Office of Inspector General

Air Traffic Control Modernization
Federal Aviation Administration

Report Number: AV-1999-065
Date Issued: March 30, 1999

Memorandum

U.S. Department of Transportation
Office of the Secretary of Transportation
Office of Inspector General

Subject: ACTION: Air Traffic Control Modernization, Federal Aviation Administration Report No. AV-1999-065

Date: March 30, 1999

From: Kenneth M. Mead
Inspector General

Reply To Attn Of: JA-10:x60500

To: Federal Aviation Administrator

On March 9, 1999, at a hearing of the Subcommittee on Transportation and Related Agencies, Committee on Appropriations, U.S. House of Representatives, we provided testimony on Federal Aviation Administration's (FAA) air traffic control modernization efforts. Our testimony focused on the Standard Terminal Automation Replacement System (STARS), Wide Area Augmentation System (WAAS), and the HOST replacement. We also discussed Free Flight, Data Link, Year 2000 compliance, and the Airport Movement Area Safety System (AMASS). Our testimony included recommendations to strengthen FAA's air traffic control modernization efforts. A copy of our statement is attached for your information.

FAA has done considerable human factors work with the Early Display Configuration of STARS. This configuration uses the existing terminal automation system software along with the STARS emergency backup system. The full STARS system however, uses different software and has additional functions. The full STARS system that will be used by the Department of Defense is currently undergoing contractor testing for acceptance. Consequently, we recommend that FAA:

- proceed with the actions necessary to address the human factors concerns in the full STARS system that have been identified for the Early Display Configuration,

- defer decisions on the remaining human factors changes needed on full STARS until testing on the Department of Defense configuration is completed,

- conduct a comprehensive analysis of all unresolved issues to determine realistic, low risk schedules and associated cost estimates for the STARS Program,

- establish exit criteria for STARS human factors and designate one person within FAA to be responsible and held accountable for making these tough decisions on when or if to implement solutions, and

- establish national Memorandums of Understanding for the resolution of human factors issues and the implementation of full STARS.

We also recommend that FAA include the cost of a secondary system of some type (for the next 15 years) in its current satellite navigation investment analysis, and that it reach agreement on HOST contract cost and terms without further delay.

The Office of Inspector General will continue to monitor FAA's air traffic control modernization efforts, including the implementation of STARS and WAAS, and the status of the HOST replacement project. 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 April 23, 1999.

If I can answer any questions or be of further assistance, please call me at (202) 366-1959 or Alexis M. Stefani, Deputy Assistant Inspector General for Aviation, at (202) 366-0500.

Attachment

#

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

For Release on Delivery
Expected at
2:00 p.m. EST
Tuesday
March 9, 1999
Report Number: AV-1999-065

Air Traffic Control Modernization

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

Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to discuss the Federal Aviation Administration's (FAA) air traffic control modernization efforts. From Fiscal Years 1982 through 1999, the Congress appropriated over $27 billion for the modernization program. FAA estimates that the effort will need an additional $14 billion for Fiscal Years 2000 through 2004. FAA is requesting $2.3 billion for Fiscal Year 2000, which represents an increase of 11 percent over the Fiscal Year 1999 appropriation level of $2.1 billion.

Before we discuss modernization, we would like to recognize the actions of Administrator Garvey to facilitate our oversight of FAA's modernization programs. Through the Administrator's example, we have attended meetings where open, candid discussions were permitted and solutions were discussed.

Today, we will discuss: (1) progress and problems over the past year with significant modernization programs, (2) "common threads" that account for schedule delays and cost growth, (3) opportunities to avoid past software development and human factors issues, and (4) the status of Year 2000 efforts and a technology to reduce runway incursions.

- There have been several modernization successes in the past year. These successes include the Display System Replacement, Air Route Surveillance Radar system, and the HOST computer replacement. However, two key modernization programs, Standard Terminal Automation Replacement System (STARS) and Wide Area Augmentation System (WAAS), continue a succession of problems that need FAA's attention. We are making recommendations concerning software development, human factors, and schedules for STARS and the costs of a back-up system for WAAS.

- "Common threads" associated with FAA modernization programs that have experienced difficulties are intensive software development, human factors issues, and unrealistic schedules – attention to these areas can prevent a repeat of past problems.

- FAA has opportunities with new programs, such as Free Flight Phase 1 and Data Link, to improve its management of software development and human factors issues. These programs are in early stages of development, and we believe there is time to address these issues. We recently issued a report on Data Link and made recommendations aimed at improving the program.

- There are other Facility & Equipment efforts underway that are essential for the efficient operation of the National Airspace System and improving safety. These

efforts include FAA's Year 2000 computer compliance and the Airport Movement Area Safety System. Regarding Y2K compliance, FAA has made progress in the past year, but major challenges remain with respect to implementation in the field. The Airport Movement Area Safety System is critical to reducing runway incursions, which have increased 75 percent since 1993. This system also has experienced problems, and the scheduled August 2000 date for final system installation is a high risk.

PROGRESS AND PROBLEMS WITH FAA MODERNIZATION PROGRAMS

Since we testified last year, there have been several modernization success stories, such as commissioning of the first Display System Replacement (new controller displays) at Seattle's Air Route Traffic Control Center and seven more Air Route Surveillance Radar systems. Now, 43 of the 44 FAA and Department of Defense radar systems have been installed. Also, new HOST computers have been delivered to 19 en route centers, and controllers at 10 centers are now using them to control air traffic on a full-time basis.

However, two key modernization programs, Standard Terminal Automation Replacement System and Wide Area Augmentation System, continue a succession of problems that need FAA's attention.

- ***Standard Terminal Automation Replacement System (STARS)***: ($940 million in program costs[1], but expected to be significantly higher) FAA's STARS Program will replace the current terminal automation system with a modern, fully digital system. STARS includes color radar displays and maintenance workstations, as well as computers and software, for over 170 terminal air traffic control facilities. STARS was designed to provide the software and hardware platform necessary to support such future air traffic control enhancements as a data link for controllers and pilots to communicate.

  Overall, the STARS Program has experienced significant cost growth and schedule delays. In September 1998, FAA informed this Subcommittee that additional funding of $293.9 million might be needed to complete the STARS Program. This amount includes over $190 million for changes to the system's computer-human interface. The STARS schedule continues to be impacted by

[1] Program costs include the Facilities and Equipment cost for the contract, program management and testing of systems. Lifecycle costs include the total cost of acquiring, operating, maintaining, supporting and disposing of a system over its useful life. The lifecycle cost estimate for STARS is $2.2 billion through 2025.

the software development needed to resolve the computer-human interface issues and other new requirements.

Because of concerns with equipment outages at the Ronald Reagan Washington National Airport terminal facility, FAA agreed to replace the controller displays sooner than originally planned. To accomplish this, FAA established the Early Display Configuration of STARS. It consists of new controller displays and maintenance workstations using the existing terminal automation system's (ARTS) computer processors and software along with the STARS emergency backup system. (In contrast, "full STARS" will completely replace ARTS with independent primary and backup systems.)

The Department of Defense (DoD), FAA's partner in the STARS acquisition, elected to receive full STARS with only a minimal number of the human factors changes requested by FAA's air traffic controllers and maintenance technicians. DoD's system is currently undergoing contractor testing for acceptance.

FAA has recognized that it will not meet its March 31, 1999 schedule for initial operations of the Early Display Configuration at Reagan National. The Early Display Configuration schedule was very aggressive, with little time in the schedule if delays occurred. FAA was unable to meet the schedule because of the delay in the start of contractor testing and numerous software deficiencies identified during testing. In addition, 20 human factors issues remain unresolved.

Last September, FAA estimated that initial operation of full STARS may not occur until June 2001, 30 months beyond the original December 1998 initial operation milestone for the Boston facility. Currently, FAA is in the process of revising the schedules for the Early Display Configuration and full STARS, and additional delay will occur.

In light of schedule delays and cost increases, we recommend that FAA defer decisions on the full range of software development needed for human factors on full STARS until testing on the DoD system is completed later this year. However, FAA should continue to address the known human factors issues (that were identified for the Early Display Configuration) in full STARS.

- ***Wide Area Augmentation System (WAAS)***: ($1 billion in program costs[2]) WAAS will augment the Global Positioning System[3] (GPS) for use in civil aviation. It will provide the capability to navigate in the en route environment and allow precision approaches to some airports in the continental United States. WAAS continues to experience schedule slippage.

  On January 5, 1999, FAA announced a revision to the implementation schedule for WAAS to allow more time to complete development of a critical software safety package. This software package determines the precise positions of the GPS and geostationary satellites, the effects of the ionosphere on the GPS/WAAS signal, and the validity of the WAAS message. As a result, the commissioning date for Phase I WAAS has been rescheduled to September 2000 from July 1999, a 14-month delay. This delay will undoubtedly require additional funding.

  WAAS technical and program uncertainties must be resolved. These uncertainties relate to interference from unintentional and intentional jamming, ionospheric variation, and the number of communications satellites needed. A GPS Risk Assessment Study[4] concluded "GPS with appropriate WAAS/LAAS [Local Area Augmentation System] configurations can satisfy the required navigation performance as the only navigation system installed in the aircraft and the only navigation service provided by FAA."

  The study provides valuable technical information on the effects of intentional and unintentional interference on GPS/WAAS and the significance of ionospheric corrections. The study identifies the need for two additional geostationary satellites to meet performance requirements. However, the study does not address how long it will take to develop measures to mitigate intentional and unintentional interference or their impact on FAA's program. Important questions exist about cost (for both FAA and airspace users), final user equipment, and milestones. Considerable work remains to be done.

  It is plausible that the final system as envisioned by the study will not be in place until 2015. This is critically important because it impacts the need to

[2] The $1.0 billion in Facilities and Equipment program costs for WAAS includes the prime contractor costs (including the terminated Wilcox contract), development of standards and procedures, technical engineering and program support, and the first year of communications costs for satellites. The WAAS lifecycle cost estimate of $3.0 billion through 2016 includes communications satellite costs estimated at $1.3 billion.

[3] The Department of Defense's GPS satellites transmit radio signals that allow properly equipped air, land, and sea users to calculate their position and speed anywhere on the earth's surface.

[4] The Johns Hopkins University Applied Physics Laboratory, GPS Risk Assessment Study Final Report (VS-99-007), January 1999.

retain the existing radio navigation infrastructure during the next 15 to 20 years. FAA estimates that the annual cost to sustain the existing radio navigation infrastructure is $170 million. Therefore, we are recommending that FAA include the costs of a back-up system of some type (for at least the next 15 years) in its current satellite navigation investment analysis. The costs should be based on detailed sustainability/supportability studies of existing navigation and landing systems.

FAA has begun to implement our October 1997 recommendation to develop a comprehensive, agreed upon plan and strategy for transitioning to satellite-based technology for air traffic management.

- ***Display System Replacement (DSR)***: ($1 billion in program costs) DSR modernizes en route traffic control centers by replacing aging and unsupportable display equipment. DSR features new color displays and consoles for controllers. It uses modern computer processing technology for improved speed, capacity, maintainability and reliability. DSR can be easily upgraded with hardware and software enhancements. It is important to note that considerable software for DSR was developed as part of the Advanced Automation System.

  The first site, Seattle, was dedicated in January 1999. DSR has been delivered to 17 of 20 domestic en route centers. DSR is on schedule to have all 20 sites operational by May 2000.

- ***HOST Replacement***: ($173 million for Fiscal Years 1998 and 1999) The HOST replacement program will replace the mainframe computers at the 20 domestic and Anchorage Air Route Traffic Control Centers, 3 oceanic and offshore sites, and 4 support facilities. In December 1997, FAA decided to replace the HOST computers 4 years earlier than expected because of uncertainty over Year 2000 compliance and, more importantly, supportability problems. To minimize risk, FAA developed a four-phased approach to implement the HOST replacement. Phase 1 replaces the mainframe computer by the Year 2000 and does not involve extensive software development. FAA plans to complete Phase 1 by October 1999. Phases 2 through 4 will involve extensive software development and the replacement of peripherals by July 2001.

  FAA has made progress with its program to replace the HOST computers. Currently, new HOST computers have been delivered to 19 centers, and controllers at 10 of these centers are now using the computers to control air traffic on a full-time basis. To ensure that the HOST replacement remains on

track, we recommend that FAA reach agreement on contract cost and terms without further delay.

COMMON PROBLEMS IN FAA ACQUISITIONS

There are "common threads" in FAA acquisitions that account for major schedule delays and significant cost growth. Several key modernization programs have experienced difficulties linked to intensive software development, human factors issues, and unrealistic schedules – attention to these areas can prevent a repeat of past problems.

- ***Intensive software development*** acquisitions have typically resulted in large cost increases and major schedule delays – an issue that has affected the pace of air traffic control modernization for more than a decade. Software problems proved to be the Achilles' heel of the Advanced Automation System, and similar challenges remain for programs such as WAAS and STARS. For example, WAAS, an intensive software acquisition, has experienced development difficulty in a critical software safety package that determines the precise positions of the GPS and geostationary satellites, the effects of the ionosphere on the GPS/WAAS signal, and the validity of the WAAS message. In contrast, the replacement of HOST computers, which is progressing on schedule, does not involve intensive software development.

  STARS is another example of an acquisition with software-related problems. Although the STARS acquisition plan was to maximize the use of a commercially available system, some development was anticipated. The initial contractor proposal estimated that 916,000 lines of software code could be used from its existing system and that 119,000 lines of new software code would be developed. As of February 1999, FAA estimates that 370,000 lines of new software code will be required. FAA now considers STARS to be a developmental system.

  FAA has recognized the need to improve its software development processes. Specifically, FAA has initiated activities to strengthen its software management processes by using an Integrated Capability Maturity Model[5] to improve the way it manages, engineers, and acquires software-intensive systems across all phases of the acquisition lifecycle.

[5] The FAA Integrated Capability Maturity Model describes the essential elements of an organization's acquisition, engineering, and management process that must exist to ensure good acquisition of software intensive systems.

FAA needs to consider a cost control mechanism for software intensive acquisitions. One option worth considering is a cost-plus-incentive fee arrangement to accomplish the work. This arrangement could inject an incentive sharing formula in what would otherwise be a cost reimbursable contract with limited contractor risk.

We recognize that improving the management of software intensive acquisitions is a long-term initiative that will not be easy. Given the complexity of FAA acquisitions, it is unrealistic to expect perfection in software development. However, effective software management is especially important in an environment of cost-reimbursable, software intensive contracts.

- ***Human factors*** examine how humans interact with machines and identify ways to enhance operators' performance and minimize errors. Given the variety and adaptability of human skills, no one solution will fully satisfy all users. Consequently, FAA must develop criteria for deciding how to weigh cost and schedule alternatives to determine which solutions to implement and when to implement them (i.e., before deployment or later during product improvement).

  The toughest decision, however, is determining when "enough is enough". FAA cannot satisfy everyone, and exit criteria can help in making some of the tough decisions. In our opinion, without exit criteria, FAA's costs to resolve human factors issues in the STARS Program will continue to increase.

  Since the October 1997 hearing before this Subcommittee, FAA has made significant progress in resolving STARS human factors issues identified by its air traffic controllers and maintenance technicians. However, more work is needed. Specifically, in December 1998, controllers validated the contractor's implementation of the Early Display Configuration human factors design changes.

  The validation showed that for 7 of the original 98 human factors issues affecting controllers, the contractor's changes did not eliminate controllers' concerns and identified 10 new human factors issues for the Early Display Configuration. Further, 3 of the 52 human factors issues affecting maintenance technicians have not been resolved. FAA is currently assessing the impact of solutions proposed for the human factors issues on the Early Display Configuration's cost and schedule.

  While progress has been made with Early Display Configuration human factors, the majority of human factors changes are expected to be needed for

the full STARS system. The human factors changes for full STARS are expected to include the changes made to the emergency backup system (Early Display Configuration) plus a significant amount of changes to the primary system.

As mentioned earlier, we recommend that FAA defer decisions on the full range of human factors changes needed until testing on the DoD system is complete. This would provide FAA controllers and maintenance technicians the opportunity to observe the full STARS system in an operational environment before making decisions on the human factors changes needed.

- ***Schedules that are unrealistic*** and do not take into account the risks associated with development affect FAA's credibility with the Congress and airspace users. Further, FAA must improve its planning and cannot afford to wait until the "11th hour" to announce a funding need to replace existing systems, as in the case of HOST.

  FAA can better manage risks by setting milestones that are not overly aggressive but achievable given the maturity of the technology. As an example, the STARS Early Display Configuration schedule for Reagan National was very aggressive and, in our opinion, did not include sufficient time to correct and retest any deficiencies identified during testing. Specifically, FAA planned to complete its operational testing only 5 days prior to the March 31 operational milestone.

  The HOST replacement is an example of the need for better planning to upgrade aging computer systems rather than waiting until the last minute when spare parts are scarce. The HOST computer system was installed in the mid-1980s and has not been upgraded since. In late 1997, faced with uncertainty about Year 2000 compliance and, more importantly, supportability issues, FAA had to make an "11th hour" decision to replace the HOST computers by 2000. As a result, FAA reprogrammed funds from other programs and established a very aggressive schedule in order to succeed by January 1, 2000.

ATTENTION NEEDED FOR PROGRAMS IN EARLY STAGES OF DEVELOPMENT

FAA has opportunities with new programs, such as Free Flight Phase 1 and Data Link, to improve its management of software development and human factors issues. Since these programs are in early stages of development, we believe there is time to address these issues.

- ***Free Flight***: Free Flight is a new concept of air traffic management that permits pilots and controllers to share information and work together to manage air traffic. With Free Flight, pilots will not have to fly routes structured around ground-based navigation systems. As a first step, FAA and industry have agreed to move forward and deploy five technologies (see the Attachment) at limited locations by December 2002 through a program called "Free Flight Phase 1."[6]

  FAA recognizes that Free Flight Phase 1 faces many traditional challenges of past modernization programs, including software development, human factors issues, and complex integration issues. FAA is requesting $184.8 million for FY 2000, and estimates Free Flight Phase 1 will cost about $750 million through FY 2002--when Phase 1 will be complete. We caution that current cost estimates do not include costs for national deployment or changes in requirements that will likely occur. Over the next year, we will review FAA's management of Free Flight Phase 1 projects with an emphasis on the risks associated with software development and human factors.

- ***Data Link***: To relieve congested voice channels, FAA and industry are moving forward to implement a data link for controllers and pilots. In its simplest form, data link is analogous to electronic mail, where a person can send a message to other people without speaking to them. After significant delays and a lack of agreement, FAA and industry have agreed on a general path to implement data link in domestic airspace. FAA intends to implement data link at the Miami Air Route Traffic Control Center in June 2002 leading to a national deployment beginning a year later in June 2003, at a cost of $645.5 million through 2015. We have made recommendations[7] aimed at improving FAA's management of Data Link efforts, mitigating risks, and making future efforts more cost effective.

  The introduction of data link has far reaching human factors implications for controllers and pilots. For example, an important issue is how controllers and pilots will use two distinct communication systems (voice and data link) to share important information. Controllers will be expected to handle both data link and non-data link equipped aircraft in the same airspace. Similarly, pilots will fly in and out of airspace where data link is not universally used. This could lead to additional workload for controllers and pilots.

---

[6] The five technologies are User-Request Evaluation Tool, Traffic Management Advisor Single Center, Passive Final Approach Spacing Tool, Collaborative Decision Making, and Surface Movement Advisor.

[7] Report on FAA's Progress and Plans for Implementing Data Link for Controllers and Pilots (Report Number AV-1999-057, February 24, 1999).

OTHER EFFORTS ESSENTIAL TO AVIATION EFFICIENCY AND SAFETY

There are other Facility & Equipment efforts underway that are essential for the efficient operation of the National Airspace System and improving safety. In this regard, we would like to make observations about FAA's Year 2000 compliance and the status of a key technology that has the potential to reduce accidents on airport runways.

- ***Year 2000 Compliance***: ($305 million in program costs) A top priority for FAA is to ensure that mission critical computer systems properly process data in the Year 2000 and beyond. FAA has 425 mission critical systems, and the 151 systems needing repair have been repaired. As of February 12, 1999, FAA completed repair on all necessary mission critical systems and had validated that 112 of these were working. FAA expects that all repaired mission critical systems will be validated and implemented by June 1999, 3 months behind the March 1999 target date set by the Office of Management and Budget.

  FAA still faces many Year 2000 computer challenges. Now that the 151 mission critical systems have been repaired, a copy of the software must be installed at each facility using the system. This is a major challenge because of the volume of activities and potential complications because facilities may have implemented software or hardware changes specific to their location.

  The Year 2000 problem has important implications for the aviation industry, including airports, aircraft manufacturers, parts suppliers, air carriers, and aircraft repair stations at home and abroad. As recently reported[8] by the General Accounting Office, U.S. airports have made progress in preparing for the Year 2000. The General Accounting Office noted that many airports are not following a comprehensive and structured approach for repairing systems and, consequently, are at risk of experiencing some equipment malfunctions. FAA has made outreach efforts and continued proactive attention is needed with national and international representatives in obtaining assurances that the air transportation industry will indeed be Year 2000 compliant.

- ***Airport Movement Area Safety System (AMASS)***: ($89 million in program costs) AMASS is designed to continually monitor airport surface traffic and

[8] General Accounting Office, Year 2000 Computing Crisis: Status of Airports' Efforts to Deal With Date Change Problem, (GAO/RCED/AIMD-99-57), January 1999.

notify air traffic controllers of potential conflicts. AMASS uses data from the Airport Surface Detection Equipment (ASDE-3) radar to identify aircraft and vehicles on the airport surface. FAA plans to install AMASS at 34 airports nationwide by August 2000. AMASS is important because it can reduce the number of runway incursions. Runway incursions have increased 75 percent; from 186 in 1993 to 325 in 1998.

FAA began to develop AMASS in 1990, and since that time, the system has experienced technical, cost and schedule problems. To provide controllers the least number of false alarms, AMASS will be deployed with limited operational capabilities. Further, a human factors review of AMASS has yet to be completed. AMASS has experienced a $30 million cost growth due to software development issues. Additionally, AMASS is behind schedule. FAA is testing AMASS at three airports and the last installation will now occur at least 4 years later than planned. The scheduled August 2000 date for final system installation is high risk.

The following sections provide more detailed information on FAA's key modernization programs.

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

STARS Continues to Experience Cost and Schedule Difficulties

The Standard Terminal Automation Replacement System, commonly referred to as STARS, will replace controller and maintenance workstations with color displays, as well as computer software and processors, at over 170 terminal air traffic control facilities. As of January 1999, FAA obligated over $304 million for STARS development and production.

The STARS Program has experienced significant cost growth and schedule delays. In September 1998, FAA informed this Subcommittee that additional funding of $293.9 million might be needed to complete the STARS Program, potentially increasing the total program cost to $1.234 billion. The estimate was based on known and projected requirements, and included over $190 million for changes to the system's computer-human interface. In our opinion, based on the human factors changes identified since September 1998, the additional funding needed to complete the STARS Program will exceed this estimate.

The STARS schedule has been impacted by the software development needed to resolve the computer-human interface issues associated with the Early Display Configuration and other new requirements. As a result, in September 1998, FAA estimated that initial operation of "full STARS" might not occur until June 2001, 30 months beyond the original December 1998 operational milestone for Boston. It

does not appear that a June 2001 milestone can be achieved, and FAA is currently working on a revised STARS schedule.

Because of concerns with equipment outages at the Ronald Reagan Washington National Airport terminal facility (Reagan National), FAA committed to replace the controller displays by March 31, 1999. To accomplish this, FAA established the Early Display Configuration of STARS. In essence, the Early Display Configuration consists of new controller displays and maintenance workstations equipment using the existing Automated Radar Terminal Systems (ARTS) computer processors and software along with the STARS emergency backup system. Through January 1999, FAA has obligated over $59 million for the contractor efforts on the Early Display Configuration. This amount includes over $46 million for human factors changes.

FAA recently recognized that the March 31, 1999 date for initial operation of the Early Display Configuration at Reagan National will not be met. Several factors contributed to this delay.

- *Contractor's Testing Delayed*: In May 1998, FAA and its contractor agreed to an aggressive schedule to reach March 1999 that called for software to be delivered by September 30, 1998, and contractor testing to be conducted from October 1, 1998, through January 1, 1999. However, the software, delivered 15 days late,

was not mature enough to begin testing. As a result, the contractor began testing on November 30, 1998; 60 days behind the original plan. Based on the revised contractor test schedule, FAA planned to complete its operational testing on March 26, 1999, only 5 days prior to the March 31 milestone for initial operation. It is now clear that such a revised testing schedule was unrealistic, and did not include sufficient time to correct and retest any deficiencies identified during testing.

- *Software Deficiencies Identified*: In late November 1998, the contractor began its testing of the Early Display Configuration. The testing identified approximately 90 Type I and II Program Technical Reports[9] (deficiencies) that, according to the contract, must be corrected before testing can be completed. Because deficiencies are expected with software development, time was included in the schedule for regression testing (retesting) of software corrections. However, there was not enough time in the aggressive Early Display Configuration schedule to make up for the number of deficiencies identified. As a result, FAA was unable to begin its operational testing as scheduled. FAA and the STARS contractor are currently

[9] Program Technical Reports (PTR) are used to document a discrepancy or anomaly identified during testing. There are four types of PTRs, with Type I indicating the most severe. Type I PTRs affect the performance of a critical function of the system. Type II PTRs have an unsatisfactory impact on key support functions.

working on cost and schedule estimates to complete testing of the Early Display Configuration.

- *Human Factors Issues Remain a Concern*: In late 1997, we reported on a number of human factors concerns raised by air traffic controllers and maintenance technicians that affected their use of the system. These concerns included a display design that could obscure the controller's view of an aircraft symbol and a keyboard design that would require significant time looking at the keyboard rather than at the air traffic control display. FAA has made significant progress in resolving STARS human factors issues affecting the Early Display Configuration that were identified by its air traffic controllers and maintenance technicians.

  Maintenance Technicians' Concerns: Of the 52 human factors issues identified by maintenance technicians, 35 issues related to the Early Display Configuration. Solutions for 30 of the 35 issues are being incorporated into the Early Display Configuration software and hardware. Two other issues have been addressed through incorporation into additional training and by completion of an ergonomics evaluation. The contractor is working on solutions for the remaining three human factors issues related to the Early Display Configuration.

Air Traffic Controllers' Concerns: Some human factors issues identified by controllers have not been included in the Early Display Configuration software and more work needs to be done. A December 1998 validation by National Air Traffic Controllers Association (NATCA) controllers of the contractor's implementation of human factors design changes showed that for 7 of the original 98 air traffic issues, the contractor's changes did not eliminate controllers' concerns and 10 new human factors issues were identified. Subsequent activities have identified solutions to these 17 human factors issues. FAA is currently assessing the cost and schedule implications to incorporate these solutions into the Early Display Configuration software.

- *System Performance Is a Concern*: There are some concerns surrounding the performance of the Early Display Configuration. According to FAA, it is possible that the Early Display Configuration will meet contract specifications for "full STARS" but will not be operationally acceptable to the controllers. In February 1999, an assessment was performed to determine whether the Early Display Configuration performance adequately supports controller tasks and air traffic control operations. Of the 50 functions demonstrated, controllers identified 4 performance-based issues during the assessment. These issues included delays in the completion of interfacility handoffs between controllers, the display of maps, and two problems when changes are made to the controller's range

displayed on the monitor. FAA is currently assessing the impact on the Early Display Configuration cost and schedule.

Before revising the Early Display Configuration or full STARS schedules, we recommend that FAA conduct a comprehensive analysis of all unresolved issues to determine realistic, low risk schedules and associated cost estimates for the STARS Program. Unresolved issues in the areas of human factors and system performance could affect FAA's ability to meet revised schedules for initial operations.

Given experiences with the Early Display Configuration intended for Reagan National, we believe FAA has opportunities to avoid past mistakes with full STARS. This is significant because the human factors changes for full STARS are expected to include the changes made to the emergency backup system (Early Display Configuration) plus a significant amount of changes to the primary system. To date, human factors work has primarily been focused on the emergency backup system.

FAA must take steps to control the costs for resolving human factors issues. When we testified last March on the human factors issues with STARS, we recommended that FAA establish exit criteria to make informed decisions. However, FAA agreed to resolve human factors issues identified by controllers and maintenance technicians for the deployment of the Early Display Configuration without establishing exit criteria.

Developing clear exit criteria is vital because all users neither view the significance of a human factors issue in the same way nor consistently agree on the best way to resolve it. This is critical because FAA is only beginning to identify human factors issues on the full STARS system.

Once potential solutions have been identified for "full STARS" human factors issues, FAA must determine the impact on program cost and schedule and make the tough decisions on when to implement the solutions (weighing safety, user acceptance and cost). We recognize that the toughest decision is determining when "enough is enough". We recommend that FAA establish exit criteria for human factors and that one person within FAA be responsible and held accountable for making these tough decisions on when or if to implement solutions.

At the same time, FAA must continue to work closely with its unions to resolve human factors and performance issues. Memorandums of Understanding are one option for doing so and could help set expectations and priorities. While FAA has an agreement with NATCA on STARS representation, additional agreements would be beneficial. As an example, in the Display System Replacement (DSR) Program, FAA and NATCA signed several Memorandums of Understanding for the Program. In addition to a representation agreement, another agreement addressed the impact of DSR on controller operations and required FAA to conduct an operational impact

assessment of the hardware and a scientific human factors evaluation of the computer-human interface. Another agreement addressed computer-human interface issues such as which changes were needed and when to incorporate them. In our opinion, the DSR deployment was expedited as a result of these union agreements.

Therefore, we recommend that national Memorandums of Understanding be used for the resolution of human factors issues and the implementation of full STARS. National Memorandums of Understanding would help expedite FAA's ability to field a system by reducing the time needed for local negotiations on issues that affect all locations.

Important Questions Remain About the Cost and Schedule of WAAS

The Wide Area Augmentation System (WAAS) is a program to augment the Department of Defense's Global Positioning System (GPS) to provide navigation and airport approach capabilities for civilian use in the National Airspace System (NAS). The lifecycle cost estimate for WAAS through 2016 is $3.049 billion. Of the $3.049 billion, Congress has appropriated about $487.4 million (16 percent). Although WAAS cost growth has been the subject of much debate, it is important to note that as of January 31, 1999, only $392.4 million (13 percent) of the estimated lifecycle costs have actually been obligated[10].

[10] Obligations represent contracts awarded, services received, and similar transactions that require payment.

FAA continues to experience schedule delays in its WAAS Program. On January 5, 1999, FAA announced a revision to the implementation schedule for WAAS to allow more time to complete development of a critical software package. This software package determines the precise positions of the GPS and geostationary satellites, the effects of the ionosphere on the GPS/WAAS signal, and the validity of the WAAS message. As a result, the commissioning date for Phase I WAAS has been rescheduled to September 2000 from July 1999, a 14-month delay. FAA will, in our opinion, experience additional cost growth associated with this 14-month delay; however, the amount is unknown until FAA completes negotiations with its contractor.

Additionally, there has been uncertainty regarding whether WAAS will be a sole or primary means of navigation. To address this question, FAA funded a GPS Risk Assessment Study. The study, published in January 1999, was conducted by the Johns Hopkins University Applied Physics Laboratory to determine if GPS and its proposed augmentation systems – the Wide Area Augmentation System and the Local Area Augmentation System (LAAS) – can satisfy the performance requirements to be the only navigation system installed in an aircraft and the only service provided by the FAA for operation anywhere in the NAS. The primary conclusions of the study were:

> GPS with appropriate WAAS/LAAS configurations can satisfy the required navigation performance as the only navigation system installed in the aircraft and the only navigation service provided by the FAA.
>
> Risks to GPS signal reception can be managed, but steps must be taken to minimize the effects of intentional interference.

The study further points out that the WAAS and LAAS configurations and the current 24 GPS satellite constellation and 4 geostationary satellites can satisfy all NAS positioning and precision approach requirements. However, some airports will require additional ground equipment to achieve the highest availability levels. The study conclusions assume that identified risk mitigation actions are instituted.

The study provides valuable technical information regarding whether GPS, and its augmentations WAAS and LAAS, can satisfy performance requirements, but considerable work remains to be done. The study is silent on how long it will take to develop mitigation measures and their impact on FAA's program. In our opinion, important questions exist about cost (for both FAA and airspace users), final user equipment, and milestones.

It is plausible that the final system as envisioned by the study will not be in place until 2015. This is critically important because it impacts the need to retain the existing radio navigation infrastructure during the next 15 to 20 years. FAA estimates that the annual cost to sustain the existing radio navigation infrastructure is $170 million. Therefore, we are recommending that FAA include the costs of a back-up system of some type (for at least the next 15 years) in its current satellite navigation investment analysis. The costs should be based on detailed sustainability/supportability studies of existing navigation and landing systems.

Important questions remain about what combination of procedures, ground systems, and avionics will be needed to meet the risks associated with intentional and unintentional interference. *Intentional interference*--or "jamming"--is by far the biggest risk to using GPS for civil aviation. The study assumes that new avionics will be available that can recognize the onset of jamming, and that new procedures will be instituted by FAA to manage such situations. While the study mentions several technologies for mitigating jamming, it does not address the technologies' level of maturity and cost.

Vice President Gore's announcements concerning two new civil signals will impact FAA's decision-making and budget. In March of 1998, the Vice President announced

that two new civil signals would be added to future satellites of the GPS constellation. The second signal will be available for general use in non-safety-critical applications such as surveying. The third signal would be located in a frequency band protected for aeronautical radio navigation, which will meet all United States and international requirements. Management of this band is the responsibility of the FAA.

On January 25, 1999, the White House announced a decision on the frequency for the third civil signal that can meet the needs of critical safety-of-life applications – including the needs of civil aviation. Plans call for this new signal to be implemented with a satellite launch scheduled for 2005. This new initiative (second and third civil signals) is estimated to cost $400 million over 6 years. This decision will impact FAA's budget. For example, FAA's contribution to the costs associated with GPS modernization and the two civil signals is approximately $131 million over 6 years, from FYs 2000 through 2005. FAA has requested $17 million for FY 2000.

This third civil signal will remove the requirement for ionospheric corrections for users equipped with dual-frequency GPS receivers. Further, if the aviation community were to shift to dual-frequency GPS receivers, the WAAS ground station requirements could be reduced significantly because the need for ionospheric corrections on the ground would be eliminated. However, WAAS ground, airborne,

and satellite equipment also will need modification to use this new safety-of-life signal. The impact is uncertain at this time.

A conclusion of the Johns Hopkins Study is the need for a national GPS plan and management commitment. In prior testimony, we recommended that FAA establish a useful and credible plan to transition to satellite-based technology. The plan must identify what systems, components, and avionics are required; and who will pay for what (FAA, users, and airports). Most important, for the plan to be realistic, this plan and any modification to it, will need a consensus by the Congress, FAA, and the aviation community. FAA has recognized this need and begun to work with the RTCA (a Federal Advisory Committee) to develop this plan and gain industry consensus.

HOST Replacement Is Progressing

In December 1997, FAA made an "11th hour" decision to replace the HOST computer system at the 20 domestic and Anchorage Air Route Traffic Control Centers, 3 oceanic and offshore sites, and 4 support facilities. The replacement is scheduled to be made 4 years earlier than expected because of uncertainty over Year 2000 compliance and, more importantly, supportability problems. The HOST computer system was installed in the mid-1980's and, in 1997, key components such as the HOST processors, were near their end-of-service life. The processors contained

unique parts, which were in extremely short supply and were no longer being produced. Further, the HOST manufacturer could no longer guarantee future engineering support for the system.

FAA estimates the lifecycle costs of the HOST replacement for Fiscal Years 1998 through 2008 at $607.3 million. These costs include $172.6 million for Fiscal Years 1998 and 1999, primarily for Phase 1. Lifecycle costs include replacing the mainframe hardware, purchasing peripherals, upgrading software, and maintaining the new system through FY 2008. FAA requested $84.9 million in program costs (Facilities and Equipment) for FY 2000.

FAA developed a four-phased approach to implement the HOST replacement. Phase 1 replaces the mainframe computers by the Year 2000, and does not involve extensive software development. FAA plans to complete Phase 1 by October 1999. Phases 2 through 4 will involve extensive software development and the replacement of peripherals by July 2001.

FAA has made progress with its program to replace the HOST computers by October 1999, as planned. Currently, new HOST computers have been delivered to 19 centers, and controllers at 10 of these centers are now using the computers to control air traffic on a full-time basis. To ensure that the HOST replacement remains

on track, we recommend that FAA reach agreement on contract cost and terms without further delay.

Agreement on Contract Cost and Terms: FAA has not reached agreement with the HOST computer replacement contractor on the cost and terms for any of the 4 phases of the program. The date to reach agreement on the HOST replacement contract has changed several times from its original date of October 16, 1998, and is now planned for May 1, 1999. In our opinion, the lack of agreement on contract cost and terms may result in increased costs because the contractor may not be as vigilant in cost control until contract terms and conditions are reached. Accordingly, FAA should reach agreement on contract cost and terms for the HOST replacement contract without further delay.

Risk Management: To manage program risks, FAA developed a Risk Management Plan. Risk management is an organized means of identifying and assessing risk, and developing, selecting, and managing options for resolving or eliminating risks. To identify and track risks, FAA established a Risk Management Database. FAA identified 22 risks in the database. As of February 11, 1999, 10 are closed, 4 are being monitored, and 8 are still open.

Additional Training on DARC: In November 1998, we reported[11] on using DARC in controlling air traffic during the HOST replacement. DARC, unlike HOST, does not provide all of the needed current flight information or provide controller alerts. We recommended that FAA ensure all center air traffic controllers receive additional training using DARC, because a large number of controllers at the five centers we visited had limited DARC operational experience. FAA agreed to increase training on DARC and, together with the National Air Traffic Controllers Association (NATCA), required each facility to evaluate the need for additional DARC training, and provide such training if necessary.

Airway Facilities Union Issues: In November 1998, the Professional Airways Systems Specialists (PASS) union notified FAA about its concerns involving staffing levels, training, maintenance, and human factors regarding HOST. PASS requested that each en route center maintain a minimum staffing level of airway facilities employees during the HOST replacement and that airway facilities personnel be adequately trained and certified before operational tasks are performed. PASS stated that airway facilities personnel would assume in-house maintenance within 1 year after Government acceptance at each center. PASS requested that a safety assessment

[11] Report on Using the Direct Access Radar Channel During the HOST Replacement Program (Report Number AV-1999-030, November 30, 1998).

and human factors assessment be performed. PASS was concerned with FAA's planned acceleration of its schedule to use the new computers in controlling air traffic at New York, the first site, and wanted to complete a bargaining agreement to resolve all issues before FAA used the HOST computer replacement to control air traffic.

FAA and Industry Move Toward Free Flight

FAA's investment decisions and budget requests are now increasingly shaped by efforts to move toward "Free Flight"[12], a new paradigm for air traffic control. As a first step, FAA and industry have agreed to move forward and deploy five technologies at limited locations by December 2002 through a program called "Free Flight Phase 1"[13]. The five technologies are User-Request Evaluation Tool, Traffic Management Advisor Single Center, Passive Final Approach Spacing Tool, Collaborative Decision Making, and Surface Movement Advisor. (See the Attachment for additional information on these technologies.)

FAA is requesting $184.8 million for Fiscal Year 2000 and FAA officials estimate Free Flight Phase 1 will cost $750 million through Year 2002, when Phase 1 will be

[12] Free Flight is a concept of air traffic management that permits pilots and controllers to share information and work together to manage air traffic. With Free Flight, pilots will not have to fly routes structured around ground-based navigation systems.

[13] The criteria for inclusion in Free Flight Phase 1 stated, among other things, that a technology should provide measurable benefits to users, must be achievable by 2002, and must expedite national or full-scale deployment of a capability.

complete. We caution that current cost estimates are not lifecycle costs and do not include costs for national deployment or changes in requirements that will likely occur. FAA has established a Free Flight Phase 1 Program Office to manage these efforts. Over the next year, we will review FAA's management of Free Flight Phase 1 projects with an emphasis on the risks associated with software development and human factors.

Progress and Plans for Data Link

Free Flight calls for controllers and pilots to make extensive use of new digital communication technology, commonly referred to as data link, to improve the safety and efficiency of the NAS. FAA intends to manage data link as a separate but related effort to Free Flight Phase 1. FAA has invested $420 million in various data link projects over the past 15 years, and the agency is requesting $42 million[14] for FY 2000 for various data link efforts. We recently reported on FAA's progress and plans for implementing data link for controllers and pilots.

Today, controllers and pilots rely on voice radios to share routine flight information (changes in altitude, speed, and heading), warnings, and weather updates, that are essential for the safe and efficient operation of aircraft in domestic airspace. This

[14] The $42 million includes FAA's Fiscal Year 2000 request for data link for en route, oceanic, and tower facilities and related efforts.

system has served aviation well, but some problems exist with respect to communication errors and misunderstandings between controllers and pilots. Additionally, when a controller must share a single radio channel with up to 25 aircraft, competition for the channel can lead to substantial delays and frustration by pilots.

Data link technology offers controllers and pilots a new way to exchange information that is expected to be faster and more reliable than current voice communications. *In its simplest form, data link is analogous to electronic mail, where a person can send a message to other people without speaking to them*. The potential benefits of controller-pilot data link communications include increased controller efficiency, reduced voice congestion, and reduced communication errors. Data link is intended to supplement many of the routine voice conversations between controllers and pilots.

After significant delays and a lack of agreement, FAA and industry have agreed on a general path to implement controller-pilot data link in domestic airspace. FAA intends to implement data link at Miami Air Route Traffic Control Center in June 2002 leading to a national deployment beginning a year later in June 2003. These milestones are ambitious, given the scope and complexity of the effort.

Implementing this technology is a long-term development effort that has many characteristics of past modernization efforts--such as human factors concerns and intensive software development--that have led to cost increases and schedule delays in other projects. Data link is early in the development phase and, therefore, FAA has opportunities to address these issues.

The cost to implement data link throughout the NAS is substantial but uncertain. FAA estimates that implementing data link will cost the agency $645.5 million through Fiscal Year 2015. This estimate does not include costs for implementing data link at tower, terminal, and oceanic facilities or for airlines to equip with new avionics.

FAA does not intend to mandate the use of data link but rather intends to build on airline investments in new digital technology over a number of years. It is important to recognize that relying solely on voluntary action could prolong the transition to data link and when benefits can be realized. This will have a corresponding impact on cost, schedule, and human factors issues.

Data Link Has Significant Human Factors Implications for Controllers and Pilots

The human factors issues for controllers and pilots represent one of the biggest challenges facing the implementation of data link. Because voice communications

play such a large role in current controller and pilot interactions, experts agree that data link will fundamentally change the way controllers and pilots communicate. There are a number of important human factors issues that need to be addressed.

- *Dual Systems*: An important issue is how controllers and pilots will use two distinct communication systems (voice and data link) to share important information. Controllers will be expected to handle both data link and non-data link equipped aircraft in the same airspace. Similarly, pilots will fly in and out of airspace where data link is not universally used. This could lead to confusion, stress, and additional workload for controllers and pilots.

- *"Head Down" Time*: The amount of "*head down*" time required of pilots and controllers to compose and send, or read and respond to data link messages is a concern. "Head down" refers to the time a controller's or pilot's attention is diverted from primary tasks. For the pilot, there is concern that responding to data link messages will detract from time spent on primary flight duties and monitoring the instrument panel.

- *Loss of "Party Line"*: Another human factors concern is the loss of "*party line*" for pilots. With the existing voice communication system, pilots can tune to a particular frequency to hear air traffic control instructions to, and pilot responses

from, other aircraft. For example, a pilot can benefit from hearing that an aircraft ahead encountered turbulence or was placed into a holding pattern. Since data link messages are delivered to individual aircraft, there is concern that data link will deprive pilots of important information pertaining to surrounding airspace.

Without an effective and reliable data link for controllers and pilots, the full expected benefits of Free Flight cannot be realized. We have recommended that FAA place a high priority on funding human factors for controllers with particular attention to (1) new air traffic control procedures for using data link, (2) controller and pilot training programs, and (3) the design of new data link equipment for displaying and sending messages. We also recommended that FAA develop a comprehensive plan for implementing the technology throughout the NAS and a strategy for using the results of the European tests of Data Link.

Key Technology for Improving Safety on Runways Continues to Experience Problems

Improving safety on the nation's runways is an urgent safety matter. Runway incursions[15] have increased 75 percent, from 186 incursions in 1993 to 325 incursions in 1998. An important technology to help reduce runway incursions and avoid accidents is the Airport Movement Area Safety System (AMASS). AMASS is a

[15] A runway incursion is any occurrence at an airport involving an aircraft, vehicle, person, or object, on the ground, that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land.

system designed to monitor airport surface traffic and alert air traffic controllers to potential collisions. AMASS uses data from the Airport Surface Detection Equipment (ASDE-3)--an airport surface radar--to identify aircraft, vehicles and pedestrians on the airport surface. ASDE-3 was a significant step forward in assisting controllers in the movement of surface traffic at airports during low visibility and night operations.

In 1991, the National Transportation Safety Board (NTSB) recommended that FAA expedite efforts to develop and implement a system to alert controllers of pending runway incursions. The recommendation was made after a runway incursion caused an accident on the runway at Atlanta Hartsfield International Airport in January 1990. NTSB listed runway incursions on its "Most Wanted" list of transportation safety improvements in 1990. In August 1991, FAA advised NTSB that AMASS would address the intent of NTSB's safety recommendation.

AMASS has experienced cost increases and schedule delays. In 1993, AMASS was estimated to cost $59.8 million and be installed in 1996. By December 1998, the cost estimate increased to $89.8 million. FAA plans to install AMASS at 34 airports nationwide by August 2000, 4 years later than anticipated.

Even when the 40 systems are deployed, FAA will limit AMASS capabilities to detecting conflicts that occur on the active runway. Controllers will not be alerted to

potential conflicts that occur on runways or taxiways that intersect the active runways. FAA is limiting AMASS capabilities because of its longstanding concern that the high rate of false alarms will adversely impact controllers in air traffic control towers. A false alarm occurs when the system detects a false radar target[16] and projects a collision hazard, thereby alerting the controller to a situation that does not exist. If excessive rates of false alarms continue, controller confidence in the system could erode and lead to controllers completely disregarding the system. FAA plans to expand AMASS capabilities at each site as the system is perfected.

A January 1999 MITRE Corporation (MITRE) report showed AMASS has limitations in detecting runway incursions. MITRE reviewed nine runway incursions that occurred between November 1998 and January 1999. Using the current AMASS configuration installed in San Francisco, MITRE reported that AMASS would have only alerted controllers to four of the nine runway incursions. The remaining five incursions would not have been detected because they occurred on runways and taxiways that intersected the active runway.

In addition to problems with false alerts, an FAA/National Air Traffic Controllers Association workgroup was formed in November 1998 to address other human factors issues. The team is actively pursuing a resolution to all issues. FAA needs to

[16] A false target, also known as "multi-path problems", occurs when radio-frequency energy radiates off buildings or other aircraft, thus creating a momentary false target on the ASDE-3 radar display.

reevaluate the AMASS schedule and ensure human factors issues are fully addressed to provide a system that is operationally suitable and increases the margin of safety.

FREE FLIGHT PHASE ONE CORE CAPABILITIES

Capability	Functions	Planned Locations
USER-REQUEST EVALUATION TOOL (URET)	Provides en route controllers with future conflict situations, up to 20 minutes prior to the start of the conflict, and allows controllers to grant user requests or resolve conflicts through the use of trial planning capability.	Atlanta Chicago Cleveland Indianapolis Kansas City Memphis Washington, D.C.
TRAFFIC MANAGEMENT ADVISOR SINGLE CENTER (TMA-SC)	Generates statistics and reports about the traffic flow and computes the scheduled time of arrival and runway assignments for each aircraft.	Atlanta Chicago Dallas/Fort Worth Denver Los Angeles Miami Minneapolis Oakland
PASSIVE FINAL APPROACH SPACING TOOL (pFAST)	Calculates and displays landing sequence numbers and runway assignments.	Atlanta Chicago Dallas/Fort Worth Los Angeles Kansas City Minneapolis
COLLABORATIVE DECISION MAKING (CDM)	A collection of tools that allow the FAA and participating airlines to electronically exchange and analyze flight, NAS capacity and status information. It also enhances the traffic flow management process.	Air Traffic Control System Command Center Airline Operation Centers
SURFACE MOVEMENT ADVISOR (SMA)	Provides real-time ARTS III or STARS data about aircraft position and estimated touchdown time to ramp control operators.	Atlanta Chicago Dallas/Fort Worth Detroit Newark Philadelphia Teterboro