Volume I

Standard Terminal Automation Replacement System
Human Factors Review

Prepared by:
Standard Terminal Automation Replacement System
Human Factors Team

Submitted to:
Chief Scientific and Technical Advisor for Human Factors

December 18, 1997

Acknowledgments

The conduct of the Standard Terminal Automation Replacement System (STARS) review required the efforts of many people from multiple organizations. The professional, technical, and logistical efforts made by these individuals and organizations, especially under the severe time constraints imposed, were exceptional and highly successful. The assessment produced critical information about the STARS Early Display Capability (EDC) system. The findings can be used to improve system performance, facilitate the deployment of terminal automation, and provide the air traffic controllers with a user-friendly system that will enable them to provide their crucial services to the National Airspace System. The Human Factors Team wishes to acknowledge the significant contributions of those organizations and, by extension, to the individuals who participated but are far too numerous to name. We thank you all.

The STARS Human Factors Team was drawn from five organizations: the Office of the Chief Scientific and Technical Advisor for Human Factors (AAR-100), the Office of System Architecture and Investment Analysis NAS Concept Development Branch (ASD-130), the William J. Hughes Technical Center Human Factors Branch (ACT-530), the Volpe National Transportation Systems Center, and the MITRE Center for Advanced Aviation System Development. The team also received human factors support from NYMA, Inc. and System Resources Corporation.

Two organizations at the Technical Center had the primary responsibility to develop and conduct the simulation exercises for the assessment. The Air Traffic Control Engineering and Test Division (ACT-200) and the Aviation Simulation and Human Factors Division (ACT-500) provided the laboratory facilities, simulation scenarios, target generation, simulation pilots, and data collection capability to support the exercises. Their expertise and proficiency produced six nearly flawless simulation runs that were the foundation for the assessment. The Technical Center also provided logistical support for the entire effort.

The air traffic controllers who participated in the assessment were extremely professional and dedicated to the objectives of the effort. We thank them and their facilities (Atlanta, Boston, Dallas-Fort Worth, Kansas City, Los Angeles, Miami, Minneapolis, New York, Phoenix, Pittsburgh, Seattle, and Washington National) for releasing them to participate for their major contributions. We also wish to acknowledge the major contributions of the National Air Traffic Controllers Association (NATCA) and, in particular, the two NATCA representatives who have been working with the STARS program. We also appreciate the participation of Professional Airways Systems Specialists (PASS) for providing a System Specialist to observe the assessment and be available for consultation.

We also want to acknowledge the contributions of the Integrated Product Team for Terminal (AUA-300) and the STARS Program Office (AUA-310) for providing all necessary coordination to expedite the integration of the prototype EDC system and facilitating the conduct of the assessment activities. We also appreciate the efforts of the manufacturers of the STARS subsystems, Raytheon Corporation and the Hughes Corporation, who provided the EDC hardware and software, facilities for planning the effort, expert advice on system operation, and support for system training.

Finally, we wish to acknowledge the contributions of other organizations in the Federal Aviation Administration who participated in the development and execution of this project. These organizations include the Air Traffic Operations Program (ATO), the Air Traffic Resource Management Program (ATX), the Air Traffic Systems Requirements Service (ARS), and the Air Traffic Systems Development Directorate (ARU). Finally, without the direction and support of the STARS HF Steering Committee, this activity would not have been possible.

Once again, the Human Factors Team wishes to recognize the superb performance of all who participated in this assessment and to thank them for their professionalism, dedication, and efforts in making this successful.

Preface

The Federal Aviation Administration formed a Standard Terminal Automation Replacement System (STARS) Working Group to identify and resolve human factors concerns with the Early Display Capability (EDC) system before it is introduced in the field.

The goals of the Human Factors Working Group were to

a. conduct an initial diagnostic usability assessment of the STARS EDC system (as configured and available December 8 through 12);

   The purpose of this activity was to document some of the issues associated with the EDC evaluation configuration and propose methodologies to address those issues. Documentation will include the approximately six previously identified air traffic issues and any others noted during the evaluation. Any issues that are resolved as a result of the assessment are to be highlighted.

b. identify additional STARS Transition/Full Service Level/Pre-Planned Product Improvements human factors research areas, from the information available to date; and

c. provide a plan to re-address the 89 previously identified HF issues from the STARS Monitor and Control Workstation study.

This report is in response to these requirements. It is divided into two volumes. Volume I contains three chapters: the Early Display Capability System Initial Diagnostic Usability Assessment report, the Transition and Pre-Planned Product Improvements Human Factors Research Application Areas and Activities report, and the Re-Evaluation of the Standard Terminal Automation Replacement System Monitor and Control Workstation Computer-Human Interface assessment plan. Volume II contains the appendixes for Volume I.

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Executive Summary

This Human Factors Review is in three chapters. It describes the findings of the initial diagnostic usability assessment of the Standard Terminal Automation Replacement System (STARS) Early Display Capability (EDC) system. This evaluation is the first stage of a comprehensive process to assess and address EDC human factors issues. It includes methodologies to resolve the issues raised and identifies STARS Full Service Level (FSL) transition and pre-planned product improvement human factors research and application engineering areas. It also presents a STARS Monitor and Control Workstation (MCW) proposal to re-evaluate the usability of that system. In response to a congressional request, the Chief Scientific and Technical Advisor for Human Factors (Chairperson of the STARS Steering Committee) directed that this report be prepared.

A planning meeting was held between the Human Factors Team (appointed by the STARS Issues Subgroup Chairperson) and National Air Traffic Controllers Association (NATCA) representatives at Raytheon Electronic Systems during the week of November 17, 1997. Starting on December 8, 1997, 14 NATCA air traffic control specialists, representing 13 terminal facilities, and 7 human factors specialists spent 2 days preparing for the EDC usability assessment and 3 days identifying EDC computer-human interface issues. The 2 days of preparation included training on Boston Terminal Radar Approach Control (TRACON) airspace and on the EDC prototype system. The next 2 days were used to identify and record usability issues during simulations with Boston TRACON air traffic scenarios on prototype EDC Terminal Controller Workstations. One day was spent exercising system functions with minimal levels of air traffic. Another day involved working scenarios with varying levels of traffic and responding to special air traffic control task-referenced events. This effort was an initial usability study and had certain limitations as discussed in Chapter 1.

Over the course of the week, human factors specialists removed redundancies and consolidated issues for presentation to the controller team on the final day. Controller input was used to refine the issues and element descriptions. This process yielded 98 items, which were categorized into 9 areas with associated elements. Issue areas included: data input, workspace ergonomics, windows, target attributes, data block attributes, display attributes, cognitive issues, menus, and system functionality. In general, the controllers did not believe that the prototype EDC system adequately supported their air traffic control tasks. It is recommended that the issues identified in the EDC usability assessment be addressed by further human factors activities and development before the system becomes operational. However, it appears that these issues can be ameliorated through the application of standard engineering practices.

Methods for resolving the usability issues include iterative rapid prototyping, design validation/usability studies, and operational performance assessments. Preparations are underway to form prototyping efforts to address the identified human factors issues. Given the short time frame available to complete these efforts for the EDC configuration of STARS, the recommended operational performance assessment may run concurrently with the EDC Operational Test and Evaluation activities. For the Initial System Capability (ISC) assessment, a

separate human performance baseline activity is recommended. A schedule of proposed activities is provided.

This report also includes a description of the research application areas associated with the STARS transition to FSL (incorporating both ISC and Full Service Capability). Although the information currently available is not sufficient to develop detailed research plans, a foundation for building them is presented. Also presented is a proposal for re-evaluating the usability of the MCW.

Volume I
Chapter 1

Early Display Capability
Initial Diagnostic Usability Assessment

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Submitted to:
Chief Scientific and Technical Advisor for Human Factors

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Chapter 1

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1. Introduction

Although the Standard Terminal Automation Replacement System (STARS) development is nearing completion, there is growing concern over human factors (HF) issues associated with computer-human interaction, controller acceptance, and the process for integrating HF engineering practices into system acquisition and development. Accordingly, the Federal Aviation Administration (FAA) and the users formed an HF Steering Committee to identify and resolve HF concerns with the STARS Early Display Capability (EDC) system before it becomes operational in the field.

This chapter addresses the STARS HF Steering Committee's requirements to conduct a structured usability assessment of the STARS EDC system (as configured and available December 8 through 12, 1997), to document HF issues, and propose methodologies for their resolution. The STARS HF Steering Committee formed two subgroups: an Issues Subgroup and a Process Subgroup. The Issues Subgroup was responsible for the EDC HF assessment. This document presents the results of the HF analyses completed by the Issues Subgroup HF Team.

1.1 Background and Context

The STARS replaces 172 Automated Radar Terminal Systems (ARTSs) at Terminal Radar Approach Control (TRACON) facilities within the National Airspace System and 199 Department of Defense systems. The strategy for replacement and enhancement of these systems is divided into three evolutionary stages: the EDC, the Initial System Capability (ISC), and the Final System Capability (FSC). The EDC stage replaces the current ARTS display consoles and the Digital Bright Radar Tower Equipment with new display hardware while maintaining the Existing Automation Service Level (EASL). It also provides a controller interface to the new Emergency Service Level (ESL) back-up system. A new Monitor and Control Workstation (MCW) also will be implemented for Airway Facilities (AF) personnel at the TRACONs. The ISC stage replaces the ARTS computers with new central computers for radar and flight data processing. It also provides the infrastructure needed to support interfaces to new Air Traffic (AT) service applications and to the enhanced Traffic Flow Management (TFM) system. In the FSC stage, new functions will be implemented for controllers. These include a range of automation capabilities that are currently in operational use at field facilities or under research and development by several government agencies.

HF activities should be integrated throughout system development. Table 1 illustrates the nature of the HF work that would be required to fully support the STARS Program. As shown in the table, the first stage is an initial diagnostic usability assessment. Iterative prototyping exercises would then be completed to evaluate and refine proposed solutions to identified problems. Next, a design validation study would be conducted under realistic conditions that simulate the essential components of users' tasks associated with the system. The goal of this study would be to confirm designs that optimize the computer-human interface (CHI). Finally, an operational performance assessment would be conducted to measure and verify safety and efficiency using the stabilized STARS and realistic operational scenarios.

Table 1. Human Factors Activities Across STARS Operational Domains and Service Levels

Operational Domain	Early Display Capability (EDC)	Initial System Capability (ISC)	Final System Capability (FSC)
TRACON	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment
TOWER	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment

MONITOR and CONTROL WORKSTATION	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment	• Diagnostic Usability Assessment • Prototyping/ Design Validation • Operational Performance Assessment

In the context of the overall STARS development effort, this report focuses on a diagnostic usability study for the TRACON EDC system. An initial diagnostic usability study has already been conducted for the MCW (Mogford, Rosiles, Koros, & Held, in press). This assessment identified 89 HF issues that may be of concern for the STARS MCW. (A list of these issues is in Volume II, Section 1.)

1.1.1 EDC System Characteristics

The first implementation of the STARS is currently scheduled for deployment at Washington National Airport during the summer of 1998. Although EDC is primarily a display replacement, there are several noticeable differences between it and the current TRACON system. For example, EDC utilizes a 20 in. x 20 in. color-capable display; the present display is smaller (18 in. diameter) and monochromatic and so does not allow for the color coding of information. Also, the knobs and switches of the ARTS console have been replaced by menus on the situation display. This changes the way a controller performs many common functions (e.g., modifying maps, altitude filters, brightness, and range rings and moving lists) and adds menus inside opaque windows that occupy portions of the situation display.

In addition to the display replacement, the EDC provides a digital equivalent to radar data now provided by the ARTS, resulting in new target symbology. A target extent symbol (i.e., trapezoid) is used to depict aircraft position and the uncertainty in an aircraft position (as a function of factors such as the distance from the radar). Currently, an aircraft is displayed with the raw radar return and a beacon symbol. New EDC radar target symbology is also used to depict primary and secondary target returns for associated and unassociated tracks, and new EDC symbology for target history has also been implemented.

There are several major differences between the EDC and the ISC/FSC versions of STARS. For example, the EDC system will still be driven by ARTS, whereas STARS will have its own automation system. This has the potential to substantially increase the capabilities of the system with associated changes in the user interface. Another difference between EDC and later stages of STARS is that EDC uses the ARTS trackball and keyboard and two new rows of function keys. Later stages of STARS use a three-button mouse and a QWERTY keyboard. (The QWERTY keyboard refers to the standard keyboard modeled after the typewriter in which the first six keys in the left portion of the top row read Q W E R T Y.) The ARTS keyboard has the keys arranged alphabetically and is considerably smaller than the proposed QWERTY version.

The hardware and software of the STARS baseline EDC system were modified to satisfy the objectives of the initial usability assessment. Four Terminal Controller Workstations at the William J. Hughes Technical Center were modified by replacing the console shelf, keyboard, and trackball and by providing software changes to accommodate the new keyboard and trackball. This included features intended to improve display control and reduce heads-down time.

The EDC console shelf design permitted recessed mounting of the keyboard and trackball on the right hand side of the shelf. The movable STARS QWERTY keyboard was replaced with a shelf-mounted ARTS ABC keyboard enhanced to provide 20 additional function keys. The movable three-button STARS trackball was removed in favor of a single-button ARTS trackball, also shelf mounted. A power supply with increased capacity for the keyboard and trackball backlighting was provided.

Software was modified to operate with the new devices. Macro commands using the 20 new function keys were included to permit single key entry to change mode, open/close windows, home cursor, acknowledge messages, and so forth. Macro commands also were implemented to streamline range scale and off-centering functions. Increased flexibility in selecting displayable target symbology also was provided. A number of known System Trouble Reports were also addressed including the ability to use Quick Keys in EASL.

1.1.2 Identification of Prior Human Factors Issues

AT HF issues associated with STARS have been identified in the past by NATCA, the FAA, the STARS Team, and others. (The STARS Team is composed of Raytheon and Hughes personnel dedicated to STARS Program.) These concerns include

a. ABC vs. QWERTY Keyboards: TRACON controllers are very experienced with the ARTS keyboard and may require training and practice with the QWERTY keyboard to overcome the automatic tendencies developed with years of practice on ARTS. In addition to transfer of training issues, there is a concern that the layout of the QWERTY keyboard may cause tasks requiring one-handed typing to be more difficult or slower.

b. Keyboard/Trackball Layout: The proposed data-entry devices (QWERTY keyboard and trackball) are larger than the current configuration (ARTS keyboard and trackball). The sizes of these devices leave less room for the flight strips and a notepad that controllers require. In addition, the trackball/cursor mapping is not the same as the current system.

c. Opaque Windows: Menus and other information are presented to controllers via windows that obscure the portion of the situation display that they occupy. Although these windows can be moved, resized, or closed, they could obscure important data (e.g., conflict alert) necessary to predict and prevent potential conflicts.

d. Aircraft Target Extent and Position Symbols: The EDC system uses a trapezoid to display the uncertainty of an aircraft position. The aircraft symbol currently displays the raw radar return with a beacon symbol. Controllers are concerned about absent or potentially confusing information contained in the target extent and position symbols.

e. History Trail: The EDC system displays the history trail of the aircraft with a series of dots (the spacing of which depends on the speed of the aircraft). The controllers suggest that this display of the trail may not be as good an indicator of the rate of turn of an aircraft as is found on the ARTS.

f. Display/Control Design: The current EDC implementation involves menu-driven steps through window lists. There is concern that the menus require attention to be directed away from the primary traffic display. This may result in an unacceptable amount of heads-down time. (Heads-down time refers to the time and attention required to perform a secondary task that detracts from the attention devoted to the air traffic situation display.) The replacement of the knobs and switches of the ARTS console by menus on the situation display may substantially increase controller workload. It replaces a task that could previously be performed with minimal visual attention (i.e., reaching over and turning a knob) with a task that requires visual attention to make trackball or keyboard entries (i.e., navigating through a menu or typing and implementing commands).

Although these concerns are not comprehensive, they present an introduction to HF issues that merit further investigation. As mentioned previously, most of these issues identified in STARS are applicable to EDC. The only exception is that the items associated with the QWERTY keyboard and STARS trackball are not relevant to the EDC configuration used in the present analysis.

1.1.3 Need for a Comprehensive HF Evaluation

From the standpoint of operational effectiveness, a suitable STARS EDC user interface is critical. User interface considerations pervade all other aspects of system design. A good user interface entails more than effective display or keyboard design. It also includes the structure and order of a user's tasks, the sources of data, what the user must do with data, where the data go, and the relationship among tasks that different users may be performing. Recent hearings before Congress raised concerns about several EDC user interface issues, and the ensuing discussions led to the recommendation for an independent HF assessment to be conducted by the FAA Office of the Chief Scientific and Technical Advisor for Human Factors (AAR-100). The Issues Subgroup Chairperson appointed a team of HF specialists from the FAA, the Volpe National Transportation Systems Center, and the MITRE Center for Advanced Aviation System Development to conduct the evaluation, with a report due to Congress by December 19, 1997. Short biographies for the HF Team are provided at the end of this chapter.

1.2 Usability Assessment Scope and Limitations

In HF engineering practice, an initial usability assessment is considered to be the beginning of an overall effort that includes rapid prototyping with design validation studies and human-in-the-loop system performance evaluation.

A usability study typically involves observation by HF specialists of users operating a developmental system under realistic conditions. The goal is to identify human-system interaction problems. The approach often uses scripts or other methods to exercise system functions. Users and HF experts take notes on how well the system supports representative tasks. Data collection tools may also include video recordings, questionnaires, and HF checklists. The issues identified by this activity are transformed into HF resolutions and then prototyped and evaluated by users. The resulting design recommendations are fed back to the engineering process. As the system matures, further usability assessments (to validate design changes) and prototyping cycles are completed, making this an iterative process.

When the system is mature, it undergoes a large-scale HF evaluation using a comprehensive set of performance metrics. A rigorous and controlled test is completed, under varying taskloads, and data are collected on safety, efficiency, performance, workload, and usability. In air traffic control (ATC), this type of evaluation usually requires considerable preparation, several weeks to run, and substantial efforts to analyze and report the results. A comprehensive HF evaluation and design effort comprises these three types of activities: usability assessment, prototyping/
evaluation, and performance evaluation. The work reported here represents the first stage in this process.

This EDC usability assessment is an initial evaluation and has several limitations. It addresses the AT HF issues regarding the EDC workstation but does not involve a direct comparison to the existing ARTS. The assessment methodology does not provide the kind of objective performance data needed to assess the impact of EDC displays or functions on controller or system performance. It also does not address the EDC tower display, QWERTY keyboard, or revisions to windows, menu structures, or target display symbols delivered after December 8, 1997. The present analysis examined the existing issues, identified other HF issues that may need to be addressed, and gathered information about the operational impact of the issues. Due to the time constraints imposed on this exercise, certain additional restrictions were necessarily placed on the data collection and analysis that limit the interpretation of the results. As with any observationally based usability study, the outcome must be interpreted within the conditions under which the observations were made. These restrictions include the following:

Limited time to train the controllers on EDC: Ideally, an evaluation of the EDC system would permit the controllers who participate to train to proficiency on the new equipment, using the training package developed for implementation. Such training and testing of the controllers' ability to use the new equipment helps to ensure that the observations made can be attributed to features of the new system and not to a lack of familiarity. The schedule imposed on this analysis did not fully provide for such training and proficiency testing. Thus, some of the controllers' judgments may be attributable to their unfamiliarity with the system.

Limited subject pool: An HF evaluation of a new system would typically employ a cross-section of controllers who are representative of the user population. These controllers would ideally not be familiar with STARS and the issues surrounding it before being exposed to the system training program. Through experience with the system, the behavior of these controllers would lend insight into aspects of the system that should be considered for modification and the training required to successfully implement the system. Because of the nature of the present analysis, the HF Team determined that it would be better served by including controllers who have had experience, however limited, with STARS. This experience would help to identify important issues in the time available by reducing the training required for controllers to learn the new system.

These and other factors associated with the time constraints may have resulted in some EDC usability issues being overlooked and point to the requirement for further HF work on the system before it is deployed. The initial analysis was designed to be the first step of a comprehensive HF methodology. It identifies features of the system that the controllers found operationally unacceptable and points to issues that require further investigation. To the extent that issues identified in the EDC system exist in STARS, the findings and their interpretations would be expected to apply. However, it should be clear that this initial analysis of EDC does not constitute an analysis of STARS.

2. Method

A structured usability assessment was used for the evaluation of the EDC system. This involved a comprehensive review of system functions using scripts for critical terminal ATC activities. HF specialists and controllers acted as evaluators, collecting information on system usability and operational effectiveness. The results were compiled and categorized into a list of HF issues that are the outcome of this report.

2.1 Participants

Twelve controllers from terminal facilities participated in the evaluation. Included were the eight controllers that were present at a planning meeting at Raytheon during the week of November 17 and four additional controllers from other TRACONs. One controller came from each of the following TRACONs: Atlanta, Dallas–Fort Worth, Kansas City, Los Angeles, Miami, Minneapolis, New York, Phoenix, Pittsburgh, and Seattle. The remaining two controllers came from Washington National TRACON. Two additional air traffic controllers played a supporting role during the evaluation.

The average age of the 12 participating controllers was 37 years ($SD = 3.8$), and they had an average of 14 years ($SD = 4.0$) experience in the terminal environment. All controllers had actively controlled traffic during each of the past 12 months. Four controllers had corrective lenses and wore these during the traffic scenarios. At the beginning of the third day of the evaluation, the controllers estimated that they had an average of 7 hours ($SD = 3.9$) experience using some version of the STARS. Controllers rated their experience with windowing operating systems as an average of 5.5 ($SD = 1.2$) on a 7-point scale where 1 represented Not Very Experienced and 7 represented Extremely Experienced.

2.2 Equipment

The HF evaluation of the EDC system was conducted at the Technical Center during the week of December 8, 1997. Four EDC workstations were configured in the ARTS Transition Laboratory. Each was equipped with an integrated ABC keyboard and recessed trackball. The workstations were situated in two rows, with two consoles on each side.

Before the first day of the usability assessment, the STARS Team identified software changes that had been prepared for the evaluation. In addition, the team identified seven open EDC software issues that might affect the HF usability assessment. During the assessment, some clarifications were made regarding radar target symbology. Specific information about each of these items is found in Volume II, Section 2.

Electronic data collection capabilities included traffic data recordings from the Target Generation Facility (TGF) and ARTS Continuous Data Recording (CDR). Voice tapes were made from the AMECOM voice switching system. Video equipment was used to record controller actions and verbal comments.

2.3 Airspace and Traffic Scenarios

The traffic simulations incorporated four sectors of simulated airspace based on four sectors of Boston TRACON airspace. This traffic provided a background against which to evaluate the EDC system. Descriptions of the sectors at Boston TRACON follow and differences between the actual and simulated sectors are noted.

Initial Departure: All aircraft that depart Boston Logan International Airport (BOS) use the Initial Departure sector. Controllers vector aircraft per a Logan-Nine Standard Instrument Departure procedure, which outlines departure instructions and noise abatement procedures. Controllers give all arrival aircraft from the southwest to the Final One sector for sequencing and approach clearances to BOS. For the EDC assessment, the Initial Departure sector was combined with the Lincoln sector, which is a westbound departure corridor sector and an inbound sector for arrivals from the Southwest.

South: The South sector receives departures from BOS, including both jet and propeller traffic departing southbound. Controllers vector arrival aircraft to runways based on the runway configuration in use and their preference. Controllers give all arrival aircraft to the Final One sector for sequencing and issuing approach clearances. In this simulation, the South sector was combined with the Plymouth sector, which is predominantly a southbound departure corridor and an inbound sector for arrival flights planned over Providence or from the Cape Cod area.

Rockport: The Rockport sector is mainly a north- and northeast-bound departure corridor and an inbound sector for arrival flights planned over Gardner, MA; Manchester and Pease, NH; or the Boston overseas arrival fix, 25 NMI east of the airport. The Rockport sector receives departures from the Initial Departure sector, including all jet and propeller traffic departing to the north and northeast. Controllers vector arrival aircraft to the runway in use and then give the aircraft to the Final One sector for sequencing and issuance of approach clearances.

Final One: Final One was the final approach control position where controllers issue all approach clearances for BOS and subsequently transfer the aircraft to the Tower Local Control for landing clearances. This position does not typically control departure traffic, though coordination for such operations may be requested. Controllers may vector an aircraft to any runway included in a particular configuration for a more efficient use of airspace or runways. In this simulation, the Final One sector was combined with the Final Two sector.

The air traffic patterns and airspace characteristics used in the evaluation were representative of the local adaptation of Boston TRACON sectors. Two Boston TRACON traffic scenarios were prepared that used different runway configurations: Land 27/22L - Depart 22R and Land 4R/L - Depart 9. In both scenarios, controllers staffed all four Boston TRACON sectors. This staffing level is lighter than a typical 90th-percentile day at Boston TRACON. There, two controllers typically staff the Final One sector, and one controller staffs a satellite airport position, for a total of six controllers.

The scenarios were based on CDR output taken from Boston TRACON. A current Boston TRACON controller verified the data and tested it in the Technical Center laboratories. Both scenarios were of moderate complexity. The scenarios contained an even mix of both jet and propeller-driven aircraft. Furthermore, they contained all aircraft flying with all Instrument Flight Rules (IFR) flight plans that either originate or terminate service at BOS. The scenarios were modified to include some Visual Flight Rules (VFR) flight plans and overflight aircraft.

The following are scenario enhancements completed for this evaluation for the two runway configurations at BOS. The baseline scenarios had 169 simulated aircraft with 80 arrivals and 89 departures. The scenarios were designed to last for 90 minutes but were typically stopped after approximately 65 minutes. The enhanced scenarios included added aircraft and activities as compared to the baseline scenarios. The two enhanced traffic scenarios were coded to run at the following five volume levels:

<u>Level 1</u> 120 Baseline Targets

<u>Level 2</u> Level 1 Plus:
35 VFR Over, Under, and Through Flights
35 IFR Over Flights

Level 3 Level 2 Plus:
6 VFR Air Files Landing Boston
Planned Events:
1 New Call Sign Request
2 New Runway Requests
1 New Aircraft Type Request
3 Weather Update Requests
1 Wrong Beacon Code
1 Point Out Beyond Filter Limits
1 Runway Change

Level 4 Level 3 Plus:
5 Additional Arrivals
1 Additional Departure

Level 5 Level 4 Plus:
35 Additional VFR Over, Under, and Through Flights
35 Additional IFR Over Flights

Details of the scenarios used in the assessment are in Volume II, Section 3.

2.4 Data Collection Instruments

In addition to the automated databases and video recordings discussed in Section 2.2, the following forms and questionnaires were used during the evaluation:

a. Background Questionnaire: This questionnaire addressed the controllers' background and experience. All controllers completed this questionnaire on the third day of the evaluation.

b. Observer Log: This form was used to record EDC HF issues. HF specialists and controllers completed it during each simulation run. Information on this form was used to build the final issues list.

c. Functions Checklist: This checklist listed important EDC functions and was used to check that all functions had been exercised. Controllers completed this checklist by the end of the third day of the evaluation.

d. Post-Scenario Questionnaire: This questionnaire addressed general questions about the EDC system and scenario realism. All controllers who worked traffic completed this questionnaire after each run on the fourth day.

e. Human Factors Specialist Questionnaire: This questionnaire was based on the *Human Factors Checklist for the Design and Evaluation of Air Traffic Control Systems* (Cardosi & Murphy, 1995). Each HF specialist completed it at the end of the fourth day of the evaluation.

f. Controller Questionnaire: This questionnaire was also based on Cardosi and Murphy (1995) and is similar to the HF Specialist Questionnaire. Controllers and HF specialists completed this questionnaire at the end of the fourth day of the evaluation.

g. Training Questionnaire: This questionnaire addressed questions about the training provided to controllers. Controllers were to complete this questionnaire at the end of the fourth day of the evaluation.

2.5 Procedure

The evaluation required 5 days to complete. Given the short preparation time available for this project, there was a risk of technical difficulties. However, no simulation problems were experienced, and all planned activities were completed.

The general schedule was as follows:

Day	Activity
Monday, December 8	Introduction to assessment
	Training on the EDC system and Boston TRACON airspace
Tuesday, December 9	Training on the EDC system and Boston TRACON airspace
Wednesday, December 10	Orientation to evaluation procedure

	Three simulation runs using scripted functions
Thursday, December 11	Three simulation runs using scripted simulation events
Friday, December 12	Meeting of participants to refine the issue and element descriptions.

A detailed daily schedule and participant rotation plans can be found in Volume II, Section 4.

2.5.1 Training

An airspace training package was sent to the controllers before the assessment and is included in Volume II, Section 5. This package contained detailed information on the airspace, runway configurations, procedures, and controller actions that they used in the simulation. The briefing package also included maps of the airspace and runway configurations.

The first day of activities included a briefing on the Boston TRACON airspace and traffic by Boston TRACON controllers. Following this was hands-on instruction on the EDC system using computer-based instruction (CBI) by the STARS Team. A traffic sample was also run on the four EDC workstations allowing all participants to familiarize themselves with the equipment and simulation environment. Controllers followed a rotation schedule, which permitted time for CBI, EDC simulation, and further airspace training. One-on-one instruction on the system was provided by STARS Team instructors in the EDC laboratory. Of the four sectors, each controller was trained and worked on only two sectors to make best use of the limited airspace training time available. Six controllers were trained on the Initial Departure and South sectors, and six were trained on the Rockport and Final One sectors. The baseline traffic scenario was used for the first part of the hands-on training, but some Level 3 scenarios were included so that the controllers had exposure to higher traffic volumes, before the first assessment day.

2.5.2 Human Factors Assessment

The third and fourth days focused on the HF usability assessment conducted against a background of simulated Boston TRACON traffic. Given the four EDC workstations, teams of three controllers were assigned to each position during each run. Controllers only worked the sectors on which they were trained. An orientation to the evaluation procedure, including instructions on the use of data collection tools, was provided on the morning of the first day of assessment. There were three 1-hour simulation runs each day to identify EDC HF issues.

To exercise the important system functions of EDC, the HF Team identified two kinds of scripted actions. The first type were those system functions that are frequently completed by controllers as part of their work, as listed in Volume II, Section 6. These functions are normally accessed when controlling air traffic or could be prompted manually if not required during a specific simulation scenario. The second type were simulation events that gave rise to specific controller tasks. These events were initiated by the controllers and simulation operation pilots (SIMOPs) or were added to the traffic scenarios, as listed in Volume II, Section 7.

The third day of the evaluation concentrated on the Functions Script. Each group of four controllers was provided with a list of the functions, in checklist format, and instructed that the goal for the third day was to exercise the system on all items on the list. Approximately one-third of the items were addressed during each simulation run, with each controller starting at a different point in the list to ensure full coverage. Only one-half of the aircraft in the baseline scenarios were run, to allow the controllers more time to focus on using system functions. Comments and observations were only collected on those functions that were problematic. EDC HF issues that emerged as a result of this activity and from other interactions with the system were noted.

Included in each scenario was a position-relief briefing given approximately halfway through the 1-hour run. This forced the users to access several EDC system functions that might not ordinarily be used while working traffic. The four controllers that were standing by were brought in to replace the four who worked traffic during the first half of the run. During the scenarios, the active controller was encouraged to focus on traffic management but also to be available for questions and brief discussions. The controllers and HF specialists were provided with structured forms for data recording. The Functions Checklist was used to ensure that all functions were exercised, and the Observer Log was used to record any issues that emerged during a run.

The fourth day of the evaluation did not involve the use of the EDC Functions Script but, instead, focused on ATC tasks prompted by aircraft activity or airspace changes. The EDC Simulation Script was administered by asking controllers and SIMOPs to initiate actions during ongoing traffic scenarios. Levels 3 and 5 traffic scenarios were used. An additional exercise performed on this day was a switch to the ESL during the last 15 minutes of the last run.

The simulation was designed to exercise specific EDC system functions and procedures not necessarily covered in the EDC Functions Script. As during the previous day, the position-relief briefing was completed about halfway through the scenario. Issues and observations regarding EDC HF problems were discussed by the active controller, observer, and HF specialist. The EDC Simulation Script items were not all exercised on each sector during every run. Instead, one to six SIMOP or controller actions per sector, per run were invoked including a runway reconfiguration, which was a general event that occurred once during each run for all sectors. Schedules for participant rotation and events for both data collection days are provided in Volume II, Section 4.

Controllers remained together in three-person teams to facilitate shared experiences and discussion during the 2 days of data collection. Each controller acted in each position (observer, initial controller, and relief controller) twice. HF specialists rotated independently of the controller teams to ensure interaction with each team. Each specialist observed each sector and controller team at least once.

After each run, the controller working traffic was asked to write down any issues, concerns, or other observations encountered. (On the fourth day, a Post-Scenario Questionnaire was also completed.) The HF specialist at each workstation then facilitated a discussion with the controllers to identify HF issues that emerged during the scenario. All issues were written down for further review. The effectiveness of the exercises was evaluated during debriefing sessions. At the end of the fourth day, the HF Specialist and Controller Questionnaires were completed.

2.5.3 Issue Consolidation

The fifth and final day of the evaluation consisted of a meeting of all participants to discuss the EDC HF concerns identified during the simulation sessions. However, before this, a significant amount of issue refinement and categorization was accomplished, making the final issue review exercise feasible within the time remaining.

There were several stages at which EDC HF issues were consolidated. Immediately following each scenario on the third and fourth days, the four participants working a position discussed the preceding run. During the simulation, they had been briefly noting any HF issues they observed. Controllers were instructed that it was not necessary to write down issues more than once. The task of the HF specialist was to ask the controllers to review and discuss their issues. These were recorded on the HF specialist’s Observer Log. The resulting lists, along with all supporting individual lists, were collected by other HF specialists and were entered into a computer for further review and processing.

The same procedure was completed during the fourth day of the assessment. However, the focus was on identifying issues that had not yet emerged. During both days, HF specialists continuously reviewed the lists and began to consolidate them and place them into categories. At the end of the fourth day, all issues were combined and consolidated for a final review on the last day of the evaluation.

The goal of the meeting on the final day of the assessment was to review the draft issues list. The HF Assessment Team requested that the controllers read the list of issues, clarify wording where necessary, remove irrelevant issues, and add any further issues, if needed. All issues raised by the controllers were recorded. A graphic showing the entire issue capture and consolidation process is shown in Figure 1.

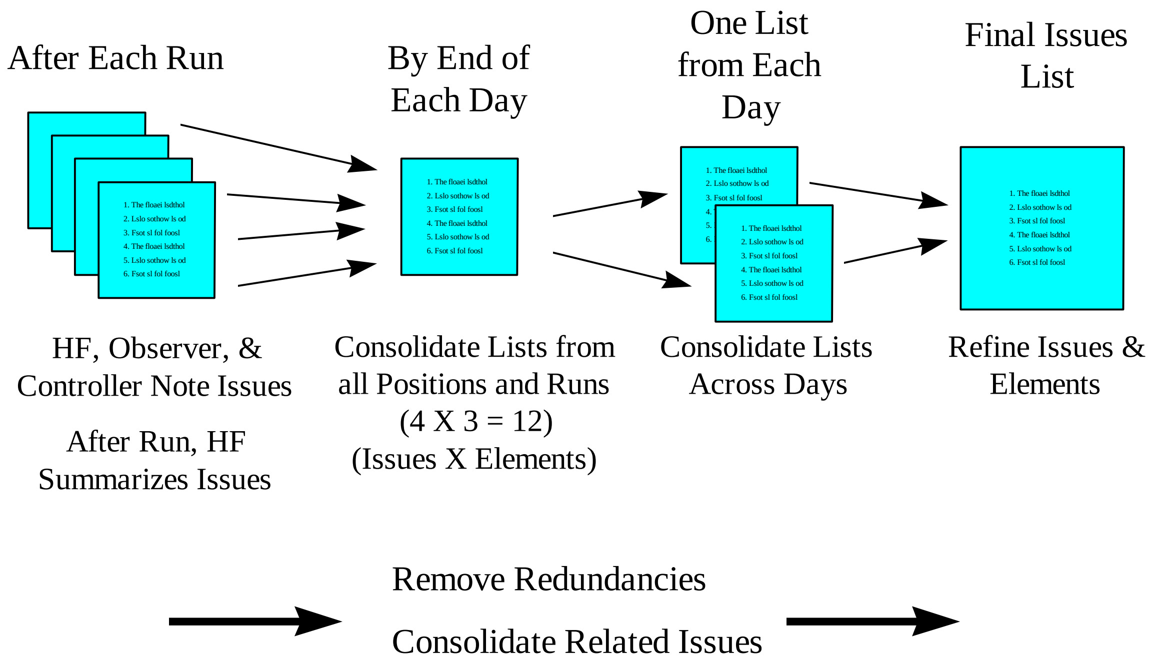


Figure 1. Issue refinement process .

Following the end of the assessment, further work was completed on the issues list. Notes taken during the final day were incorporated, and items were consolidated and summarized. The resulting final list is discussed in the Results Section of this report.

3. Data Analysis

The sources of data included the issues lists created during the simulation runs, questionnaires, videotape recordings, and the finalized issues list developed during the fifth day of the exercise. They are summarized in the Results Section.

4. Results

This section reviews the conduct of the simulation and includes the final issues list that resulted from the EDC HF assessment activities. The data collected from the Post-Scenario and HF Questionnaires are also summarized.

4.1 Technical Outcomes

The EDC system (as delivered to the Technical Center by December 8) operated without interruption throughout the week. The system's stability, given the significant modifications made to prepare for the assessment, demonstrated an apparent robustness of the underlying software.

The Technical Center and STARS Team staff fully integrated the EDC prototype into the simulation environment. The simulation support staff developed realistic air traffic scenarios of varying degrees of complexity that allowed all of the functions under evaluation to be exercised. The STARS Program Office provided all necessary coordination to expedite the integration of the prototype EDC system and facilitate the conduct of the assessment activities.

4.2 EDC Human Factors Issues

4.2.1 General Categories

The final EDC HF issues list was divided into nine general categories. For most categories, there are several elements with associated HF items. The categories and elements are:

1. DATA INPUT
   1.1 Keyboard
   1.2 Trackball
   1.3 Cursor Operation
   1.4 Homing
2. WORKSPACE ERGONOMICS
3. WINDOWS
4. TARGET ATTRIBUTES
   4.1 Target Extent, Beacon Code, and Position Symbol
   4.2 History Trails
5. DATA BLOCK ATTRIBUTES
6. DISPLAY ATTRIBUTES
   6.1 Color, Size, Brightness, Etc.
   6.2 Centering
7. COGNITIVE ISSUES
   7.1 Memory/Workload/Errors
   7.2 Attention/Situation Awareness
8. MENUS
9. SYSTEM FUNCTIONALITY
   9.1 Missing Functions
   9.2 Unneeded Functions
   9.3 System Response/Feedback
   9.4 Unsatisfactory Function Operations
   9.5 Switching Between ESL and EASL

4.2.2 Overview of Issues

Highlights of findings for the EDC system HF assessment for each category are discussed in the following sections. The detailed list of issues is found in Table 2. Items that may be resolved by making allowances for artifacts of the simulation environment or by considering information the STARS Team provided are annotated. The six previously identified AT HF issues from Section 1.1.2 are also discussed in the context of the current findings.

There were no specific problems noted regarding the physical layout of the ABC keyboard. However, a double row of function keys had been added for the EDC prototype. Specific issues were raised regarding the new way functions are performed using the EDC keyboard and trackball. The controllers commented that the macro key assignments, layout, groupings, and labels are not optimal. An example is the location of the Escape key, which is in the center of the bottom row. (See Volume II, Section 8 for a copy of the Macro Key Reference Card.)

There are unpredictable and distracting cursor movements. The cursor sometimes jumped out of the active window or to the home position. This effect was observed in several windows and display locations. For example, the cursor sometimes jumped when it touched the top bar of the OPS window. In another example, the cursor automatically moved to the OPS window when composing a STARS message using command language in the Preview window. The controllers noted that they must be aware of and cautious about the placement of the cursor when making keyboard data entries. For example, when the cursor is in "home box" for EDC data entry, the controller cannot make ARTS keyboard entries. There were several other problems with cursor homing as described in the issues list.

The opaque windows implemented for the EDC system were observed to obscure important display information about the air traffic situation. This included handoffs, weather, and aircraft calling controllers on the sector frequency. This caused many of the controllers to place windows in less preferred positions around the periphery of the situation display, outside of the accustomed visual scan pattern, to reduce the chance of hiding this information. Longer trackball movements were then required to access the windows. There were additional issues regarding window access and display that are described in the detailed issues list.

Table 2. EDC Controller Workstation Human Factors Issues

ID	Category	Issues
1	Data Input	
1.1	Keyboard	The macro key assignments, layout, groupings, and labels are not intuitive. An example Escape key.
		The Clear key does not work for all clear functions. Also, the Clear feature for the Previ use because two different keys are required. The Clear key and Escape key for EDC are
		The luminance of keys is not uniform; the brightness is too high on light keys or too dark keys.
1.2	Trackball	The controller needs to use two hands to change size of window or menu (e.g., ARTS dat
1.3	Cursor Operation	There are unpredictable and distracting cursor movements. The cursor will sometimes ju window or to home position. This effect was observed in several windows and display lo the cursor jumps when it touches the top bar of the OPS window. In another example, w message in the Preview Area using the command language, the cursor automatically goes
		The controller must be aware of and cautious about the placement of the cursor when ma entries. For example, when the cursor is in the "home box" for EDC data entry, the controlle ARTS keyboard entries (e.g., initiating track start without moving cursor out of home bo when keyboard data entry is initiated with the cursor in the OPS window, the entry is los (i.e., window focus must be actively captured to make data entry). Also, two attempts we the range because the cursor was in the ARTS area and not in EDC.
		Cursor placement must be accurate over a button. Cursor placement accuracy is overly is provided when the cursor is on top of a button.
		To move any ARTS list or systems area, the EDC automatically moves the cursor to the corner. The controller then has to find it and move the cursor to the desired location. (Po functionality problem in the simulation.)
1.4	Homing	There are two homes: ARTS home and EDC home.
		The Home function is correlated with X, Y position on screen and not slaved to the Previ position.
		When the cursor is located in the Preview Area, the Home key (M8) will not work (Syst STARS EDC Macro Key Reference Card.)
		The position symbol does not disappear from the center of display as in ARTS.
		The cursor does not always default to the center of the display.
		It adds an additional keystroke to hit HOME on every entry.
2	Workspace Ergonomics	With two people working (e.g., handoff position or trainer) it may be difficult to operate test did not involve two-controller operations). The status window, position symbols, and to read when viewed at an angle by a second controller.

ID	Category	Issues
3	Windows	Opaque windows were observed to obscure handoffs, weather, and the ability to locate tr frequency.
		Opaque windows forced the controller to put windows in unusual locations. With the AI can be moved so that they are in the scan pattern. Because EDC windows are opaque, th outside the scan pattern (e.g., in the corners). Locating windows at screen corners to avo means the controller must move the cursor a long way to access windows on opposite cor
		Windows can be moved outside of situation display and off the screen, which may hide c
		When windows are resized, using font control, they may appear partly off the screen.
		It is difficult to lock onto windows in order to move them. Required multiple attempts to windows are overlapped, it is not possible to select title bar underneath.
		Moving the window across the display momentarily erases (approximately .5 sec.) all po previously covered by the menu.
		There is a counter-intuitive design by which newly opened menus and newly closed icon relocated to their respective former location.
		Window icon may be hidden behind open window if the open window is in the left corne
		If status window is iconified then the alert messages cannot be seen.
		The Tab list is sometimes difficult to reposition. As it is repositioned across the screen, unintended location.
		The controller attempted to move the OPS window to the lower right corner. The window center of the display.
4	Target Attributes	
4.1	Target Extent, Beacon Code, and Position Symbol	Cannot clearly distinguish target extent, beacon code, and position symbols. Clutter fro target extent symbol, and beacon code symbol make it difficult to identify who has contr
		If you have Mode C in the data block, you may not need the information in the beacon sy with the cross is difficult to see. The Mode C symbol on IFR is not needed but for VFR and therefore cannot be turned off. The beacon symbols increase the clutter on the displ
		The target extent symbol and data block display updates are not synchronized causing a "slin target extent symbol may jump ahead of the beacon and position indicator. The effect is expanded map range. Visually annoying and may lose separation inadvertently.
		There is no indication when primary radar is lost. The symbols for a primary and secon readily and independently distinguishable so the controller can distinguish the type of re tell the difference between the ARTS representation of primary and the target extent sym
		The target extent symbol rotation around the radar source incorrectly implies turning.

ID	Category	Issues
		Some ambiguity and potential impact on controller performance exists with respect to th separation, because of the trapezoid size, edge, corner, change in shape, rotation, etc., of Excessive separation could be required for simultaneous parallel approaches on parallel symbol entering the Non-Transgression Zone.
		Not able to adjust brightness of target extent, target type, and position symbols so that yo and controlling sector at the same time. Cannot see target extent symbol set on low brigh (e.g., at 60 mile range).
4.2	History Trails	History trails as depicted are unsatisfactory. History trail color, size, shape, and intensit trails are longer for faster aircraft, and do not fade causing more display clutter. The exi give more accurate information on rate of turn.
		History trails do not disappear when target lands.
5	Data Block Attributes	In ESL, it is not possible to determine target altitude if it is outside of the filter limit ran
		Do not need to toggle off top or bottom line of data block.
		Double data block display on certain aircraft; EASL and ARTS are displayed on top of e
		Squawk Code: On the existing system, there is an immediate display of squawk via targe indicator in data block. On EDC, there is only a white square in the position symbol. T
		On limited data blocks, altitude readout appears on top line farther away from position s block.
		On limited data blocks, there is no way of knowing if it is a VFR or another controller's IFR
		Leader line could be changed individually but not globally. Could not find this type of s
		It is not clear which features are required to be in EDC Display menu (current, beacon, p 2). There are several selections that may not be relevant to EDC, but are used in ESL. N available.
		Data block shifts from side to side as line 2 timeshares between aircraft type and ground
6	Display Attributes	
6.1	Color, size, brightness, etc.	Six levels of weather may be displayed, but it is difficult to discriminate between them. The what levels are enabled for display but does not show which ones are available. In the cu available weather is indicated. There is no summation weather mode in EDC.
		If green data block text is over a white map line, the data block text is obscured.
		Green in menus means "available" and white means "selected." This is inconsistent wi stereotype on the use of these colors.
		The brightness of borders on the windows is too high and cannot be controlled.
		When the OPS functions are used to change the OPS window brightness to the lowest set possible to read the items in the window.
		Aircraft in handoff status flash on highest and lowest setting only. The brightness differe much and cannot be altered.

ID	Category	Issues
		For displayed items, low brightness is too low and medium is too high (e.g., range of bri not sufficient, either too bright or too dim).
6.2	Centering	Re-centering Display: For point outs, it is not possible to know where the aircraft is com necessary to reset new center each time. This is keyboard intensive and time consuming. Re always work the first time.
		If the user accidentally hits the OC key, and if your scope is offset, then the scope is re-c
7	Cognitive Issues	
7.1	Memory, Workload, and Errors	There is an "overhead" associated with remembering what the cursor position is and what fu from the various windows and display areas. For example, the controller had to re-enter because he did not remember that the cursor was in the Preview Area after changing AR In another example, if the controller forgot that the cursor was in the EDC window, the v accessed.
		There are too many two-character codes/abbreviations to remember in the menu hierarch
		As complexity increases, the data entry problems increase.
7.2	Attention, Situation Awareness	When entering data, controllers sometimes inadvertently moved trackball or the cursor "jump lose the window focus and entry or to make additional erroneous entries.
		Controllers tended to focus a great deal of visual attention in the OPS window. They ch the window to the exclusion of the radar display (e.g., missed handoffs).
		When initiating an implied function (e.g., change map number using the keyboard), the scope for feedback, which increases the amount of time it takes to complete the task.
8	Menus	The menu system is very complicated, which leads to high heads-down time during scan menu option lists are too long to quickly find desired options. Too many steps are requir change display attributes such as brightness, range, and center. Current status (on/off) a parameters (e.g., range rings, brightness, and font size) are not readily available without request it or search through menus.
		In some cases, the controller must press the Enter or Done key to activate a command, bu action is required to activate a menu selection other than choosing it.
		Options in menus and quick keys do not always use consistent labels (e.g., HS and HI fo selections are labeled "other," which is not descriptive of their contents.
		Controller was unable to back out of an initiated action (e.g., in Display menu, hitting th undo the preliminary settings; also occurred during map selection). There was no capab original settings. Menu navigation is not reversible; cannot back out or back up. If an e necessary to start over at the beginning. The Beacon menu is destructive if the user need
		Some linked menu selections are mutually exclusive. System did not automatically dese selections as new ones are selected. For example, when the controller deselected Weathe other weather levels.

ID	Category	Issues
		Difficulty in deselecting brightness, weather, and range functions.
		Continuous control over some attributes (e.g., brightness, centering, and range) is not av
		EDC requires controller to check for and maintain consistency between EASL and ART This check requires searching through multiple menus. For example, three sets of filter at start (ESL, EASL, and ARTS).
		Sometimes a menu is automatically displayed when using key actions causing the scope
9	System Functionality	
9.1	Missing Functions	In ESL, a target outside filter limits cannot be displayed for quick look. (Could be an art
		Cannot control position of ARTS data tags that are not under sector control or outside fil
		Cannot establish a controller's preferred display characteristics (preference set) to which the to eliminate resetting of individual preferences for display parameters.
		There are no procedures to check the accuracy of the system at time of sign-on or after re verify radar alignment and no way to display information on radar alignment.
		Conflict alert and Mode C intruder alert did not appear in the Conflict/Minimum Safe A
9.2	Unneeded Functions	Display of X, Y coordinates in the center of the screen while moving windows obscures
		In ESL, it is possible to toggle filter limits completely off, which is inappropriate. ESL disabled so that all aircraft are visible.
9.3	System Response, Feedback, and Status	There is a noticeable delay between sending a command and its execution (e.g., handoff accept 1-4 seconds, quick look data blocks), especially when the processor is busy.
		There is no feedback on controller keystrokes in the Preview Area for OPS window entrie is iconified.
		There is no feedback on change in settings in the display on some items (e.g., Display m not change from green to white when options were selected but situation display did chan
		It is possible to enter commands in ARTS or EDC mode. It is necessary to look at the di mode it is in, which is time consuming. EDC and ARTS commands have some commo unintended actions. For example, when controllers entered an ARTS Quick Look comm in the EDC OPS window, EDC understood the command to change leader length. There make the controller aware.
		There is no immediate feedback from the radar target when a VFR beacon code changed
		In ESL, there is no message to indicate that ARTS has returned to service.
		It is not possible to localize the source of the workstation audible alarm to an individual speaker on the workstation keyboard, but because of a software bug, the alarm came out
		There is no preview feedback to the operator about the current and desired level of bright selection are not provided until it changes the brightness level. Feedback from brightnes help make choice quickly.

ID	Category	Issues
9.4	Unsatisfactory Function Operations	When an aircraft track was suspended, the tag went to the Coast/Suspend list but then au seconds. It should have stayed in the Coast/Suspend list until dropped or manually track an artifact of the ARTS build.)
		Sector combine worked/sector de-combine did not work. (This may be an artifact of the
		Values in the range menu did not always work. Sometimes options did turn white on rig selections did not take effect on situation display.
		Global offset of data tags via ARTS multifunction entry did not always work.
		Controllers experienced several unsuccessful attempts to accept handoffs.
		Controllers could not designate runway type in several attempts.
		Three attempts were required to center maps after runway change.
		Mark and Hook functions are difficult to use. Mark has multiple uses (e.g., offsetting of ring center). The operation of the uses is inconsistent.
		Some parameters must be set under both EDC and ARTS. An example is changing altit filter is set under EDC, the unassociated targets do not get suppressed unless the altitude ARTS. Separate associated and non-associated altitude filter limits are missing in ESL.
		The controller used three methods (Multifunction Y, B727; Multifunction Y, OK, B727; area in data block, but none of them worked. The system returned a format error. (May build and may be true only on the initial departure position).
		After being handed off to center, cannot change data block call sign, Y, and H areas.
		The auditory alarm did not reset when the condition causing it was eliminated.
9.5	Switching between ESL and EASL	There is only one keystroke needed to switch between ESL and EASL. It is easy to chan Conversely, if the cursor is inadvertently in the ARTS window in EASL, then the contro ESL mode.
		Display settings (e.g., weather, range, brightness, range rings) changed when switching from ESL to EASL. The loss of settings is especially important when switching to emer Controller awareness of system status is affected (i.e., controller noticing and responding switches).
		Controller could not return to EASL without completing the action of setting altitude filt limits menu area) for ESL.

Several problems were reported regarding the target extent, beacon code, and position symbols. The current ASR-9 configuration is composed of the ASR-9 primary radar and a secondary antenna running simultaneously on a single platform. The primary radar return is sometimes referred to as the "skin paint," a direct reflection of the radar signal from the aircraft. The secondary return comes from the transponder on the aircraft. These data are received from the radar in digital form and are split into digital information that goes to the ARTS computer and reconstituted analog information that goes directly into the analog input on the ARTS display.

On the display, the information coming from the analog port is displayed as a radar primary "blip" and a larger secondary radar "slash." The secondary or beacon video can be in one of six different sizes, depending upon the range of the aircraft from the radar. The primary and secondary symbols are displayed directly adjacent to each other but are not overlaid (as in Figure 2). This is sometimes referred to as the "top hat" due to the stacked primary blip and secondary slash presentation.

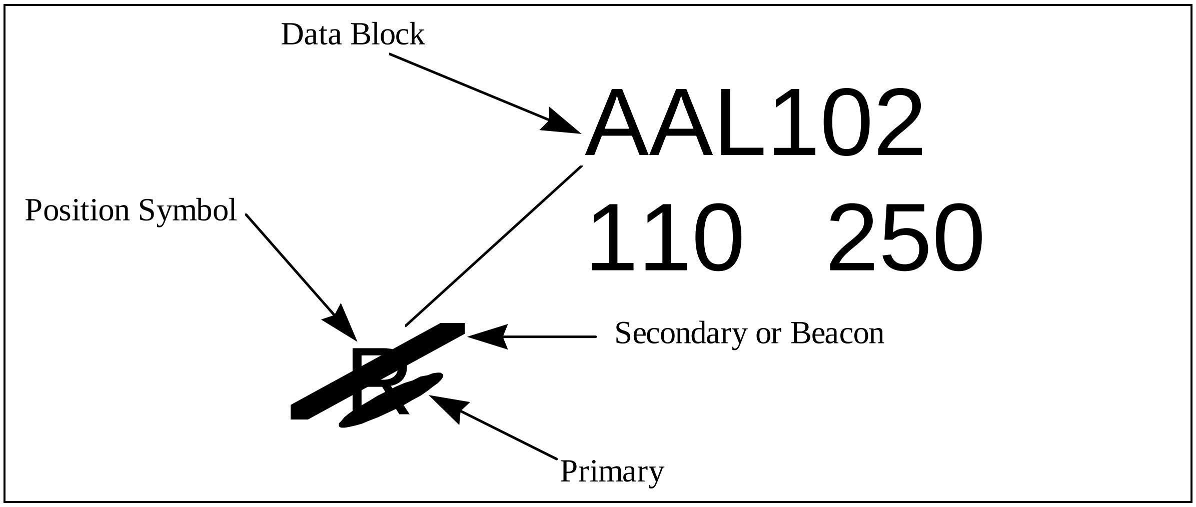


Figure 2. ARTS target.

The digital information on the display that comes from the ARTS includes the data block, leader line, and track position symbol. If the data block is owned by the controller at a particular display, then that controller's position symbol is overlaid on the analog top hat information, and the data block information is connected to the position symbol by the leader line. If the aircraft is not owned by the controller at a particular display, a square, asterisk, triangle, or plus sign is overlaid on the top hat.

In the EDC system, a target extent symbol represents aircraft position uncertainty. It is in the form of a trapezoid that changes size continuously as a function of range from the radar source. The beacon symbol is a small box that may contain horizontal and vertical lines showing additional Mode C information. The primary is represented by an "X." The data block, leader line, and track position symbol are displayed in a similar manner to the ARTS (see Figure 3 for details).

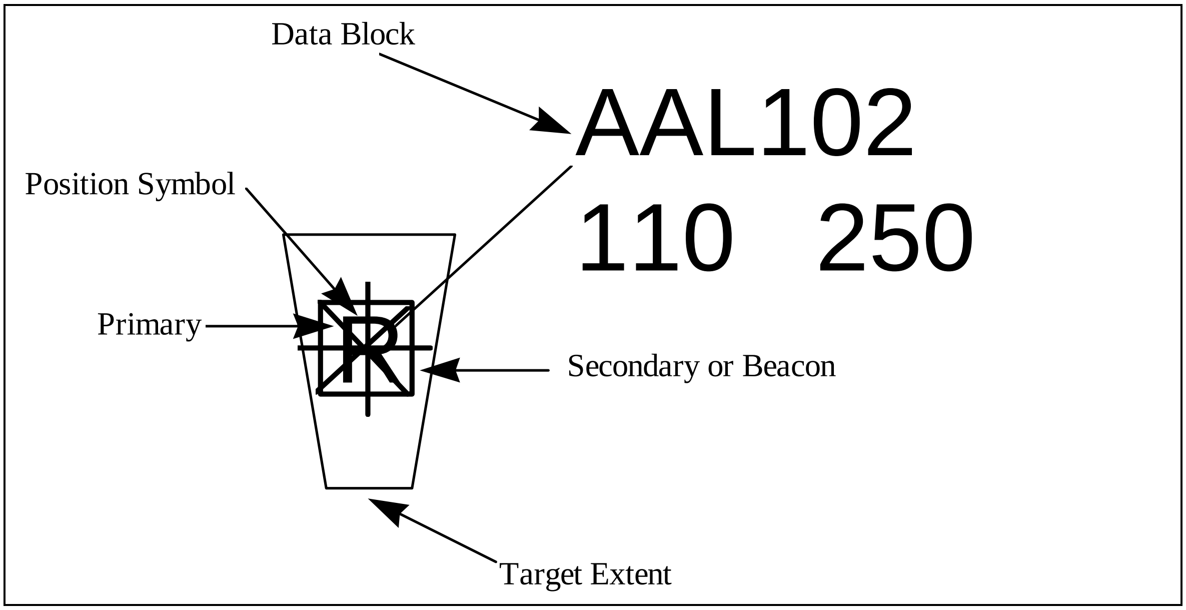


Figure 3. Early Display Capability target.

During the assessment, controllers reported that they could not clearly distinguish the EDC target extent, beacon code, and position symbols. STARS Team staff provided advice on display setup to try to rectify this problem on the fourth day of the evaluation. (See Volume II, Section 2 for the information the STARS Team provided.) However, difficulty seeing the position symbol persisted. This included the following issues:

- The clutter from the superimposed symbols made it difficult to determine which controller had responsibility for an aircraft. This is a critical piece of information required by TRACON controllers.
- The small beacon symbol, with its coding, was also difficult to see.
- The target extent and data block display updates are not synchronized, causing a "slinky" effect. The target extent symbol may jump ahead of the beacon and position indicators. The controllers noted that this was visually annoying and suggested that, in some cases, it may cause false conflict alerts. The target extent symbol can represent either the primary or beacon target. As a result, there is no clear indication that the primary has failed.
- The method chosen to represent the target extent symbol may make it appear that it is turning as the aircraft moves across the display.
- Some ambiguity and potential impact on controller performance may exist with respect to the standards applied to separation, including those related to the trapezoid size, edge, corner, change in shape, or rotation of the target extent symbol. Controllers noted that excessive separation could be required for simultaneous parallel approaches on parallel runways to avoid the symbol entering the Non-Transgression Zone.
- There were also comments that the history trail color, size, shape, and intensity add to display clutter. The existing ARTS history trails may give more salient information on aircraft rate of turn.

Some data block characteristics drew comments. In the ESL mode, it was not possible for the controller to access altitude information on aircraft that were outside the altitude filter settings. Multiple options for display of data block information do appear to be necessary and resulted in the display of double data blocks when enabled. The indication of a squawk code was difficult to distinguish. There are also several attributes of the display that need attention, including weather symbology and the color, brightness, and flashing of some screen items.

Many controllers commented that the EDC menu system is complicated and confusing, which could lead to excessive heads-down time. The menu option lists are too long to quickly find desired options. Too many steps are required to set up, check, and change display attributes such as brightness, range, and center. Current status and value of system parameters (e.g., range rings, brightness, and font size) are not readily available without the controller having to request it or navigate through menus. The EDC quick key assignments are difficult to learn and confusable (e.g., "HI" and "HS" mean "History" in different sub-menus). (See Volume II, Section 9 for a copy of the Quick Key Reference Card.) The EDC system also requires the controller to check for and maintain consistency between EASL and ARTS parameter settings (e.g., altitude filter limits). This requires searching through multiple menus.

Issues regarding system functionality included several specific items. Addressing these issues would improve the usability of the system. For example, it is possible to enter commands in ARTS or EDC mode. It is necessary to look at the display to find out the mode it is in, which is time consuming. EDC and ARTS commands have some commonality that can result in unintended actions. When controllers entered an ARTS Quick Look command while the cursor was in the EDC OPS window, EDC understood the command to change leader length. There was no feedback to alert the controller that the wrong action had been taken. Also, the "Mark" and "Hook" functions are difficult to use. Mark has multiple uses (e.g., offsetting of map and setting of range ring center). The operation of the uses is inconsistent.

The last main issue was "Switching between ESL and EASL." Presently, there is only one keystroke needed to switch between ESL and EASL. It is easy to change inadvertently. Conversely, if the cursor is in the ARTS window in EASL, then the controller cannot select the ESL mode. Display settings (e.g., weather, range, brightness, and range rings) change when switching from EASL to ESL and from ESL to EASL. The loss of settings is especially important when switching to ESL.

4.3 Previously Identified STARS Human Factors Issues

This section addresses the previously identified AT HF issues (from Section 1.1.2) in terms of the findings of the current analysis.

a. ABC vs. QWERTY Keyboards: An ABC keyboard similar to the one used in the existing ARTS was the only keyboard assessed in this study. The controllers did not mention any issues about the main keyboard layout or operability with the EDC system. They did, however, suggest several issues associated with the additional function keys located above the main keyboard. These were related to the function key layout, logic, and readability.

b. Keyboard/Trackball Layout: The EDC had an ARTS-type keyboard and trackball recessed in the workstation surface. The original issues centered on a modular keyboard and trackball that occupied considerable workspace area. Controllers reported they had limited writing workspace with the non-recessed QWERTY keyboard. Controllers did not report any issues with writing space using the recessed ABC keyboard and trackball. They did report several concerns on trackball slew rate and sensitivity of the cursor when selecting/picking menu options.

c. Opaque Windows: The controllers reported several issues associated with the opaque windows in that they could not see aircraft tracks or weather areas that were located behind these windows.

d. Aircraft Target Extent and Position Symbols: The controllers reported that the target symbology was confusing and very difficult if not impossible to read.

e. History Trail: Controllers reported several problems associated with the history trail relating to its brightness, shape, update rate, and display clutter.

f. Display/Control Design: The controllers noted many display inconsistencies, an increase in heads down time, concern about situational awareness, and greater workload associated with the EDC hierarchical menu structure.

4.4 Questionnaire Data

After each run on the fourth day of the evaluation, each controller who worked traffic completed the Post-Scenario Questionnaire. This questionnaire consisted of six 7-point Likert-type scales addressing issues such as controller workload and simulation realism.

Controllers rated how well the EDC system supported their ATC activities during the run. The average rating for this item was 1.8 (*SD* = 0.6), indicating that they believed the EDC system supported their ATC activities poorly. Controllers rated their average workload during the run as 4.0 (*SD* = 1.9), indicating moderate workload. Controllers compared the complexity of the traffic scenario to the average complexity at their home facility. The average rating for this item was 2.9 (*SD* = 1.7), suggesting that the scenarios in the evaluation were less complex than the traffic in their home facilities. Controllers also rated the extent to which technical problems or limitations of the simulator interfered with their ability to control traffic. The average rating for this item was 3.9 (*SD* = 2.2), indicating that technical problems and simulator limitations had a moderate impact on controllers' ability. (Respondents may have understood this question to refer to the EDC system as well as the simulator.) Controllers rated the extent to which problems with the SIMOPs interfered with their normal ATC activities. The average rating for this item was 2.6 (*SD* = 2.2), suggesting that problems with SIMOPs had little impact. Controllers compared the realism of the traffic scenario with actual ATC. The average rating on this item was 5.0 (*SD* = 1.2), reflecting moderate realism.

At the end of the fourth day of the evaluation, all controllers and HF specialists completed the Controller Questionnaire. This questionnaire consisted of 40 True-False or Yes-No items that addressed issues such as the quality of visual displays, cognitive workload, data entry procedures, and data entry and control devices. Volume II, Section 10 lists the number of controllers who responded True (or Yes), False (or No), or No Opportunity (N/O) for each item. Most controllers gave negative responses to nearly every item. HF specialists gave a larger proportion of positive responses than controllers but still responded negatively to the majority of the items, indicating a dissatisfaction with the features in question. Volume II, Section 11 lists this information for the HF Specialists.

HF specialists also completed the Human Factors Specialist Questionnaire. This questionnaire consisted of 44 True-False or Yes-No items, addressing issues such as the quality of visual displays, data entry procedures, and data entry and control devices. Volume II, Section 12 lists the number of HF specialists who responded True (or Yes), False (or No), or N/O for each item. As on the Controller Questionnaire, HF specialists usually gave mixed responses but generally answered in a negative direction, indicating that aspects of the system did not adequately support the controllers' tasks. HF specialists also responded N/O for many items on this questionnaire, suggesting that more research is needed to address the identified HF issues.

The HF Team Lead was asked by controller representatives to not administer the training questionnaire. However, the NATCA National STARS representative offered the following statement:

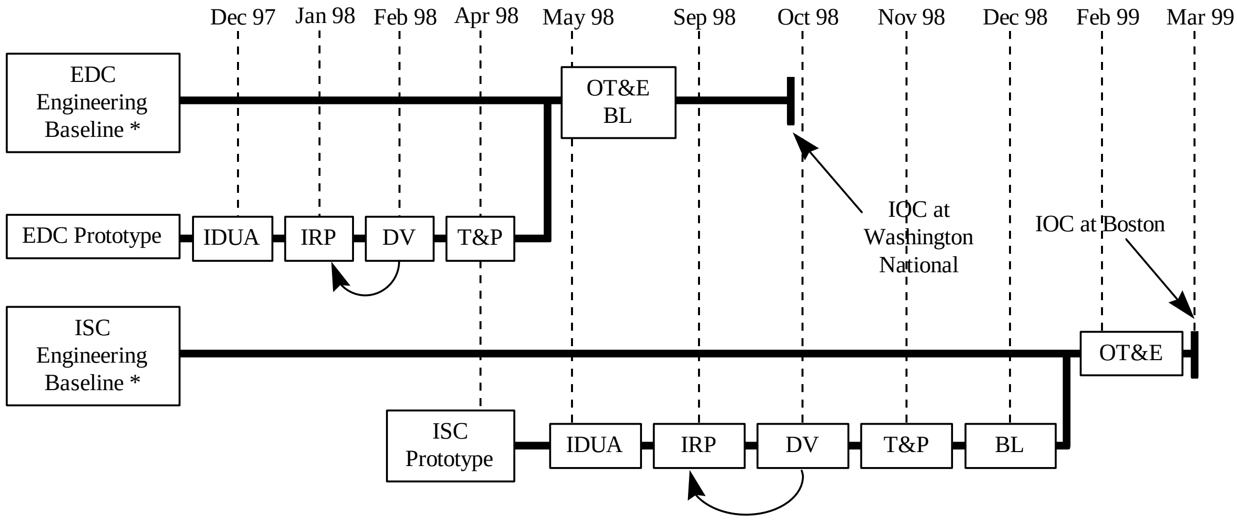
> Given the caliber and experience level of the air traffic controllers that participated in the "Preliminary EDC Human Factors Analysis," the training provided by the FAA, WJHTC, and Raytheon personnel was quite adequate to:
>
> 1. The quality of training provided,
> 2. The ATC knowledge, skills, and abilities of the controller participants, and
> 3. The streamlined (reduced) operational procedures utilized.
>
> Issues and concerns identified during this assessment can only be attributed to problems encountered with equipment and software design, and not with inadequate training or participant preparation (personal communication, December 17, 1997).

5. Conclusions and Recommendations

This EDC Initial Diagnostic Usability Assessment revealed several HF issues and concerns that should be systematically addressed before the system is fielded. (It should be noted that to complete the initial assessment of EDC, a review of the system from the perspective of Tower operations is required).

The HF specialists who participated in the evaluation agreed that a timely and structured research and engineering process should be established to mitigate the operational and programmatic risks identified in this report. Steps have already been taken to identify the resources needed for such efforts. This section presents an overview of the HF Team's recommendations to establish this process and address these concerns.

The STARS Program Office and STARS Team had been involved in making EDC improvements to address concerns identified by controllers prior to this evaluation. By working on these issues concurrently and independently of the engineering baseline using a prototype system, the program continued with formal engineering testing while CHI and other HF issues were being addressed. Using this model as an analogue, the HF Team developed the following engineering process recommendations to address current EDC and future ISC HF concerns, as described in Figure 4.



*** Includes AT & AF System Components.**

<u>Note</u>: All Dates are Draft Pending Review.

IDUA = Initial Diagnostic Usability Assessment

IRP = Iterative Rapid Prototyping

DV = Design Validation

T & P = Training and Procedures Evaluation

BL = Performance Assessment Baseline

IOC = Initial Operating Capability

Figure 4. Proposed schedule of human factors activities to facilitate STARS EDC and ISC deployment .

5.1 Near-Term Recommendations

The results of the EDC Initial Diagnostic Usability Assessment have been catalogued in this report. It is recommended that the results of the usability assessment be used to guide research and engineering activities through the remainder of the program. As Figure 4 indicates, this is an iterative process of prototyping and design validation that is in parallel with other program activities. Our design philosophy for the development and refinement of the EDC interface is human centered. The system designer is part of a team of developers and air traffic controllers who work to optimize system performance by keeping the controller involved throughout the design evolution.

It is recommended that coordinated efforts be established to include NATCA, STARS Program Office, STARS Team, and AT and HF representatives to develop solutions for design deficiencies identified during the EDC prototype evaluation. These efforts should include controllers to identify design alternatives, develop emulation prototypes (using advanced interface design tools), and evaluate these prototypes in operational studies. The Research Development and Human Factors Laboratory (RDHFL) at the Technical Center is currently being outfitted with two STARS consoles to facilitate the conduct of these evaluations. The STARS Team is also preparing for rapid prototyping activities.

Rapid prototyping tools have matured sufficiently to provide robust CHI prototypes that can be used to explore concepts, refine design alternatives, and provide a stable platform to conduct limited-scale operational evaluations. The RDHFL is currently developing an emulation version of the STARS EDC interface that will be routed to STARS consoles and used in the evaluation. Engineers are also linking the Micro-TGF to provide aircraft targets to the prototype EDC interface. This capability will enable the team to rapidly develop and assess design solutions in a medium-to-high fidelity operational setting.

It is recommended that several independent teams be established to address the general issue areas discussed in the Results Section of this report including data input, workspace ergonomics, windows, target attributes, data block attributes, display attributes, cognitive issues, menu structures, and system functionality. These teams should work with training and procedures personnel to integrate design changes and create a cohesive and usable EDC system interface. User groups can be brought in to operationally evaluate the prototyped systems. When appropriate, operational run-offs should be conducted between design alternatives, incorporating quantitative and qualitative data collection to objectively determine which alternatives should be implemented.

As the interface design matures, it is recommended that the STARS Program Office work with representatives from the STARS Team to schedule technology/HF injections into the engineering baseline of the EDC system. Ideally, the STARS Program Office and the STARS Team engineers should participate in the design and evaluation of the EDC rapid prototypes. Their consultation on engineering feasibility, given system architecture, is essential to the success of this approach.

Once the system interface design changes have been implemented and tested from an engineering perspective, an operational controller performance-oriented evaluation should be conducted. Most likely, given the aggressive schedule of the program, this will take place during system Operational Test and Evaluation. This baseline will include measures of controller performance, workload, system usability, safety, and capacity. The methodology of this effort should include multiple replications of high fidelity, medium scale simulations with high volume traffic scenarios, and a good cross section of TRACON controllers. The results of this effort can be compared to the existing ARTS baseline and may also be used for comparison to future STARS builds (e.g., ISC). These data could serve as a human performance benchmark of the system and should also provide valuable objective validation of improvements made as a result of the prototyping effort.

5.2 Mid-Term Recommendations

As Figure 4 indicates, it is recommended that an ISC prototype be provided to the Technical Center in Spring 1998. This system can then be subjected to a similar process to the EDC effort discussed in this report. In addition, any lessons learned from the current activity that may improve the process should be integrated into the HF work used to facilitate the deployment of ISC. Additional studies could be conducted to examine operational and HF issues associated with ISC. For example:

a. ABC vs. QWERTY keyboards: What are the operational and training implications of each? How well will either support future operations concepts?

b. Workload and Situational Awareness Issues: Studies should be conducted to examine the impact of design changes (most notably, windows and menu-driven display attributes) on controller performance, workload, and situational awareness.

Other research studies will be conducted as identified by the issues that emerge from the initial diagnostic usability assessment conducted on ISC. The HF Team also recommends that the program office establish an HF issue tracking system to monitor progress, prioritize efforts, and manage change to the engineering baseline.

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STARS Human Factors Team Short Biographies

Mark D. Rodgers, STARS Issues Subgroup Chairperson and STARS Human Factors Team Lead, received his Ph.D. in experimental psychology from the University of Louisville in 1991. Upon graduation, he took a position as an Engineering Research Psychologist at the Federal Aviation Administration Civil Aeromedical Institute (CAMI). While at CAMI, Dr. Rodgers was responsible for directing the development and initiating the national deployment of the Systematic Air Traffic Operations Research Initiative (SATORI) for use as an air traffic training and incident investigation tool. Dr. Rodgers worked at CAMI for 4 years before joining the FAA Office of System Architecture and Investment Analysis in Washington, DC. In his current position, Dr. Rodgers provides consultation and directs research on HF issues associated with future National Airspace System operational concepts. His research interests include the assessment of taskload, human performance, system performance and modeling, situation awareness, and issues related to complexity in air traffic control and their application to the evaluation of air traffic control technology.

Richard H. Mogford, STARS Human Factors Assessment Lead, received his B.A. degree in psychology from York University in 1974 and his M.A. degree in psychology from Sonoma State University in 1978. He worked for 10 years in rehabilitation and neuropsychology. Dr. Mogford obtained his Ph.D. from Carleton University in experimental psychology and human factors in 1990. Immediately after university, he worked for a Transport Canada contractor on the Canadian Automated Air Traffic System. He was then employed for 5 years as a contractor for the Federal Aviation Administration William J. Hughes Technical Center in Atlantic City, NJ where he was involved in a variety of air traffic control human factors projects. He is currently working for the FAA with the Human Factors Branch (ACT-530) at the Technical Center as an Engineering Research Psychologist and is lead for Airway Facilities Human Factors. Dr. Mogford's research interests focus on human-machine interaction in air traffic control systems. He has extensive experience managing large-scale simulation studies. He is President of the South Jersey Chapter of the Human Factors and Ergonomics Society.

Mark S. McMillen, Simulation Lead, received his Bachelor of Science in Applied Science and Technology from Thomas A. Edison State College in 1990. Since joining the FAA in 1984, Mr. McMillen was an Air Traffic Control Assistant at the Kansas City Air Route Traffic Control Center and certified as a Full Performance Level Air Traffic Control Specialist at the Atlantic City TRACON and control tower. After transferring to the William J. Hughes Technical Center in 1990, he worked as a specialist and then a project lead in the Real-Time Simulation group. In his current position as the TFM Laboratory manager, Mr. McMillen is responsible for providing a laboratory environment to support the development, demonstration, testing, and evaluation of Air Traffic Management (ATM) Integrated Product Team products and decision-support tools. As an air traffic control subject matter expert, Mr. McMillen works closely with FAA Headquarters, the NASA Ames Research Center, field facilities, and other researchers to provide the high-fidelity simulations and test environment needed to meet ATM field-development milestones. He is currently the focal point for the Center-TRACON Automation System research being conducted in the TFM Laboratory.

Glen Hewitt, STARS Human Factors Future Issues Lead, is currently serving as a Scientific and Technical Advisor for Human Factors in Federal Aviation Administration Research and Acquisitions. Previously, he provided human factors support for system operational test and evaluation as a Senior Principal Scientist with the Atlantic Research Corporation. Prior to that, he served with the Department of Defense where he conducted manpower and force planning, modeling, and analyses. In addition, he was instrumental in the development and implementation of Manpower and Personnel Integration (MANPRINT) and Human-System Integration (HSI) programs. In 1987, he fulfilled a Fellowship Program in Human Factors and Operations Research with the RAND Corporation. He is the author of a number of articles, handbooks, and guides on human factors applications and programs. He is a graduate of both the Army Command and General Staff College (Planning and Analysis) and the Navy Naval Command College (Policy and Economic Decision Making). He is a Certified System Professional from the International Certified Computer Professionals. He holds a B.S. in engineering from the United States Military Academy and an M.S. in systems management and safety from the University of Southern California.

Joseph Galushka, STARS Human Factors Specialist, is the Human Factors Applications Lead for the Human Factors Branch (ACT-530) at the Federal Aviation Administration William J. Hughes Technical Center. Mr. Galushka holds an undergraduate degree in psychology from Penn State University, a master's degree in human factors from Wright State University, and did additional graduate work in experimental psychology at the University of Louisville. Mr. Galushka has been practicing applied human factors in aviation for over 10 years with the Department of Defense and the Federal Aviation Administration. He has conducted large- and small-scale simulations to establish baselines of controller performance using new and existing systems. Mr. Galushka is currently working with the Chief Scientific and Technical Advisor for Human Factors and the Deputy Director of Air Traffic Requirements Service to formalize and improve the integration of human factors in the development of air traffic systems.

D. Michael McAnulty,STARS Human Factors Specialist, is the manager of the Human Factors Branch (ACT-530) at the Federal Aviation Administration William J. Hughes Technical Center but is currently on detail to FAA Headquarters as Scientific and Technical Advisor for Human Factors in AAR-100. Before becoming a manager, Dr. McAnulty was an Engineering Research Psychologist for the FAA Aviation Security Human Factors Program. Prior to joining the FAA, he was principal scientist for ANACAPA Sciences Inc. where he managed the Aviation Human Factors Program. Dr. McAnulty also has experience as an industrial/organization psychologist for a retailing corporation and as a university instructor. He holds a Ph.D. in industrial/ organizational psychology with a minor in human factors engineering and a master's degree in experimental psychology. Dr. McAnulty has published over 60 professional articles and reports and is a licensed private pilot.

Karol Kerns, STARS Human Factors Specialist**,** is a lead scientist with the MITRE Corporation, McLean, VA, in the FAA-sponsored Center for Advanced Aviation System Development (CAASD). She received her B.A. degree cum laude in psychology from LaSalle University in 1974 and her M.S. and Ph.D. degrees in experimental psychology from Saint Louis University in 1976 and 1980. Since joining MITRE in 1983, she has been responsible for the application of the human factors principles and methods to the development of FAA advanced automation projects including air traffic control decision support systems and aeronautical data link applications for the en route, terminal, and tower environments. Her principal duties included developing operational concepts detailing the human-computer function allocation, prototyping the human-computer interface portion of the system, designing and conducting human-in-the loop operational simulations, and participating in government-industry standards committees. In 1991, she became a coordinator of the Human Factors Engineering Specialty Group, which provides human factors engineering services to a wide range of aviation system research and development projects throughout CAASD. Dr. Kerns currently chairs an SAE subcommittee on Flight Deck Information Management, which is developing human factors guidelines and requirements for data link systems.

Kim M. Cardosi, STARS Human Factors Specialist, received her Ph.D. in experimental psychology from Brown University in 1985 and her private pilot certificate in 1990. For the past 10 years, she has been a human factors specialist at the John A. Volpe National Transportation Systems Center, part of the US Department of Transportation Research and Special Programs Administration. She has conducted extensive research in controller-pilot voice communication and was the Volpe Center human factors lead in evaluating the Conflict Resolution Advisory (a decision support tool designed for en route controllers). Dr. Cardosi is co-editor of *Human Factors in the Design and Evaluation of Air Traffic Control Systems*. She currently conducts research on the use of color in air traffic control displays and is the Volpe Center human factors lead on the Advanced Air Transportation Technology program with the NASA Ames Research Center.

Acronyms

AF	Airway Facilities
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal Systems
AT	Air Traffic
ATC	Air Traffic Control
ATM	Air Traffic Management
BOS	Boston Logan International Airport
CAASD	Center for Advanced Aviation System
CAMI	Civil Aeromedical Institute
CBI	Computer-Based Instruction
CDR	Continuous Data Recording
CTAS	Center-TRACON Automation System
EASL	Existing Automation Service Level
EDC	Early Display Capability
ESL	Emergency Service Level
FAA	Federal Aviation Administration
FSC	Final System Capability
FSL	Full Service Level
HF	Human Factors
HSI	Human-System Integration
IFR	Instrument Flight Rules
ISC	Initial System Capability
MANPRINT	Manpower and Personnel Integration
MCW	Monitor and Control Workstation
NATCA	National Air Traffic Control Association
N/O	No Opportunity
SATORI	Systematic Air Traffic Operations Research Initiative
SIMOP	Simulation Operation Pilot
STARS	Standard Terminal Automation Replacement System
TFM	Traffic Flow Management
TGF	Target Generation Facility
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules

Volume I
Chapter 2

Transition and Pre-Planned Product Improvements Human Factors Research Application Areas and Activities

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Standard Terminal Automation Replacement System
Human Factors Team

Submitted to:
Chief Scientific and Technical Advisor for Human Factors

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Chapter 2

Table of Contents

1. Introduction

Under the Standard Terminal Automation Replacement System (STARS) program, the purchase of the commercially available air traffic control system will include systematic upgrades through STARS transition states (Early Display Capability, Initial System Capability [ISC], and Final System Capability [FSC]). These upgrades include incorporating pre-planned product improvements (P^3Is) that enhance the system to meet the long-term STARS functionality. Program requirements and engineering best practices stipulate that in addition to the full assessment of human factors (HF) considerations in early versions, STARS must also undergo comprehensive and systematic incorporation of human factors. This should be performed during the design, development, testing, and implementation of the transition states and enhancements of the acquisition. Because the full definition of the transition states and enhancements has not yet been determined, this chapter provides only an outline of the required research, application areas, and activities necessary to ensure the STARS transition states and enhancements achieve human-system interfaces that meet program productivity and safety requirements.

However, if an integrated human factors program for far-term STARS enhancements is to be achieved, it is essential to begin that work now. Each of the enhancements must be analyzed to understand the status of any previous human factors work, including the requirements and goals that underlie existing designs, especially those that identify any unresolved issues. Moreover, an early look across the planned enhancement packages such as Center Terminal Approach Control (TRACON) Automation System (CTAS)/Final Approach Spacing Tool (FAST) and data link will allow human factors specialists to anticipate display and procedural integration issues and plan appropriate studies. This early participation is a critical element of the integrated HF process recommended by the STARS HF team.

2. Background

In accordance with the Terminal Enhancement Integration Program (TEIP), STARS will be installed in two phases: ISC and FSC. The first Operational Readiness Demonstration (ORD) for STARS ISC is scheduled for 1998, and the first STARS FSC ORD is scheduled for 1999. Under this acquisition strategy, successfully developed P^3I systems will be capable of interfacing with STARS through the Applications Interface Gateway (AIG). This functionality will be facilitated through group software releases called Enhanced System Capability (ESC) Packages. The first ESC Package (ESC-1) is planned for ORD in the year 2000, and the second ESC Package (ESC-2) is planned for 2001.

Additional packages will follow each year thereafter. Because these terminal enhancements are to be implemented in several independent packages, each package will be acquired using the Acquisition Management System (AMS) and must accommodate the requirements for an integrated human factors program. As proposed by the TEIP, a terminal architecture will be defined with the goal of integrating functional enhancements by linking common functional elements between programs and, thereby, realizing synergistic operational benefits between programs. The integration of human factors research and application will be a major component of this plan.

3. STARS Transition States and Enhancements

As the program is currently structured, the STARS ISC baseline includes the AIG and the Enhanced Traffic Management System (ETMS). The AIG provides the capability for P^3I products to interface with the STARS system. The STARS FSC baseline will support the Final Monitor Aid, Converging Runway Display Aid, and the Controller Automated Spacing Aid, which are considered P^3I programs. FSC enhancement candidates planned for the program are categorized as major, minor, and proposed.

3.1 Major Enhancement Candidates

Major enhancements are those upgrades with established terminal interface requirements, those with firm Automated Radar Terminal System (ARTS) requirements and those that, when implemented, will have a substantial impact upon the ARTS or STARS platforms (i.e., requires significant amounts of inboard software). They include

a. CTAS/FAST,

b. All Purpose Structured Eurocontrol Radar Information Exchange,

c. Automated Barometric Pressure Entry,

d. Terminal Data Link, and

e. Selective Interrogation.

3.2 Minor Enhancement Candidates

Minor enhancements are those planned upgrades that also have established terminal interface requirements. This category lists enhancements that have delineated Air Traffic Services requirements for implementation and have a relatively minor impact upon the ARTS or STARS platforms (e.g., programs that interface with ARTS/STARS only to receive data). Currently, identified programs include

a. Airport Movement Area Safety System,

b. Precision Runway Monitor, and

c. Surface Movement Advisor.

3.3 Proposed Enhancement Candidates

Proposed enhancements are those upgrades without established terminal specifications. This category identifies enhancements that are included in the Mission Need Statement (MNS) and Operational Requirements Document for STARS but require further research and development. These projects are in various stages of maturity and concept development.

- Traffic Alert and Collision Avoidance Resolution Advisory Display
- Surveillance System Processing Enhancements
- Automatic Dependent Surveillance-Broadcast Data Integration

- Multisensor Fusion Tracker
- Conflict Alert/Mode-C Intruder Performance Enhancements
- Flight Data Input/Output Integration into STARS
- Flight Data Processing Upgrade
- STARS/STARS Interface
- Free Form Text
- Terminal Controller Position-Defined Airspace
- Weather Enhancements
- Enhanced Traffic Management System (ETMS Upgrade)
- Incorporate ASR-9 Remote Control into STARS

4. Human Factors Research and Application Areas and Activities

To achieve the objective system performance levels, it is necessary to conduct a broad range of human factors research and application activities. These activities will be in support of the STARS transition and P^3I functions and operations during their development and integration. Furthermore, these activities will acquire and apply the information necessary to understand the human capabilities and limitations related to the STARS transition states and P^3Is. Through the coordinated conduct of this set of activities, human factors will be applied to identify and resolve risks and tradeoffs related to such issues as

a. computer-human interface;
b. controls, displays, and alerts;
c. operational procedures and practices;
d. transitioning incremental prototypes and revisions;
e. system component integration;
f. workforce productivity, workload, usability, and task performance;
g. training for new automation operation and maintenance;
h. equipment, workspace, and workplace design;
i. manpower and staffing;
j. unique skills, abilities, characteristics, and tools;
k. communications and teamwork;
l. job and organizational design; and
m. safety, health, and environmental considerations.

Within each of these research and application areas reside several important issues that deserve significant consideration. Volume II, Section 13 provides a sampling of some of the salient issues associated with these transition states and enhancements that need to be addressed.

Through an appropriate set of activities devised to support the identification and resolution of human performance issues, human factors will be systematically integrated in the planning, design, development, acquisition, evaluation, deployment, and sustainment of STARS transitioning, upgrades, and enhancements. A description of the set of essential human factors research and application activities follows.

4.1 Human Performance Metrics and Baselines

As the STARS P^3I capabilities are acquired to replace or augment those currently deployed, human performance metrics and baselines are required. These metrics and baselines will quantify current and future operational efficiency and effectiveness, facilitate market survey analysis, assess progress during system development and implementation, and support system performance tests and evaluation. The products of this activity include

a. baseline assessments and periodic measurements of STARS P^3I upgrades using human-system performance metrics;

b. consistent metrics to assess and compare STARS P^3I human and human-system performance (e.g., standardized STARS metrics and measurement techniques for assessing operator/maintainer workload, staffing and training for vendor solutions during market surveys);

c. methods and capabilities to benchmark P^3I human-system performance, usability, and suitability (e.g., development and application of techniques, tools, facilities, and procedures for determining and mitigating potentially high levels of individual and team communication requirements in the terminal area);

d. ways to show the link between varying levels of human performance to operational system capabilities (e.g., the measures of workload related to the transition state and maturity of a STARS technology and computer-human interface [CHI]); and

e. development of a comprehensive set of scenarios, system/subsystem configurations, environmental measures, and simulation concepts for conducting baseline and subsequent assessments (e.g., operational scenarios for terminal operations to conduct evaluation of procedural STARS P^3I changes).

4.2 Congruent Computer-Human Interface Prototypes

CHI prototyping is required to reduce the risk of higher software and hardware costs resulting from changes and modifications subsequent to initial designs, especially those attributable to the human-system integration (HSI) and CHI requirements. As STARS P^3I capabilities are acquired that employ Commercial-Off-the-Shelf (COTS) software, Non-Developmental Items (NDI) equipment, and vendor CHI solutions, a well-planned HSI program will enhance the development of common interfaces, consistent CHI, and compatible functions and procedures. The products of this activity include

a. concepts and prototypes for compatible P^3I (e.g., compatible CHI STARS related upgrades);

b. common CHI designs for systems/subsystems migrating to STARS (e.g., common function and form interfaces for subsystems transitioning into the STARS transition states);

c. tools, techniques, resources, and capabilities to rapidly prototype new CHI designs, assess vendor CHI solutions, and evaluate the impact of varying CHI alternatives (e.g., assess the strengths and weaknesses of new CHI designs and specifications for STARS transition states and P^3I applications);

d. technical standards and specifications for STARS future CHI designs (e.g., common core functions, display characteristics, and operational procedures for STARS tower and TRACON applications); and

e. STARS CHI configuration management capabilities to compare CHI compatibility between system/subsystem components and to design new subsystem CHIs.

4.3 Human-in-the-Loop Simulations

Human-in-the-loop simulations of STARS P^3I systems/subsystems allow human performance characteristics to be systematically analyzed and evaluated. Areas of task loading, task sequencing, information processing, and crew coordination need to be examined to identify and resolve potential risks and opportunities. In addition, this examination will be used to gain an early indication that the level of human performance associated with a system, subsystems, or transition states will be adequate to support required STARS P^3I performance requirements. The primary products of this activity include

a. simulation results/findings that verify critical tasks, validate task analyses, refine procedure designs, assess training regimen designs, and identify implied operation and maintenance diagnostic and problem solving activities;

b. comprehensive and consistent assessments and measurement of human performance within systems and across the integration of systems; and

c. realistic mission scenarios (developed for the various upgrades and enhancements with sufficient fidelity to ensure objective, quantifiable measures) that will allow repeated examination of human performance in a realistic future STARS environment.

4.4 Task Analysis and Workload Measurement

Measures of time and accuracy (e.g., error rate) provide valuable insights into human-system performance, supplementing subjective rating scales that offer insights into user attitudes and feelings but which do not always correlate with objective measures of performance. The high levels of automation to be incorporated in the STARS P^3I must be examined for their impact on the tasks of the operators and maintainers, especially for cognitive-type tasks (interpreting displays, analyzing information, considering alternative actions, and assessing faults and failures). The primary products of this activity include

a. analyses and measurements that describe human-system performance at the required component level of the system/subsystem;

b. validated tools and techniques, both objective and subjective, to provide measures of the cognitive tasks and workload placed upon future STARS operators and maintainers; and

c. data sources to support the development of task analyses.

4.5 Workstation Integration

Without advanced integration planning and analysis, workstation design and implementation become reactive to the continual flow of new transition requirements, displays, and control devices. To ensure the required level of performance for the STARS P^3I capabilities, workstation integration activities (i.e., planning, analysis, and implementation) must be systematically conducted. The primary products of this activity include

a. descriptions and designs of complex workstation configurations;

b. design guidelines for the systematic integration of a variety of control and display devices to enhance STARS operator and maintainer performance; and

c. design and implementation analyses, alternatives, and recommendations for the configuration of future workstations and STARS P^3I workstation environments.

4.6 Human Component Life Cycle Costs, Benefits, and Tradeoffs

It is necessary to supplement the human factors information available to support the decisions made on alternative approaches to, and program plans for, meeting STARS P^3I requirements. This activity will support the STARS P^3I with easily accessible, quantifiable information that reflects a human performance perspective by developing reliable sources of data and integrating this data into investment analysis and programmatic decisions. This activity will provide human factors information to (a) conduct the necessary alternatives evaluations, (b) assess current and future affordability, (c) contribute to the tradeoff analyses and investment decisions, and (d) resolve cost/effectiveness issues during solution implementation. The products of this activity include

a. identification and description of STARS human factors variables impacting costs, benefits, and tradeoffs (e.g., the types of operational benefits related to human performance on new and upgraded system components);

b. methods for, and results from, the prediction and assessment of the relevant STARS human factors opportunities and risks that significantly impact system performance (e.g., identifying the operator cognitive workload for critical functions/tasks);

c. the quantification of human performance variables and their relationships (e.g., human-system performance cost/benefit relationships for new display concepts);

d. accessible sources of information related to human factors costs, benefits, and tradeoffs (e.g., development of accessible data sources providing relevant program documentation and records such as task and training analysis information); and

e. assessments of STARS P^3I concepts and system developments on the affordability, costs, benefits, risks, and tradeoffs associated with human factors including personnel selection, staffing, training, and human-system performance.

4.7 Human Factors Program Documentation

During the conduct of activities related to STARS service level transitions and pre-planned improvements, human factors inputs to program documentation will provide essential information by which to plan, develop, test, implement, and sustain the system/subsystem being acquired. It will be necessary to properly document the human factors considerations for the integration of human factors into other program management decisions and into contractor/vendor requirements. Whereas the method by which this documentation has traditionally occurred is changing (especially with increased dependence upon software, COTS/NDI, and rapid prototyping; decreased dependence on standards; less restrictive documentation and specification; and shorter acquisition times), there is, nevertheless, a requirement for significant human factors expertise applied to the documentation of human performance information. Products of this activity include inputs to documentation related to human performance limitations, human resource constraints, human-system issues and considerations, human factors specifications, user (operator and maintainer) performance test plans and procedures, human factors inputs to contract deliverables (Contract Deliverable Requirements Lists, Data Item Descriptions, Statement Of Work), and other AMS documents.

Human factors documentation inputs define human performance requirements and criteria, identify human performance and resource tradeoffs, specify human performance thresholds, establish an approach to ensure human performance supports system performance, and define the specific tasks and activities to be conducted. In addition to other enumerations and annotations of human factors in other program documentation (e.g., task analyses, market surveys, affordability assessments, test reports), the key program documents in a system acquisition requiring experienced input relative to human factors are as follows.

- Mission Need Statement: The MNS defines a mission capability shortfall or technological opportunity the FAA should address and includes consideration of major human resource and human-system performance issues. Incorporation of major human resource and performance considerations provide a basis for addressing constraints related to the human component of the required capability.
- Requirements Document: This establishes the performance baseline and operational framework for an acquisition program and includes human-system interfaces and human performance requirements. It is in this document that detailed consideration of human-system interfaces and human performance requirements, characteristics, and criteria are initiated.
- Investment Analysis Report: This summarizes the analytical and quantitative information developed during investment analysis in the search for the best means for satisfying a mission need and identifies the human resource and performance tradeoffs in terms of cost and benefit. Identifying the human resource and performance

tradeoffs provides insight into their impact on the operational suitability and effectiveness in quantifiable cost and benefit terms.

- Acquisition Program Baseline: This establishes the performance, cost, schedule, and benefits baseline with which an acquisition must be implemented. It includes human-system performance thresholds and concepts for conducting the human factors program. Identifying these thresholds and concepts for conducting the human factors program establishes a reference point for all future system human factors tradeoffs in operational suitability and effectiveness.

- Acquisition Strategy Paper: This defines the overall strategy by which an acquisition program will be implemented and outlines the strategy and objectives for the supporting human factors program. Providing a human factors strategy helps ensure that the solicitation addresses critical human factors contractor services.

- Integrated Program Plan: This describes the detailed planning for all aspects of the program implementation and specifies the human factors program tasks, activities, controls, responsibilities, and schedule. The human factors portion of this document provides an early and clear definition of the work to be conducted under the human factors program.

4.8 Estimated Level of Human Factors Effort

Each transition state, upgrade, and enhancement will require some aspect of the seven activities delineated above. However, the level of human factors effort must be tailored to the specific product; the timing of the product; the relevant human-system performance issues; and the associated consequences of potential tradeoffs, deficiencies, and opportunities. While the appropriate tailoring should be accomplished through a thorough assessment of the transition state or enhancement, Volume II, Section 14 provides an estimate of the relative level of human factors anticipated for the proposed STARS transitions and enhancements. This section also rates each of the transition states (i.e., high, medium, and low) and enhancements for the seven major human factors research and applications activities. It is recognized that some human factors activities have already been accomplished and are included in the total level required. It further recognizes that only the residual efforts will be conducted in the future.

5. Implications for the Future

This chapter provides evidence that there is a need and ample opportunity to capitalize on the capabilities and limitations of the human component for the STARS program in order to achieve stated objectives for safety and productivity. The chapter also suggests major implications for designing a comprehensive human factors program to ensure this achievement. Some of these include the following:

- The impact of design and development on human performance are only fully evident if the human factors program employs a rigorous approach to human factors engineering. Such an approach requires the research and application activities to use methods that comprehensively address (a) representative user (operator and maintainer) characteristics; (b) human-system performance metrics/data; (c) functional scenarios across all tasks and operational requirements; (d) representative training for operators, maintainers, and supervisors; and (e) stabilized baseline system configurations.

- In addition to certain requirements of STARS identified as candidates for P^3I, the government may also authorize improvements to STARS hardware, software, and firmware to maintain technological currency and to enhance system capabilities. As these technology changes are made, so too, must changes to the efforts associated with the human factors program.
- Because the government may order improvements separately, or concurrently with, other improvements (improvement sets), variations in the human factors program may result. These incremental upgrades may consist of modifications to hardware, software, documentation, support tools, procedures, and data necessary to effect the upgrade. As requirements for the incremental upgrades to the design and development are defined, changes to the human factors program must also be specifically delineated.
- Although there are unknowns associated with the specific design features of the STARS transition states and enhancements that must be addressed, there are also human performance implications (such as in the site training programs). These implications are related to differences in equipment configuration at each site and the timing and duration of the transition or enhancement at each site. As configurations and candidate enhancements are site-adapted, the human performance considerations of those adaptations must also be addressed.
- The current definitions of the human interfaces with STARS transition states and enhancements are insufficiently mature to estimate accurately the full implications on human performance or to determine the full scope of the human factors requirement associated with this program. A significant effort is required to define the human interface and integration requirements across all STARS program future developments.

6. Conclusions

The critical impact of human factors on acquisitions is well documented in programs, studies, and analyses. The FAA Acquisition Management System states, "Integrated Product Teams must assure that planning, analysis, development, implementation, and in-service activities for equipment, software, facilities, and services include human factors engineering to ensure performance requirements and objectives are consistent with human capabilities and limitations." As in other programs, human factors must be integrated with the STARS engineering and development effort, its transition states, and enhancements throughout the acquisition process.

This approach employs human factors in the context of the total system concept in which the operator, maintainer, and operating environment are integral components of the system. When human factors is applied early in the acquisition management process, it enhances the probability of increased performance, safety, and productivity; decreased life cycle staffing and training costs; and becomes well-integrated into the program's strategy, planning, cost and schedule baselines, and technical tradeoffs. These benefits are equally applicable to COTS acquisitions such as STARS, with its transition states and enhancements, as well as developmental programs.

Volume I
Chapter 3

Re-Evaluation of the
Standard Terminal Automation Replacement System
Monitor and Control Workstation
Computer-Human Interface

Prepared by:
Standard Terminal Automation Replacement System
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Submitted to:
Chief Scientific and Technical Advisor for Human Factors

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Chapter 3

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1. Introduction

This assessment plan outlines the methodology to conduct a follow-up evaluation of the computer-human interface (CHI) of the Standard Terminal Automation Replacement System (STARS) Monitor and Control Workstation (MCW). At the request of Terminal Systems Division (ARU-200), the Human Factors Branch (ACT-530) conducted the original study (Mogford, Rosiles, Koros, & Held, in press). That investigation evaluated both the MCW Full Service Level (FSL) and Emergency Service Level (ESL) systems. The current test replicates the methodology used during that study to determine the effects of MCW software improvements.

1.1 Background

The original investigation employed a CHI Review Team composed of Engineering Research Psychologists and an Airway Facilities (AF) Subject Matter Expert. The team was assembled from ACT-530 personnel at the Federal Aviation Administration (FAA) William J. Hughes Technical Center. That investigation assessed the usability of the MCW in the context of the human factors (HF) information contained in the *STARS System/Subsystem Specification* (SSS) (FAA, 1997), and with regard to criteria in the *Human Engineering Design Criteria for Military Systems, Equipment and Facilities* (MIL-STD-1472D) (DOD, 1989); *Human Factors Design Guide for Acquisition of Commercial-Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems* (Wagner, Birt, Snyder, & Duncanson, 1996); and *American National Standard for Human Factors Engineering of Visual Display Terminal Workstations* (ANSI/HFS 100-1988) (HFS, 1988). CHI Review Team members conducted this evaluation in the STARS laboratory at the Technical Center during the week of April 7, 1997. They used a script of representative AF tasks to test each system and conducted a side-by-side comparison. They analyzed the resulting data and presented it to ARU-200 on April 23, 1997 (Mogford, et al., in press). The current test will employ the same methodology and script to investigate the CHI of the ESL and FSL systems.

During the original study, the CHI Review Team identified HF concerns for each service level (i.e., the FSL and ESL systems) and for both systems when compared side-by-side. Significant concerns within the FSL CHI included the number of user interface styles (i.e., graphical, command line, and character-based menu interfaces) and the number of status codes used. HF concerns for the ESL system included the number of user interface styles, cumbersome mouse actions, improper status coding, and limited access to system information. The main CHI of the ESL system was entirely different from the FSL system, yet it also required users to employ graphical, command line, and character-based menu interfaces. When compared side-by-side, the team noted that the FSL and ESL systems had independent and inconsistent interfaces. This lack of consistency requires the user to learn two different CHIs, mouse interaction styles, and status coding schemes. A list of the STARS MCW HF issues is provided in Volume II, Section 1.

The team concluded that the MCW system represented a collection of unintegrated and independently formatted CHIs. They recommended that the MCW CHIs be internally and externally integrated into a single system. This should help to minimize human error and enable systems specialists to more easily navigate and access required system functions in a consistent manner.

1.2 Scope and Limitations

This evaluation will assess the usability of the current version of the MCW CHI design (including the FSL and ESL systems). The proposed assessment is limited to a usability evaluation of the MCW. It focuses on the ability of the user interface to support systems specialists' tasks. Data on the safety, efficiency, performance, and workload levels associated with this design will not be collected. This kind of HF evaluation may be conducted when the system nears maturity.

2. Method

Two methods will be employed. First, the CHI Review Team will assess the MCW system with respect to HF requirements contained in the SSS and evaluate its adherence to HF guidelines and standards. Second, the Review Team will conduct a usability evaluation of the MCW in the STARS lab.

2.1 Participants

A CHI Review Team will be assembled. It will be comprised of six AF systems specialists and three HF specialists familiar with AF systems.

2.2 Materials

The Review Team will use several reference documents including the SSS, MIL-STD-1472D, the AF Human Factors Design Guide, and the ANSI document. Checklists will be developed from these sources, as needed.

The team will use two super VHS recorders to capture activity as each task in the test script is performed. A scan converter will capture the screen activity, while a camera with a wide-angle view captures keyboard and other related activities.

2.3 Scripts

During the CHI review, the Review Team will use a script of representative AF tasks to perform activities on the FSL and ESL systems. The script employed for the initial evaluation (Volume II, Section 15) will be checked for completeness and revised as needed. The team will execute the script on each system and then on both systems in parallel to conduct the side-by-side comparison.

2.4 Procedure

The Review Team will apply the same methodology that was employed during the first evaluation. The following subsections detail these procedures.

2.4.1 Specifications and HF Guidelines Review

The Review Team will examine system functionality (i.e., FSL and ESL) with respect to the HF information contained in the SSS. The team will also determine whether each system adheres to good HF practices by applying HF guidelines in the sources listed in Section 2.2. A table of the information contained in these sources will be generated and issues that represent a departure from accepted HF practices will be documented.

2.4.2 Usability Evaluation

The CHI Review Team will use the test script to exercise the FSL and then the ESL functions during the CHI review test period. They will complete the appropriate data collection forms (Volume II, Sections 16 and 17) as the script is performed. These forms contain the 89 issues (45 FSL items, 21 ESL items, and 23 items relevant to both systems) that were identified during the initial evaluation. Since that evaluation, the STARS program office has worked with the vendor to address these issues. Each issue will be re-evaluated to determine its current status and new issues will be added as needed.

The Review Team will perform the same test script on both service levels in parallel after completion of the independent evaluations. A side-by-side comparison of the two service level CHIs will be performed to evaluate the compatibility of controls and displays. The team will follow the script to access each function on the two interfaces and make notes regarding similarities and differences that are relevant to efficiency and safety of operation. This information will be entered into the data collection form contained in Volume II, Section 18. A form for Review Team members to record additional comments is provided in Volume II, Section 19.

3. Results Format

The results will include findings from the two CHI evaluation activities, specifications and HF guidelines review, and the compatibility evaluation. The procedure for each is presented in the following subsections.

3.1 Specifications and HF Guidelines Review

The CHI Review Team will assess the usability of the MCW with respect to the information contained in the SSS and general HF guidelines. Issues such as screen format, color coding, and information content will receive particular attention.

3.2 Usability Evaluation

The CHI Review Team will consolidate all comments generated as the test script was performed on each system and during the side-by-side comparison. Redundancies will be removed and a final list of issues will be created. This list will be augmented by information contained in the videotapes (as needed) to determine the usability of the FSL and ESL with regard to each function tested. Compatibility of the two service levels will also be addressed. The CHI Review

Team will provide recommendations, as appropriate, to address usability issues. In addition, design areas that represent good HF practices will be identified.

4. Proposed Schedule

- Conduct CHI evaluation (Schedule to be determined).

- Deliver draft and final reports to ARU-200 at approximately 6-week intervals after the review takes place. The report will contain conclusions from all data analysis activities and the resulting recommendations.

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