Free Flight Phase 1 Technologies: Progress To Date and Future Challenges

Federal Aviation Administration

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U.S. Department of Transportation
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Memorandum

Subject:	ACTION: Report on Free Flight Phase 1 Technologies: Progress to Date and Future Challenges AV-2002-067	Date:	December 14, 2001
From:	Alexis M. Stefani Assistant Inspector General for Auditing	Reply to Attn. of:	JA-10:x60500
To:	Federal Aviation Administrator		

This report presents the results of our review of the Federal Aviation Administration's (FAA) Free Flight Phase 1 (FFP1) initiative. Our objective was to evaluate the technologies identified as part of FFP1 with emphasis on cost, schedule, human factors, and software development. In addition, we evaluated plans for expanding the FFP1 effort (and other technologies planned for implementation) during the 2003 to 2005 timeframe, and the interface between Free Flight technologies and other modernization efforts. We adjusted our objectives to reflect two major intervening developments—the publication of the Operational Evolution Plan and the recent terrorist attacks against the United States.

We are making recommendations aimed at improving FAA's management of Free Flight efforts, mitigating risks in light of the terrorist attacks, and ensuring various modernization efforts are effectively coordinated and integrated. The coordination/integration issue is of particular relevance as it pertains to the relationship between the June 2001 Operational Evolution Plan and the Free Flight program.

We periodically discussed this report and its recommendations with the Director of the Free Flight Phase 1 Program Office, the lead official for the agency's Operational Evolution Plan, and the Director of Research and Acquisitions during our review and have taken their comments into consideration. On August 20, 2001, we held an exit conference with your staff, including the lead agency official responsible for the Operational Evolution Plan, the Director and Deputy Directors of the Free Flight Office, and officials from the Office of System Safety and Air Traffic Services. We incorporated their comments as appropriate. FAA program officials generally agreed with our report and stated that actions are underway to address our recommendations.

In accordance with the Department of Transportation Order 8000.1C, we would appreciate receiving your response within 30 days. If you concur with our recommendations, please indicate for each recommendation the specific actions taken or planned and target dates for completion of these actions. If you do not concur, please provide your rationale. Furthermore, you may provide alternative courses of action that you believe would resolve the issues presented in this report.

We appreciate the cooperation and assistance of the Free Flight Phase 1 Program Office and other FAA organizations during this audit. If you have any questions concerning this report, please call me at (202) 366-1992 or David A. Dobbs, Deputy Assistant Inspector General for Aviation, at (202) 366-0500.

Attachment

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Federal Aviation Administration

OBJECTIVES AND BACKGROUND

Modernizing the Nation's air traffic control system has been and will continue to be an important factor in enhancing the safety, security, and efficiency of air travel in the United States. The Federal Aviation Administration (FAA) has embarked on a $837.7 million effort, called Free Flight Phase 1 (FFP1), which is expected to improve the flow of air traffic by fielding various technologies at specific locations between 1998 and 2002.[1] This report examines FAA's progress to date in developing and implementing FFP1 technologies, the role these technologies will play in enhancing capacity and reducing delays, and the impacts on FAA's modernization initiatives of the publication of the Operational Evolution Plan and the recent terrorist attacks.

The objective of our review was to evaluate the technologies identified as part of FFP1 with particular emphasis on cost, schedule, human factors, and software development. In addition, we evaluated plans for expanding the FFP1 effort (and other technologies planned for implementation) during Free Flight Phase 2 (FFP2), which covers the 2003 to 2005 timeframe, and the interface between these technologies and other modernization efforts. We adjusted our objectives to reflect two major intervening developments: the publication of FAA's Operational Evolution Plan in June 2001 and the September 11th terrorist attacks on the United States.

The ultimate goal of Free Flight is to increase the capacity and efficiency of the National Airspace System by better managing available airspace. As Free Flight matures, it will provide pilots with more flexibility, under certain conditions, to fly from city to city instead of being restricted to a series of fixed routes that are based on the limitations of ground-based systems, principally radar. The potential benefits of Free Flight include shorter flight times and fuel savings.[2]

FFP1 is *an initial step* toward Free Flight and introduces, at select locations, new information-exchange technologies and automated controller tools, which are

[1] The FFP1 strategy is defined in the August 1998 RTCA document titled Government/Industry Operational Concept for the Evolution of Free Flight (Addendum 1).

[2] Under Free Flight, air traffic restrictions are only imposed to ensure separation of aircraft, to preclude exceeding airport capacity, to prevent unauthorized flight through special use airspace, and to ensure safety. Restrictions are limited in extent and duration to correct an identified problem. Any activity that removes restrictions represents a move toward Free Flight.

designed to enhance the flow of air traffic. FFP1 technologies play an important role in FAA's Operational Evolution Plan, which outlines the actions needed to enhance capacity over the next decade.

In April 1999, FAA estimated the total cost of FFP1 to be $837.7 million from Fiscal Year (FY) 1998 through FY 2007. Of this total, *deploying* FFP1 technologies was estimated to cost $628.8 million from FY 1998 through FY 2002, and *sustaining* the technologies from FY 2003 through FY 2007 was estimated to cost another $208.9 million. As of September 2001, FAA had obligated about $501.8 million, or about 80 percent of its budget for deploying the new technologies at limited locations.

RESULTS

The Free Flight Program is a comparatively well managed effort due, in part, to its limited nature and "build a little, test a little, and deploy a little" approach. Improved information exchange systems between airlines and FAA on flight schedules and adverse weather have been the most successful and cost effective investments, and they have made important contributions in managing the flow of air traffic.

The more complex automated controller tools have made only modest capacity improvements at some locations and have proven to be far more difficult and costly to develop than anticipated. There have been schedule slippages and cost increases. Work has stopped on one initiative that was intended to help controllers sequence aircraft for landing at large hub airports, and funding should be deferred until solutions have been decided upon.

The Free Flight Program has been impacted by two major intervening events: FAA's commitment to the Operational Evolution Plan, which represents the agency's new blueprint for enhancing capacity over the next decade, and the September 11th terrorist attacks. Important questions exist about how to move forward and at what pace with Free Flight and the agency's new plan.

When the demand for air travel rebounds, so too will the need to enhance capacity and reduce capacity shortfalls. But it will occur against the need to address a range of security and sustainment needs that FAA neither planned nor budgeted for. Therefore, FAA needs to pause in the planning and management of Free Flight and the Operational Evolution Plan to assess security risks with the Free Flight concept, which technologies should receive priority, and how the agency's diverse efforts can be more effectively linked together.

Our results focus on: (1) the need to assess the implications of the September 11th terrorist attacks on Free Flight Program objectives, budget, and implementation milestones; (2) linking the Free Flight Program with FAA's Operational Evolution Plan; and (3) Free Flight Program implementation to date—risk areas in addition to security that require management attention.

FAA Needs to Assess Implications of September 11th Terrorist Attacks on the Free Flight Program as Well as Linkage of Free Flight Program to Operational Evolution Plan

FFP1 and the Operational Evolution Plan represent an $11.5 billion investment for new capacity initiatives between 2001 and 2010, exclusive of the costs to provide air traffic services and to build new runways. Assessing the impacts of September 11th and linking FFP1 and the Operational Evolution Plan not only has significance for the pace of modernizing the National Airspace System and enhancing security of air travel but also has enormous budgetary implications.

Before September 11, 2001, FAA and the aviation community's most pressing priority was expanding aviation system capacity and managing airspace to accommodate the demand for air travel and reduce delays and cancellations. FFP1, which FAA introduced in 1998, was expected to play a central role in efficient use of aviation system capacity by better managing traffic flow through new technologies, air traffic control procedures, and improved communication among airlines, pilots, and controllers.

FFP1 was to be introduced at select locations in a phased approach and be complete by the end of 2002. The current schedule calls for Free Flight Phase 2 to begin in 2003, which will consist of geographic expansion of the new automated controller tools and the introduction of controller to pilot data link communications at a cost of $810.2 million. FFP1 consists of:

- **Information-exchange technologies,** such as Collaborative Decision-Making, which links airlines with FAA's Air Traffic Control System Command Center (Command Center) and permits real-time information exchanges on airline schedules and allocation of arrival slots; and the Surface Movement Advisor, which provides real-time information to airlines and airline ramp towers on aircraft approaching an airport, and

- **Automated controller tools** that will help perform tasks that controllers do today manually or with mental calculations, such as detecting conflict between aircraft 20 minutes in advance and automatically generating landing sequences to smooth out arrival patterns and increase the number of aircraft that can be handled at high activity airports.

Gridlock–Summer 2000. Delays and cancellations reached intolerable and record levels in the summer of 2000—more than one in every four flights were delayed or canceled. The average delay was over 50 minutes, and delays in excess of 2 hours sitting on the runway had risen 230 percent over prior years at the 30 largest airports.

In the aftermath of summer 2000, it became clear that FFP1 would not, at least in the near term, materially relieve the congestion, delays, and cancellations that were placing the aviation system in near gridlock, even at locations where it was being phased in. FFP1 initiatives could provide modest incremental relief, but the demand for air travel and additional flights quickly obscured even those modest gains.

Instead, a multifaceted approach—one much more comprehensive than FFP1—would be required to address the Nation's capacity problems. This approach encompassed satellite navigation and weather technologies that were never part of the FFP1 effort as well as airspace redesign; new runways; expedited environmental clearances; increased use of non-hub airports; and demand management methods, possibly including peak hour pricing. The full range of required actions could not possibly be accomplished immediately and some actions, such as new runway construction, can take years to approve and complete. Nevertheless, it became imperative that the summer of 2001 not be a repeat of the summer of 2000. Secretary of Transportation Mineta made clear during his confirmation hearings that preventing a recurrence would be a top and urgent priority.

Summer 2001. The summer of 2001 in fact showed improvement over the summer of 2000 by almost all measures. Cancellations dropped substantially. Delays were still high, but they were somewhat shorter. Delay time spent sitting on runways also dropped substantially. This was due, in part, to the fact that anticipated labor strikes and slowdowns were averted by the efforts of management, labor, and the Administration. Also, several airlines adopted more sensible scheduling practices at hub airports, business travel declined substantially due to economic conditions, and weather conditions were much improved compared to summer 2000.

Also, in October 2000, FAA introduced "capacity benchmarks" that established baselines for the maximum number of aircraft an airport could handle by time of day. In June 2001, FAA introduced its Operational Evolution Plan—a multibillion dollar 10-year blueprint for expanding capacity through new runways, new air traffic control procedures, airspace redesign, and new technologies. As such, the Operational Evolution Plan eclipsed FFP1 as the agency's principal capacity enhancing initiative.

During summer 2001, FFP1's principal contribution was not the use of the more expensive automated controller tools, but rather the comparatively less costly collaborative information exchange between airlines and FAA on flight schedules and weather to manage aircraft flow across the Nation. This was almost universally regarded as a positive and much-needed improvement. The other FAA effort that made a difference was revised air traffic control procedures at several "choke points" (all of which are east of the Mississippi River); however, this was not a part of Free Flight.

September 11th Implications. FAA's Operational Evolution Plan blueprint was only 3 months old when disaster struck on September 11, 2001, in New York, Washington, and Pennsylvania. The terrorist acts, combined with a decrease in air travel from a softening economy, prompted a dramatic and immediate change in priorities from meeting the demand for air travel to aviation security. Major airlines reduced flights by 22 percent so the immediacy of a major capacity shortfall is now temporarily on the back burner. Although airlines have kept the remaining flights relatively full (with load factors comparable to last year's levels), they have done so by significantly reducing fares. As a result, domestic revenues were down 38 percent in October 2001 as reported by the Air Transport Association. FAA expects traffic to recover in the 18 to 24 month timeframe.

When confidence in air travel is restored and the economy rebounds, so too will capacity shortfalls—it would be shortsighted to suggest otherwise. When this occurs, it will do so against the backdrop of a need to ensure that aircraft in flight, landing, or taking off will be secure.

There is uncertainty about what the budget and milestones for capacity enhancing initiatives like Free Flight and the Operational Evolution Plan ought to be. This is especially true in light of what are certain to be large and unplanned expenditures for security at a time of revenue shortfalls for the Aviation Trust Fund, airlines, and airports.

The time is right, therefore, for FAA management to pause in the execution of the agency's Free Flight initiatives and the Operational Evolution Plan to assess budgetary priorities, project milestones, and whether changes are needed in project priorities or design in light of September 11th. FAA has begun to assess its priorities and investment strategies. The results of at least an initial assessment should be reported to the Secretary and the Congress in time for deliberations on FAA's fiscal year 2003 budget in spring 2002. Specifically, FAA should:

- **Assess security risks associated with the ultimate goal of Free Flight and determine how those risks will be mitigated.** Free Flight in its end state will shift more responsibility for flight path decisions to the pilot in command, with the ultimate goal of providing pilots with more flexibility to fly from city to city on user-preferred routes, instead of being restricted to fixed routes. Although the economic and airspace capacity benefits of this are generally accepted, the security and safety issues associated with air traffic controllers trying to manage large numbers of aircraft that opt to use this flexibility are not well understood.

- **Determine which Free Flight technologies should receive priority and which ones should be deferred**. For example, the User Request Evaluation Tool could, with some modifications, provide controllers with an alert on aircraft that abruptly change flight paths. On the other hand, work has stopped on the passive Final Approach Spacing Tool because of serious technical problems. Also, some Free Flight technologies, such as data link communications, will require airlines to invest in and equip their aircraft with new avionics. FAA officials believe that the economic downturn will prompt airlines to postpone investment decisions for 18 months to 2 years, which will impact agency and airline investments.

- **Reconcile and harmonize the budgets and management of the Free Flight Program and the Operational Evolution Plan**. At present, these two initiatives have similar goals, but are separately managed and need to be better integrated. The Free Flight Program was the centerpiece of FAA's technology effort to better manage airspace and increase the efficiency of the National Airspace System. When FAA launched its Operational Evolution Plan in June 2001, this changed and the new plan became the agency's focus for enhancing capacity.

  FAA plans to invest $11.5 billion between 2001 and 2010 in the Operational Evolution Plan, which includes FFP1 initiatives, for capacity enhancement, exclusive of costs to provide air traffic services, build new runways, or address security concerns. The Operational Evolution Plan includes satellite-based systems, such as Automatic Dependent Surveillance-Broadcast,[3] Local Area

[3] Automatic Dependent Surveillance-Broadcast (commonly referred to as ADS-B) uses the Global Positioning System and is being developed through the Safe Flight 21 initiative. Aircraft equipped with ADS-B avionics transmit position information, along with aircraft identification, altitude, velocity, and possibly intent data to ground systems and other properly equipped aircraft using wireless data link communications.

Augmentation Systems for precision landings, airspace redesign, data link communications, and weather technologies—all of which are outside the Free Flight Program. The full benefits of Free Flight depend on the success of these projects, but they are, at present, not part of or accountable to the Free Flight Program and are separately managed by other FAA offices. This was an issue before September 11th and remains an issue today.

- **Assess the implications of September 11th, the financial shape of the industry and airports on the budgets and milestones of capacity-enhancing initiatives, such as Free Flight and the Operational Evolution Plan, which includes major runway projects**. The issue here is not simply one of FAA's budgetary resources and the fact that security and capacity initiatives will compete for budget dollars. It is also likely that FAA will need to retain and up-grade long-range radars for security reasons, which was not something for which the agency had planned. Also, major runway projects rely heavily on financing from the Airport Improvement Program and Passenger Facility Charges, and on-airport and airline revenue. Current financing plans need to be revisited to ascertain whether these funds will still be available on the planned timetable or whether spending will be redirected to security-related projects.

Free Flight Phase 1 Program Progress and Implementation to Date—Risk Areas in Addition to Security That Warrant Management Attention

Overall, we found that FAA has made progress in implementing elements of FFP1, particularly the daily exchange of information between the airlines and FAA's Command Center. However, work remains with the new automated controller tools, which account for about 80 percent of the FFP1 investment. In fact, there have been schedule slips and cost overruns, and in the case of one new tool (the passive Final Approach Spacing Tool), work has stopped because of serious technical problems. The following summarizes the status of FFP1 technologies.

-- New Information Exchange Systems --

- *Surface Movement Advisor* (SMA) provides airport ramp tower operators and Airline Operations Centers with real-time positional information and estimated touchdown times for aircraft approaching within 30 miles of the airport. This information, which was previously unavailable to airlines, helps airlines predict aircraft arrivals and coordinate gates, refueling, and baggage-handling equipment. SMA, with a cost of $7.8 million, is the least complex initiative and has been fully deployed at all six planned locations. It is helping airlines to better coordinate air and ground operations.

- *Collaborative Decision-Making* (CDM) allows FAA's Air Traffic Control System Command Center and participating airlines to share, for the first time, real-time information on schedules and projected airport demand and capacity. During certain weather-related delays, this enables FAA to more efficiently allocate reduced capacity. With an estimated cost of $64.4 million, CDM is largely complete and links airlines with FAA's Command Center. It has provided the largest bang for the buck of all FFP1 initiatives.

-- New Automated Controller Tools --

- *User Request Evaluation Tool* (URET) is a decision-support conflict probe that assists controllers in managing air traffic, supporting pilots' requests for flight plan changes, and detecting potential conflicts between aircraft and between aircraft and restricted airspace. It also introduces electronic flight data to enhance flight data management currently accomplished with paper flight strips, which controllers use to track the position of aircraft. URET, with an estimated cost of $296.7 million, is costing more to develop and deploy than FAA anticipated. Prototype systems are helping airlines reduce flight distances. A production version of URET has been deployed to one location and deployment of production systems will occur at six other locations over the next year.

- *Center-Terminal Radar Approach Control Automation System* (CTAS) helps controllers transition aircraft from en route to terminal airspace and provides runway assignments. The Traffic Management Advisor (TMA) and passive Final Approach Spacing Tool (pFAST) are collectively known as "CTAS". CTAS was estimated to cost $224 million; TMA was planned for eight en route facilities and pFAST for six terminal facilities. TMA has been deployed to six of eight facilities and has been shown to incrementally enhance capacity, but pFAST is another story. Work has stopped on pFAST because of technical problems, and it cannot be deployed as originally planned.

Of all the FFP1 initiatives, pFAST—which helps air traffic controllers sequence aircraft for landing—has proven to be the most difficult and disappointing, and the new tool cannot be successfully deployed to six locations within cost and schedule baselines as originally planned. Problems are the result of FAA and the National Aeronautics and Space Administration (NASA) misjudging the tool's technological maturity, and complex site-specific adaptation issues.

We expressed concerns about pFAST development in August of this year. FAA stopped work on pFAST in September 2001 and is exploring alternatives for moving forward, now called a "CTAS terminal solution," which will provide controllers with runway assignments but will not sequence aircraft for arrival. The information will be provided on a monitor next to the controller's display. Funding for the surviving elements of pFAST development should be deferred until a clear-cut approach has been decided upon. Absent further justification and demonstration that problems are resolved, we see no reason for further funding of pFAST.

There are three general risk areas with the software intensive controller tools that need management attention and have an important bearing on future FAA acquisitions.

- *Contract Management and Ensuring Accountability*: FAA has relied on time and material contracts to develop CTAS, which proved to be the most difficult and complex of all initiatives. With a time and material contract, payments are based on the time spent and materials used by the contractor. There is no direct linkage between payment and successful work performed, nor are there strong incentives for contractors to control costs or use labor efficiently—all risks are with the Government.

  FAA established new contracting vehicles for CTAS in October 2001, which allows the agency to compete between two vendors and use alternative pricing arrangements. We have some reservations. First, it remains unclear how FAA will execute the contract and define the scope of work. The new vehicle could be a positive step or an open-ended arrangement leaving the risk with the Government. Second, according to an FAA official, this new contracting vehicle can be used for both FFP1 and FFP2 efforts but some work for FFP1, which will continue for the next year, will remain on a time and material contract. FAA must move away from time and material contracts for software intensive acquisitions. We are recommending that funding be contingent on doing so.

- *Budgeting and Assessing Costs*: The development of the new controller tools has been more time consuming and expensive than FAA anticipated. URET will cost more than anticipated to develop and stay on schedule, and there are strong indications that there will be additional cost increases with the new tools. Moreover, the site-specific nature of the new tools raises concerns about the costs not just to develop and deploy but also to sustain them, which will place additional pressures on FAA's Operations account.

  FAA needs to submit a revised budget for Free Flight that reflects the costs to deploy the automated tools, new security requirements, reductions in systems not urgently needed, and reduction in funds for elements that cannot be deployed due to technical problems.

- *Ensuring Controller Acceptance and Human Factors*: FFP1's new automated controller tools have important human factor implications in terms of workload, situational awareness, and teamwork for the controller workforce.

  The most effective way to ensure that controllers use the new tools is to enter into agreements with the controllers' union at both the national and local levels. To date, FAA has a national agreement for URET but not for TMA, and a number of local agreements are still needed for these new tools.

  Controllers essentially have veto power over the new systems because the existing agreement with the controllers' union, which expires in 2003, clearly states that FAA must negotiate changes resulting from revisions to technology, procedures, or airspace that affect controllers. If controllers do not accept the new tools, the objectives of Free Flight will not be met because benefits are contingent on almost universal usage.

PRINCIPAL FINDINGS

SOFTWARE DEVELOPMENT IS PROVING MORE COMPLEX AND COSTLY THAN ANTICIPATED

URET and CTAS are the most complex and expensive FFP1 technologies. Schedules have always been aggressive, and there is considerable overlap between development and production activities, particularly with elements of CTAS. These factors—coupled with extensive human factors issues—have led to major problems with previous modernization efforts. Table 1 provides information on the growth in the lines of computer code, estimated costs, and obligations for URET and CTAS.

Table 1. Lines of Software Code and Projected Costs
for FFP1 Controller Tools

Technology	Estimated Lines of Code (Dec. 1999)	Estimated Lines of Code (June 2001)	Estimated Costs Through FY 2002 (Dollars in Millions)	Funds Obligated Sept. 2001, (Dollars in Millions)
URET	526,000	613,000	$296.7	$241.9
CTAS (TMA and pFAST)	832,000	1,665,000	$224.2	$180.0
Total	1,358,000	2,278,000	$520.9	$421.9

Note: Estimates include data on pFAST, on which FAA has stopped work while the agency explores options for moving forward.
Costs include contract and program costs but not previous research and development. Figures for lines of code do not include the effort required for customizing CTAS to each deployment site.

Source: FAA's FFP1 Program Office.

We note that technologies being deployed during FFP1 are still evolving. The goal of FFP1 was not to achieve perfection but rather to get new technologies into the field quickly and gain operational experience—results thus far reflect this tradeoff.

- URET will cost more than FAA planned, due to growth in the number of lines of computer code and lower-than-anticipated productivity. Prototypes are in use at two locations, and a production system has been deployed at one of seven locations. *FAA and the prime contractor for URET now estimate that the development is likely to cost between $194.8 million and $207.6 million at completion—about 14 to 21 percent more than the original estimate of about $172 million.*

- CTAS is proving more difficult than anticipated, and the cost to successfully deploy the technology is uncertain. TMA systems are in at six locations but work on pFAST has been stopped due to serious technical problems.

  Although NASA conceived CTAS as a single system, past problems with contractor performance forced FAA to redistribute the workload between contractors. TMA and pFAST became two separate acquisitions that were to be developed and implemented independently. *The number of lines of code that needed to be developed and tested has doubled to almost 1.7 million since December 1999.*

FAA relied on time and material contracts to develop CTAS. With a time and materials contract, payments are based on the time spent and materials used by the contractor. There is no direct linkage between payment and successful work performed, nor are there strong incentives for contractors to control costs or use labor efficiently—all risks are with the Government.

A key cost and schedule driver for pFAST was *site adaptation*—the effort required to customize the tool to specific airspace. It became clear that the new tool could not be deployed within cost and schedule baselines. pFAST software was developed specifically for Dallas-Fort Worth airspace, but each airport is unique, having different runway configurations, restrictions, and local procedures, that the prototype of pFAST could not readily accommodate.

FAA's "build a little, test a little, and deploy a little" philosophy makes sense with the new controller tools, but it remains unclear when development work is actually complete and a system is mature enough to go forward. In the future, FAA needs to do a better job of assessing the *technological maturity* of new systems before deploying them and using the appropriate contracting vehicle.

NEW AUTOMATED CONTROLLER TOOLS HAVE FAR-REACHING HUMAN FACTORS IMPLICATIONS FOR THE CONTROLLER WORKFORCE

FFP1's new automated controller tools have profound human factors implications because they will change the way controllers amend flight plans, keep track of aircraft data, and prepare aircraft for landing. The tools are expected to provide the greatest benefit when controllers are handling large numbers of aircraft. To its credit, FAA has involved controllers in the development of the new tools, formed controller teams to test the tools and help foster acceptance, and developed an extensive human factors action plan for the implementation of FFP1 technologies. Table 2 summarizes the key human factors issues for the new tools.

Table 2. New Automated Controller Tools and Key Human Factors Issues

New Automated Controller Tool	Key Human Factors Issues
URET: helps controllers detect conflicts between aircraft 20 minutes in advance and introduces *electronic flight data*.	• Acceptance, workload, and teamwork. • Instances when controllers must revert back to paper flight strips. • Integration with TMA, Data Link, and new weather products.
TMA: helps en route controllers *sequence* aircraft for landing and provides *runway assignments*.	• Acceptance and workload. • New way of managing air traffic – *time-based metering*.
pFAST: helps TRACON controllers *sequence* aircraft for landing and provides *runway assignments*. This new tool became controversial with controllers; FAA has stopped work on pFAST.	• Acceptance and workload – *terminal operations are the most challenging with complex safety dimensions*. • New way of ordering aircraft for landing and balancing runways.

FFP1's controller tools represent FAA's first major attempt to introduce automation to the controller workforce as an aid to decision making. For example, URET enables controllers to detect potential conflicts between aircraft up to 20 minutes into the future. It also *introduces electronic flight data to enhance flight data management currently accomplished with paper flight strips,* which controllers have used to keep track of aircraft since before the introduction of radar. Similarly, CTAS helps controllers sequence aircraft for landing and assign runways—tasks that controllers do today with mental calculations.

FAA has taken a number of steps to address human factors issues associated with the new controller tools, but challenges remain.

- Controller acceptance of the new controller tools is essential to maximize the potential benefits. However, use of the tools is currently optional, and controller acceptance is not assured.

  Controllers are gaining valuable experience with the new tools at selected air traffic control facilities, but it remains uncertain how quickly controllers will accept the new tools. Controllers we interviewed at Memphis and Indianapolis Centers who have experience with URET have mixed feelings about the new tool but were generally supportive of efforts to use electronic flight data.

  According to FAA, the most effective way to ensure controllers use the tools is to enter into agreements with the controllers' union at both the national and local levels. While such agreements cannot guarantee that controllers will always follow the advice provided by the new tools, they could formally address a number of potential stumbling blocks to acceptance. In addition, Article 48 of the collective bargaining agreement with the controllers' union clearly states that FAA must negotiate changes arising from revisions to technology, procedures, or airspace that affect controllers.[4]

FAA has a number of agreements, which are reflective of a limited deployment. FAA needs to continue to obtain these agreements and revise them as more experience is gained. Future agreements should establish a path for universal usage of the new tools. This is critical because controllers essentially have veto power over the new systems and the benefits to a facility depend on almost universal usage by controllers.

- As FAA continues to implement the new tools, it will need to continue to pay close attention to a number of cross-cutting human factors issues, including the impacts of automation on *controller workload, situational awareness, teamwork, and what happens when a new controller tool is not available*. As controllers gain experience and come to depend on the tools, key issues will focus on how controllers deal with failures, errors, exceptions, and rare events. As additional experience is gained, training programs and procedures will need to be revised, which in turn will spur the need for additional human factors research and "lessons learned" analyses.

- The *combined impact* of the various new technologies on controllers is also an important issue that deserves greater attention. Until recently, new automated systems have been developed and used in relative isolation from one another. During FFP1, only one facility, Atlanta Center, will receive two tools—URET and TMA.[5] However, during FFP2, en route controllers might be using URET, TMA, and new weather products to help manage air traffic. Continued human factors work, including "human-in-the-loop" simulations (using experienced controllers in a laboratory), is needed to ensure new technologies work in a synergistic fashion and do not degrade safety.

- New automated controller tools—as well as other Free Flight technologies planned for the future, such as Data Link—will have important impacts on the selection, training, and staffing levels of the controller workforce. For example, a number of aviation industry officials we interviewed contend automated systems will allow fewer controllers to handle more traffic, similar to the way automation in the aircraft cockpit allowed a transition from a three-person flight crew to a two-person crew. On the other hand, the National Air Traffic Controllers Association contends that URET will require additional staffing at some facilities. It is too early to determine which position is correct.

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[4] See Agreement between the National Air Traffic Controllers Association AFL/CIO and the Federal Aviation Administration (September 1998).

[5] Initially, FAA planned to install both URET and TMA at Chicago Center as well, but FAA no longer plans to deploy TMA at this facility during FFP1.

FAA MUST TAKE A NUMBER OF STEPS TO ENSURE THE LONG-TERM SUCCESS OF ITS FREE FLIGHT INITIATIVES

The September 11th terrorist attacks involving commercial U.S. aircraft and the softening economy have important implications for FAA's modernization efforts. According to the Director for Research and Acquisitions, FAA will place greater emphasis on security and sustainment matters than capacity enhancing initiatives. FAA remains committed to the overall Free Flight concept but recognizes that some changes in direction and emphasis are needed.

We note that FAA recently unveiled its Operational Evolution Plan*,* which lays out the improvements that are planned over the next decade to enhance capacity. The plan has similar goals to Free Flight and includes satellite-based systems, such as Automatic Dependent Surveillance-Broadcast, which will be managed outside the purview of Free Flight. Moreover, FAA needs to address how program execution, management, and the budgets of various efforts—the Operational Evolution Plan, FFP1, and FFP2—can be harmonized in a concrete fashion.

Harmonizing FAA's initiatives is critical because of the extraordinarily complex interdependencies among modernization efforts. The National Airspace System is a complex "system of systems"—slips in one effort can negatively impact another. Interdependencies focus on the programmatic issues (dollars and milestones) as well as the systems and procedures that have to be brought together on time to deliver the capability. Concerns with human factors, software development, and interdependencies with other systems (e.g., HOST and weather systems) will become even more pronounced over the next several years. FAA must take a number of steps to increase the long-term chance of success.

- Safety and Certification. Experts caution that automation could introduce new safety issues that were not, and could not be, anticipated.[6] As the tools evolve, FAA needs to continually assess the tools' potential safety impacts, which will involve testing the new tools as well as the procedures for using them.

  Continued attention to safety is particularly important because FFP1 technologies will be deployed at some of the same air traffic control facilities that have witnessed increases in operational errors.[7] As we have previously reported, the increasing number of operational errors is an important safety issue—nationwide, they have increased by 51 percent from 764 in FY 1996 to

[6] See Flight to the Future: Human Factors in Air Traffic Control, National Research Council, 1997, and Human Factors Certification of Advanced Aviation Technologies, edited by John A. Wise, V. David Hopkin, and Daniel J. Garland, 1994.
[7] An operational error occurs when separation standards between aircraft are not maintained.

1,154 in FY 2000.[8] To date, FAA reports no incident is traceable to an FFP1 tool. It would be prudent for FAA to get an independent, scientific assessment of the tools' potential impacts on safety to assess failure modes and what happens in rare or unusual circumstances.

A related question focuses on whether the new controller tools should go through *certification*—the process for ensuring a new system works as advertised. Because FAA views URET and CTAS as advisory tools rather than "mission critical" tools used to control air traffic, the agency contends that certification is not needed. However, the lines between an advisory tool and a mission critical tool are likely to blur in day-to-day operations as controllers begin to depend on them to help separate aircraft.

FAA decided not to certify the FFP1 technologies during the FFP1 timeframe. However, a recent change in FAA's certification requirements has expanded the definition of systems requiring certification to include those that provide certain decision support information. In view of this change, FAA needs to revisit its analysis for each FFP1 technology to determine if and when the technology needs to begin the certification process.

- Integrating New Weather Technologies. According to FAA, bad weather, such as thunderstorms, is a leading cause of flight delays. Bad weather causes re-routing of aircraft and closure of runways, which reduce airport capacity and cause ripple effects nationwide. There is widespread agreement that FAA needs to develop better ways to predict and recover from bad weather.

  The new automated controller tools, CTAS and URET, depend on getting accurate information on weather conditions (e.g., wind, temperature, and pressure data) for sequencing aircraft and detecting potential conflicts. While currently available weather information (based largely on reports from the National Weather Service) will suffice in the near term, the performance of the new tools could be enhanced with better weather information.

  FAA is pursuing the *Weather and Radar Processor* and *Integrated Terminal Weather System* acquisitions to provide more accurate weather information to en route and TRACON controllers. The combined cost of these two systems is about $425 million. The Weather and Radar Processor will support URET and elements of CTAS. However, the Weather and Radar Processor has experienced technical problems, and controller concerns about how graphical information will be displayed on controllers' screens remain unresolved.

[8] See Actions to Reduce Operational Errors and Deviations Have Not Been Effective (Report No. AV-2001-011, December 15, 2000).

Critical weather information must be presented to controllers in a format that improves their situational awareness without increasing workload. FAA needs to focus greater attention on integrating new air traffic management technologies with improved weather technologies and how the information will be displayed on controllers' screens.

- Linkage With Airspace Redesign Efforts. FFP1's controller tools and FAA's National Airspace Redesign efforts are inextricably linked. Changes being considered as part of the National Airspace Redesign effort will affect many of the facilities where FAA is deploying new controller tools. Any changes in the airspace design at these facilities may trigger changes in the adaptation and/or software of the new controller tools deployed there.

  In the near term, FAA is focusing its efforts on *seven top-priority choke points*, all of which are east of the Mississippi River, that directly impact flights into and out of the New York/New Jersey metropolitan area. In the longer term, technological improvements in communications, navigation, surveillance, and automation are expected to allow for more flexibility in airspace design. FAA plans to complete the National Airspace Redesign effort for the entire country by the end of 2006.

  Because of the close interdependency of Free Flight deployment and National Airspace Redesign efforts, FAA needs to ensure a high degree of coordination exists between the two programs to control costs and reduce adaptation and/or software development risks. FAA must also ensure that the new controller tools have the built-in flexibility needed to easily adapt them to an evolving National Airspace System.

- Assessing the Combined Benefits of the FFP1 Technologies. FFP1's approach represents the first time FAA has made an effort to quantify the benefits and impacts of new systems from a before and after perspective. An important question facing FAA is how well the various FFP1 technologies will work together—in other words, whether the use of one technology will positively or negatively impact the benefits provided by another technology and to what extent. How the FFP1 technologies work in concert is not well understood; *benefits may not be additive for a particular flight*.

  There is also room for additional *simulation modeling* to analyze the combined benefits of the FFP1 technologies, the impact of planned airspace changes on these benefits, and the impact of these technologies on safety. Today, new models are sufficiently realistic and detailed to help decision-makers examine how introducing new technologies affects operations throughout the National Airspace System.

RECOMMENDATIONS

We recommend that FAA:

- Pause in the management and planning of the Operational Evolution Plan and various Free Flight initiatives to assess what changes are needed in light of September 11th. This assessment should address:

  (1) the security risks of the Free Flight concept and planned mitigation strategies,

  (2) which technologies should receive priority and which ones can be deferred,

  (3) how budgets and management of Free Flight and the Operational Evolution Plan will be harmonized and reconciled, and

  (4) the implications of September 11th, general economic conditions, and the financial shape of the airline industry for the budgets and milestones of capacity-enhancing initiatives.

  This assessment should be completed in time for deliberations on FAA's Fiscal Year 2003 budget request.

- Defer funding for further development of pFAST—or the CTAS terminal solution—until a clear-cut strategy for moving forward has been assessed in terms of cost and benefits, validated, and decided upon.

- Avoid time and material contracts for software intensive acquisitions. Contracts should be negotiated with alternative pricing arrangements, award fees, and incentives. Funding for CTAS development should be contingent on moving completely away from time and material contracts.

- Conduct human factors work that examines the combined impact of new technologies (such as conflict alerts, electronic flight data, and enhanced weather information) on controllers, including "human in the loop" simulations. Key issues to be researched include safety, workload, situational awareness, and teamwork.

- Make targeted use of advanced modeling to assess impacts of multiple Free Flight initiatives on enhancing capacity and reducing delays. This effort should address technology, procedures, and airspace redesign. It should also be linked to FAA's work on *capacity benchmarks* and the Operational Evolution Plan.

- Monitor the safety impacts, including operational errors and deviations, of new controller tools. FAA should conduct an independent scientific safety assessment of the new tools, which should examine both the short- and long-term safety impacts, including the transition period when the tools are brought on line, failure modes, and what happens when a tool is not available.

- Ensure controller acceptance of the new automated controller tools by obtaining national and local agreements with controllers. The agreements should be updated as more experience is gained with new tools, and they should set parameters for progressing from limited to universal usage of the tools.

We make additional recommendations in the body of this report.

AGENCY COMMENTS AND OFFICE OF INSPECTOR GENERAL RESPONSE

During our work, we periodically met with FAA officials from the FFP1 Program Office and have taken their comments regarding software development, human factors issues, and programmatic risks into consideration in preparing this report. We also discussed this report with the Associate Administrator for Research and Acquisitions and incorporated his views where appropriate.

On August 20, 2001, we held an exit conference with FAA program officials, which included the senior agency official responsible for implementing the NAS Operational Evolution Plan; the Director and Deputy Director of the Free Flight Office; and officials from the Office of System Safety, Air Traffic Services, and Airway Facilities Services. We have incorporated their comments as appropriate. At that meeting, FAA program officials concurred with our analysis and recommendations.

After we made adjustments to our report to reflect the events of September 11th, we discussed it with the Associate Administrator for Research and Acquisitions, the lead official responsible for the agency's Operational Evolution Plan, and the Director of Free Flight Phase 1. These officials generally agree and noted that actions are underway to address our concerns.

While FAA officials agreed that it is prudent to pause in the execution of the Operational Evolution Plan and Free Flight initiatives to assess priorities in light of recent events, they noted—and we agree—that the agency must be wellpositioned when the demand for air travel returns. FAA expects the demand for air travel to rebound within the next 18 to 24 months.

With respect to pFAST, FAA points out that it has stopped work on the tool and the agency is now exploring options for moving forward. Free Flight officials believe that some elements of pFAST can provide benefits and improved situational awareness for controllers. In our opinion, this decision must be based on a careful consideration of costs, site-specific benefits, and dependencies with other modernization efforts. Absent further justification and demonstration that problems are resolved, we see no reason for further funding.

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CHAPTER I. FFP1 TECHNOLOGIES WILL INCREMENTALLY ENHANCE CAPACITY

Free Flight Phase 1 (FFP1) is well past the halfway point and the Federal Aviation Administration (FAA) has obligated almost 80 percent of its budget for deploying the new FFP1 technologies. FAA has made progress in implementing elements of FFP1. FAA's analysis of benefits suggests that FFP1 technologies can incrementally enhance the capacity of the National Airspace System (NAS). However, it should be kept in mind that the nature and extent of these capacity enhancements will vary from site to site, and will not be fully understood until late 2002, when all of the technologies are expected to be deployed.

WHAT IS FREE FLIGHT PHASE 1?

The goal of Free Flight is to increase the capacity and efficiency of the NAS by eliminating restrictions and better managing available airspace. As Free Flight matures, it will gradually transform the NAS from today's centralized command-and-control system to a system that allows controllers and pilots to collaboratively choose more efficient and economical routes.

FFP1 is *an initial step* toward Free Flight. Free Flight relies on a wide range of technologies, which includes satellite-based navigation. In essence, FFP1 represents some of the ground elements of the larger Free Flight concept. FFP1 introduces, at select locations, the following new information-exchange technologies and automated controller tools, which are designed to enhance the flow of air traffic.

Information-Exchange Technologies

- Surface Movement Advisor (SMA) - provides airport ramp tower operators and Airline Operations Centers with real-time positional information and estimated touchdown times for aircraft approaching within 30 miles of the airport. This information, which was previously unavailable to airlines, helps airlines predict aircraft arrivals and coordinate ground support services (e.g., gates, refueling, and baggage-handling equipment) more efficiently.

- Collaborative Decision-Making (CDM) - allows FAA's Air Traffic Control System Command Center and participating airlines to share, for the first time, real-time information on schedules and projected airport demand and capacity. During certain weather-related delays, this information exchange will enable FAA to more efficiently allocate available capacity.

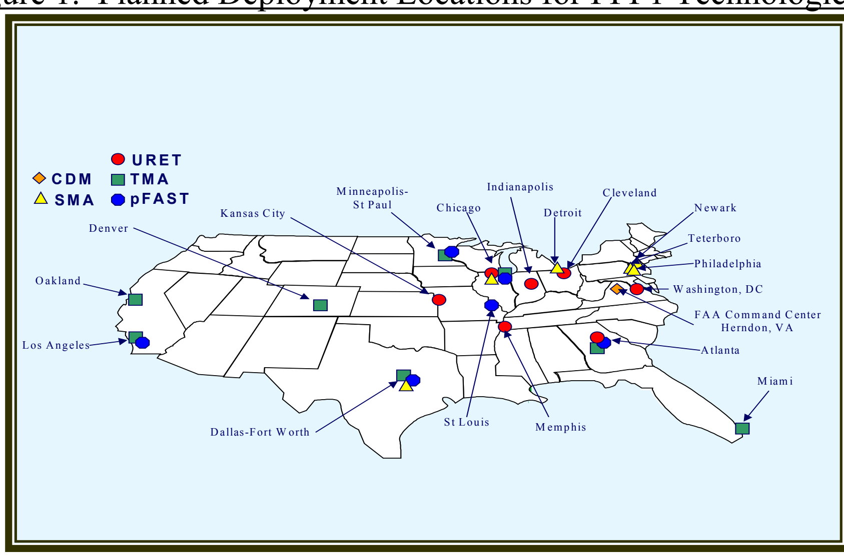
Automated Tools for the Controller

- User Request Evaluation Tool (URET) – is a decision support conflict probe that assists controllers in managing traffic, supporting pilots' requests for flight plan changes, and detecting potential conflicts between aircraft and between aircraft and restricted airspace. It uses electronic flight data to *enhance flight data management currently accomplished with paper flight strips*, which controllers use to track the position of aircraft.

- Center-Terminal Radar Approach Control Automation System (CTAS) – includes the *Traffic Management Advisor (TMA)* and *passive Final Approach Spacing Tool (pFAST).* During peak rush periods, TMA performs calculations previously performed by controllers to help determine when, where, and at what rate aircraft will transition from en route to TRACON airspace and provide preliminary runway assignments. pFAST was intended to pick up where TMA leaves off by calculating the final runway assignments for aircraft in TRACON airspace and scheduling the aircraft for landing in such a way that demand is evenly balanced across runways.

FFP1 reflects FAA's philosophy of "build a little, test a little, and deploy a little" before committing to deploy large, complex systems throughout the NAS. FAA's goal was to get the technologies to the field as quickly as possible and begin to assess benefits. By the end of 2002, FAA plans to deploy FFP1 technologies, which are at varying levels of maturity, at select locations (See Figure 1) to assess benefits and operational impacts.

Figure 1. Planned Deployment Locations for FFP1 Technologies



Source: FAA

Table 1.1 summarizes the planned deployment schedule for each FFP1 technology.

Table 1.1. Deployment Schedule Planned for Each FFP1 Technology

FFP1 Technology	Planned Deployment Schedule
SMA	Six airports—Chicago O'Hare (December 1999), Dallas-Fort Worth (December 1999), Detroit (December 1998), Newark (December 1999), Philadelphia (December 1998), and Teterboro (December 1999).
CDM	FAA's Command Center and participating airlines' operations centers—Enhanced Ground Delay Program (September 1999), Initial Collaborative Routing (July 1999), and NAS Status Information (June 2001).
URET	Seven Centers—Atlanta, Chicago, Cleveland, Indianapolis, Kansas City, Memphis, and Washington (August 2002).
TMA	Eight Centers—Atlanta (February 2002), Chicago (to be determined), Denver (March 2001), Fort Worth (April 2000), Los Angeles (November 2001), Miami (May 2002), Minneapolis (December 2000), and Oakland (August 2002).
pFAST	Six TRACON facilities—Atlanta (September 2001), Chicago (to be determined), Dallas-Fort Worth (April 2000), Los Angeles (August 2001), Minneapolis (December 2001), and St. Louis (April 2002).

Note: Deployment of TMA at Chicago Center will be determined after the completion of a review and redesign of the airspace surrounding Chicago.

Source: FAA data.

In April 1999, FAA estimated the total cost of FFP1 to be $837.7 million from fiscal year (FY) 1998 through FY 2007. Of this total, *deploying* FFP1 technologies was estimated to cost $628.8 million from FY 1998 through FY 2002, and *sustaining* the technologies from FY 2003 through FY 2007 was estimated to cost another $208.9 million. FAA has not revised its estimate. Table 1.2 shows the estimated cost for FFP1.

Table 1.2. FAA's Baseline Cost Estimate for FFP1 (April 1999)

Activity	Estimated Cost (Dollars in Millions)
Total – Deploy FFP1 Technologies (FY 1998 through FY 2002)	$628.8
• CDM	$64.4
• SMA	$7.8
• URET	$296.7
• CTAS	$224.2
• FFP1 Integration	$35.7
Total – Sustain FFP1 Technologies (FY 2003 through FY 2007)	$208.9
Total - Deploy and Sustain FFP1 Technologies (FY 1998 through FY 2007)	$837.7

Note: FFP1 Integration includes activities that cut across FFP1 technologies, such as performing human factors work and conducting assessments of benefits.
Source: FAA data.

CDM AND SMA ENHANCE THE EXCHANGE OF INFORMATION AMONG NAS USERS

Collaborative Decision-Making

CDM, with an estimated cost of $64.4 million, is an information-exchange technology that is comprised of three major components—Enhanced Ground Delay Program, Initial Collaborative Routing, and National Airspace System Status Information. CDM is arguably the most successful FFP1 initiative to date.

> **Collaborative Decision-Making**
>
> - Potential benefits. CDM links participating airlines with FAA's Command Center and provides FAA with real-time information on changes to airlines' schedules. During periods of bad weather, CDM enables FAA to reallocate arrival slots that would have previously gone unused to airlines that can use them.
> - Estimated cost. $64.4 million
> - Deployment status. Deployment is complete.

CDM links 45 participating airlines with FAA's Command Center and facilitates the real-time exchange of information on changes to flight schedules. For the first time, FAA and airline decision-makers have a common understanding of the demands placed on the NAS and the systemwide impacts of bad weather, which is a leading cause of delays.

According to FAA, CDM is helping the agency better manage the effects of inclement weather on airport capacity. Inclement weather, such as thunderstorms, can trigger rerouting of aircraft, a shift to instrument flight rules, or the closing of runways (which reduces the number of aircraft an airport can accommodate). Before CDM, FAA did not have information on how airlines changed their flight schedules (e.g., by delaying or canceling flights) in response to reductions in airport capacity caused by bad weather. Consequently, when FAA implemented ground delay programs,[1] it often reserved capacity for flights that airlines had already canceled or delayed. As a result, FAA delayed many flights longer than necessary.

Now, when inclement weather causes FAA to propose a ground delay program, airlines may change their flight schedules in response and communicate these changes to FAA. Airlines may cancel, combine, swap, or delay flights, in turn,

[1] During periods of bad weather, an airport's capacity is often reduced—for example, by the closure of one or more runways. Because capacity is reduced, the airport cannot accommodate all of the aircraft scheduled to use the airport's resources (e.g., arrival and departure runways). For reasons of safety and fuel efficiency, FAA imposes delays on aircraft scheduled to arrive at the affected airport while they are still on the ground at their originating airports rather than waiting until after they are airborne. Such a plan for delaying the departure of aircraft while they are still on the ground is called a ground delay program.

affecting the availability of arrival slots. CDM uses a complex process to distribute any unused arrival slots by looking at the flights of other airlines to determine whether any may be moved up to fill the vacated slots.

CDM does not add new capacity, but it helps make better use of reduced capacity during inclement weather. By using arrival slots more efficiently, CDM reduces FAA-assigned delays during ground delay programs, according to FAA metrics. While CDM has helped airlines make better business decisions regarding the use of aircraft, these benefits have been largely transparent to the traveling public. CDM only reduces delays resulting from weather-related reductions in capacity, not those resulting from mechanical or other problems, and CDM's impact will be limited by the extent to which reduced capacity was inefficiently allocated prior to CDM.

Surface Movement Advisor

SMA, at an estimated cost of $7.8 million, provides airline ramp tower and Airline Operations Center personnel with information, which was previously unavailable, on the location of aircraft within 30 miles of an airport. SMA was deployed on schedule,[2] and it is the least complex and technologically challenging initiative in the FFP1 portfolio.[3]

Surface Movement Advisor

- Potential benefits. SMA provides real-time information to Airline Operations Centers and airline ramp towers on aircraft approaching within 30 miles of an airport that can be used to compute estimated touchdown times. Airlines use this information to avoid costly diversions and coordinate ground support operations.
- Estimated cost. $7.8 million
- Deployment status. SMA has been fully deployed at all six planned airports.

SMA was originally intended to enhance airline ground operations—gate operations, baggage handling, and aircraft refueling—but airlines are finding additional uses for the technology. For example, at the request of Northwest Airlines, SMA was deployed at its Minneapolis Airline Operations Center in addition to the airport

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[2] SMA was deployed at Detroit Metropolitan Wayne County Airport and Philadelphia International Airport in December 1998 and at Chicago O'Hare International Airport, Dallas-Fort Worth International Airport, Newark International Airport, and Teterboro Airport in December 1999. In addition to the deployment planned for FFP1, SMA was deployed at Hartsfield Atlanta International Airport, Lambert St. Louis International Airport, and Minneapolis-St. Paul International Airport in May 2000 and Chicago Midway Airport, Dallas-Love Field, New York John F. Kennedy International Airport, and New York LaGuardia Airport in June 2000. It has also been deployed at Airline Operations Centers of American Airlines, Continental Airlines, Northwest Airlines, Southwest Airlines, Trans World Airlines, United Airlines, and U.S. Airways.

[3] The SMA system being deployed as part of FFP1 is a scaled-down version of the prototype system developed by the National Aeronautics and Space Administration and deployed at the Hartsfield Atlanta International Airport in 1997.

ramp tower at Detroit Metropolitan Wayne County Airport as originally planned. Northwest is using SMA data to improve situational awareness, reduce the number of aircraft diversions, and improve planning for missed approaches. Northwest and FAA estimate that SMA helps Northwest avoid an average of three to five diversions[4] per week for aircraft destined for Detroit during weather-impacted periods. Northwest estimates the cost of each diversion is between $5,000 and $50,000, depending on the aircraft and distance of the diversion.

NEW AUTOMATED TOOLS FOR CONTROLLERS HELP ENHANCE THE FLOW OF AIR TRAFFIC

User Request Evaluation Tool

The MITRE Corporation has been developing URET since 1995, and prototypes have been in daily use since 1997 at the Indianapolis and Memphis Centers. FAA's data indicate that use of the tool has increased largely because controllers are now able to enter amendments to flight plans directly to the HOST computer (the nerve center of the en route facility) at the click of a button. URET will also be integrated with the new Display System Replacement, which provides en route controllers with modern displays.

User Request Evaluation Tool

- Potential benefits. URET enables controllers to evaluate proposed changes to flight plans by modeling the planned flight paths of aircraft and by indicating conflicts with other aircraft. Prototype systems are helping controllers shorten flight distances and remove altitude restrictions, thereby helping to reduce the airlines' fuel consumption.
- Estimated cost. $296.7 million.
- Deployment status. Prototypes are in use at two locations, and one of seven production systems has been delivered.

URET helps controllers amend flight plans, remove altitude restrictions,[5] and shorten flight distances, which in turn can save airlines time and fuel. FAA reports that, to date, Indianapolis Center has lifted or modified about 20 restrictions, which saves the airlines about $1 million annually. For example, in May 2000, URET enabled controllers at Indianapolis Center to permanently remove an arrival restriction into Pittsburgh, which had constrained aircraft to an altitude of 29,000 feet or below. Although not a direct result of any URET test, controllers decided that they no longer required the restriction because they had URET to search the airspace for potential conflicts. Each day, nine aircraft were affected by this restriction. U.S. Airways estimates that the removal of this restriction allows these nine aircraft to fly at more fuel-efficient altitudes for

[4] Aircraft diversions primarily occur as a result of poor weather (reducing the airport acceptance rate), mechanical problems (forcing aircraft to land prior to their destination), or terminal congestion (resulting from unavoidable en route and terminal delays).
[5] Altitude restrictions are put in place to separate air traffic passing through the same area of the NAS.

almost 90 nautical miles daily, which translates to approximately $125,000 in annual fuel savings.

Center-TRACON Automation System

FAA and the airline industry consider CTAS one of the most promising technologies for enhancing airport capacity because it helps controllers to transition aircraft from en route to terminal airspace for approach and landing. CTAS was pioneered by NASA and consists of two components—TMA (for Centers) and pFAST (for TRACONs). TMA was originally planned for eight sites and pFAST for six sites. FAA has stopped work on pFAST and is exploring options for moving forward.

Center-TRACON Automation System

- Potential benefits. TMA generates routes and schedules to meter fixes, provides scheduled and estimated times of arrival, assigns runways, and produces sequence lists for arrival traffic at high altitudes. By smoothing out arrival demand, TMA is expected to increase Airport Acceptance Rates and the actual number of operations equipped airports can handle. pFAST generates final runway assignments and arrival sequence numbers for arrival traffic in TRACON airspace. pFAST was anticipated to help TRACON controllers better balance runways, accept more aircraft from high altitude controllers, and increase the number of operations that equipped airports can handle.
- Estimated cost. $224.2 million
- Deployment status. TMA prototype is in use at one of the eight planned locations, and production systems are at various stages of deployment at another five locations. Work on pFAST as envisioned for FFP1 has stopped and FAA is exploring alternatives.

Versions of TMA, at varying stages of deployment, are in use at six Centers—Fort Worth, Atlanta, Denver, Los Angeles, Miami, and Minneapolis.

Controllers at Fort Worth Center are using TMA during peak rush periods (also referred to as arrival banks) to smooth out arrival demand, and anecdotal evidence indicates that using TMA increases the Dallas-Fort Worth acceptance rate. According to FAA, because TMA has been in uninterrupted use at the airport since a major airspace redesign, the agency has been unable to analyze the performance of TMA from a "before" and "after" perspective. However, long-time air traffic managers at Fort Worth Center report that using TMA has increased the Airport Acceptance Rate by approximately six aircraft during peak rush periods.

Although the measurement of TMA's performance at Minneapolis Center is in its early stages, preliminary results indicate that TMA is improving traffic flows into Minneapolis Airport. According to FAA's preliminary analysis, TMA is increasing the airport's capacity by about three operations during each of the eight busiest 30-minute peak rush periods per day. Table 1.3 shows how TMA impacts operations.

Table 1.3. TMA Has Increased the Number of Operations (Arrivals and Departures) at Minneapolis During 30-Minute Peak Rush Periods

During Each 30-Minute Peak Rush Period	TMA "Off"	TMA "On"	Amount of Increase
Number of Arrivals under Visual Flight Rules	32.4	33.1	0.7
Number of Operations under Visual Flight Rules	52.4	55.3	2.9
Number of Arrivals under Instrument Flight Rules	29.8	31.1	1.3
Number of Operations under Instrument Flight Rules	50.5	53.4	2.9

Source: FFP1 Program Office

Before work stopped, pFAST was helping controllers to land more aircraft at Dallas-Fort Worth. According to FAA, when pFAST was being used, controllers were able to increase Dallas-Fort Worth's acceptance rate by approximately 2.5 aircraft per hour.

OBSERVATIONS ON ANTICIPATED BENEFITS OF FFP1 TECHNOLOGIES

- An important lesson learned is that the nature and extent of benefits from the new technologies differ from facility to facility due to, among other factors, differences in airspace complexity, traffic mix, local procedures, number of runways, and runway configurations. Thus, the benefits from CTAS in airspace surrounding Dallas-Fort Worth might not be replicated at other airports. For example, Dallas-Fort Worth airport in particular has certain characteristics—seven runways, five of which are parallel—that play to CTAS strengths for sequencing aircraft.

- According to FAA, demand at Dallas-Fort Worth quickly increased to fill the additional capacity provided by the FFP1 technologies, and delays continue to increase. As long as demand continues to increase, additional capacity provides no assurance that delays will improve, particularly at large hub airports. A recent analysis by the MITRE Corporation of throughput and delay at LaGuardia shows that as demand rises, there comes a point at which the gentle increase in delay turns into a steep increase with each additional flight.[6]

- FAA is doing a good job of collecting data on the benefits of the new technologies but will not have a firm understanding of these benefits until

[6] "Demand Dependence of Throughput and Delay at New York LaGuardia Airport" (The MITRE Corporation, Center for Advanced Aviation System Development, October 9, 2000).

systems are fully deployed. At each site where a new controller tool is being installed, FAA plans to collect 1 year of baseline data, allowing the agency to compare performance from a "before" and "after" perspective. In measuring benefits, FAA is focusing on operational user benefits—such as Airport Acceptance Rates, throughput, flight times and distances, and removing restrictions—as well as costs. Notwithstanding FAA's efforts, there are two areas that warrant much closer attention.

-- First, an important question facing FAA is how well the various FFP1 technologies work together—in other words, whether the operation of one technology positively or negatively impacts the benefits provided by another technology and to what extent. How the FFP1 technologies work in concert to enhance capacity and reduce delays is not well understood.

-- Second, there is room for additional *simulation modeling* to analyze the combined benefits of the FFP1 technologies, the impact of planned airspace changes on these benefits, and the impact of these technologies on safety. Today, new models are sufficiently robust with a high degree of fidelity to help decision-makers examine how the introduction of new technologies affects operations throughout the NAS.

Because benefits of new technologies vary by location, FAA needs to make sure that it deploys new technology where it can receive the largest capacity benefits for the investment. Use of simulation modeling would be useful in targeting the deployment of new technologies. It could also prove useful for assessing changing industry patterns affecting capacity and modernization efforts, such as greater use of regional jets and potential impacts of airline consolidation. FAA should build on its ongoing modeling work to develop capacity benchmarks and begin using new analytical techniques on a targeted basis.

RECOMMENDATION

We recommend that FAA make targeted use of advanced modeling to assess impacts of multiple Free Flight initiatives on enhancing capacity and reducing delays. This effort should address technology, procedures, and airspace redesign. It should also be linked to FAA's work on *capacity benchmarks* and the NAS Operational Evolution Plan.

CHAPTER II. SOFTWARE DEVELOPMENT IS PROVING MORE COMPLEX AND COSTLY THAN ANTICIPATED

URET and CTAS involve the development, refinement, and testing of almost 2.3 million lines of complex computer code (See Table 2.1), which has grown by almost 70 percent since December 1999. Together, URET and CTAS comprise over 80 percent of the cost to deploy FFP1. Schedules have always been aggressive, and these tools depend on the development of complex mathematical formulas for detecting conflicts between aircraft and sequencing aircraft for arrival.

Table 2.1. Lines of Software Code and Estimated Costs for FFP1 Controller Tools

Technology	Estimated Lines of Code as of Dec. 1999	Estimated Lines of Code as of June 2001	Percentage Increase	Estimated Costs Through FY 2002 (Dollars in Millions)	Funds Obligated as of Sept. 2001 (Dollars in Millions)
URET	526,000	613,000	17%	$296.7	$241.9
CTAS	832,000	1,665,000	100%	$224.2	$180.0
Total	1,358,000	2,278,000	68%	$520.9	$421.9

Note: Estimates include work for pFAST, which has been stopped while FAA explores options for moving forward. Costs include contract and program costs but not previous research and development. Figures for lines of code do not include the effort required for customizing TMA and pFAST to each deployment site. CTAS code growth represents a split in baselines with approximately 750,000 lines of NASA carry code.

Source: FAA's FFP1 Program Office.

Although FAA's "build a little, test a little, and deploy a little" approach has helped mitigate some of the problems that have plagued past FAA acquisitions, several significant risks remain. First, URET will cost more than FAA is projecting. Second, CTAS is proving more difficult than anticipated, and the cost to successfully deploy the tool is uncertain. Finally, although most of the initial development work for the new controller tools has been completed, site adaptation is a key cost and schedule driver for CTAS.

In December 1999, we made recommendations to FAA regarding how it could strengthen its overall management of both URET and CTAS. We recommended that FAA (1) negotiate contracts with provisions for earned value management and software metrics, (2) require contractors to correct deficiencies and fully implement earned value management techniques, and (3) identify appropriate software metrics for FFP1 technologies.

We emphasized that FAA should avoid time and material contracts, which increase risks to the Government because they provide the contractor no incentive to control costs or stay on schedule. While FAA agreed with our recommendations and has taken steps to improve earned value management reporting and use software metrics, it continued to rely on time and material contracts for CTAS.

URET WILL COST MORE THAN FAA PLANNED

FAA remains committed to deploying URET to all FFP1 locations by the end of 2002. In January 2001, the contractor began the task of integrating and testing the tool in the field. However, the total cost of the tool will be higher than originally planned.

FAA and Lockheed Martin, the prime contractor for developing URET, both acknowledge that URET is incurring cost overruns to stay on schedule.[7] Lockheed Martin's cost-plus-incentive contract for developing URET had an initial estimated cost of about $172 million. However, in May 2001, Lockheed Martin and FAA estimated that the total cost of the contract would range between $194.8 million and $207.6 million at completion, or about $23 million to $36 million (14 to 21 percent) more than originally estimated.

According to FAA and the contractor, the main reasons for the cost overruns are computer code growth and lower-than-anticipated productivity with respect to software development. For example, FAA underestimated the number of lines of computer code that would be needed to complete the capabilities planned for URET. Since December 1999, URET has experienced code growth of about 17 percent. Code growth during high-level design for the trajectory tool (the component of URET that models the flight paths of aircraft) resulted in cost overruns exceeding $2.2 million. Further cost overruns are likely because considerable work remains with respect to deploying, adapting, and testing the tool in the field.

CTAS IS PROVING MORE DIFFICULT THAN ANTICIPATED

It has become more difficult and time-consuming than FAA anticipated to transition CTAS from a research system to a production system. Moreover, FAA and NASA misjudged the maturity of pFAST.

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[7] FAA has also deferred some capabilities which controllers have agreed are not critical to URET's functionality. For example, the auto-coordination capability, which provides controllers with another means to transition aircraft affected by URET from one sector to another, has been moved to a later date.

CTAS code requirements had doubled from the original estimate of 832,000 lines of code to an estimate of about 1.7 million, excluding the work required to customize the tool for each location. FAA attributes most of the increase to its December 1999 decision to separate the CTAS baselines (TMA and pFAST) and redistribute the workload among contractors.[8]

The TMA segment of CTAS is proving more mature and will face less difficulty being implemented during FFP1 than pFAST. TMA has been deployed to six centers, and controllers at these centers are gaining experience using the tool.

pFAST, on the other hand, has proven to be far less mature than FAA anticipated, and the new tool cannot be deployed as originally planned. The sequencing function of pFAST became controversial with controllers. During our visit to the Dallas-Fort Worth TRACON, we observed that one of the most important benefits of pFAST—providing controllers with the sequencing order for landing aircraft—was being suppressed because of technical problems and controller concerns. FAA subsequently stopped work on the new tool and FAA officials told us that controllers are no longer using it at Dallas Fort-Worth TRACON.

The key cost and schedule driver for pFAST became adaptation—the effort required to customize the tool to the specific airspace surrounding each site. pFAST software was developed specifically for Dallas-Fort Worth airspace, but each airport is unique, having different runway configurations, restrictions, and local procedures. Furthermore, *pFAST is dynamic*, meaning that it must be able to change quickly when, for example, the airport changes runway configurations due to winds or adverse weather. Adapting pFAST to the airspace of more congested airports, such as Southern California (Los Angeles) TRACON, along with their operational and procedural complexities, was difficult for FAA because it required operational considerations that NASA's baseline was not specifically designed to accommodate.

OBSERVATIONS ON SOFTWARE DEVELOPMENT AND SUSTAINMENT

- *First, in the future, FAA needs to do a better job of assessing the technological maturity of new systems before deploying them.* Greater attention to maturity is needed because (1) FAA and NASA misjudged the maturity of pFAST and (2) Free Flight Phase 2 (FFP2) includes considerable research efforts that have an uncertain maturity level. Both NASA and the Department of Defense categorize technological maturity (from 1 to 9 technology and implementation readiness levels) that would help FAA facilitate technology transfer and assess

[8] CTAS code growth represents a split in baselines with approximately 750,000 lines of code developed by NASA, which FAA refers to as "carry code."

maturity before committing to deployment. We note that FAA has begun to examine this matter.

- *Second, as we noted in December 1999, FAA needs to avoid time and material contracts.* To expedite work, FAA relied on existing contracts. The majority of work on CTAS has been performed on contracts where payments were based on the time spent and material used by the contractors—payments were not directly linked to deliverables. There was no direct linkage between payment and actual work performed, nor were there strong incentives for the contractor to control costs or use labor efficiently—all risks were with the Government. FAA has established a new contract vehicle for CTAS but some work will remain on a time and material contract. FAA should avoid time and material contracts for software intensive acquisitions.

- *Finally, a related software issue is the cost to sustain the new tools. FAA should begin tracking the cost to sustain the new software-intensive tools in considerable detail, because it will need this information to properly plan its operations budget.* The sustainment costs for the limited deployment of the new tools is estimated to be about $208.9 million from FY 2003 through FY 2007, but the costs could be much greater due to the site-specific nature of the tools and the sensitivity to airspace changes.

  FAA officials we interviewed are concerned that sustainment costs, which principally focus on adaptation and/or software, will place additional stress on FAA's operations account. The new automated tools are sensitive to changes in air traffic control procedures and airspace. In fact, the effectiveness of the new tools depends on their ability to keep pace with such changes. Consequently, procedural and airspace changes may trigger changes in adaptation and/or software. FAA needs to begin tracking the associated sustainment costs once deployment is complete to ensure adequate funding is available in the future to keep the new tools working properly.

RECOMMENDATIONS

We recommend that FAA:

1. Avoid time and material contracts for software-intensive acquisitions. Contracts should be negotiated with alternative pricing arrangements, award fees, and incentives. Funding for CTAS development should be contingent on moving completely away from time and material contracts.

2. Submit a revised budget for Free Flight, which reflects the costs to deploy the automated tools, new security enhancements, reductions in systems not

urgently needed, and reduction in funds for elements that cannot be deployed due to technical problems.

3. Defer funding for further development of pFAST—or the CTAS terminal solution—until a clear-cut strategy for moving forward has been assessed in terms of cost and benefits, validated, and decided upon.

4. Based on NASA and the Department of Defense initiatives, develop “technology readiness metrics” for FAA’s “build a little, test a little, and deploy a little" Free Flight initiatives.

5. Begin tracking sustainment (and related adaptation) costs associated with the new tools once deployment is complete, and reflect these costs in future FFP2 planning.

6. Prepare a “lessons learned” analysis of FFP1’s software development experiences for use in improving the management of other NAS modernization efforts.

CHAPTER III. NEW AUTOMATED TOOLS FOR THE CONTROLLER HAVE FAR-REACHING HUMAN FACTORS IMPLICATIONS FOR THE CONTROLLER WORKFORCE

The new FFP1 tools for the controller will change the way controllers manage air traffic. The tools are expected to provide the greatest benefit when controllers are handling large numbers of aircraft. To its credit, FAA has involved controllers in the development of these systems, formed controller teams to test the tools, and developed human factors plans for URET and CTAS. However, some uncertainty exists about what productivity enhancements can be obtained, and how quickly controllers will accept the tools. The changes brought about by these tools will also have important implications in terms of controller selection, training, and staffing levels.

FAA has taken a number of steps to address human factors issues associated with the new controller tools, and controllers are gaining valuable experience, but significant challenges remain.

- As FAA continues to implement the new tools, the agency will need to pay close attention to the impacts of automation on *controller workload, situational awareness, teamwork, and what happens when a new tool is not available*. As experience is gained and controllers come to depend on the new tools, important questions will need to be answered about how controllers deal with failures, errors, and unusual events. This means that training programs and procedures will need to be revised, which in turn, will spur the need for additional human factors research and "lessons learned" analyses.

- The *combined impact* of the various new technologies on controllers is also an important issue that deserves greater attention. Until recently, new automated systems have been developed and used in relative isolation from one another. During FFP1, only one facility, Atlanta Center, will receive two tools—URET and TMA.[9] However, during FFP2, en route controllers might be using URET, TMA, and new weather products to help manage air traffic. At some time in the future, they will also be using data link communications. Continued human factors work, including "human-in-the-loop" simulations (using experienced controllers in a laboratory), is needed to ensure new technologies work in a synergistic fashion and do not degrade safety.

- According to FAA, the most effective way to ensure controllers use the tools is to enter into agreements with the controllers' union at both the national and

[9] Initially, FAA planned to install both URET and TMA at Chicago Center as well, but FAA no longer plans to deploy TMA at this facility during FFP1.

local levels. To date, FAA has a handful of agreements, which are more reflective of a limited deployment than a traditional, nationwide deployment.

URET INTRODUCES CONFLICT PROBE CAPABILITIES AND ELECTRONIC FLIGHT DATA

URET has important human factors implications because, in addition to providing conflict probe and trial planning capabilities, *it will use electronic flight data to enhance flight data management currently accomplished with paper flight strips, which controllers use to track air traffic*. Flight strips currently play a key role in how controllers manage the flow of traffic and predate the introduction of radar.

At present, each air traffic control facility prints out strips of paper for each flight traveling in the airspace managed by the facility. These strips of paper contain information about the flight, including the airline, flight number, aircraft type, altitude, and departure and arrival locations. Controllers use these paper flight strips to facilitate their awareness of the relationships between aircraft and to strengthen their memory of flight data. Efforts in the late 1980s and early 1990s to move toward automated flight data were highly controversial and were not successful.[10]

Controllers using URET at Memphis and Indianapolis Centers have mixed feelings about URET but were generally supportive of efforts to use electronic flight data. Since the introduction of a two-way link between URET and the HOST computer, which allows controllers to make revisions to flight plans at a click of a button, use of the new tool has steadily increased.

Experts caution that automating the presentation and updating of flight data (e.g., by placing the data in electronic form on the URET displays) could affect the controllers' mental picture and situational awareness of air traffic.[11] In addition, there are a number of human factors issues with URET that FAA teams are addressing, including the impact on controller teamwork and procedures for transitioning back to paper flight strips when URET is not available.

CTAS INTRODUCES A NEW WAY OF MANAGING AIR TRAFFIC

CTAS also has important human factors implications because it introduces a new procedure for managing the flow of air traffic. TMA—the en route segment—will require many air traffic controllers to change their technique for metering aircraft from miles-in-trail to *time-based.*

[10] A key element of the Advanced Automation System was to provide automated flight data to controllers.
[11] See The Future of Air Traffic Control: Human Operators and Automation, National Research Council, 1998.

The most commonly used technique today is miles-in-trail metering, which manages the flow of air traffic by imposing a specified minimum separation distance between aircraft. *Time-based metering*, on the other hand, manages air traffic by assigning each aircraft a time at which the aircraft should reach a specified point in the airspace (called a meter fix). Currently, three of the seven en route centers scheduled to receive TMA during FFP1 use time-based metering.[12]

Time-based metering is a cornerstone of Free Flight, and FAA intends to fully shift to time-based metering some time in the future. According to FAA, time-based metering enables controllers to estimate separation distances between aircraft more precisely and merge traffic from several converging flight paths into a common arrival stream—important attributes for a Free Flight environment.

Acceptance of time-based metering will vary significantly by location, and it will take time for controllers to gain trust in the new system. For example, controllers we interviewed at Fort Worth Center who are currently using time-based metering indicated that they were comfortable using the technique. However, during our visit to Minneapolis Center, we were told that controllers still were not comfortable using time-based metering even though they had been using this technique for several years.

An important issue focuses on the need for aircraft to hit their "meter fixes" more precisely to realize the maximum potential benefit of TMA.[13] The realization of benefits depends on all controllers using TMA and having a clear understanding of meter times.

Although CTAS makes only modest changes to what controllers see on the radar display, it significantly affected how TRACON controllers do their job with respect to sequencing arriving aircraft. pFAST—the terminal segment of CTAS—changes the way controllers prepare aircraft for landing by providing controllers with landing sequences and runway assignments, which are displayed on the radar screen.

pFAST became controversial with controllers and FAA stopped work on the new automated tool. We note that the terminal and tower environments are difficult to change, and the challenges should not be underestimated. In these environments, the controller is the potential single point of failure and must accomplish both time- and safety-critical functions.

[12] These three centers are Denver, Fort Worth, and Minneapolis.

[13] In order for TMA to provide maximum benefits, controllers must deliver their aircraft to meter fixes within plus or minus 1 minute of the assigned times. At the time of our visit, we were informed that controllers at Minneapolis Center were delivering aircraft to fixes within plus or minus 3 minutes.

URET and CTAS may refine the controller's job to the extent that new operational practices and techniques will be required, which could entail substantial changes in the selection and training of controllers. Because the full impact of these changes is unknown, FAA needs to be forward looking and identify what training will be required for current controllers as well as new hires.

CONTROLLER ACCEPTANCE IS NEEDED TO MAXIMIZE THE BENEFITS OF NEW CONTROLLER TOOLS

FAA has extensive efforts underway to gain controller acceptance, which include forming national and local air traffic control user teams, conducting demonstrations and training, and providing experience on prototypes.

For the new controller tools to be most effective, all controllers must use them when the tools are available. According to URET user teams, all controllers in all sectors of an en route center must use the technology in order for the full benefit to be realized.

According to FAA, the most effective way to ensure controllers use the new tools is for FAA to enter into agreements with them at both the national and local levels. *Moreover, Article 48 of the existing National Air Traffic Controllers Association Union Agreement clearly states FAA must negotiate changes arising from revisions to technology, procedures, or airspace that affect controllers*.[14]

Such agreements between FAA and the National Air Traffic Controllers Association would formalize when and how the tools would be used. While these agreements cannot guarantee, nor should they, that controllers will always follow the advice provided by the tools, they could formally address a number of potential stumbling blocks to acceptance, such as overtime pay, training, and controllers' liability in the event using the tools led to an operational error or deviation. To date, a number of agreements have been reached, which are reflective of a limited deployment, and work remains. (See Table 3.1.)

[14] The provisions of the Union Agreement are presented in the document titled Agreement Between the National Air Traffic Controllers Association AFL/CIO and the Federal Aviation Administration, Department of Transportation, dated Sept. 1998.

Table 3.1. Status of National and Local Agreements with Controllers Regarding the Use of New Controller Tools

New Controller Tool	Status
URET	FAA and the Controllers Union reached a national agreement in July 2001, which covers the URET functionality that will be delivered to the seven FFP1 sites. Local memorandums of agreement have also been signed for the prototype systems at the Indianapolis and Memphis centers and a local agreement for Kansas City was signed in November 2001. Local Agreements are needed for the remaining four sites.
TMA	There is no national agreement. A local memorandum of understanding has been signed for the system at Los Angeles Center. TMA operating procedures have been developed, agreed to by FAA and the National Air Traffic Controllers Association, and incorporated into Fort Worth Center's standard operating procedures. Informal agreements are in effect at Denver and Minneapolis Centers but there are no local agreements at the other FFP1 sites.
pFAST	PFAST has been controversial and work has stopped while FAA explores options for moving forward. FAA and the National Air Traffic Controllers Association reached a national agreement in May 2000, which covers only the pFAST functionality that will be delivered to the six FFP1 sites and expires 90 days after the date that deployment at the last of these six sites is completed. A local order and local agreement between FAA and the National Air Traffic Controllers Association have been developed to describe how pFAST will be used at the Dallas-Fort Worth TRACON. Local memorandums of understanding have been signed for the systems at Minneapolis and Southern California TRACONs but not for the other FFP1 sites.

RECOMMENDATIONS

We recommend that FAA:

1. Conduct human factors work that examines the combined impact of new technologies (such as conflict alerts, electronic flight data, and improved weather data) on controllers, including "human in the loop" simulations. Key issues to be researched include safety, workload, situational awareness, and teamwork.

2. Ensure controller acceptance of the new automated controller tools by obtaining national and local agreements with controllers. The agreements should be updated as more experience is gained with new tools, and they should set parameters for progressing from limited to universal usage of the tools.

CHAPTER IV. FAA MUST TAKE A NUMBER OF STEPS TO ENSURE THE LONG-TERM SUCCESS OF ITS FREE FLIGHT INITIATIVES

FAA is finalizing a plan for FFP2, which includes the geographic expansion of URET and TMA, and the introduction of new technologies, such as Data Link, from 2003 through 2005. FAA estimates FFP2 will cost over $800 million, excluding costs for Data Link, which are still being refined. (See Table 4.1.)

Table 4.1. FAA's Plan for FFP2, as of June 2001

Technology	FFP2
URET	9 additional Centers
pFAST	None planned
TMA	4 additional Centers
CDM	20 Centers, FAA Command Center, and Airline Operations Centers (enhanced version)
SMA	None planned
Collaborative Routing Coordination Tools	20 Centers and FAA Command Center
Data Link (Builds 1 and 1A)	20 Centers

Note: This table does not include the several research efforts that FAA plans to accelerate during FFP2.
Source: FAA data.

FAA is rethinking its investment strategy with respect to Free Flight and related efforts in light of the September 11th terrorist attacks. FAA is reassessing the scope and direction of its Operational Evolution Plan, which lays out the improvements that are planned over the next decade to enhance capacity. The plan has similar goals to Free Flight and includes satellite-based systems, such as *Automatic Dependent Surveillance-Broadcast*, which will be managed outside the purview of Free Flight. FAA needs to articulate how new security concerns will be addressed and exactly how program execution, management, and the budgets of various efforts—the Operational Evolution Plan, FFP1, and FFP2—can be harmonized in a concrete fashion.

The time is right for FAA to pause in the execution of Free Flight initiatives and the Operational Evolution Plan to assess budgetary priorities and design in light of September 11th. A number of important questions need to be addressed.

- In light of September 11th, are there security risks with the ultimate goal of Free Flight, and if so, how will they be mitigated?

- Which Free Flight technologies should receive priority and which ones should be deferred?

- How will the budgets and management of Free Flight and the Operational Evolution Plan be harmonized and reconciled?

- What are the implications of September 11th, general economic conditions, and the financial shape of the airline industry on the budgets and milestones of capacity-enhancing initiatives, such as Free Flight and the Operational Evolution Plan?

Linking FAA's plans is critical at this juncture because of the extraordinarily complex interdependencies among modernization efforts. The NAS is a complex "system of systems"—slips in one effort can negatively impact another. Interdependencies focus on the programmatic issues (dollars and milestones) as well as the systems and procedures that have to be brought together on time to deliver the capability. Concerns with human factors, software development, and interdependencies with other systems (e.g., HOST and weather systems) will become even more pronounced over the next several years.

A key issue focuses on how the air and ground systems under development will work together, and how the transition from a command-and-control to a more flexible system envisioned under the general concept of Free Flight can be realized. In moving forward, FAA must consider a number of actions that will increase the long-term chances for success. These include (1) continuing to monitor safety impacts and revisiting the issue of certification, (2) integrating weather technologies with Free Flight tools,[15] (3) coordinating Free Flight technologies with airspace redesign efforts, and (4) assessing the combined benefits of the Free Flight technologies.

SAFETY AND CERTIFICATION ARE IMPORTANT ISSUES

Experts caution that automation could introduce new safety issues that were not, and could not be, anticipated. Further, introduction of new technologies often has unintended consequences, such as increasing the number of incidents during a transition period.

FAA must continue to assess the safety impacts of the Free Flight technologies. This is a complex issue that involves testing the new tools, as well as the procedures for using them. As experience is gained, FAA should get an independent assessment of the tools' impacts on safety.

[15] For the purpose of this discussion, we refer to the tools introduced during FFP1 and FFP2 collectively as Free Flight tools.

Free Flight technologies will be deployed at many of the same air traffic control facilities, such as Cleveland and Chicago Centers, which have witnessed the largest number of operational errors.[16] The increasing number of operational errors is an urgent safety issue—nationwide, they have increased by 51 percent from 764 in FY 1996 to 1,154 in FY 2000 (See Table 4.2). However, as of June 2001, no incident is traceable to an FFP1 tool.

Table 4.2. FY 2000 Top 10 Facilities for Operational Errors, Changes from FY 1996, and Free Flight Technologies They Are Scheduled to Receive During Phase 1

Rank	Facility	Number of Errors FY 1996	Number of Errors FY 2000	Percent Increase	Free Flight Technologies Facility Is Scheduled to Receive During Phase 1
1	Washington Center	24	102	325%	URET
2	Cleveland Center	32	74	131%	URET
3	New York Center	44	71	61%	None
4	Chicago Center	26	70	169%	URET and TMA
5	Indianapolis Center	39	54	38%	URET
6	Atlanta Center	36	40	11%	URET and TMA
7	Memphis Center	21	38	81%	URET
8	Dallas-Fort Worth Center	23	34	48%	TMA
9	Los Angeles Center	19	33	74%	TMA
10	Denver Center	11	33	200%	TMA

Source: OIG

A related question focuses on certification—the process for ensuring a new system works as advertised. FAA views URET and CTAS as advisory tools rather than "mission critical" tools used to control air traffic. However, the lines between an advisory tool and a mission critical system are likely to blur in day-to-day operations.

FAA determined that the various FFP1 technologies, principally URET and CTAS, did not need to be certified during the 2002 timeframe. At the time of FAA's decision, a new system had to be certified if it provided (1) moment-by-moment positional information (e.g., radar systems); (2) communications (e.g., between pilots and controllers, between controllers and controllers, or between

[16] An operational error occurs when separation standards between aircraft are not maintained.

centers and centers); (3) weather data used during take-off and landing; or (4) power to a system that required certification.

In August 2000, FAA updated its "General Maintenance Handbook for Airways Facilities," in which the agency expanded the requirements for certification.[17] Now, any FAA NAS system, subsystem, or service directly affecting the flying public needs to be certified when it provides "decision support information that could affect aircraft heading, altitude, routing, control, or conflict awareness." In view of this change, FAA needs to revisit its analysis for each technology introduced during FFP1 to determine if and when the technology needs to begin the certification process.

INTEGRATING NEW WEATHER TECHNOLOGIES

An important consideration in reducing delays and meeting the demand for air travel is to integrate better weather forecasting and prediction capabilities. According to FAA, during 2000, air travelers experienced more flight delays than any year on record, and nearly 70 percent of the delays were caused by bad weather. FAA's Operational Evolution Plan includes efforts to address the impacts of bad weather around airports and on high-altitude traffic.

The flexibility to adjust to severe weather conditions has disappeared at all levels in the NAS as demand has grown to fill capacity at key airports. Bad weather conditions cause FAA to re-route aircraft, reduce the flow of aircraft, and close runways and airports – which severely reduces capacity and has a ripple effect throughout the NAS.

Integrating weather technology with Free Flight initiatives is important to help FAA better predict, manage, and recover from poor weather conditions. Making NAS performance on poor weather days look more like performance on good weather days is an important element for reducing delays. A key aspect to meeting this objective is to integrate better weather technology with traffic management tools to support the collaborative planning process.

The new automated controller tools, CTAS and URET, depend on accurate information on weather conditions. While current weather information (based largely on reports from the National Weather Service) will suffice in the near term, FAA officials told us that the performance of new tools will be enhanced with better weather forecasting information to plan and recover from severe weather.

[17] FAA Order 6000.15C, "General Maintenance Handbook for Airway Facilities," August 11, 2000.

FAA is pursuing the *Weather and Radar Processor* for en route controllers and the *Integrated Terminal Weather System* for TRACON controllers. The Weather and Radar Processor will support both URET and elements of CTAS. However, this system is experiencing serious technical problems, which are resulting in cost increases and schedule slips. In addition, a number of human factors issues have been raised, which focus on how graphical information will be displayed on controllers' screens. The Integrated Terminal Weather System is on schedule for deployment in 2002 (See Table 4.3).

Table 4.3. Cost and Status of the Weather and Radar Processor and Integrated Terminal Weather System

Technology	Cost	Status
Weather and Radar Processor provides en route meteorologists and air traffic controllers at en route facilities with more accurate graphical weather information to help identify weather conditions that may adversely impact air traffic operations.	$143.6 million for 21 sites	The Weather and Radar Processor has experienced delays and a 14-percent cost overrun due to a number of complex technical and human factors issues. FAA is in the process of re-baselining the funding accordingly. The first system is scheduled to be operational in January 2002—2 1/2 years later than originally planned.
Integrated Terminal Weather System provides air traffic management specialists in the terminal area with easy-to-understand graphical weather information to help detect and predict weather conditions.	$282.1 million for 37 sites	The first systems are scheduled to be operational in December 2002 at Kansas City and Houston. We note that benefits will vary from location to location.

Note: Costs include facilities and equipment costs but exclude operations costs.
Source: OIG analysis of FAA data

Critical weather information must be presented to controllers in a format that improves their situational awareness without increasing workload. As we noted earlier in this report, the combined impact of the new tools and related efforts (e.g., the new weather technologies and Data Link) is a key issue that needs to be addressed. FAA needs to place greater attention on integrating new air traffic management technologies with improved weather technologies and how the information will be displayed on controllers' screens.

We note that in FFP2, FAA intends to deploy *the Collaborative Routing Coordination Tool*, which can help controllers reroute aircraft around storms. While work is still needed to obtain controller acceptance, research is being conducted to integrate weather technology with the Collaborative Routing Coordination Tool to more accurately assess traffic flow alternatives, help reduce delays, and efficiently reroute aircraft around severe weather.

DEPLOYMENT OF FREE FLIGHT TECHNOLOGIES NEEDS TO BE CLOSELY COORDINATED WITH NATIONAL AIRSPACE REDESIGN EFFORTS

Free Flight technologies and FAA's National Airspace Redesign efforts are inextricably linked. The National Airspace Redesign effort is FAA's attempt at a comprehensive, national effort to revamp the Nation's airspace to meet the rapidly increasing operational demands placed on the system.[18] The overall design of the airspace has not changed appreciably in the past few decades, and current routes are structured by the location of ground-based navigational aids, which often constrain operations.

FAA's near-term efforts to achieve these goals include redesigning routes in all regions, analyzing the present route structure for procedural inefficiencies, redesigning airspace sectors, and redesigning traffic flows. In addition, FAA, in coordination with the aviation community, has identified seven top-priority choke points that have a direct impact on the flows into and out of the New York/New Jersey metropolitan area.

The major focus of FAA's initial airspace redesign efforts will be to relieve congestion in these seven choke points. For the most part, near-term changes will not require major infrastructure modifications and will be based on today's technologies. In the longer term, technological improvements in communications, navigation, surveillance, and automation will allow for more flexibility in airspace design initiatives.

It is important to note that the airspace changes being considered as part of the National Airspace Redesign effort are in the same places where FAA is introducing Free Flight tools and could impact their deployment. The close interdependency of Free Flight deployment and National Airspace Redesign speaks to the need for a high degree of coordination between the two programs. For example, opening the Northern California TRACON will affect the routes and handling of arrivals into San Francisco. Any significant changes to the airspace surrounding San Francisco will significantly impact the planned deployment of TMA at Oakland Center during FFP1. To its credit, FAA has adjusted its deployment schedule to delay the deployment of TMA at Oakland Center until it has finalized the surrounding airspace design.

[18] For additional information on FAA's National Airspace Redesign efforts, refer to FAA's National Airspace Redesign Strategic Management Plan.

RECOMMENDATIONS

We recommend that FAA:

1. Pause in the management and planning of the Operational Evolution Plan and various Free Flight initiatives to assess what changes are needed in light of September 11th. This assessment should address:

   - the security risks of the Free Flight concept and planned mitigation strategies,

   - which technologies should receive priority and which ones can be deferred,

   - how budgets and management of Free Flight and the Operational Evolution Plan will be harmonized and reconciled, and

   - the implications of September 11th, general economic conditions, and the financial shape of the airline industry for the budgets and milestones of capacity-enhancing initiatives.

   This assessment should be complete in time for deliberations on FAA's fiscal year 2003 budget request.

2. Monitor the safety impacts, including operational errors and deviations, of new controller tools. The agency should conduct an independent scientific safety assessment of the new tools, which should examine both the short- and long-term safety impacts, including the transition period when the tools are brought on line, failure modes, and what happens when a tool is not available.

3. Periodically review the need to certify FFP1 technologies as they evolve. Based on these reviews, establish a plan for certifying FFP1 technologies.

4. Ensure a high level of coordination between Free Flight automated tools and airspace redesign efforts. The Free Flight Program Office or another appropriate office should track airspace redesign efforts in greater detail through program reviews and include such information in FFP1 monthly reports.

5. In its plan for FFP2, establish *checkpoints* for assessing progress and making "go/no go" investment decisions, and clearly distinguish between deployment and research efforts.

6. Assess the short- and long-term needs of new controller tools in terms of weather data, and develop a plan for providing weather enhancements to the controller, including how this information will be displayed.

EXHIBIT A

OBJECTIVES, SCOPE, AND METHODOLOGY

The objective of our review was to evaluate the technologies identified as part of FFP1 with particular emphasis on cost, schedule, human factors, and software development. We also evaluated the anticipated benefits of the new technologies and plans for expanding the FFP1 effort (and other technologies planned for implementation) during Free Flight Phase 2, which covers the 2003 to 2005 timeframe. We adjusted our objectives to reflect two major intervening developments: the publication of FAA's Operational Evolution Plan in June 2001 and the September 11th terrorist attacks on the United States.

We performed our work at FAA Headquarters and the FFP1 Program Office in Washington, D.C., and other locations between October 1999 and May 2001 in accordance with Government Auditing Standards as prescribed by the Comptroller General of the United States.

- We reviewed (1) selected reports and testimonies issued by our office and the General Accounting Office; (2) FAA policies on acquisition management; (3) FFP1 program files from 1998 to the present; (4) relevant reports and other literature on topics such as air traffic control modernization, certification, human factors, software development, earned value management, and National Airspace Redesign; (5) independent assessments of FAA's FFP1 efforts; and (6) information on current and past FFP1 activities on FAA and other aviation-related web sites.

- We analyzed financial data on the FFP1 program and verified our results with the program's budget office.

- We analyzed FFP1 contractors' earned value management data to estimate the total costs of the contracts at completion and the potential magnitude and causes of any cost overruns.

- We analyzed benefits data published by the FFP1 Program Office to determine the reported benefits of the FFP1 technologies.

- We interviewed (1) the FFP1 Director, Product Managers, and other FFP1 Program Office staff; (2) managers and staff of other relevant FAA offices including those with responsibility for certification, air traffic operations, air traffic requirements, human factors, software development, union negotiations, and budgeting; (3) representatives of American Airlines, Delta Air Lines, Federal Express, Northwest Airlines, Southwest Airlines, and US Airways; (4) representatives of the NASA Ames Research Center and the MITRE Corporation; (5) representatives of industry groups, such as the Air Transport Association, Airline Dispatchers Federation, and RTCA; and (6) representatives from air traffic controller associations.

- We attended a wide range of FFP1 progress meetings, including the Joint Resources Council, Acquisition Review, Human Factors Review Board, Monthly Program Review, and weekly progress meetings. We also attended RTCA Steering Committee and subgroup meetings.

- We conducted site visits, observed operations, and interviewed controllers at various FFP1 deployment sites, including the Air Traffic Control System Command Center, Atlanta Air Traffic Control Tower, Atlanta Center, Atlanta TRACON, Dallas-Fort Worth TRACON, Fort Worth Center, Memphis Center, Minneapolis Center, and Minneapolis TRACON. We also visited the NASA Ames Research Center.

PRIOR AUDIT COVERAGE

In December 1999, we issued a report titled Management of Software-Intensive Acquisitions for Free Flight Phase 1 (Report No. AV-2000-028, December 21, 1999), which evaluated FAA's progress toward developing the software required for URET and CTAS. FAA concurred with our recommendations to strengthen use of earned value management techniques and software metrics for tracking progress of software-intensive acquisitions.

EXHIBIT B

MAJOR CONTRIBUTORS TO THIS REPORT

The following Office of Inspector General staff from Washington, D.C., contributed to this report. The work was done under the direction of David A. Dobbs, Deputy Assistant Inspector General for Aviation.

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