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Report to Congressional Requesters

August 2001

NATIONAL AIRSPACE SYSTEM

Free Flight Tools Show Promise, but Implementation Challenges Remain

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Abbreviations

CDM	Collaborative Decision Making
FAA	Federal Aviation Administration
pFAST	passive Final Approach Spacing Tool
SMA	Surface Movement Advisor
TMA	Traffic Management Advisor
URET	User Request Evaluation Tool

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United States General Accounting Office
Washington, DC 20548

August 31, 2001

The Honorable Ernest F. Hollings
Chairman, Committee on Commerce,
Science, and Transportation
United States Senate

The Honorable John D. Rockefeller IV
Chairman, Subcommittee on Aviation
Committee on Commerce, Science,
and Transportation
United States Senate

To help meet the growing demand for air travel, the Federal Aviation Administration (FAA), in collaboration with the aviation community, is implementing a new approach for air traffic management known as free flight. Under this approach, FAA is moving gradually from its present use of highly structured rules and procedures for air traffic operations to a more flexible approach, which increases collaboration between FAA and the aviation community. By using a set of new automated technologies (tools) and procedures, free flight is intended to increase the capacity and efficiency of our nation's airspace system while helping to minimize delays. Two of these tools, the Traffic Management Advisor and the passive Final Approach Spacing Tool, provide controllers with a more efficient and effective means to increase the capacity of our nation's airspace system by better scheduling, sequencing, spacing, and assigning aircraft to runways. These two tools are expected to allow more aircraft to land during peak periods of traffic, thus increasing capacity and minimizing delays. Another tool, the User Request Evaluation Tool, allows controllers to make more efficient use of the existing airspace by allowing aircraft to fly optimal or more direct routes, thus helping to reduce delays at major airports.[1] Collectively, these tools are also designed to achieve the above benefits without negatively affecting safety.

[1]Our review focused on these three tools because they account for 80 percent of the budget for phases 1 and 2. We did not review two other automated tools—the Surface Movement Advisor and the Collaborative Decision Making—because generally they had been implemented at all phase 1 locations before we started this review, and FAA plans to include additional capabilities in phase 2.

In 1998, we issued a report that identified the challenges facing FAA in its efforts to implement free flight in a cost-effective manner.[2] Since that report, FAA has moved aggressively with its phased approach to deploying free flight tools to gain operational experience before making a total commitment to the program. During the first phase, FAA has been deploying the new tools to selected locations generally on or ahead of schedule and has been measuring their benefits. Under the schedule developed with the aviation community, FAA plans to complete this first phase by the end of calendar year 2002, at a cost of about $630 million. In March 2002, the agency plans to make an investment decision—estimated at $717 million—on whether to move to the next phase,[3] which would result in a long-term funding commitment from FAA as part of its plan to meet the nation's air transportation needs.[4]

Because of the importance of the free flight program to the future operation of our nation's airspace system and FAA's upcoming investment decision, the Chairmen of the Committee on Commerce, Science, and Transportation and the Subcommittee on Aviation asked us to review the program's status to help them determine whether FAA will be in a position by March 2002 to make a decision to move to the next phase. This report discusses (1) the technical and operational issues that could impair the ability of the free flight tools to achieve their full potential and (2) the extent to which these tools will increase capacity and efficiency while helping to minimize delays in our nation's airspace system. To determine the technical and operational issues associated with the tools, we used recognized best practice criteria for developing, managing, and evaluating software projects. To gain further insight into these issues, as well as the tools' benefits, we held formal discussion group meetings with controllers, maintenance technicians, and supervisors who were part of nationwide user teams for one of the tools and interviewed individual users for the other two tools. In addition, we interviewed program and contractor officials and examined documentation on the goals and benefits from

[2]*National Airspace System: FAA Has Implemented Some Free Flight Initiatives, but Challenges Remain* (GAO/RCED-98-246, Sept. 28, 1998).

[3]The estimated investment of $717 million is the total development costs for fiscal years 2001 through 2010.

[4]In June 2001, FAA released its 10-year *Operational Evolution Plan*, which identifies near-term (2001), mid-term (2002 through 2004), and long-term (2005 through 2010) plans for increasing efficiency and capacity, managing delays, and maintaining safety. FAA anticipates completing phase 1 and beginning phase 2 of its free flight program in its near- and mid-term plans.

these tools. Appendix I provides additional details on our scope and methodology.

Results in Brief

Collectively the free flight tools have demonstrated some benefits. By March 2002, FAA should have sufficient information to make an investment decision about deploying the Traffic Management Advisor tool to additional sites in phase 2. However, the agency's current deployment schedule might not allow it to collect sufficient data to make a similar determination about the further deployment of the User Request Evaluation Tool. Because of the risks associated with the passive Final Approach Spacing Tool, FAA has decided not to deploy this tool in phase 2. FAA is addressing technical and operational issues that could affect the ability of these tools to achieve their full capabilities. The major technical challenge is ensuring that the User Request Evaluation Tool can effectively work with other key air traffic control systems. While FAA has been testing this tool to ensure that it effectively works with other key systems, this testing has not yet been completed. Ensuring that URET works as intended is important so FAA can fully realize the tool's benefit of increasing controllers' productivity. We are recommending that FAA collect and analyze data to better ensure that the technical issue with this tool is resolved before moving forward.

As for operational issues, FAA's greatest challenge is effectively managing the cultural changes in controllers' roles and responsibilities that using the free flight tools entails and communicating the capabilities of the Traffic Management Advisory tool to controllers. The program's heavy reliance on technology will require them to shift from their traditional ways of managing air traffic. For example, most controllers rely on their professional judgment to sequence properly separated aircraft that are starting to descend into the airspace near an airport. To sequence an aircraft's descent with the Traffic Management Advisor tool, controllers will rely on the computer to assign a certain time for that aircraft to arrive at a predetermined point in the airspace near an airport. Training in free flight's new tools is integral to air traffic controllers' and other users' fulfilling their new roles and responsibilities as well as developing their confidence in using new technologies. Although users have indicated that they lack the specialized expertise to develop training, FAA has been relying primarily upon them to develop and present it. We are making a recommendation for FAA to improve the training being developed and provided so users can become proficient with these new tools. As for the Traffic Management Advisor tool, users expressed uncertainties regarding what capabilities the tool will provide because FAA has not communicated

this information to them. As a result, it is difficult for users to know what to expect and for FAA to evaluate benefits.

Preliminary data have indicated that the free flight tools have the potential to increase both capacity and efficiency. However, because the future demand for air traffic services is expected to outpace the increases expected from the tools, the collective length of the delays during peak periods will continue to increase but not to the extent they would have without them. For example, FAA's analyses indicate that the collective length of delays would increase by about one-half hour with the tools as opposed to by 1 hour without the tools. In May 2001, FAA established quantifiable goals for increasing system capacity—ranging from 3 to 5 percent—for two of the three free flight tools. FAA's preliminary data show that the Traffic Management Advisor and the passive Final Approach Spacing tools have met some of the capacity goals, and the agency expects data from additional sites to produce similar results so that, by March 2002, it will have sufficient data to support the decision to move forward. The goal for the third tool—the User Request Evaluation Tool—is to increase system efficiency (by using direct routings) by 15 percent within the first year of being fully implemented, which reduces flight time and fuel costs for the airlines. Although FAA's data demonstrate that this tool has met this objective at two facilities and collectively saved the airlines approximately $1.5 million per month in operating costs, the data are based on the prototype system. While FAA states that the actual system will essentially have the same capabilities as its prototype, until that system is deployed and its benefits measured the extent of these benefits remain uncertain. Moreover, the benefits that FAA has documented for using this tool reflect savings for a segment of a flight—when an airplane is traveling through high-altitude airspace—not the entire flight from departure to arrival. Consequently, these savings could be diminished as an airplane flies into more congested airspace. We are making recommendations to ensure that FAA's goals for these tools are worth the investment.

Background

Recent advances in aircraft technology, including advanced collision avoidance and flight management systems, and new automated tools for air traffic controllers enable a shift from air traffic control to collaborative air traffic management. Free flight, a key component of air traffic management, will provide pilots with more flexibility, under certain conditions, to fly more direct routes from city to city. Currently, pilots primarily fly fixed routes—the aerial equivalent of the interstate highway

system—that often are less direct because pilots are dependent on ground-based navigational aids.

Through free flight, FAA hopes to increase the capacity, efficiency, and safety of our nation's airspace system to meet the growing demand for air transportation as well as enhance the controllers' productivity. The aviation industry, especially the airlines, is seeking to shorten flight times and reduce fuel consumption. According to FAA's preliminary estimates, the benefits to the flying public and the aviation industry could reach into the billions of dollars when the program is fully operational.

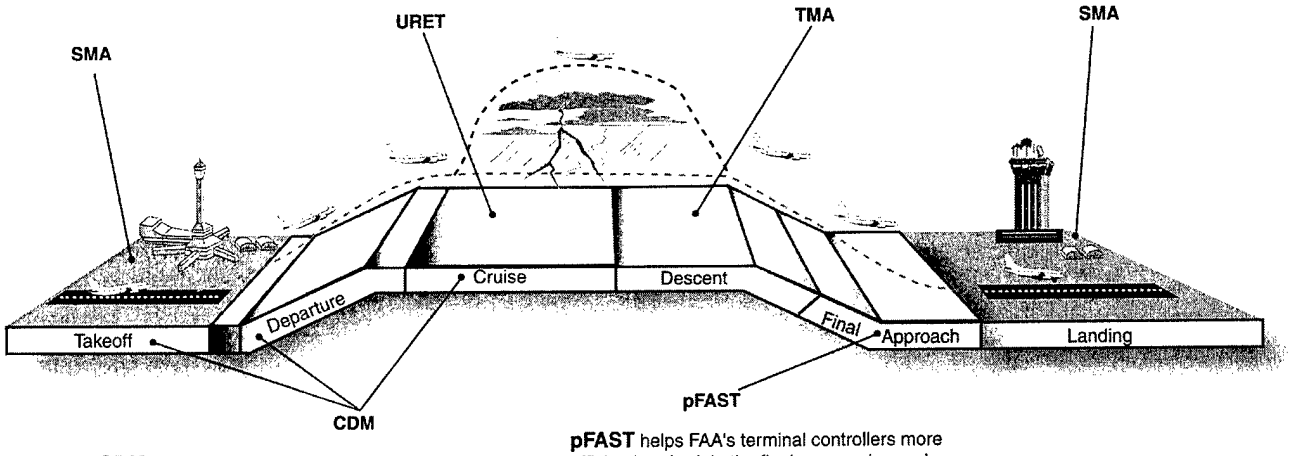
In 1998, FAA and the aviation community agreed to a phased approach for implementing the free flight program, established a schedule for phase 1, and created a special program office to manage this phase. During phase 1, which FAA plans to complete by the end of calendar year 2002, the agency has been deploying five new technologies to a limited number of locations and measuring their benefits. Figure 1 shows how these five technologies—Surface Movement Advisor (SMA), User Request Evaluation Tool (URET), Traffic Management Advisor (TMA), Collaborative Decision Making (CDM), and passive Final Approach Spacing Tool (pFAST)—operate to help manage air traffic. According to FAA, SMA and CDM have been deployed at all phase 1 sites on or ahead of schedule. Table 1 shows FAA's actual and planned deployment dates for URET, TMA, and pFAST.

Figure 1: Use of Free Flight's Tools to Help Manage Air Traffic

SMA helps airlines more efficiently manage aircraft movement on the ground.

URET helps FAA's en route controllers automatically identify conflicts and respond to pilots' requests for route changes in the en route airspace.[a]

TMA helps FAA's en route controllers and traffic managers more efficiently schedule properly separated aircraft as they transition into the terminal airspace around capacity-constrained airports.[b]



CDM helps FAA and the airlines electronically exchange and analyze information on flight status and airspace capacity.

pFAST helps FAA's terminal controllers more efficiently schedule the final sequencing and assign runways to aircraft in the terminal airspace.

[a]En route airspace usually extends above 18,000 feet for commercial aircraft.
[b]Terminal airspace begins about 5 miles and ends about 50 miles from the airport and generally extends up to 10,000 feet above the ground.

Source: FAA.

Table 1: Phase 1 Deployment Dates for TMA, pFAST, and URET

Location	TMA	pFAST	URET
Dallas-Fort Worth	June 1996[a]	February 1999[a]	
Minneapolis	June 2000	June 2001	
Denver	September 2000		
Los Angeles	November 2000	February 2001	
Atlanta	February 2001	March 2001	February 2002
Miami	May 2001		
Oakland	September 2001		
Saint Louis		October 2001	
Indianapolis			December 2001[b]
Memphis			November 2001[b]
Kansas City			December 2001
Cleveland			January 2002
Washington, D.C.			January 2002
Chicago			February 2002

[a]Prototypes of TMA and pFAST (not the actual models to be deployed) are being used.

[b]A prototype of URET (not the actual model to be deployed) has been used at these locations since November 1997.

Source: GAO's presentation of FAA's data.

To measure whether the free flight tools will increase system capacity and efficiency, in phase 1, FAA has been collecting data for the year prior to deployment and initially planned to collect this information for the year after deployment before making a decision about moving forward. In December 1999, at the urging of the aviation community, FAA accelerated its funding request to enable it to complete the next phase of the free flight program by 2005—2 years ahead of schedule. During this second phase, FAA plans to deploy some of the tools at additional locations and colocate some of them at selected facilities.[5] FAA also plans to conduct research on enhancements to these tools and incorporate them when they are sufficiently mature. FAA plans to make an investment decision in March 2002 about whether to proceed to phase 2. However, by that date, the last site for URET will have been operational for only 1 month, thus not allowing the agency to collect data for 1 year after deployment for that site before deciding to move forward. (See table 1.) FAA officials told us that

[5]In May 2000, FAA named the director for Free Flight Phase 2, during which FAA plans to deploy the tools at fewer locations than the aviation industry had recommended because of technical challenges with selected tools, infrastructure limitations, and other budgetary priorities.

because the preliminary data showed that the benefits were occurring more rapidly than anticipated, they believe it is unnecessary to wait for the results from the evaluation plan to make a decision about moving forward.

To help airports achieve their maximum capacity for arrivals through free flight, FAA's controllers will undergo a major cultural change in how they will manage the flow of air traffic over a fixed point (known as metering). Under the commonly used method, controllers use "distance" to meter aircraft. With the introduction of TMA, controllers will have to adapt to using "time" to meter aircraft.

URET's Major Technical Challenge Is Making It Work With Other Systems

The major technical challenge with deploying the free flight tools is making URET work with FAA's other air traffic control systems. While FAA does not think this challenge is insurmountable, we believe it is important for FAA to resolve this issue to fully realize URET's benefit of increasing controller productivity. Initially, controllers had expressed concern about how often they could rely on TMA to provide the data needed to effectively manage the flow of traffic. However, according to FAA and subsequent conversations with controllers, this problem was corrected in May 2001 when the agency upgraded TMA software and deployed the new version to all sites. To FAA's credit, it has decided not to deploy pFAST to additional facilities in phase 2 because of technical difficulties associated with customizing the tool to meet the specific needs of each facility, designing other automated systems that are needed to make it work, and affordability considerations.

Ensuring that URET is compatible with other major air traffic control systems is a crucial technical challenge because this requires FAA to integrate software changes among multiple systems. Among these systems are FAA's HOST, Display System Replacement,[6] and local communications networks. Compounding this challenge, FAA has been simultaneously upgrading these systems' software to increase their capabilities. How well URET will work with these systems is unknown because FAA has yet to test this tool with them. FAA has developed the software needed for integration and has begun preliminary testing.

[6]HOST is the en route centers' system for processing flight and radar data that are displayed on the controllers' workstations. The Display System Replacement is the en route workstation that graphically displays the flight plan and radar data processed by the HOST computer. The Display System Replacement replaces 20- to 30-year old workstations and provides a platform for transitions to other air traffic control enhancements.

Although problems have been uncovered during testing, FAA has indicated that these problems should not preclude URET's continued deployment. By the end of August 2001, FAA expects to complete testing of URET's initial software in conjunction with the agency's other major air traffic control systems. FAA acknowledges that further testing might uncover the need for additional software modifications, which could increase costs above FAA's current estimate for this tool's software development and could cause the agency to defer capabilities planned for phase 1.

Ensuring URET's compatibility with other air traffic control systems is important to fully realize its benefits of increasing controllers' productivity. URET is used in facilities that control air traffic at high altitudes and will help associate and lead controllers work together to safely separate aircraft. Traditionally, an associate controller has used the data on aircraft positions provided by the HOST computer and displayed on the Display System Replacement workstation to assess whether a potential conflict between aircraft exists. If so, an associate controller would annotate the paper flight strips containing information on their flights and forward these paper flight strips to the lead controller who would use the Display System Replacement workstation to enter flight plan amendments into the HOST. URET users we spoke with said that this traditional approach is a labor-intensive process, requiring over 30 keystrokes. With URET, an associate controller can rely on this tool to automatically search for potential conflicts between aircraft, which are then displayed. URET also helps an associate controller resolve a potential conflict by automatically calculating the implications of any change prior to amending the flight plan directly into the HOST. According to the users we spoke with, these amendments require only three keystrokes with URET.

While FAA's Phased Approach Is Appropriate, Adapting to the Cultural Changes and Improving Communications Are Major Operational Challenges

FAA, controllers, maintenance technicians, the aviation community, and other stakeholders agree on the importance of using a phased approach to implementing the free flight program. This approach allows FAA the opportunity to gradually deploy the new technologies at selected facilities and users to gain operational experience before total commitment to the free flight tools. It basically follows the "build a little, test a little, field a little" approach that we have endorsed on numerous occasions. To FAA's credit, the agency has appropriately used this approach to determine that it will not deploy pFAST in phase 2. We also agree with major stakeholders that adapting to the program's tools poses the greatest operational challenge because they will change the roles and responsibilities of the controllers and others involved in air traffic services. However, the success of free flight will rely on agencywide cultural changes, especially with controllers, who trust their own judgment more than some of FAA's new technologies, particularly because the agency's prior efforts to deploy them have had significant problems.[7] Without training in these new tools, air traffic controllers would be hampered in fulfilling their new roles and responsibilities. Another major challenge is effectively communicating TMA's capabilities to users. Because FAA has been deferring and changing capabilities, it has been difficult for controllers to know what to expect and when from this tool and for FAA to ensure that it provides all the capabilities that had been agreed when FAA approved the investment for phase 1.

The Roles, Responsibilities, and Methods for Air Traffic Control Will Change

During our meetings with air traffic controllers and supervisors, their biggest concern was that the free flight tools would require cultural changes in the way they carry out their responsibilities. By increasing their dependence on automation for their decisionmaking, these tools are expected to help increase controllers' productivity. Moreover, the tools will require changes in commonly recognized and accepted methods for managing traffic.

[7]Key systems under FAA's air traffic control modernization program, of which the free flight program is a major part, have often had difficulty in meeting cost, schedule, and performance requirements. Because of the size, complexity, cost, and problem-plagued past of FAA's modernization program, we have designated it a high-risk information technology investment since 1995. FAA's modernization program is one of four high-risk systems development and modernization efforts. See *High-Risk Series: An Overview* (GAO/HR-95-1, Feb. 1995); *High-Risk Series: Information Management and Technology* (GAO/HR-97-9, Feb. 1997); *High-Risk Series: An Update* (GAO/HR-99-1, Jan. 1999); and *High-Risk Series: An Update* (GAO-01-263, Jan. 2001).

Controllers and supervisors emphasized that URET will increase the responsibilities of the associate controllers in two important ways. First, their role would no longer be focused primarily on separating traffic by reading information on aircraft routes and altitudes from paper flight strips, calculating potential conflicts, and manually reconfiguring the strips in a tray to convey this information to a lead controller. With the URET software that automatically identifies potential conflicts up to 20 minutes in advance, associate controllers can be more productive because they will no longer have to perform these manual tasks. Second, they can assume a more strategic outlook by becoming more focused on improving the use of the airspace. URET enables them to be more responsive to a pilot's request to amend a flight plan (such as to take advantage of favorable winds) because automation enables them to more quickly check for potential conflicts before granting a request. Although the controllers said they look forward to assuming this greater role and believe that URET will improve the operational efficiency of our nation's airspace, they have some reservations.

Achieving this operational efficiency comes with its own set of cultural and operational challenges. Culturally, controllers will have to reduce their dependency on paper flight strips as URET presents data electronically on a computer screen. According to the controllers we interviewed, this change will be very challenging, especially at facilities that handle large volumes of traffic, such as Chicago, because the two facilities that have received URET have taken several years to become proficient with it even though they have less traffic. Operationally, controllers said that URET's design must include some backup capability because they foresee the tool becoming a critical component in future operations. Moreover, as controllers become increasingly experienced and reliant on URET, they will be reluctant to return to the former manual way because those skills will have become less current. As new controllers join the workforce, an automated backup capability will become increasingly essential because they will not be familiar with controlling traffic manually with paper flight strips. Currently, FAA is not committed to providing a backup to URET in either phase because the tool is only a support tool, not a mission-critical tool that requires backup. However, the agency is taking preliminary steps to provide some additional space for new equipment in the event it decides to provide this backup. Depending on how the agency plans to address this issue, the cost increase will vary.

For TMA, controllers emphasized during our discussions that using time rather than distance to meter properly separated aircraft represents a

major cultural shift. While controllers can visually measure distance, they cannot do the same with time. As one controller in a discussion group commented, TMA "is going to be a strain, ... and I hate to use the word sell, but it will be a sell for the workforce to get this on the floor and turn it on and use it." Currently, controllers at most en route facilities use distance to meter aircraft as they begin their descent into an airport's terminal airspace. This method, which relies on the controllers' judgment, results in the less efficient use of this airspace because controllers often add distance between planes to increase the margin of safety. With TMA, controllers will rely on the computer's software to assign a certain time for aircraft to arrive at a predetermined point. Through continuous automatic updating of its calculations, TMA helps balance the flow of arriving flights into the congested terminal airspace by rapidly responding to changing conditions. The controllers at the first three of the en route centers that have transitioned to TMA easily accepted it because they had been using time to meter air traffic for 20 years. However, as other en route centers transition to TMA, the controllers' receptivity will be difficult because they have traditionally used distance to meter air traffic. FAA management realizes that the controllers' transition to metering based on time versus distance will be challenging and has allowed at least 1 full year for them to become proficient in using the tool and begin to reap its full benefits. As a result, the Free Flight Program Office has established a 1-year period for controllers to become trained and comfortable with using this tool.

Controllers Believe That Their Efforts to Provide Adequate Training Have Been Hampered

FAA is relying heavily on national user teams to help develop training for TMA and URET.[8] However, because of a lack of training development expertise and other factors, their efforts to provide adequate training for TMA have been hampered. Controllers said that, while they have knowledge of TMA, they are not specialists in developing training and therefore need more assistance from the program office. Also, because only a few key controllers have experience in using TMA, the teams have had to rely on them to develop a standardized training program while working with local facilities to tailor it to their needs. Moreover, these controllers are being asked to troubleshoot technical problems. Finally, controllers said the computer-based training they have received to date has not been effective because it does not realistically simulate operational conditions. FAA is currently revising its computer-based training to provide more realistic simulations.

[8]These teams are comprised of controllers, technicians, and supervisors.

Because using the free flight tools will require controllers to undergo a complex and time-consuming cultural change,[9] developing a comprehensive training program would greatly help FAA's efforts to implement the new free flight technologies. Communicating to users how the new tools will benefit the organization and them will greatly enhance the agency's training strategy. While FAA's training plans for URET are preliminary because it is undergoing testing and is not scheduled for deployment until the latter part of 2001, we believe that providing adequate training in advance is essential for controllers to become proficient in using this tool.

Lack of Communication on TMA's Capabilities Leaves Users Uncertain About the Tool's Benefits

Our discussions with controllers and FAA's TMA contractor indicated that in order to address local needs and to fix technical problems with TMA, FAA deferred several aspects of the tool that had been established for earlier deployment in phase 1. FAA officials maintain that these capabilities will be deployed before the end of phase 1. However, if these capabilities are not implemented in phase 1, pushing them into phase 2 will likely increase costs and defer benefits. For example, TMA's full capability to process data from adjacent en route centers has been changed because FAA determined that providing the full capability was not cost effective. While controllers said that even without this full capability, TMA has provided some benefits, they said that deferring some aspects of the tool's capabilities has made it less useful than they expected. Moreover, controllers maintain that FAA has not clearly communicated the changes with the tool's capabilities to them. Without knowing how the tool's capabilities are being changed and when the changes will be incorporated, it is difficult for users to know what to expect and when and for FAA to evaluate the tool's cost, schedule, and ability to provide expected benefits.

[9]For a discussion on organizational culture within FAA, see *Aviation Acquisition: A Comprehensive Strategy Is Needed for Cultural Change at FAA* (GAO/RCED-96-159, Aug. 22, 1996) and *Major Management Challenges and Program Risks: Department of Transportation* (GAO-01-253, Jan. 2001).

Preliminary Data Indicate That the Free Flight Tools Will Probably Increase Capacity and Efficiency, Thereby Slowing the Growth in Delays

FAA has begun to measure capacity and efficiency gains from using the free flight tools and its preliminary data show that the tools provide benefits. FAA expects additional sites to show similar or greater benefits, thus providing data to support a decision to move to phase 2 by March 2002. Because the future demand for air traffic services is expected to outpace the tools' capacity increases, the collective length of delays during peak periods will continue to increase but not to the extent that they would have without them.

Early Results Show Capacity and Efficiency Increases

When FAA, in collaboration with the aviation industry, instituted the phased approach to implement its free flight program in 1998, the agency established a qualitative goal for increasing capacity and efficiency. In May 2001, FAA announced quantifiable goals for each of the three tools. For URET, FAA established an efficiency goal to increase direct routings by 15 percent within the first year of being fully implemented. Achieving this goal translates into reduced flight times and fuel costs for the airlines. The capacity goals for TMA and pFAST are dependent upon whether they are used together (colocated) and whether any constraints at an airport prevent them from being used to their full potential to expand capacity. If they are used together (such as at Minneapolis), FAA expects capacity to increase by 3 percent in the first year of operations and by 5 percent in the following year. However, at Atlanta, which is constrained by a lack of runways, the goal is 3 percent when these tools are used together. If only one of these tools is deployed (such as at Miami), FAA expects a 3-percent increase in capacity. While FAA has established quantifiable goals for these tools, the agency has only recently begun to develop information to determine whether attaining its goals will result in a positive return on the investment. Making this determination is important to help ensure that the capacity and efficiency gains provided by these tools are worth the investment.

As previously shown in table 1, the actual systems that will be deployed for TMA and pFAST have only recently been installed at several locations or are scheduled to be installed this winter. To date, prototypes of these tools have been colocated at one location, and the actual equipment has been colocated at three locations. TMA is in a stand-alone mode at two locations. FAA reported that TMA achieved its first-year goal of a 3-percent increase in capacity at Minneapolis, and the agency is collecting data to determine whether the tool is meeting its goals at the other

locations. Most of FAA's data regarding the benefits provided by these tools are based on operations of their prototypes at Dallas-Fort Worth. These data show that TMA and pFAST achieved the 5-percent colocation goal. However, the data might not be indicative of the performance of the actual tools that will be deployed to other locations because Dallas-Fort Worth does not face the constraints affecting many other airports (such as a lack of runways).

Because FAA does not plan to begin deploying the actual model of URET until November 2001, the agency's data on its benefits have been based only on a prototype. At the two facilities—Indianapolis and Memphis—where the prototype has been deployed since 1997, FAA reported that URET has increased the number of direct routings by over 17 percent as of April 2001. According to FAA's data, all flights through these two facilities were shortened by an average of one-half mile, which collectively saved the airlines approximately $1.5 million per month in operating costs. However, the benefits that FAA has documented for using URET reflect savings for just a segment of a flight—when an airplane is cruising through high-altitude airspace—not the entire flight from departure to arrival. Maintaining URET's benefits for an entire flight is partly dependent on using it in conjunction with TMA and pFAST. Although a researcher at the Massachusetts Institute of Technology, who is reviewing aspects of FAA's free flight program, recognizes URET's potential benefits, the researcher expressed concerns that its benefits could be lessened in the airspace around airports whose capacity is already constrained. Likewise, in a study on free flight supported by the National Academy of Sciences and the Department of Transportation, the authors found that the savings attributed to using direct routings might "be lost as a large stack of rapidly arriving aircraft must now wait" in the terminal airspace at constrained airports.[10] Although URET can get an airplane closer to its final destination faster, airport congestion will delay its landing. While TMA and pFAST are designed to help an airport handle arrivals more efficiently and effectively, they cannot increase the capacity of an airport's terminal airspace beyond the physical limitations imposed by such constraining factors as insufficient runways or gates.

In contrast, FAA's Free Flight Program Office believes that the savings observed with the prototype of URET will accrue when the actual tool is

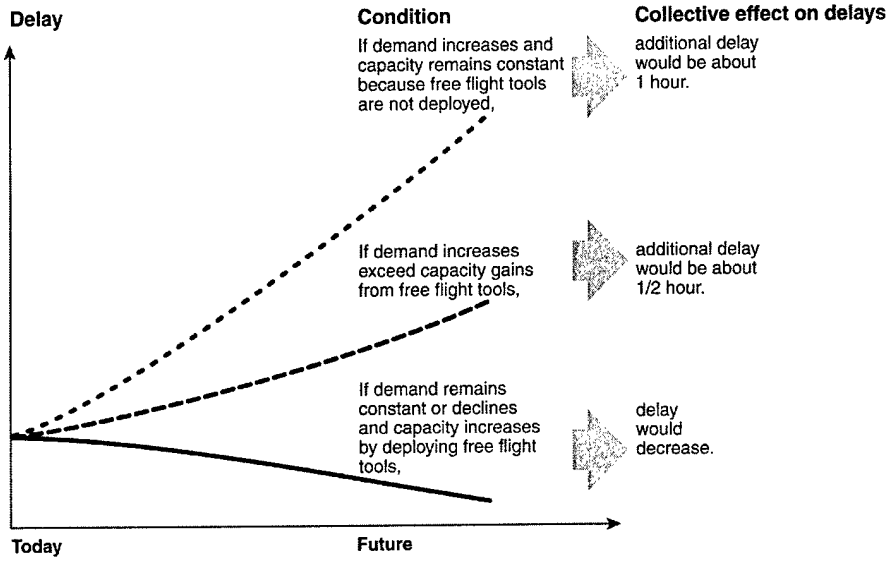
[10]Christopher D. Wickens and Anne S. Mavor, et al., *The Future of Air Traffic Control: Human Operators and Automation*, Commission on Behavioral and Social Sciences and Education, National Research Council, National Academy Press, 1998.

used in conjunction with TMA and pFAST. FAA plans to have procedures in place by the time these three tools are used together so that URET's benefits will not be reduced. However, the colocation of these three tools is not expected to occur until February 2002, which is only 1 month before the agency plans to make an investment decision for phase 2. Thus, we believe that FAA will not have enough time to know whether URET's benefits would be reduced.

Free Flight Tools Are Expected to Slow the Growth in Air Traffic Delays

During peak periods, the demand for air traffic currently exceeds capacity at some airports, causing delays. FAA expects this demand to grow, meaning that more aircraft will be delayed for longer periods. Free flight tools have the potential to allow the air traffic system to handle more aircraft (increase capacity) but not to keep up with the projected growth in demand. Thus, they can only slow the growth of future delays. They cannot fully eliminate future delays or reduce current delays unless demand remains constant or declines. FAA's model of aircraft arrivals at a hypothetical congested airport, depicted in figure 2, illustrates the projected impact of the tools. According to the model, if demand increases and the tools are not deployed (capacity remains constant); the collective delays for all arriving flights (not each one) will increase by about an hour during peak periods. But if demand increases exceed capacity increases from deploying the tools, these delays will only increase by about half an hour.

Figure 2: Relationships Among Demand, Capacity, and Delay



Source: GAO's conceptual presentation of FAA's model.

FAA Has Noted Other Benefits From the Free Flight Tools

While recognizing that the free flight tools will provide other benefits, FAA has not quantified them. According to FAA, although TMA and pFAST are designed to maximize an airport's arrival rates, they also can increase departure rates because of their ability to optimize the use of the airspace and infrastructure around an airport. Regarding URET, FAA maintains that by automating some of the functions that controllers had performed manually, such as manipulating paper flight strips, the tool allows controllers to be more productive.

Conclusions

If FAA's data continue to show positive benefits, the agency should be in a position by March 2002 to make a decision to deploy TMA to additional sites. However, FAA might not be in a position to make an informed decision on URET because the schedule might not allow time to collect sufficient data to fully analyze the expected benefits from this tool during phase 1.

Currently, operational issues present the greatest challenge because using the free flight tools will entail a major cultural shift for controllers as their roles and responsibilities and methods for managing air traffic will change. While FAA management has recognized the cultural changes involved, they have not taken a leadership role in responding to the magnitude of the changes. In particular, while involving controllers in developing and delivering training on these new tools, FAA has not provided support to ensure that the training can be effectively developed and presented at local sites. Because the agency has been changing the capabilities of TMA from what had been originally planned but not systematically documenting and communicating these changes, FAA and the users of this tool lack a common framework for understanding what is to be accomplished and whether the agency has met its goals.

While the free flight tools have demonstrated their potential to increase capacity and save the airlines money, only recently has FAA established quantifiable goals for each tool and begun to determine whether its goals are reasonable—that they will result in a positive return on investment. Because several factors influence the benefits expected from the tools, it is important for FAA to clearly articulate the expectations for each tool by specific location.

Recommendations

To make the most informed decision about moving to phase 2 of the free flight program, we recommend that the Secretary of Transportation direct the FAA Administrator to take the following actions:

- Collect and analyze sufficient data in phase 1 to ensure that URET can effectively work with other air traffic control systems.
- Improve the development and the provision of local training to enable field personnel to become proficient with the free flight tools.
- Determine that the goals established in phase 1 result in a positive return on investment and collect data to verify that the goals are being met at each location.
- Establish a detailed set of capabilities for each tool at each location for phase 2 and establish a process to systematically document and communicate changes to them in terms of cost, schedule, and expected benefits.

Agency Comments

We provided a draft of this report to the Department of Transportation and the National Aeronautics and Space Administration for their review and comment.

We met with officials from the Office of the Secretary and FAA, including the Director and Deputy Director Free Flight Program Office, to obtain their comments on the draft report. These officials generally concurred with the recommendations in the draft report. They stated that, to date, FAA has completed deployment of the Surface Movement Advisor and the Collaborative Decision Making tools on, or ahead of, schedule at all phase 1 locations and plans to complete the deployment of the remaining free flight tools on schedule. FAA officials also stated that the agency is confident that it will be in position to make an informed decision, as scheduled in March 2002, about moving to the program's next phase, which includes the geographic expansion of TMA and URET. Furthermore, FAA stated that the free flight tools have already demonstrated positive benefits in an operational environment and that it expects these benefits will continue to be consistent with the program's goals as the tools are installed at additional sites. In addition, FAA officials provided technical clarifications, which we have incorporated in this report, as appropriate.

We acknowledge that FAA has deployed the Surface Movement Advisor and the Collaborative Decision Making tools on schedule at various locations. Furthermore, the report acknowledges that the free flight tools have demonstrated benefits and that the agency should have the data on TMA to make a decision about moving forward to phase 2 by March 2002. However, as we note in the report, FAA faces a significant technical challenge in ensuring that URET works with other air traffic control systems. Moreover, the data on URET's benefits reflect those of the prototype system. FAA is scheduled to deploy the first actual system in November 2001 and the last in February 2002—just 1 month before it plans to make an investment decision. With this schedule, the actual system might not be operational long enough to gather sufficient data to measure its benefits. Furthermore, FAA has yet to overcome the operational challenge that is posed when controllers use TMA and must shift from the traditional distance-based method of metering air traffic to one based on time. If FAA can not satisfactorily resolve these issues, the free flight program might not continue to show positive benefits and could experience cost overruns, delays, and performance shortfalls.

The National Aeronautics and Space Administration expressed two major concerns. First, it felt that the benefits provided from the TMA tool justified its further deployment. Our initial conclusion in the draft report, that FAA lacked sufficient data to support deploying this tool to additional sites, was based on FAA's initial evaluation plan, which required at least 1 year of operational data after each tool had been deployed. FAA officials now believe that waiting for full results from the evaluation plan before making a decision to move forward is no longer necessary because TMA's performance results are occurring more rapidly than anticipated. This report now acknowledges that the agency should have the data it needs to make a decision to move forward with this tool. Second, NASA felt that the report was unclear regarding the nature of our concerns about the reliability of TMA's data. The discussion in the draft report indicated that FAA lacked sufficient data to show that it had addressed our concerns with TMA. FAA officials provided this support, and this report has been revised accordingly. In addition, National Aeronautics and Space Administration officials provided technical clarifications, which we have incorporated into this report, as appropriate. (See appendix II for the National Aeronautics and Space Administration's comments.)

As agreed with your offices, unless you publicly release its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies of this report to interested Members of Congress; the Secretary of Transportation; the Administrator, Federal Aviation Administration; and the Administrator, National Aeronautics and Space Administration. We will also make copies available to others upon request.

If you have questions about this report, please contact me at (202) 512-3650. Key contributors are listed in appendix III.

Gerald L. Dillingham

Gerald L. Dillingham, Ph.D.
Director, Physical Infrastructure

Appendix I: Objectives, Scope, and Methodology

Because of the importance of the free flight program to the future operation of our nation's aviation system and the upcoming decision about whether to proceed to the next phase, the Chairmen of the Senate Committee on Commerce, Science, and Transportation and the Subcommittee on Aviation asked us to provide information to help them determine whether the Federal Aviation Administration (FAA) will be in a position to decide on moving to the next phase. This report discusses (1) the significant technical and operational issues that could impair the ability of the free flight tools to achieve their full potential and (2) the extent to which these tools will increase efficiency and capacity while helping to minimize delays in our nation's airspace system.

Our review focused on three free flight phase 1 tools—the User Request Evaluation Tool, the Traffic Management Advisor, and the passive Final Approach Spacing Tool—because they account for approximately 80 percent of FAA's $630 million estimated investment for phase 1 and approximately 80 percent of FAA's $717 million estimated investment for phase 2.[1] We did not review the Surface Movement Advisor or the Collaborative Decision Making tools because generally they had been implemented at all phase 1 locations when we started this review and FAA does not intend to deploy their identical functionality in phase 2.

To obtain users' insights into the technical and operational issues and the expected benefits from these tools, we held four formal discussion group meetings with nationwide user teams made up of controllers, technicians, and supervisors from all the facilities currently using or scheduled to receive the Traffic Management Advisor during phase 1. We also visited and/or held conference calls with controllers, technicians, and supervisors that used one or more of these tools in Dallas, Texas; southern California; Minneapolis, Minnesota; Memphis, Tennessee; Indianapolis, Indiana; and Kansas City, Kansas.

Additionally, to determine whether there were any significant technical and operational issues, we considered selected best practices for developing, managing, and evaluating projects from the Software Engineering Institute's Capability Maturity Models℠ for software

[1]The $630 million estimated investment represents development costs for fiscal years 1998 through 2002, and the $717 million estimated investment represents the total development costs for fiscal years 2001 through 2010.

development and acquisition.[2] Based on these criteria, we interviewed FAA officials in the Free Flight Program Office, the Office of Air Traffic Planning and Procedures, and the Office of Independent Operational Test and Evaluation. To review test reports and other documentation highlighting technical and operational issues confronting these tools, we visited FAA's William J. Hughes Technical Center in Atlantic City, New Jersey, and FAA's prime contractors that are developing the three free flight tools. We also visited the National Aeronautics and Space Administration's Ames Research Center at Moffett Field, California, to understand how its early efforts to develop free flight tools are influencing FAA's current enhancement efforts.

To determine the extent to which the free flight tools will increase capacity and efficiency while helping to minimize delays, we analyzed the relevant legislative and Office of Management and Budget's requirements that recognize the need for agencies to develop performance goals for their major programs and activities. We also interviewed FAA officials in the Free Flight Program Office and the Office of System Architecture and Investment for information on the performance goals of the free flight tools during phase 1. In addition, we held discussions with officials from RTCA, which provides a forum for government and industry officials to develop consensus-based recommendations. We also reviewed documentation explaining how the tools are expected to and actually have helped increase system capacity and efficiency, thereby helping to minimize delays.

We conducted our review from October 2000 through July 2001, in accordance with generally accepted government auditing standards.

[2]Capability Maturity Model is the service mark of Carnegie Mellon University and is registered in the U.S. Patent and Trademark Office.

Appendix II: Comments From the National Aeronautics and Space Administration

National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

Dr. Gerald L. Dillingham
Director, Civil Aviation Issues
General Accounting Office
Washington, DC 20548

AUG 6 2001

Subject: GAO Draft Report: National Airspace System: Free Flight Tools Hold Promise, but FAA Will Lack Sufficient Data to Decide on Moving Forward (GAO-01-932)

Thank you for giving us the opportunity to review this draft report and provide our comments prior to final publication. We have had individuals at Ames Research Center and NASA Headquarters provide input into our comments. This response covers the major points for your records as the formal Agency response.

- NASA is concerned with the investment conclusions reached by the report based on the reported technical performance of Traffic Management Advisor (TMA) and passive Final Approach Spacing Tools (pFAST). (Reference pages 14-16, "Preliminary Data Indicate That Free Flight Tools Will Probably Increase Capacity and Efficiency, Thereby Slowing the Growth in Delays.") In particular, "Early Results Show Capacity and Efficiency Increases, but Data Are Inconclusive," demonstrated that the FAA minimum success criteria for Minneapolis and Dallas-Fort Worth were all exceeded by actual performance of the TMA and pFAST technologies. Further, in "Free Flight Tools Are Expected to Slow the Growth in Air Traffic Delays," the report indicates that the decision-support tools will slow the growth of future delays. The accompanying figure, "Relationship Among Demand, Capacity, and Delay" shows the collective effect on delays with the decision-support tools deployed, as well as when the tools are not deployed. More specifically, the figure shows that if demand increases, deploying the decision-support tools would cut additional delays in half. It appears by the report's analysis that the data show that the tools have benefit that would justify a conclusion supporting further deployment with appropriate conditions as cited elsewhere in the report.

- A more specific comment addresses the concerns regarding the accuracy and reliability of TMA aircraft position data. On page 8, the report states that the FAA claims to have resolved these problems. Consequently, it is not clear if there is still a problem or not, and if there is a problem, the nature of the problem. Our understanding, based on discussions with officials in the Free Flight Office, is that the "position errors" from TMA were in fact due to a fault in interface logic to the Host

computer. This fault has been corrected and the manifestation of that problem in TMA no longer exists.

- It is important to understand that TMA does not compute instantaneous aircraft position data. These data come from the Host and are used by TMA to predict future aircraft positions in the absence of controller intervention. These predictions of position are then used by TMA to recommend scheduled meter fix crossing times to assure a smooth flow of traffic into the (Terminal Radar Approach Control) TRACON. The generated schedules can be judged in terms of the ability of the controller to meet the scheduled times, not their accuracy. Based on several years of testing, NASA has found the TMA trajectory predictions to be very accurate and the schedules to be very useable by controllers. This is consistent with the controller observation noted in your report that "When it's running it's right on the money." The ability to accurately predict future aircraft positions is fundamental to improve the performance of the air transportation system.

If you require any further assistance, please call Herbert Schlickenmaier on 358-4638.

Daniel R. Mulville
Associate Deputy Administrator

cc:
R/Mr. Venneri

Appendix III: GAO Contacts and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

In addition to those named above, Nabajyoti Barkakati, Jean Brady, William R. Chatlos, Peter G. Maristch, Luann M. Moy, John T. Noto, and Madhav S. Panwar made key contributions to this report.

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