included in the MANOVA since errors were only recorded on the three Spatial Interpretation tasks. Overall assessment data were excluded as they transcended task type.

Procedure. Subjects were divided into four groups with three participants in each. Two groups received the C-IOS condition followed by the E-IOS condition, while the other two groups started with the E-IOS condition and ended with the C-IOS. Subjects who started with the C-IOS condition received a self-paced training booklet to familiarize them with basic operation of the C-IOS. They were then taken individually to a testing room to perform the C-IOS scenario with the "stand-alone" test apparatus set up in the C-IOS configuration. Self-paced training took about 15 minutes. Subjects were tested individually, with each test session lasting about 20 minutes. After their test session, each subject returned to the training room and the next subject took his place. After all three subjects completed C-IOS testing, the test apparatus was changed to the E-IOS configuration. Subjects studied a self-paced E-IOS training package followed by individual testing with the E-IOS configuration. The two other groups of subjects followed a similar process, starting with E-IOS training and testing and finishing with C-IOS training and testing.

Results

Overall effects. The results most definitely substantiate the superiority of the E-IOS over the C-IOS on all four dependent measures. These results are depicted in Figure 1, where the data have been collapsed across tasks for each measure. With regard to response time, tasks using the E-IOS were performed in 13.8 sec. on average compared to 44.9 sec. for the C-IOS, more than three times faster. Instructor-supplied difficulty ratings showed a comparable difference, with the E-IOS rated at 1.3, near the low end of the scale, compared to 3.1 for the C-IOS. Similarly, the coaching index showed the superiority of the E-IOS, as only 4% of trials required coaching compared to 20% for the C-IOS. Finally, the three trials for which distance estimation error was computed showed the C-IOS condition to result in substantially greater error, with a mean of 4.8 NM, compared to its E-IOS counterpart, with a mean of 1.8 NM.

The MANOVA was used to test for the effects of IOS condition (C-IOS versus E-IOS) for current conditions, threat manipulation, and distance estimation tasks, with response time, coaching, and difficulty rating as dependent measures. As expected, the multivariate F (Wilk's Lambda) for IOS condition was significant (F=50.931, df = 3/9, p<.001). Follow-up testing on the individual response measures showed that the E-IOS resulted in shorter response times (F=66.538, df = 1/11, p<.001), lower difficulty ratings (F=56.107, df = 1/11, p<.001), and less frequent need for coaching (F=6.763, df = 1/11, p<.025) relative to the C-IOS. Treatment order (E-IOS first versus C-IOS first) was not statistically significant, and in fact had virtually no effect on any of the measures.

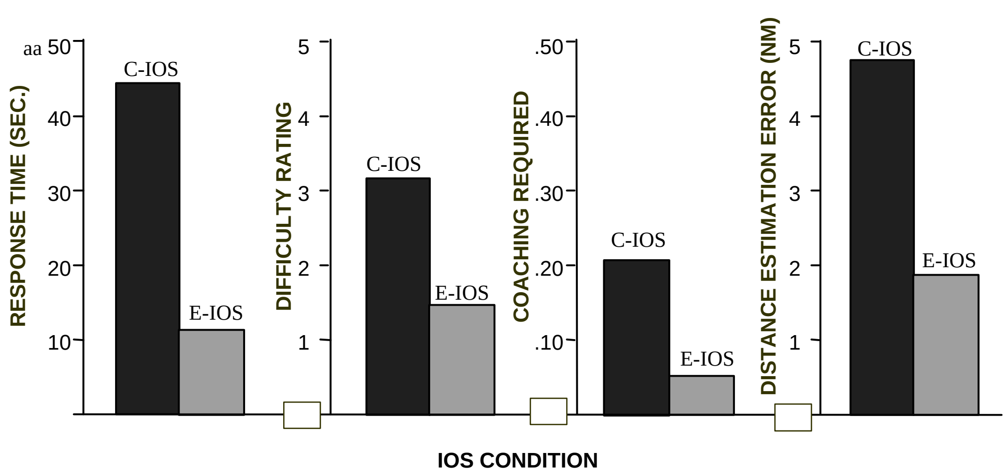

Figure 2. Overall mean performance for the E-IOS and C-IOS conditions.

For the fourth dependent measure, distance estimation error, a univariate ANOVA was performed to assess the impact of IOS condition. To control for inflation of Type I error due to this second analysis of IOS effects, a Bonferonni adjustment procedure was employed to maintain an experiment-wise alpha level of .05. Dividing the experiment-wise alpha by two, all results are compared against a nominal alpha of .025 (Harris, 1994). This did not affect the significance of any IOS treatment effects. A univariate ANOVA on the error index showed that it, too, was significantly reduced under the E-IOS condition (F=12.77, df = 1/11, p<.004).

Findings by Task Type. To further explore the tasks for which the E-IOS is most useful and whether there are limits to its impact on usability, we next looked at the effects between and within task types. The main effect of task type was found to be statistically significant (Wilk's Lambda F=73.136, df = 6/6, p<.001) as was the interaction between task type and IOS condition (Wilk's Lambda F=33.102, df = 6/6, p<.001).

Figures 3 and 4 present the averages for these task categories for response time and average difficulty rating, respectively. Looking first at Figure 3, we see that, consistent with the significant interaction, the superiority of the E-IOS on response time varies greatly with type of task. In particular, the response time differences are fairly small for the *Current Conditions* tasks, with the E-IOS enjoying only a 3.6 sec. advantage. However, this difference increases dramatically for the *Spatial Interpretation* tasks, to 14 sec. The differences are even larger for the *Threat Manipulation* tasks. In this case, the average under the C-IOS condition is more than 80 sec. compared to less than 16 sec. for the E-IOS. Follow-up testing showed that the impact of IOS condition on response time was significantly greater for *Threat Manipulation* tasks (F=49.331, df = 1/11, p<.001) relative to the other two tasks (F=4.320, df = 1/11, p<.064).

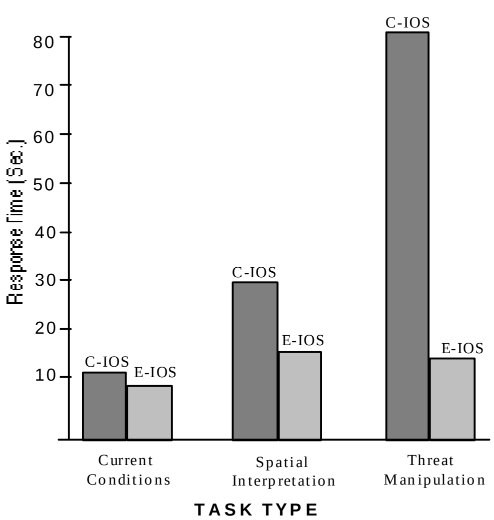

Figure 3. Average Response Time by IOS Condition & Task Type.

Figure 4 shows the average instructor difficulty ratings by IOS condition for all four task categories. Note that this figure includes an *Overall Assessment* category that reflects the summary ratings obtained on Tasks 1 and 15. The results completely mirror those in the previous figure. The E-IOS advantage is clearly the smallest for the *Current Conditions* category, intermediate for *Spatial Interpretation*, and largest for *Threat Manipulation*. Follow-up testing on the pairwise mean differences supported the increasing impact of the E-IOS on rated difficulty across the first three task categories (F=29.276, df = 1/11, p<.001; F=85.578, df = 1/11, p<.001). The overall assessments provided by instructors at the beginning and end of the evaluation session overwhelmingly endorse the superiority of the E-IOS versus the C-IOS for supporting usability, ease of use, and learning speed. A separate analysis of the *Overall Assessment* task revealed a significantly higher difficulty rating for the C-IOS condition (t=10.94, df = 11, p<.001).

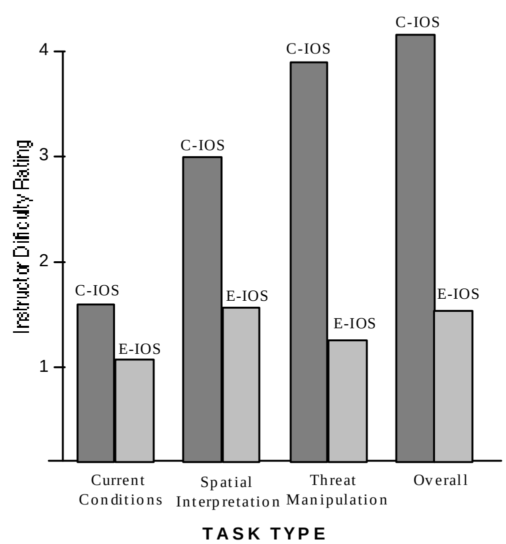

Figure 4. Average Difficulty Rating by IOS Condition and Task Type.

The final dependent measure in this MANOVA was the proportion of trials in which subjects required coaching to arrive at an acceptable solution to the various tasks. Due to the low overall levels of coaching in the data, univariate follow-up testing did not reveal a significant interactive effects in the data ($F=3.477$, $df = 1/11$, $p<.089$; $F=1.165$, $df = 1/11$, $p<.303$), though the trend in the data was toward more coaching required for the familiar C-IOS. This suggests a very quick learning process for the new E-IOS interface.

Discussion

The data from this study unequivocally demonstrate the superior instructor performance supported by the E-IOS compared to the C-IOS. The greater usability of the E-IOS was evident in all three types of tasks—reporting information from the Current Conditions windows, interpreting spatial information, and threat manipulation—as well as in overall assessments of the two systems. Moreover, this superiority was found in all four dependent measures collected, including speed, accuracy, incidence of coaching, and task difficulty ratings. Though not reported above, the performance advantage offered by the E-IOS was present in **all 12 subjects tested**, not just in the mean differences. As expected, the drag-and-click capabilities offered by the Windows interface inherent in the E-IOS supported substantial gains in response efficiency compared to the cumbersome line entry-select features of the C-IOS. However, even the more subtle changes in the E-IOS, such as the reorganized Current Conditions windows, were associated with statistically significant gains relative to the C-IOS.

As a technical aside, it is worth noting that despite the large effect sizes observed, the present study was a fairly conservative test of the E-IOS's superiority in three key ways. First, due to the nature of the task requirements, subjects were told at the beginning of certain trials the threat site number they would be manipulating. This obviated the need for subjects to access the Threat Site page in the C-IOS condition as would normally be the case. Had this been required, the differences in response time, rated difficulty, and errors would have been much greater. Second, due to programming limitations, we were not able to employ an active touch-screen for the C-IOS condition. As a result, subjects had to use a (second) Trackball to make line-select entries on the second display. Based on subjects' comments during and after the study, the use of the Trackball was viewed as clearly superior to the C-IOS's present touch-screen, further understating the IOS differences in a conservative direction. The third, and probably most severe limitation, is that the threat map display (TMD) on the E-IOS was implemented as a single, static map sheet instead of the dynamic version that will ultimately be deployed. Had the map been dynamic, moving in real-time with aircraft movements, it is likely that subjects' employment of E-IOS capabilities to manipulate threats and interpret spatial information would have even been greater. But despite these limitations, the superior usability of the E-IOS was evident in all aspects of testing.

As a final point, it is instructive to consider the quantitative impact of the E-IOS in the context of an actual training session. In the present study, the E-IOS reduced the average time to manipulate a single threat by more than one minute. If one considers that a typical scenario might require the instructor to manipulate some one-dozen threats several times, this translates into a savings of almost one-half hour over the course of a session, time which could profitably be used to give hands-on instruction to the trainees. Even spatial interpretation tasks, such as estimating the range and bearing to a tactically significant landmark, are performed 14 sec. faster. Over the course of a training session, this will translate into substantial savings in time and effort. In addition, the percentage of threat manipulation tasks requiring coaching drops from 28% to 3% under the E-IOS, underscoring the greater ease of learning and use under the new system. Based on the strength of these results, the authors strongly recommend that the squadron adopt a wholesale replacement of the present IOS with the advanced features and capabilities of the E-IOS.

Implications for Training. All instructors were enthusiastic about the E-IOS. However, some offered suggestions for further IOS improvements. For example, several subjects suggested that terminal area data from sectional charts be included as a map option along with JOGs and TPCs. One instructor had the novel insight that the user could benefit from seeing the missile flyout pattern on the map by displaying a dotted line emanating from a threat icon after it fires. Also, several instructors expressed a preference to have threat icons backlit by inverse video so they would stand out from the terrain better. Revised color selections would also help visibility. In addition, many instructors indicated that the threat labels on the TMD should be larger, more legible, and distinctive. They also want to have the ability to move waypoints and see their objective information displayed as a pop-up window. These features should be incorporated into the next version of the E-IOS.

Given the enthusiastic support of the MH-53J instructors who took part in E-IOS design and evaluation (both Air Force and contractor) the next logical step is to incorporate the E-IOS software and Trackball into the MH-53J WST. We anticipate that this simulator IOS modification will be completed by fall 1998. When this happens, we will be able to assess the impacts on actual training.

The MH-53J community is not alone in its frustration with traditional IOSs. Instructors from other 58 SOW weapon systems have also expressed a great deal of interest in adopting these changes for their simulators as well. The 58 SOW implementation plan reflects this broad "grass root" support. The next steps beyond MH-53J WST integration will be to document lessons learned, and then expand the application to all 58 SOW simulators. The potential benefits of E-IOS capabilities extend well beyond 58 SOW. As one example, the Air Education and Training Command (AETC) may use the E-IOS functions as the basis for specifying a common command-wide IOS template. More generally, the kinds of capabilities built into the E-IOS should be considered in all applications where flight simulators are used for EW instruction.

The control and SA problems that were documented in this simulator study also plague EW training inflight. So far, the E-IOS has drastically improved real-time observation and control of the dynamic EW environments of high fidelity flight simulators. AETC plans to package these IOS capabilities with an airborne EW and environment simulation system for use inflight where aircraft EW avionics would be "stimulated." This extends the original On-Board EW Simulator (OBEWS) concept by integrating not only the EW simulation with an environmental simulation (terrain database for line-of sight and clutter calculations), but also integrates the controlling mechanism (E-IOS). Anticipated benefits of this expansion to the flight environment are more complete EW training than is now available combined with lower costs due to a reduced need for range time.

SUMMARY

The present study provides a strong empirical basis for adding the advanced features of the E-IOS. Drag-and-drop capabilities support more efficient threat manipulation and assessment. The cultural and terrain features on the TMD support more accurate spatial interpretation and higher levels of SA. Users are able to obtain faster, more accurate estimates of heading and range information. The Trackball is highly compatible with the TMD's iconic representation of tactical and navigation information. The grouping of like information within the Current Conditions window supports more efficient reporting, not only for the pilot instructors but for flight engineers as well. Also, the improvement in system use is just as pronounced for highly experienced users of the present IOS as it is for inexperienced instructors; hence, the benefits associated with the E-IOS will accrue to **all** simulator instructors who conduct EW training.

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