Office of Inspector General

Federal Aviation Administration's
Standard Terminal Automation
Replacement System (STARS)

Report Number AV-1998-012
Date Issued: November 17, 1997

Memorandum

Subject: <u>ACTION</u>: Federal Aviation Administration's Standard
Terminal Automation Replacement System
Report No. AV-1998-012

Date: November 12, 1997

From: Kenneth M. Mead
Inspector General

Reply to
Attn of:

To: Federal Aviation Administrator

On October 30, 1997, at a hearing of the Subcommittee on Transportation and
Related Agencies, Committee on Appropriations, U.S. House of Representatives, we
provided our observations on the Federal Aviation Administration's (FAA) Standard
Terminal Automation Replacement System (STARS) Program. A copy of our
statement is attached for your information.

We recommended that FAA (1) perform a human factors engineering evaluation on
STARS, (2) establish a credible process to identify and prioritize human factors
issues, and (3) create a mechanism to effectively resolve them. FAA could execute
National Memorandums of Understanding with the unions representing air traffic
controllers and maintenance technicians as a mechanism to effectively resolve issues
identified in the human factors engineering evaluation.

During the hearing, Dr. George Donohue, Associate Administrator for Research and
Acquisitions, and Mr. Ronald Morgan, Director of Air Traffic, concurred with our
recommendations and agreed to take appropriate actions. Congressman Wolf,
Subcommittee Chairman, encouraged FAA to contract with Mitre Corporation to
assist in the human factors evaluation and act as a facilitator to bring FAA and union
representatives together to resolve the human factors issues. Congressman Wolf
requested that FAA report to the Subcommittee by December 15, 1997, on the
actions that will be taken to resolve the human factors issues.

In addition to the human factors issues, we discussed three risk areas in the STARS Program. One area, designated by FAA as high risk, is software development. The other two areas are system testing and training. Problems in these areas could cause the milestone for operation of the first STARS site to slip. We did not make recommendations in these areas.

The Office of Inspector General will continue to monitor FAA's STARS Program including the resolution of human factors issues and the status of early hardware deployment. We will keep you informed of our progress and results.

Please reply in accordance with Department of Transportation Order 8000.1C on the specific actions taken or planned to address the recommendations and target dates for completion of these actions. We would appreciate your written response by December 15, 1997.

If I can answer any questions or be of any further assistance, please call me on x61959 or Lawrence H. Weintrob, Assistant Inspector General for Auditing, on x61992.

Attachment

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**Before the Subcommittee on
Transportation and Related Agencies,
Committee on Appropriations,
U.S. House of Representatives**

Observations on the Federal Aviation Administration's Standard Terminal Automation Replacement System (STARS)

**Statement of Kenneth M. Mead
Inspector General
U.S. Department of Transportation**

Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to report on the Federal Aviation Administration's (FAA) Standard Terminal Automation Replacement System, commonly referred to as STARS. STARS is a very important program. The $940 million program will replace aging equipment at 172 terminal air traffic control facilities with a new automation system. The life cycle costs of the STARS program through the year 2025 are estimated at $2.2 billion. The current schedule has the first site to be operational in December 1998 with the last site operational in February 2005.

Our testimony will first address the human factors issues that have been identified by air traffic controllers and maintenance technicians that, in their view, could reduce controller efficiency and possibly impact air traffic safety. For example, STARS uses a format similar to Microsoft Windows™ to provide information to air traffic controllers. This information is provided in windows that can be moved, resized, or closed as needed. The background of these windows is opaque and will obscure the controller's view of aircraft behind them.

Secondly, we found several reasons why these human factors issues have been highlighted at this stage of the STARS program. Although human factors evaluations are required under FAA's Acquisition Management System, we found program documents acknowledging that human factors evaluations would be limited because of the STARS acquisition approach. FAA chose an aggressive schedule which compressed an estimated 32 months of development and testing into 25 months. Additionally, the STARS procurement relies heavily on commercially available products. The winning contractor's proposal for STARS relied on systems developed for air traffic controllers in other countries that do not have the same terminal operations as the United States. FAA had air traffic controller and maintenance technician involvement in the development of STARS requirements. However, a formal process was not established to identify, prioritize, and resolve human factors issues as the system was being developed.

Finally, we will briefly discuss three other areas in the STARS program that potentially could cause the December 1998 milestone for operation of the first site to slip. One area, designated by FAA as high risk, is software development. The other two areas are system testing and training. Problems in these areas could also cause this key milestone to slip.

STARS development is nearing completion. However, there is still time for FAA and the users to work together in identifying and resolving the human factors issues and fielding a system that meets the user needs. We recommend that FAA (1) perform a human factors engineering evaluation on STARS; (2) establish a credible process to identify and

prioritize human factors issues; and (3) create a mechanism to effectively resolve them. FAA could execute National Memorandums of Understanding with the unions representing air traffic controllers and maintenance technicians as a mechanism to effectively resolve issues identified in the human factors engineering evaluation.

The STARS Program

In the 1980's, FAA recognized the need to replace the existing Terminal Radar Approach Control facility (TRACON) automation equipment. As part of the Advanced Automation System Program, the Terminal Advanced Automation System was estimated to cost $166 million and be implemented by 1998. In 1994, the then FAA Administrator restructured the troubled Advanced Automation System, canceling the terminal automation segment. FAA then initiated a new terminal modernization program called Standard Terminal Automation Replacement System (STARS).

STARS will replace controller and maintenance workstations with color displays, as well as computer software and processors at 172 TRACONs. The STARS program cost is approximately $940 million and its estimated life cycle cost is $2.2 billion through 2025. In September 1996, FAA awarded a contract to Raytheon Electronic Systems for the development and implementation of the system. The first operational STARS system is scheduled for December 1998 at the Boston TRACON. The last site is scheduled to be operational in February 2005.

Attached to this testimony is a schedule, as of September 1997, of the STARS program.

Human Factors Issues Identified With the STARS Design

> *"Human factors discovers and applies information about human abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use."*

The study of human factors examines how humans interact with machines and identifies ways to enhance operators' performance and minimize errors. Given the variety of human skills and adaptability, no one solution will fully satisfy all users. Consequently, not all users view the significance of a human factors issue in the same way nor consistently agree on the best way to resolve the issue.

The following list provides examples of the key human factors issues identified by users.

Opaque Windows. STARS uses a format similar to Microsoft Windows™ to provide information to air traffic controllers. This information is provided in windows that can be moved, resized, or closed as needed. The background to these windows is opaque and will obscure the controller's view of an aircraft symbol behind them. These opaque windows will also reduce the usable area on the controller's display.

Heads-Down Time. The current controller workstation has knobs allowing the controller to operate many functions while continuing to view the display. Because STARS is a digital display, functions currently operated with knobs will be accomplished with menus accessible from windows and lists. Controllers are concerned that the keyboard design, combined with window-driven menus, will require significant time looking at the keyboard rather than the air traffic control display. For example, to change the brightness of the display on the existing system requires turning a knob. STARS requires four keystrokes and use of the trackball.

Keyboard. STARS uses a keyboard similar to those used on personal computers. The STARS keyboard differs dramatically from the current controller keyboard which has a unique alphabetical (ABC) layout.

In addition, unlike the existing keyboard, the STARS keyboard is larger and movable. These differences can change the human-to-computer interface.

Aircraft Display. Information displayed on the STARS screen to represent an aircraft's position does not provide sufficient details about an aircraft's position and movement. For example, the existing system shows a tail behind the target indicating where the aircraft has been. On STARS, this history is shown by a series of widely spaced dots.

Trackball. The trackball is a data input device similar to a mouse on a personal computer. The human factors issues identified with the trackball include its size and weight, how it works, and the lack of backlighting on the trackball buttons. In addition, the trackball cannot be adjusted for left- or right-handed users.

Writing Space. The STARS workstation cannot accommodate a writing tablet without the controller moving the keyboard to an awkward position. Controllers need writing space to write notes on and, in some facilities, use the space for flight strips.

Primary Versus Backup Maintenance Workstation. To repair or maintain the primary STARS system or the backup STARS system, maintenance technicians must use two different screens. However, the information displayed on the screens is not the same for the two systems. For example, visual alarms are not the same between primary and backup STARS. To indicate a problem, primary STARS uses color coding and flashing images, while backup STARS only has color coding. This could cause confusion in a stressful situation.

We do not know how much it will cost or how long it will take FAA to fix these human factors issues. The only estimate provided was to resolve the opaque windows issue with transparent windows. This estimate was $1 million and 2 months for software development. Further, until a human factors evaluation is conducted, FAA will not know if there are other human factors issues that must be addressed for the successful fielding of STARS.

Why This Happened

We are now nearing completion of STARS development, and FAA and the contractor are scheduled to begin formal acceptance testing in January 1998. However, as discussed, there are several human factors issues that must be addressed before STARS can be used.
Although human factors evaluations are required under FAA's Acquisition Management System, we found FAA documentation acknowledging that human factors evaluations would be limited because of the STARS acquisition approach. FAA chose an aggressive schedule which compressed an estimated 32 months of development and testing into 25 months. Additionally, the STARS procurement is relying heavily on commercially available products. The STARS system proposed by Raytheon was developed for use by controllers in other countries. The volume of air traffic and the complexity of airspace in other countries is different than that of the United States terminal air traffic environment. To accommodate unique features of United States controllers and the air traffic environment, some refinements will be required. While FAA has had air traffic controller and maintenance technician involvement in the development of STARS requirements, a formal process was not established to resolve human factors issues during STARS development.

Limited Human Factors Evaluations Conducted
FAA has conducted limited human factors evaluations of STARS, primarily consisting of paper prototypes, technical discussions, and some demonstrations of newly designed functions. In April 1997,

FAA human factors staff performed a computer human interface evaluation which was limited to the maintenance workstation. This evaluation identified 89 issues, many of which will be resolved.

FAA determined that comprehensive human factors evaluations could not be conducted because of the acquisition approach used for STARS. Specifically, the STARS Human Factors Plan, dated February 23, 1995, stated "The STARS acquisition schedule does not provide time for any human factors design development. Furthermore, the schedule only provides limited time for resolution of any [computer human interface] issues. . . ." In addition, the plan stated "The [commercial] requirement limits the human factors design of STARS hardware and display computer human interface (CHI) to that which is commercially available. It may not accommodate the unique needs of a specific target user group." Subsequently, FAA planned to conduct a human factors evaluation of the original STARS design, however, it was never conducted.

FAA's decision to limit human factors evaluations was not consistent with its Acquisition Management System. Further, FAA should have considered the recommendations for improving human factors engineering contained in the September 1994 Mitre Corporation report to FAA on human factors lessons learned from the Advanced Automation System acquisition. Mitre suggested five steps for addressing human factors.

- More effective use of prototyping to help developers understand user needs so they can address operational requirements effectively.

- More timely and appropriate use of controller teams to avoid alienation of controllers, costly system redesigns, and system weaknesses.

- Better integration of specialized human factors expertise throughout the development process.

- Collection of objective data at appropriate times during the process to validate the opinions of controller teams and the judgment of human factors experts.

- Establishment of a mechanism for making the necessary trade-offs between an ideally human-oriented design and a design that is technically and financially feasible.

In addition to the Acquisition Management System requirements and the Mitre report, FAA's own guidance shows that limiting human factors evaluations will result in higher costs and schedule delays. According to FAA's 1995 report entitled *Human Factors in the Design and Evaluation of Air Traffic Control Systems*, ". . . early consideration of human factors issues will result in potential problems being detected earlier, and resolved earlier, than if human factors planning is delayed. . . . Initially, it is more expensive (in terms of time and funding) to deal with human factors considerations than to ignore them. However, an initial human factors investment pays high dividends, in terms of costs and schedule, in later stages of acquisition where changes are more costly and difficult to make."

Aggressive Schedule Chosen

The STARS acquisition approach was oriented toward rapid procurement and system deployment to meet critical and immediate field needs. To meet these needs, FAA established a very aggressive schedule. As early as March 1996, FAA determined it was a major challenge to meet first-site operation in December 1998. To illustrate, the original engineering estimates required 32 months for software development and testing, however, to meet the December 1998 date, a constrained schedule of 25 months was planned.

Commercially Developed Software Used

FAA determined that one way to accelerate the acquisition process was to use existing software and hardware rather than develop a new system. STARS is FAA's first major acquisition to maximize the use of Commercial-Off-The-Shelf (COTS) and Non-Developmental Item hardware and software. STARS' requirements were written in a general way to give competitors latitude to propose a commercial solution to meet FAA's needs. The general nature of these requirements may result in a system that meets the contract requirements, but without refinement, may not be suitable for use in unique environments. For example, the contract requirement for writing space is "The [controller workstation] shelf shall accommodate one data entry set and provide sufficient space for one 8.5" x 11" pad of paper (standard letter) and one 6" x 9" pad of paper (standard stenographic notebook) without overhanging the shelf." In order to obtain this writing space, the controller must move the STARS keyboard and trackball to a position that makes their use awkward.

Limited User Involvement

A key to positive user acceptance of new equipment is their involvement in the design and development. However, to be effective, user involvement must be extensive, representative of the user group, and timely.

Controllers and maintenance technicians were effectively involved in developing requirements for STARS. In 1994, when the Advanced Automation System failed, a National Air Traffic Controllers Association (NATCA) member led the working group that reevaluated terminal requirements and ultimately developed STARS requirements. Controllers and maintenance technicians also participated in the process that resulted in FAA awarding the STARS contract to Raytheon.

Since contract award in September 1996, FAA did not use air traffic controllers and maintenance technicians, representing a wide variety of facilities, to evaluate STARS and provide feedback on its operational suitability until recently. In the last 30 days, a team of controllers representing seven facilities visited the contractor's STARS laboratory to review this system.

The role of the union representatives has been advisory in nature since contract award. No Memorandums of Understanding between FAA and the unions were executed to formalize their responsibilities until 1997. In September 1997, FAA and NATCA signed an agreement establishing a position for one national representative and a regional point-of-contact in each FAA region. No Memorandum of Understanding has been executed with the maintenance technicians' union.

The national representative for the controllers' union provides technical expertise and identifies the potential impact of STARS on controllers as well as coordinating site surveys, reviewing documents provided by the contractor, and notifying FAA of unresolved issues. The Memorandum of Understanding does not provide specific responsibilities for the regional points-of-contact except for one to act as a back-up to the national representative.

By comparison, in the Display System Replacement (DSR) Program, FAA established a formal process regarding users' involvement. FAA, in collaboration with NATCA, signed two Memorandums of Understanding in 1996 for the DSR Program. One agreement designates a controller to represent the union as a national representative and establishes one controller in each region as the point-of-contact for activities related to deployment, testing, and evaluation. The second agreement addresses the impact of DSR on controller operations. It requires FAA to conduct an operational impact study of the hardware and to conduct a scientific human factors evaluation of the computer human interface. A working group that includes the regional controllers resolves any issues at the national level. As a result of this process, numerous human factors issues were identified and a mechanism exists to resolve the remaining open issues.

<u>Actions Needed</u>

STARS development is nearing completion, but there is still time for FAA and the users to work together to resolve the human factors issues and field a system that will meet the users' needs.

FAA should perform a human factors evaluation on STARS and, working closely with controllers and maintenance technicians, resolve issues identified to field a system that meets users' needs. Until FAA completes this evaluation, it will not be able to fully assess the cost and schedule implications associated with resolving the human factors issues.

Conducting human factors evaluations to identify the issues is not enough. It is imperative that FAA and the unions establish a credible process to prioritize and resolve the human factors issues. Memorandums of Understanding are one option for doing so.

<u>Other Risk Areas</u>

In addition to the human factors issues, there are three areas that present a risk to the STARS program's cost and/or schedule. These areas are software development, testing, and training.

<u>Software Development</u>. FAA has identified software development as a high risk area that potentially could affect its ability to meet the December 1998 date for the first operational site. Raytheon was unable to meet the September 1, 1997, contracted milestone for software development. FAA and the contractor established a new milestone of November 15, 1997. At this time, FAA estimates an additional 4 to 5 month schedule slip for software completion and Raytheon acknowledged a 0 to 3 month schedule slip. The key reasons for the slip include a) Raytheon's slower than expected staffing of software developers and engineers, b) an increase in the amount of software to be developed, and c) lower productivity rates than anticipated by the contractor. Further delays in software development will affect the STARS testing and training schedules.
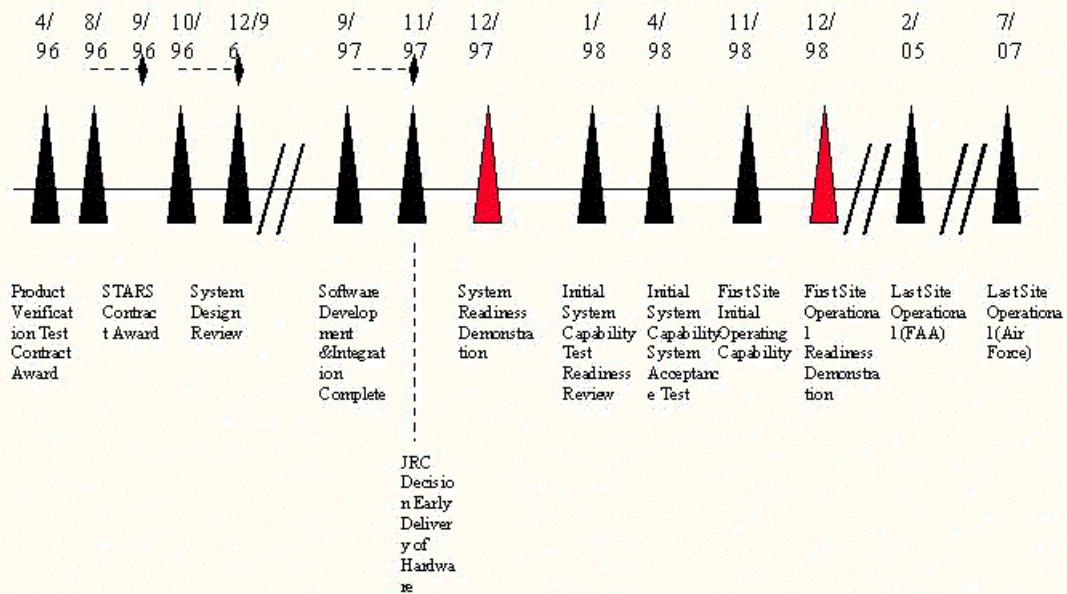
<u>Testing</u>. The STARS test schedule is extremely aggressive with no room for slippage. FAA's formal system operational testing is scheduled for the period of April through July 1998, with the first site to be operational in December 1998. In our opinion, the schedule does not include time to rewrite code to correct the deficiencies identified during formal tests and to retest those areas. Also, delays in software development could increase the risk that testing will not be completed on schedule.

<u>Training</u>. Controller training on STARS is currently at least 2 weeks behind schedule and cannot be completed until STARS software is completed and formal FAA testing has been performed. Also, the cost of training will increase because FAA has requested additional training for software maintenance support personnel, earlier training for maintenance technicians, and the purchase of STARS keyboards for use in training courses. Further delays in software development and testing will also increase the risk that the training schedule will not be met.

The Office of Inspector General will continue to monitor this program and will report on STARS as appropriate.

Mr. Chairman, this concludes our statement. I would be pleased to answer questions.

STARS SCHEDULE
AS OF SEPTEMBER 1997

| 4/96 | 8/96 | 9/96 | 10/96 | 12/96 | | 9/97 | 11/97 | 12/97 | | 1/98 | 4/98 | 11/98 | 12/98 | | 2/05 | 7/07 |

Product Verification Test Contract Award

STARS Contract Award

System Design Review

Software Development &Integration Complete

System Readiness Demonstration

Initial System Capability Test Readiness Review

Initial System Capability System Acceptance Test

First Site Initial Operating Capability

First Site Operational Readiness Demonstration

Last Site Operational (FAA)

Last Site Operational (Air Force)

JRC Decision Early Delivery of Hardware