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Report to the Chairman, Subcommittee on Transportation, Committee on Appropriations, House of Representatives

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AIR TRAFFIC CONTROL

Continued Improvements Needed in FAA's Management of the NAS Plan

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Resources, Community, and
Economic Development Division

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The Honorable William Lehman
Chairman, Subcommittee on Transportation
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

At your request, we evaluated the status of the Federal Aviation Administration's National Airspace Systems Plan. This report presents the current cost and schedule estimates for the plan's most significant projects, along with our findings, conclusions, and recommendations regarding the agency's management of the air traffic control modernization effort.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 17 days from the date of this letter. At that time, we will send copies to interested congressional committees; the Secretary of Transportation; and the Administrator, Federal Aviation Administration. We will also make copies available to others upon request.

This work was performed under the direction of Kenneth M. Mead, Associate Director. Major contributors are listed in appendix III.

Sincerely yours,

J. Dexter Peach

J. Dexter Peach
Assistant Comptroller General

Executive Summary

Purpose

The dramatic increases in air travel after airline deregulation have strained the capabilities of the nation's air traffic control system. Moreover, aging and obsolete equipment are limiting the Federal Aviation Administration's (FAA) ability to handle the increased air traffic efficiently. Since 1981, when FAA issued its National Airspace System (NAS) Plan to modernize the air traffic control system, GAO has reported frequently on various aspects of the plan. The Chairman, Subcommittee on Transportation, House Committee on Appropriations, has requested that GAO monitor NAS Plan implementation. As part of that role, GAO has distilled much of its work to date into this report to provide current information on

- the additional resources modernization likely will require before its benefits are realized,
- the causes and effects of delays in the schedules of the NAS Plan's major systems, and
- what GAO believes that FAA should do to improve its NAS Plan management.

Background

The NAS Plan is intended to modernize the air traffic control system by the year 2000 and permit continued safe and efficient air travel. Equipment will be updated and many functions will be automated. FAA has established specific goals concerning safety, system operating efficiency, and productivity of its air traffic controller and maintenance work forces. These goals, together with estimated project costs and schedules in the NAS Plan, form the basis for the amount the Congress authorizes for modernization.

FAA's NAS Plan includes 92 separate projects needed to upgrade air traffic control, including radars, computers, and communications networks. The Department of Transportation has designated 12 of these as "major systems acquisitions" because of their high cost or critical need and, as such, they receive special management review. Because these 12 projects account for two-thirds of FAA's cost estimate for the whole plan, GAO focused on them as indicators of the plan's overall progress.

Results in Brief

FAA expected a $12 billion, 10-year modernization effort, but the need for additional equipment and design changes could double that cost and time estimate. This is because FAA's inexperience in large-scale procurement caused it to underestimate the complexity of the task. This, in turn, led to many projects being delayed to accommodate design changes

or solve technical problems. Also, the inadequacy of the plan's initial design resulted in the need for added equipment and requirements being subsequently identified. With modernization delayed, productivity gains expected from the NAS Plan have been deferred and air traffic control system improvements for decreasing congestion and enhancing safety have been postponed.

GAO concluded in earlier reports that problems exist with three of FAA's critical management tools, specifically, FAA's methodology for estimating the benefits of NAS Plan projects, its policy toward operational testing and evaluation, and its ability to integrate the NAS Plan with other major agencywide plans. Although GAO recommended corrective actions with which FAA generally agreed, FAA still needs to follow through in several areas to improve these tools and thereby its management of the NAS Plan.

Because of the expanded scope of the NAS Plan and the imminent availability of more accurate benefit-cost analyses, GAO believes the agency should revise the NAS Plan to more accurately reflect project benefits and all modernization efforts.

Principal Findings

Modernization Cost to Significantly Increase

FAA has awarded contracts to develop or produce 80 of the projects, including 8 of the major systems. Field installation has begun for 4 of its 12 major systems and is complete for the Host computer, which has replaced computers at FAA's 20 en route air traffic control centers.

Despite these accomplishments, NAS Plan projects are behind their 1983 schedules by an average of 3 years. In particular, the major systems' schedules have been extended from 1 to 5 years. Also, because new projects and changes to existing ones have expanded the extent of modernization, GAO believes that at least $25 billion may need to be appropriated by the year 2000 instead of the $16 billion currently estimated by FAA.

Causes and Effects of NAS Plan Delays

The Office of Management and Budget (OMB) Circular A-109 recommends a prudent acquisition strategy to help agencies acquire costly and complex systems. The strategy calls for top agency management to reassess the concept, design, and test results at key points in the systems'

lives. OMB also advises operational testing, or a "fly-before-buy" approach, before committing to significant production.

However, lacking experience in developing and integrating large-scale systems, FAA tried to force-fit projects into predetermined schedules. In doing so, FAA moved several of its major systems into full production without demonstrating at an earlier point that the systems function properly. In addition, FAA has only now begun to plan for operational testing and evaluation of its major systems—6 out of 12 of these systems started production without such testing. This, coupled with FAA's underestimating the size and complexity of the development effort, has led to costly and time-consuming problems involving (1) performance requirements added to systems after initial schedules were developed and (2) contractors' difficulties in designing new software.

Unresolved Weaknesses in FAA's NAS Plan

Although FAA is planning improvements, action is still needed to correct weaknesses and implement improvements in three areas. First, FAA overstates some projects' benefits because estimates of benefits due to passenger time savings and FAA productivity increases are too high. Thus, setting priorities and making trade-offs among projects whose benefits have a high passenger time savings component are difficult. The two most costly projects, microwave landing and advanced automation, are examples of such projects. Although FAA agrees that its benefit-cost methodology could be improved and studies are underway to do this, changes have not been implemented.

Second, while FAA now plans to operationally test and evaluate its major systems before committing to significant production, this function would be enhanced if performed independent of the developing unit. Otherwise, FAA runs the risks that such testing will not be objective because program managers will face the sometimes competing goals of achieving a system that both works and is produced on time and within budget.

Third, FAA officials agree that more needs to be done in implementing a long-range planning policy that the Congress and such organizations as the President's Aviation Safety Commission and the Office of Technology Assessment recently have said is needed. The policy's purpose is to coordinate needs of air traffic control, airspace, and airports, with expected needs for such work force skills as maintenance workers and air traffic controllers. A plan to coordinate personnel needs is the latest agencywide document needing integration with the NAS Plan. Without this agencywide oversight, FAA cannot be assured that separate plans for these interrelated NAS components will be integrated effectively.

Revised Modernization Plan Is Needed

GAO believes that the NAS Plan should be revised for two reasons: First, by (a) not including all projects needed to modernize the air traffic control system and (b) incorrectly estimating many project benefits, the NAS Plan is neither a complete nor accurate picture of what FAA needs to modernize the air traffic control system. Second, if a more comprehensive plan were available, FAA could better coordinate the NAS Plan with other agencywide plans for building airports, making airspace changes, and managing human resources. FAA also would be better able to establish schedules that reflect the ability of its work force to install, operate, and maintain the new equipment.

These revisions would provide the Congress and FAA with more realistic projections of the agency's total needs and foster more informed decisions on user tax authorization and annual appropriations needed to fund air traffic control modernization.

Recommendations

In addition to following through on recommendations GAO has made in the past regarding FAA's benefit-cost methodology and operational testing policy, GAO recommends that the Secretary of Transportation direct the FAA Administrator to revise the modernization plan by

- identifying all needed projects and their associated benefits, costs, and schedules so that relative priorities can be set based on benefit-cost ratios, mission need, or safety considerations and
- reflecting in project schedules and quantity requirements the results of other agencywide plans for airspace changes, airport development, and human resource management.

Views of Agency Officials

GAO made the contents of a draft of this report available to responsible FAA and Department of Transportation officials who provided their individual but informal views on the draft. These views are incorporated throughout the report as appropriate. In particular, officials noted that the NAS Plan was revised in August 1988, after our audit work had terminated. On the basis of its review of the new plan, however, GAO believes that its conclusions and recommendations are still valid. As requested, GAO did not obtain official written comments on a draft of this report.

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Abbreviations

AAS	Advanced Automation System
ARSR	Air Route Surveillance Radar
ASARC	Aviation System Acquisition Review Committee
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
AWOS	Automated Weather Observing System
CWP	Central Weather Processor
DOT	Department of Transportation
FAA	Federal Aviation Administration
FSAS	Flight Service Automation System
FSS	Flight Service Station
GAO	General Accounting Office
IBM	International Business Machines Corporation
IFR	instrument flight rules
MLS	Microwave Landing System
NARE	National Airspace Review Enhancement
NAS	National Airspace System
NPIAS	National Plan of Integrated Airport Systems
OMB	Office of Management and Budget
RCL	Radio Communication Link
RE&D	Research, Engineering, and Development
RML	Radio Microwave Link
SEIC	Systems Engineering and Integration Contractor
TDWR	Terminal Doppler Weather Radar
TSARC	Transportation Systems Acquisition Review Council
VFR	visual flight rules
VSCS	Voice Switching and Control System

Introduction

In 1981, the Federal Aviation Administration (FAA) embarked on a long-term program to modernize, automate, and consolidate its air traffic control system. The program is called the National Airspace System (NAS) Plan. It is funded out of the federally-managed Airport and Airway Trust Fund, which is replenished with receipts from various air travel excise taxes—primarily an 8 percent tax on tickets. The NAS Plan's purposes are to achieve safer airspace and a more efficient air traffic control system at a reasonable cost to the government and the air travel community.

Updated annually, the 1987 NAS Plan consists of 92 projects. FAA has designated 12 of these projects as major system acquisitions because of their high cost—over $150 million each—and their importance to the overall plan. These major systems include radars, computers, and communication systems. To help technically direct the plan and ensure that the projects fit together properly, FAA hired in 1984 a contractor to provide systems engineering and integration services for up to 10 years.

FAA Responsible for Air Safety and Commerce

The Federal Aviation Act of 1958, as amended (49 U.S.C. 1303, 1348, and 1655, subparagraph c), makes the Secretary of Transportation responsible for ensuring the safe and efficient use of the nation's airspace and for fostering civil aeronautics and air commerce. The Department of Transportation (DOT) has authorized FAA to provide air navigation services for in-flight navigation, access to the airway system, and guidance in the approach and landing phase of flight; air traffic services to ensure separation of flights in the air and at terminal areas; and pre-flight and in-flight assistance to pilots. These services began in the 1930s as an air navigation network and now consist of extensive navigation, surveillance, communication, and control facilities known as the Air Traffic Control (ATC) system.

Need for Modernization

The air traffic control system of the late 1970s was a blend of several generations' technologies and equipment, much of it labor intensive and obsolete. In some cases, for example, tube-type electronics rather than solid-state devices are still used. FAA recognized that the ATC system could be operating with much greater efficiency by increasing its use of automation. For example, automation could replace the controllers' practice of managing their work load on the basis of flight plan data coded on paper strips torn by hand from teleprinters. Instead, this manual system will be replaced by an electronic system in which several data items can be shown next to multiple map graphics. A controller will

be able, for example, to view a close-up map of an important portion of the airspace sector in a corner of the display while still viewing the full sector in the center of the display and flight information off to the side. Automation also could expedite and make more reliable the aircraft exchanges from one controller to another. Contractor estimates say the new system will operate 25 times faster than today's system, and a system of distributed (decentralized) data processing will enable the system to be fully operational 99.9995 percent of the time, or all but three seconds of a year.

In addition to these kinds of potential efficiency gains, FAA forecast that increases in demand for air travel—brought on by airline deregulation of the late 1970s—would continue. It also anticipated that meeting this demand safely and efficiently would require improved and expanded services, additional facilities and equipment, improved work force productivity, and the orderly replacement of aging equipment. So, in December 1981, FAA published its broad NAS Plan to modernize, automate, and consolidate the existing ATC system by the year 2000.

Overview of the National Airspace System Plan

The NAS Plan's overall objectives are to achieve a significantly safer and more efficient NAS through the year 2000, while constraining costs incurred by the government and airspace users. It is meant to integrate the various improvements to the ATC system—for example, replacing computers, increasing automation, modernizing the communication network, consolidating ATC facilities, and upgrading navigational aids—into a single program, while eliminating major deficiencies and costs of the current system.

While focusing primarily on capital improvements relating to air traffic control, the plan also has significant ramifications for airports, airspace procedures, and work force planning. For example, as more modern equipment enables the ATC system to operate more efficiently, thus allowing more aircraft to depart, travel en route, and arrive in a given time period, pressure is expected to be placed on airports to accommodate this increased air traffic. The mix of labor skills needed also will be changing. In addition, the equipment's operating characteristics and capabilities—the shorter, curved approaches allowed by the microwave landing system, for example—will necessitate some changes in airspace definitions and flight procedures. Chapter 4 provides more details on the integration of the NAS Plan with other airport, airspace, and work force planning issues.

NAS Plan Goals

The specific goals of the plan have remained the same from 1981 to 1987. These are to

- operate a National Airspace System that keeps pace with the national aviation demand;
- accommodate users' (scheduled airlines and general aviation pilots) increasing demand for air traffic control services so that they can operate with a minimum of artificial constraints and with fuel efficiency;
- reduce operational errors by 80 percent between 1984 and 1995;
- reduce risks of midair and surface traffic collisions, landing and weather-related accidents, and collisions with the ground;
- increase air traffic controller and flight specialist productivity by a factor of at least two by the year 2000, compared with 1980;[1]
- reduce technical staff required to maintain and operate the new ATC system by one-third—to 7,735—by the year 2000 compared with 1980; and
- maintain the overall system cost of field operations at the 1980 budgeted cost of $1.48 billion when adjusted for inflation, excluding the capital cost of modernization.

Management of NAS Plan Acquisitions

Like each of the annual NAS Plan updates before it, the 1987 plan is subdivided according to the air traffic control system's six major elements: en route, terminal, flight service and weather, ground-to-air, interfacility communications, and maintenance and operations support. Ninety-two separately managed projects fall into these groups and range in cost from several hundred thousand dollars to several billion dollars. DOT has designated 12 of the 92 projects for special management review and refers to them as "major system acquisitions." These projects either exceed $150 million in acquisition costs or are a critical part of the NAS Plan.

The special management review that FAA originally planned to give the major systems includes attention from the top management levels in FAA and DOT. At critical points in the life of an acquisition, decisions were to be made on whether to advance the project into the next phase of its development, to discontinue the project, or to redirect the project along new conceptual lines. To make these decisions, FAA planned for the project office to prepare a "key decision memorandum" discussing the risk factors and other considerations relevant to approving the project for further development. The Transportation Systems Acquisition Review

[1] Flight service specialists staff FAA's flight service stations and provide weather briefings, file flight plans, and provide other weather-related services for pilots.

Council, chaired by the Department of Transportation's Deputy Secretary and composed of other top management officials in the Department, then would have reviewed the memorandum and other pertinent materials and approved or disapproved the continued development. Chapters 3 and 4 detail how and why FAA did not always follow the special review process, which is recommended by the Office of Management (OMB), as well as how this omission affected NAS Plan implementation.

Roles Projects Play in ATC System

The ATC system manages all aircraft flying under "instrument flight rules." These aircraft account for virtually all scheduled airlines' flights.[2] The ATC's management extends over the entire course of the flight, beginning at the flight's departure terminal, continuing through various en route points of contact, and ending with the airport terminal at the flight's destination. Throughout the flight, the aircraft and its pilot are in contact with various surveillance mechanisms (radars) and are guided by controllers to avoid hazardous weather and other aircraft and to clear or approach airports. This ensures that the aircraft maintain safe distances between each other and that they are guided to safe landings at their destinations.

The NAS Plan's 12 major system acquisitions will play important roles in four of the six ATC elements: en route, flight service station and weather, ground-to-air communications, and interfacility communications. NAS Plan projects involving these elements include sophisticated radar, improved automation, and others, as follows:

En Route Systems

- Voice Switching and Control System (VSCS). The VSCS will enhance voice communications at 23 large air traffic control facilities by improving the ability of communications to be switched among controllers and between controllers and pilots.
  FAA expects VSCS to increase controller productivity and reduce overall communications costs because equipment will be owned rather than leased.
- Advanced Automation System (AAS). This system's acquisition cost is about $5 billion, making it the most expensive program in the NAS Plan.

[2]Aircraft fly under either instrument or visual flight rules (IFR or VFR). IFR aircraft must be controlled and in contact with an air traffic controller, while VFR aircraft are only monitored by controllers. VFR aircraft, however, must follow the rules and flight procedures governing the specific airspace in which they choose to fly and are restricted from some airspace around major airports for safety reasons.

FAA plans for AAS to replace the computer hardware, software, and air traffic controller work stations at airport tower, terminal area, and en route air traffic control facilities. AAS also will include development of new software—called AERA—to predict en route aircraft positions, check for potential conflicts, and provide controllers with alternative solutions to resolve potential conflicts.

According to FAA, AAS benefits include (1) increasing controller productivity and ATC system availability, (2) saving fuel and passenger time, and (3) reducing operating costs. Benefits also are expected to accrue from automating many functions now performed by controllers and consolidating en route and terminal facilities.

- Host computer system. The Host computer replaced the existing computers at FAA's 20 en route air traffic control centers with new, higher capacity computers. The Host uses a modified version of the previous air traffic control software. FAA justified the Host computer acquisition on the basis of existing computers' capacity limitations and the agency's inability to implement operational and safety enhancements until additional capacity was available.

Flight Service and Weather Systems

- Flight Service Automation System (FSAS). This system is automating the way FAA provides weather data to pilots before take-off. For example, one new telephone service allows pilots to record their flight plans and obtain recorded messages concerning weather for both the general area and popular air routes, thus avoiding or reducing the time needed to talk to a flight specialist. It will also provide improved access to FAA's system of notifying pilots of very recent information concerning changes to any aspect—facility, procedure, service, or hazard—of the National Airspace System. The 317 manual Flight Service Stations (FSS) that existed in 1981 are scheduled to be consolidated into 61 automated FSSs.
- Central Weather Processor (CWP). This system's purpose is to collect, synthesize, and disseminate weather data from all sources and produce data that are tailored to users' specific needs.
- Automated Weather Observing System (AWOS). FAA plans to install this system primarily at nontowered airports where no human weather observers are currently stationed. At some towered airports, the system also will replace the current system of human observers. It will provide data describing nine critical airport weather elements. This information will be sent directly to pilots by computer-synthesized voice.

Ground-To-Air Systems

- Airport Surveillance Radar (ASR-9). Serving as one of FAA's hazardous weather detection systems, the ASR primarily is a short-range, highly accurate system for monitoring aircraft movement and position within a radius of about 50 miles from the airport terminal. Air traffic controllers use ASR aircraft position data to keep aircraft safely separated and control their movements into and out of the airport.

  In replacing the older models, the ASR-9 will provide controllers improved aircraft detection; improved hazardous weather information; and a six-level weather display, each showing a different degree of precipitation severity.

- Air Route Surveillance Radar (ARSR-4). Able to search long distances, ARSR-4 radars provide air traffic controllers with radar coverage of both en route aircraft and weather information. These radars rely only on signals reflected off of aircraft or weather and are called primary radars. The ARSR-4s are the fourth in a series developed to supplement "beacon radars," which, unlike primary radars, receive more precise signals from aircraft and are controllers' main source of air traffic surveillance information. Despite their precision, however, beacon radars provide no weather information, and they require aircraft to be specially equipped with transponders to send coded signals to the radar. In contrast with beacon radars, ARSRs pick up all aircraft within their range regardless of whether the aircraft have transponders. Also, the ARSR-4 will provide the new AAS with data on aircraft range and direction.
- Microwave Landing System (MLS). This system's purpose is to guide specially equipped aircraft to safe landings in reduced visibility conditions. Because it can guide approaching aircraft from a wider angle than can the Instrument Landing Systems currently in place, FAA believes that MLS will allow more varied landing approaches. This could permit aircraft to land more frequently and could give pilots more flexibility in choosing approach paths to the airport than possible using the existing systems. This would enhance an airport's capacity to accept landing aircraft and could mitigate the noise effects of aircraft by directing the noise over less populated areas than is possible with current landing systems.
- Mode S. The Mode S system consists of sensors and antennae on the ground for receiving and transmitting information from and to aircraft. Mode S will replace existing radar beacon systems aboard commercial and general aviation aircraft. Unlike the current beacon system, in which all aircraft within range respond to signals from the ground radar, Mode S will enable separate addressing by specific aircraft. This will reduce signal interference and establish a message channel for the

aircraft to exchange data with the ground. In addition, when combined with the "data link" and weather communication processor, which are separate programs within FAA, Mode S will enable pilots to obtain directly various weather data now available only through the controllers as they have time. For the system to operate, however, aircraft will have to be equipped with new Mode S avionics.

- Terminal Doppler Weather Radar (TDWR). To help guard against wind shear around airports, FAA is planning to install the TDWR as its primary, ground-based wind-shear detection system. By detecting fast-developing wind velocity variations, this radar helps to identify the presence of wind-shear conditions. Currently, pilots and controllers rely on other less responsive radars and sensors to detect wind shear.

Interfacility Communications Systems

- Radio Microwave Link (RML) replacement with Radio Communication Links (RCL). FAA is planning to install the RCL to replace and upgrade existing RML communications lines used to transmit voice and radar data communications nationwide; these include weather and air traffic information. Current needs are met with a mixture of FAA-owned and -leased communication lines. However, the FAA-owned equipment is outdated and expensive to maintain and the leased lines are becoming increasingly expensive. In addition, the FAA-owned equipment will not meet NAS Plan requirements for both system expansion and flexibility to accommodate new facilities and consolidation of facilities.

Funding the NAS Plan

The NAS Plan is funded through the Airport and Airway Trust Fund. This fund was established by the Airport and Airway Revenue Act of 1970 (Title II of Public Law 91-258) as a repository for the tax monies paid by aviation users and as a source of funds for federal aviation programs. Most of the fund's revenues come from the current 8-percent tax on passenger airline tickets. Over the years, these revenues have exceeded expenditures. Consequently, the fund has built up a substantial unappropriated balance—the difference between revenues available and amounts appropriated—of about $7.2 billion

The Airport and Airway Improvement Act of 1982 (Title V of Public Law 97-248, 49 U.S.C. 2201-2225) reauthorized the Trust Fund for 5 years and enabled the continuation of two programs to ensure the continued safe operation of the nation's airspace system. Both programs are financed by the Trust Fund. The first—the Airport Improvement Program—continued the grants-in-aid for airport development previously available under earlier legislation. The second program—the Airway

Improvement Program--makes monies available to FAA to operate and maintain the nation's air navigation system. It is under this program that the Congress appropriates monies to carry out the NAS Plan.

At the end of fiscal year 1987, the Congress reauthorized the fund for another 5 years (fiscal years 1988 through 1992), although the taxes and program authorizations were extended only another 3 years. The effect has been to continue the programs established in the 1970 act. To prevent large unappropriated balances from building up again during this period, a "trigger mechanism" was established. This mechanism reduces fund revenues by 50 percent beginning January 1, 1990, for fiscal years 1988 and 1989 if appropriations are less than 85 percent of authorized amounts for airport grants, research, and facilities and equipment for those years.

FAA Has Assistance in Technical Direction of the NAS Plan

The magnitude of the NAS Plan convinced FAA, DOT, and others that FAA needed help in managing the plan. Therefore, in 1984 FAA contracted with Martin Marietta Corporation to provide technical and programmatic support in managing and technically directing nearly all facets of the plan's implementation. The 10-year, $900 million systems engineering and integration contract (SEIC) was developed to meet specific technical needs as well as allow an evolving relationship between the contractor and FAA.

Development of the SEIC

When FAA first published its NAS Plan in December 1981, some doubt existed as to whether FAA could implement such a large and complex undertaking. The plan required about a fivefold increase in FAA's facilities and equipment annual funding for design, production, and implementation of the specified projects. In addition, the projects could no longer be managed or treated as independent entities because they were interrelated within the overall NAS through hardware and software interfaces and data exchanges. Furthermore, these major projects were to be managed through development, testing, production, integration, and installation without disruptions to the operational air traffic control system. Concerns, therefore, arose about the capability of FAA's limited work force to implement the NAS Plan successfully.

A major impetus for developing the SEIC came from a White House Science Council Panel convened to review the NAS Plan. In its November

1982 report, the panel stated that, although FAA had made a commendable start on the task of modernizing the nation's air traffic control system, much work remained to be done before the existence of a plan could be acknowledged. According to the panel, the NAS Plan contained a loosely structured set of worthwhile goals, but contained no comprehensive analysis of the crucial systems issues that would arise in formulating and implementing the plan. The panel recommended that a single, prime systems contractor be charged with the formulation, design, and systems integration of the entire NAS Plan. This work should be done in response to explicit goals laid down by FAA, the panel said. The intent of having a prime contractor was to establish between FAA and other subcontractors a technical buffer with responsibility for overall design and technical direction.

Officials in the Office of the Secretary of Transportation and FAA defined the role such a contractor might play as including the following key points:

- FAA/DOT must retain accountability to the NAS users and the Congress.
- A single individual within FAA would be designated as manager of the NAS Plan.
- FAA would retain system/subsystem procurement and contracting functions.
- The contractor would make the transition into a leadership role involving technical direction for major programs.

SEIC Responsibilities

FAA replaced the Science Council Panels' recommendation of a "prime" contractor with the concept of support contractor with significant technical responsibility but little contract authority. Thus, in January 1984, FAA competitively awarded to Martin Marietta a contract for systems engineering and integration, a set of tasks that includes supporting FAA in many ways. These include technical interpretation of specifications, management responsibility over a limited number of projects, technical and management support to FAA project managers, and technical direction to contractors of individual NAS systems. The contract, including options, covers a 10-year period to ensure continuity throughout implementation of the NAS Plan. The value of this cost plus award fee contract is currently estimated at about $900 million over the 10-year period.

A unique feature of the contract is the concept of "mission responsibility," in which a partnership role is established so that the contractor is motivated to work with FAA to implement the NAS Plan within schedule,

cost, and performance objectives. The contractor is involved in nearly all phases of NAS Plan implementation. However, unlike a prime contractor, the SEIC is not responsible for either the initial design or directly controlling individual system vendors.

In fulfilling the contract, the contractor must carry out activities in four basic areas. First, the contractor must acquire or develop certain management tools required to control and oversee the NAS Plan, such as benefit-cost analysis and project planning and tracking systems. Second, the contractor is tasked with designing the overall system engineering and integration of the plan. This work includes the allocation of FAA functions to the various NAS projects, determining technical requirements for projects, and defining interfaces between projects. Third, the contractor is responsible for transition planning and architectural and engineering designs for the most complex sites in the NAS Plan. Transition planning includes determining what has to be done and when it must be done during the evolution of the ATC system from the old facilities and equipment to the new. Areas addressed in transition planning include system hardware and software, logistics, maintenance, and training personnel to operate and maintain the new systems (but do not include training of air traffic controllers). Finally, Martin Marietta provides technical and management support to FAA project managers and technical direction to contractors of seven individual NAS projects.

Objectives, Scope, and Methodology

This report is a milestone in a planned series of reports responding to a request by the Chairman, Subcommittee on Transportation, House Committee on Appropriations, that we monitor FAA's implementation of its NAS Plan. Following that request, we initiated a series of reviews on individual NAS Plan projects and other aspects of FAA's management of ATC modernization. This report coincides with FAA's transition from primarily designing the NAS Plan and developing individual projects to a new phase of deploying the new systems in the field.

Our primary objectives are to reiterate and consolidate in one report key conclusions that we have drawn in the past regarding the NAS Plan and to highlight improvements we believe are needed to improve the future management of the plan. To do this, we are providing

- information on the additional resources that modernization likely will require before its benefits are realized;
- an analysis of the causes and effects of development delays experienced by the most costly and complex NAS Plan projects; and

- our conclusions regarding FAA's weaknesses in managing the NAS Plan and what we believe FAA should do in the future to improve that management.

Until recently, the major NAS Plan projects have been in either conceptual or developmental phases, with the implementation of a few projects such as Host computer and Flight Service Automation having begun in 1986. Our focus, therefore, necessarily has been on the problems faced by the NAS Plan projects during their system development phases rather than during system implementation. This is not to say that problems have not or will not occur during FAA's implementation of its NAS Plan. Indeed, as we testified before congressional appropriations committees in March and April this year, we believe that problems during this last acquisition phase could adversely affect the NAS Plan schedule.[3] We are continuing to monitor this phase of the plan. Our future reporting regarding NAS Plan implementation will include such areas as the implementation of specific projects in FAA's regions and a major contract that FAA has awarded to help it install the systems in the field.

We recognize that the Congress has several specific and immediate questions about the NAS Plan and its current status, questions that are not answered definitively in the plan itself or in testimony provided by FAA officials. Some of these questions involve such issues as whether the NAS Plan (1) represents a system of projects necessary to improve capacity and safety or whether some projects offer little added value, (2) is integrated from a technical and schedule perspective, (3) is coordinated with the implementation of the airport plan to meet the needs of the national air transportation system, and (4) is presenting the Congress with budget requests that correspond to actual program requirements. Therefore, an additional objective of this report is to recommend actions which, if taken by FAA, would enable FAA to better answer such questions.

We issued our first report on FAA's NAS Plan in 1982. Since then, we have provided the Congress with information on various aspects of the plan in many written reports and oral testimonies (see app. I). Much of the information in this report is derived from those earlier reports but has been updated and placed in today's perspective. In addition, to provide the current status of the major NAS Plan projects, we discussed those

[3]FAA Appropriations Issues (GAO/T-RCED-88-32 and -35, Mar. 31 and Apr. 12, 1988).

projects and their relationship to other parts of the plan with appropriate FAA project management officials and with officials of the FAA Technical Center in Pomona, New Jersey. We analyzed cost and schedule documentation provided to us by FAA and discussed various aspects of the plan with officials of FAA's SEIC.

After this introductory chapter, chapter 2 provides status information on the extent of schedule extensions and cost increases for the plan as a whole as well as for the plan's 12 major system acquisitions. Chapter 3 discusses our analysis of the causes and effects of delays in development schedules of NAS Plan projects. Chapter 4 presents issues facing FAA that need attention if FAA is to improve its management of the NAS Plan through the year 2000. Chapter 5, contains our conclusions and recommendations regarding FAA's management of the NAS Plan.

We conducted our review from June 1987 to May 1988. Consequently, we did not perform a detailed review of FAA's June 1988 NAS Plan update, which was released in August 1988. We believe, however, that this does not affect the validity of our conclusions and recommendations. Our work was performed in accordance with generally accepted government auditing standards.

NAS Plan Schedule and Cost Status

Since its publication in 1981, the NAS Plan and the air traffic control modernization effort associated with it have evolved from a 10-year, $11.7 billion effort to a 20-year endeavor that could require appropriations of approximately $25 billion. While FAA is now implementing some projects in the field, it has experienced delays in implementing all 12 of the NAS Plan's major system acquisitions. In addition, the estimated cost of completing the modernization effort has increased significantly because FAA has added new projects to the effort, requested a risk allowance authorization, and proposed numerous engineering changes to existing projects.

Although System Implementation Advances, NAS Plan Is Behind Schedule

FAA is making progress toward implementing its plan for modernizing the air traffic control system: Over 50 percent of all NAS Plan projects have started delivery and, according to FAA, 80 of the plan's 92 projects—including 8 of the plan's 12 most costly projects—were under a development or production contract at the end of fiscal year 1988. Among the plan's most notable accomplishments during the past 6 years is the implementation of the Host computer.

Despite implementation progress so far, though, most NAS Plan projects have encountered delays and cost increases (see ch. 3 for a discussion of the causes and effects of these delays). For example, the plan's most expensive project—the Advanced Automation System—has not yet undergone full-scale development, and production is still 5 years away. FAA's latest estimate is that the project's first installation will occur in 1993, 3 years later than noted in the 1983 NAS Plan.

Delays in Implementation

To measure how far project schedules have been extended, we used the 1983 NAS Plan as a baseline.[1] We compared first and last implementation dates—those dates when FAA expects to begin operating units of a given project at the first operational site and at the last site—in the 1983 plan with those dates in the 1987 plan. Using the two plans, 72 project comparisons were possible—including 10 major system acquisitions—because that many projects are common to both plans.[2] As shown in table 2.1, the average estimated delay for all 72 matching projects was

[1]According to the manager of the NAS Program Management Staff, the milestones in the first NAS Plan, issued in December 1981, were determined without an adequate understanding of the difficulties that the NAS effort entailed. FAA believes the milestones in the 1983 plan update were better defined and that this plan represents a reasonable baseline from which to measure progress.

[2]The 1983 NAS Plan contained 80 projects; the current 1987 plan contains 92 projects. In many cases the new projects are simply aspects of the original projects that have now become separate projects.

1.4 years at the first field site and 3.2 years at the last site. The table also shows that the plan's major system acquisitions have experienced delays despite the more intense management review these projects should receive. Estimated delays in these systems' implementation dates average 2.6 years at the first site and 2.7 years at the last site.

Table 2.1: Years of Delay in Implementing Projects at the First and Last Operational Sites Between 1983 and 1987

	First site implementation	Last site implementation
All NAS projects		
Mean 1.4	3.2	
Median	0.0	2.0
Range	-1 to 7	−8 to 8
Major system acquisitions		
Mean 2.6	2.7	
Median	3.0	2.0
Range	1 to 4	0 to 5

Note: Negative numbers in the table indicate that some projects are being implemented before the dates planned for them in 1983.

Status of NAS Plan's Major Projects

As shown in table 2.2, most of the major system acquisitions have reached the later phases of the OMB acquisition process. Stages in the OMB acquisition process include determining mission needs, identifying and exploring alternative design concepts, demonstrating alternative concepts, full-scale development and limited production, and full production. (These stages are described in more detail in chapter 3 and appendix II.)

Table 2.2: Status of NAS Plan's Major Systems

	OMB acquisition phase	Change in first site operational date	Change in cost since date noted	Percent change
En route systems				
Voice Switching and Control	Full-scale development and limited production	5 years, from 1986 to 1991	To $539 million from $258 million in 1982	109
Advanced Automation	Full-scale development and limited production	3 years, from 1990 to 1993	To $4.9 billion from $3.2 billion since 1985	53
Host Computer	Full production	6 months, from early to late 1988	To $416 million from $460 million in 1984	−10
Flight service and weather systems				
Flight Service Automation	Full production	2 years, from 1984 to 1986	To $520 million from $449 million since 1981	16
Automated Weather Observation	Full production	3 years, from 1986 to 1989		

(continued)

	OMB acquisition phase	Change in first site operational date	Change in cost since date noted	Percent change
Central Weather Processor	Full-scale development and limited production	4 years, from 1990 to 1994		
Ground-to-air systems				
Terminal Radar Program	Full production	3 years, from 1985 to 1988	To $575 million from $558 million in 1984	4
Mode S	Full production	4 years, from 1986 to 1990	To $503 million from $482 million in 1984	4
Microwave Landing	Full production	3 years, from 1985 to 1988	To $1.5 billion from $1.2 billion in 1984	25
Long Range Radar	Full production	7 years, from 1985 to 1991	To $714 million from $600 million in 1984	19
Terminal Doppler Weather Radar	Full production	(new project)		
Interfacility communications systems				
Radio Microwave Link Replacement	Full production	1 year, from 1985 to 1986	To $284 million from $264 in 1987	8

Modernization Cost Estimate Is Growing

FAA's 1983 baseline NAS Plan covered the 10-year period from 1982 to 1992. At that time, FAA estimated that the plan would cost $11.7 billion to implement. FAA currently estimates that completing the plan will require 10 more years and an additional $4.1 billion. Thus, FAA's current cost estimate for the 1987 NAS Plan update totals $15.8 billion. However, FAA's figures significantly underestimate the actual cost of both the NAS Plan and the projects, which are clearly part of the ATC modernization effort.[3] If several categories of additional costs to the original plan are added, the cost of the 1987 NAS Plan rises to $17.8 billion. Further, adding the costs of new related projects brings the total potential NAS Plan cost to nearly $25 billion.

As shown in table 2.3, FAA and the SEIC have identified several categories of cost additions to the original NAS Plan. For example, the SEIC has identified and FAA has approved about $10 million in engineering changes to existing NAS projects; another $480 million in engineering changes await FAA funding approval. The SEIC has also proposed a $1 billion "risk reserve" to compensate for understated procurement costs for existing NAS projects. By combining these with FAA's current $15.8 billion estimate, the cost of the 1987 NAS Plan update is more accurately estimated at $17.3 billion.

[3]FAA Appropriations Issues (GAO/T-RCED-88-32, Mar. 31, 1988).

Table 2.3: Estimated Appropriation Needs for NAS Plan and Associated Modernization Efforts

(In billions of current dollars, 1982-2000)

	Cost	Cumulative total
FAA's 1987 estimated NAS Plan cost	$15.82	$15.82
Cost additions		
Approved engineering changes to existing projects[a]	0.01	15.83
Pending engineering changes to existing projects	0.48	16.31
Risk reserve for understated costs of existing projects	1.00	17.31
Additional ATC modernization costs	7.57	$24.88
Total	**$24.88**	

Note: Dollar figures in this table were generated from data reflecting actual appropriations from fiscal years 1982-1987 and FAA-estimated appropriations needed for fiscal years 1988-2000.

[a]Engineering changes typically are proposed by contractors during the later phases of development or during production when it is found that some part of a system should be produced differently—from an engineering, materials, or practical standpoint—from what is called for in the design or engineering interpretation of that design. These changes can either reduce or increase costs.

Source: Estimates of "cost additions" made by SEIC.

In addition to these revisions to the baseline NAS Plan, NAS projects and equipment will require additional air traffic control modernization costs. While these projects were not included in the original NAS Plan, they are clearly part of the modernization effort. In fact, FAA has acknowledged that they are needed to maintain safe and efficient air traffic control before the full implementation of the NAS Plan. Therefore, these projects have a direct link to NAS Plan goals and objectives. Some of the projects that have received preliminary approval include additional airport surveillance radars, long-range radars, and advanced surveillance and communications equipment. Other new projects include fuel storage tanks and continued NAS support activities such as facility relocations beyond 1992. The SEIC estimates that it will cost about $6.5 billion to implement these additional requirements, and this could raise the estimated cost of the NAS modernization effort to over $24 billion.

Besides these capital requirements, the NAS Plan has an associated research and development cost of over $1 billion through 1993, over $700 million of which has been spent through fiscal year 1987. As shown in table 2.3, this would bring the total estimated cost to complete the NAS Plan to about $25 billion, as of August 1988. By the year 2000, however, total costs could be more or less, depending on additional changes needed, projects added, or even a reduced NAS Plan scope. Costs may also be influenced by competing project or funding priorities within FAA and the Airport and Airway Trust Fund.

Causes and Effects of NAS Plan Development Problems

Any of the NAS Plan's 92 projects could cost more, take longer to deploy, or be less effective than expected. And, because of the high cost and complex nature of the plan, this would be true even under the best of circumstances. Indeed, as discussed in chapter 2, the costs of most major NAS Plan acquisitions have increased and delays have occurred. Moreover, FAA risks further costs and delays before these projects are fully deployed.

Minimizing the risks of acquiring such major systems was at the heart of the federal procurement guidance issued by OMB in 1976. The guidance recommended specific points in a system's life at which its development should be reviewed by top agency management. Although FAA designated its major systems to receive such review, it has not always followed OMB's guidance, and it has bypassed two or more key decision points for most of the NAS Plan's major systems. This omission is one of the main reasons that the plan's major systems have experienced development problems such as inadequately specified requirements, unanticipated technical problems, and inadequately tested systems.

These development problems subsequently led to schedule delays which, in turn, resulted in postponed achievement of productivity and safety benefits and a large unappropriated balance in the Airport and Airway Trust Fund. Schedule delays also frustrate FAA's ability to accurately plan for the appropriate number of personnel needed to maintain the systems being delayed, especially if these are the air traffic control system's more labor-intensive components, such as controllers and maintenance technicians.

Nature of Project Development Problems

In the past, FAA's system development approach, which included decisions to bypass OMB-suggested progress reviews, resulted in development and production contracts being awarded with

- inadequately defined functional, performance, operational, and quantity requirements;
- unanticipated technical hurdles, primarily software development problems; and
- inadequate testing of systems before production.

These problems required FAA to add time for additional development, testing, and evaluation. Table 3.1 gives an overview of the development problems that have caused delays in the NAS Plan's major systems.

Table 3.1: Development Problems That Have Delayed Major Systems

Major System	Inadequately defined requirements	Testing, technical, or software problems
En route system		
Voice Switching and Control	Yes	Yes
Advanced Automation	Yes	Yes
Host Computer	No	Yes
Flight service and weather system		
Flight Service Automation	No	Yes
Automated Weather Observation	Yes	Yes
Central Weather Processor	No	No
Ground-to-air system		
Terminal Radar Program	No	Yes
Mode S	No	Yes
Microwave Landing	Yes	Yes
Air Route Surveillance Radar	Yes	No
Terminal Doppler Weather Radar	No	No
Interfacility system		
Radio Microwave Link	No	No

Source: Attachment to the April 8, 1987, statement of Martin T. Pozesky, Acting Deputy Associate Administrator for NAS Programs, FAA, before the Subcommittee on Aviation, Senate Committee on Commerce, Science, and Transportation, and discussions with FAA NAS project managers.

FAA agrees that such development problems have contributed to NAS Plan delays. Moreover, FAA has made a "mid-course adjustment" to its NAS Plan, which includes several initiatives aimed at strengthening FAA's control over the plan and making some funding issues more visible. It is too early to tell whether this adjustment will affect plan delays.

OMB Major System Acquisition Guidance

OMB Circular A-109 divides the major system acquisition process into four phases that precede full production. The guidance calls for top agency management to review the acquisition's progress, problems, and risks before deciding whether to advance into the next stage. The recommended phases are

- determining mission need, which includes defining and validating requirements early in the acquisition process by focusing on and defining mission need and program objectives;
- identifying and exploring alternative design concepts;
- demonstrating alternative design concepts by fabricating, testing, and evaluating the systems to determine that the proposed system will meet

mission needs effectively before full-scale development and limited production are begun; and

- full-scale development and limited production to include independent testing of system performance in an operational environment.

The process outlined in the OMB guidance attempts to minimize potential problems with the development and procurement of complex major systems by increasing top management's awareness of the technical, operational, and economic risks associated with the system. The intent is to reduce the potential for cost growth, schedule delays, and performance deficiencies and to avoid prematurely committing major systems to production. OMB encourages demonstrations of critical or difficult-to-develop functions and subsystems before the agency commits to develop the system. Although FAA officials have noted their disagreement with our reading of this policy, the guidance contained in Circular A-109 explicitly states that operational tests in a realistic environment are required before full production is authorized.[1] This is because, generally speaking, the later in the acquisition process that changes are made, the more costly it is. The worst case occurs when changes are made to a system design late in the production phase. By not following the disciplined approach outlined by OMB, FAA has increased the risk of encountering cost, schedule, and performance problems associated with a major system acquisition. (See app. II for a more detailed explanation of the acquisition process recommended in Circular A-109.)

FAA Has Not Adequately Defined Operational and Quantity Requirements

Generally speaking, changes to a system's requirements—the specifics that define how it will operate, how many are needed, or how it will meet the needs of its users—can occur throughout the acquisition process; however, these changes become more disruptive as projects advance into design, development, and production. We believe that the likelihood of major requirements changes during later phases of the process can be reduced by conducting the analyses and making trade-offs during the first two phases of the acquisition process and by establishing these analyses as prerequisites to management approving advancement to subsequent phases. Therefore, in the past, we have recommended that FAA adhere to the Circular A-109 process, which calls for agencies to define operational and quantity requirements early in the acquisition process.

[1]The only exception to this is when it is not physically or financially practicable or possible to perform the tests or in cases of extreme urgency, as noted on page A-109-10 of Circular A-109, Apr. 5, 1976.

By not accurately defining or planning for operational or quantity requirements for several major system acquisitions, FAA contributed to these systems' problems. Three of these major systems illustrate such problems: the Advanced Automation System (AAS), Voice Switching and Control System (VSCS), and Terminal Doppler Weather Radar (TDWR).

AAS. Soon after FAA awarded two AAS design phase contracts to Hughes Aircraft Company and International Business Machines Corporation (IBM) teams, the agency developed additional system performance requirements. These included adding color to the controller work station display, adding several advanced automation functions, and designing the display panel for the VSCS communications console. (This was to ensure compatibility between the VSCS and AAS hardware because, although these two projects are being designed independently, each must accommodate the other's hardware.) By adding new requirements at this point, however, FAA may not have thoroughly evaluated AAS requirements before awarding the design contracts. In fact, as noted earlier, FAA did not submit the AAS for approval at either of the first two decision points, points that specifically focus on identifying and validating requirements.

At the time, FAA officials justified the break with the guidance because they believed that the new requirements would be worth risking a potential schedule extension and cost increase during the design phase. The additional delays and cost increases that the AAS subsequently encountered, however, were greater than anticipated because FAA underestimated the complexity of these requirement changes. Moreover, 2 years after the AAS contractors were asked to design the VSCS displays, FAA transferred VSCS display design responsibility to the VSCS contractors.

VSCS. Before awarding the design contract, FAA made major revisions to this system's requirements. For example, a change was made to revise the operational requirements thereby doubling the number of units to be produced. This led to cost increases and added about 4 years to the system's development schedule. More recently, in response to other development delays, FAA has decided to reduce some requirements, defer other requirements to the production phase, and transfer a requirement to design the controller displays from the AAS contractors to the VSCS contractors. Additional requirement changes are also possible. For example, a January 1988 program office status report indicated that costs to plan VSCS deployments at field sites had not been included in current estimates, and that, if FAA decides to deploy additional terminal

area facilities under the AAS program, additional VSCS systems may be required.

TDWR. Before being included in the 1987 NAS Plan update, this system's development schedule was delayed 1 year because of revisions to the draft specification and time needed to evaluate various options for where to locate the radars. These are issues that, according to Circular A-109, should have been addressed before full-scale development of the radar system was begun. Had this been done during the first two system acquisition phases, the schedule delay might have been avoided. In addition, although FAA now plans to award a production contract in 1988, FAA's TDWR program office and its support contractors still question whether some technical requirements can be met. In particular, their questions involve (1) the "precursor requirement" to identify the windshear condition 1 minute before it occurs and (2) the notification requirement to alert the pilot 1 minute before he or she encounters hazardous conditions.

Contractors' Technical Problems Caused Delays

In several cases, FAA believed that developing a new system would involve little risk because off-the-shelf technology would be used. However, after the contracts were awarded, FAA discovered that substantial hardware and software development was required. The resultant technical obstacles that we identified most often related to problems that the contractors encountered in designing and coding the software.

The first two phases of the OMB review provide important information to more accurately estimate the complexity of development efforts. The guidance also calls for testing systems in realistic conditions before committing to large-scale production. (Ch. 3 discusses such testing policy in further detail.) If FAA had followed the guidance, the agency might have anticipated and avoided delays caused by software development difficulties. Problems with software have contributed to the development schedules of eight of the NAS Plan's major systems being delayed. The extent to which technical problems will be overcome is uncertain in some cases, while in others, additional problems can be expected.[2] Four major systems—AAS, Flight Service Automation System (FSAS), Mode S, and the Microwave Landing System (MLS)—illustrate some of the software development problems.

[2]DOT's Office of the Inspector General is addressing this issue as part of its fiscal year 1988 audit plan. The audit's objective is to assess FAA's application of software engineering methodologies toward resolving software development problems on major NAS Plan projects.

AAS. Contractor delays in completing the system design have caused extensive delays in this system's schedule. The design delays occurred because FAA and the contractors underestimated the complexity of this system's software and hardware design requirements. FAA has adjusted the remaining schedule to more accurately reflect the effort required to meet the stringent AAS requirements. Because the AAS design and development is still incomplete, however, we believe that additional problems could occur, further extending the full-scale development phase.

FSAS. The modernization program for this activity has been delayed about 2 years, in part because of problems developing the software for the new automated system, called Model 1.[3] To correspond with OMB's recommended phasing of activities, this software should have been developed before committing to and embarking on production. However, FAA has corrected all the technical problems with Model 1 that it considered critical before accepting the system for operation in the first three automated flight service stations. For the problems that remain, FAA has developed "interim operating procedures" to carry out the functions that Model 1 still cannot perform. For the most part, these procedures involve reformatting messages that Model 1 does not recognize into ones that it does and will accept.

Mode S. Contractor delays in completing the detailed system design contributed to this system's 4-year delay. Although Circular A-109 calls for systems to be developed and tested before committing to production, FAA awarded a Mode S production contract before the system was designed.

MLS. A 2-year delay in the MLS schedule has been caused by problems in contractor software coding and delayed receipt of valid frequency assignments.[4] FAA awarded a production contract in January 1984, although key portions of the system had not been demonstrated and the design concept had not been verified as sound. (Circular A-109 recommends such verification.) In March 1986 the contractor advised FAA that it had been unable to develop some needed software and would have to subcontract for software development. As a result, FAA contracted to buy 178 systems, even though the contractor had not at that time demonstrated through operational testing that the system would satisfy

[3]Aviation Services: Automation and Consolidation of Flight Service Stations (GAO/RCED-88-77, Feb. 8, 1988).

[4]Microwave Landing Systems: Additional Systems Should Not Be Procured Unless Benefits Proven (GAO/RCED-88-118, May 26, 1988).

FAA's requirements. FAA officials have disagreed with us on the sufficiency of MLS testing and have stated that the MLS development program has closely followed Circular A-109. Nevertheless, the FAA Administrator recently stated that operational testing will be performed before the system is deployed in the field. Also, FAA is now planning to use revised performance specifications for the second round of procurement.

Although FAA recognized the importance of testing MLS in the airport environments in which it is to be used, the project was allowed to enter production after only limited testing of MLS units not built to FAA specifications. Thus, the potential benefits as well as the system's safety and reliability remain in question. For example, special airport approaches made possible with MLS have been tested only in a nonoperational environment, one that does not provide realistic conditions.

FAA Does Not Believe Its System Development Approach Is Faulty

We believe that solving development problems early in the acquisition cycle is less time-consuming and costly than solving them after design has been resolved or production has started. FAA officials believe, however, that little schedule time has been lost due to any variation from the Circular A-109 process and that most of the changes in requirements have been relatively minor. FAA officials disagree with our conclusion that the schedules of many major systems have been extended, in part, because FAA's system development approach does not allow enough time to identify requirements and solve technical problems. Instead, the officials attribute their inability to adhere to project schedules to their practice of force-fitting projects into a predetermined NAS Plan schedule and to their inexperience in developing and integrating large-scale hardware and software systems of the kind being acquired for the NAS Plan. However, Circular A-109 was established to minimize the acquisition risks inherent in situations just like this.

FAA Made Mid-Course Adjustments

During 1987, FAA made what it called a "mid-course adjustment" to its management of the NAS Plan. The adjustment consisted of a series of five management initiatives, a refocusing of the SEIC's work, and a reevaluation of the NAS projects and their key schedules. The full effect of this adjustment on NAS Plan project schedules and costs will take time to be felt; however, for information purposes we highlight several of FAA's management initiatives below:

- FAA provided additional visibility to NAS Plan cost and scope changes by adding to the NAS Plan "blue pages" that identify new capital needs. FAA

also initiated the policy of budgeting for unknown costly contingencies by requesting as part of the appropriation an amount known as a "risk reserve."

- FAA assigned to the SEIC the technical direction responsibility for six NAS projects, including one major system acquisition—the TDWR.
- FAA began emphasizing various strategies to save money and time and improve efficiency. These include using commercial capabilities where possible, such as contracting with IBM to maintain the Host computer, and instituting an internal "value engineering" process that identifies potential changes to any phase of contractors' operations that will increase NAS Plan efficiency. This process has identified a potential $240 million in savings and provides a mechanism for identifying alternative project and business strategies, such as leasing versus buying.

Delays Caused by Development Problems Have Immediate and Long-Term Effects

As FAA acknowledges, the original NAS Plan project schedules were optimistic, given the complexity of the systems being developed by these projects. We believe that closer adherence to OMB guidance would have allowed FAA to more accurately estimate the effort required and to take steps to minimize delays. The primary effect of delays experienced during development phases is, to some extent, to push system implementation into the future and increase costs. Slowed acquisition rates, in turn, result in a series of other ramifications, including

- unrealized FAA work force productivity gains resulting in premature staff reductions and consequent decreases in service,
- a growing unappropriated balance in the trust fund, and
- a commercial aviation industry facing a growing demand for service without simultaneous improvement of air traffic control system effectiveness.

Premature Staff Reductions Decrease ATC System Service

FAA has projected that it would realize major productivity improvements through innovations such as remote maintenance monitoring of NAS Plan systems, automating weather briefings and safety inspection system, replacing the computers and raising the automation level of the air traffic control system, and consolidating flight service stations. These improvements would allow FAA to reduce staff required to maintain the new system by one-third—to 7,735—by the year 2000 compared with 1980.

However, FAA had been reducing part of its work force before the NAS Plan systems intended to increase productivity have been completely

implemented. In particular, anticipating that maintenance productivity gains would occur earlier, FAA allowed the number of maintenance personnel to decline to 86 percent of what the staffing standard called for at the end of fiscal year 1986. Although maintenance staffing grew during fiscal year 1987 from 8,306 to 8,667, it still was only 90 percent of the staffing standard of 9,346. This staffing level is inadequate to maintain current equipment, provide training on new systems, and develop new technicians to replace the anticipated heavy retirements in this work force through 1995.

The potential for controller productivity gains, a major goal of the NAS Plan, also has been affected by project delays. NAS Plan systems to be introduced in the near term will provide only limited controller savings. FAA does not expect the more significant productivity improvements until the late 1990s when AAS is scheduled to be in place. But additional extensions to this project's schedule—first site installation has already been extended by 3 years—would further postpone potential controller productivity gains. In addition to having AAS's labor-saving features not fully available for another decade, this situation is exacerbated by increases in air traffic, which place additional demands on the controller work force and FAA's ability to maintain it.

A final example of staff reductions affecting the service that can be expected from the air traffic control system is in the area of flight service stations. The most pressing problem at the moment relating to the Flight Service Station modernization program is staffing, as we reported in February 1988.[5] While reductions in the flight service specialist work force have occurred, they have not been matched by a comparable gain in productivity because of consolidation and automation delays. Further delays in closing the stations may worsen the problem. If the work force is reduced further, more stations may have to temporarily close or reduce their hours of service, resulting in increasing time periods when no weather observations are made. In light of these facts, we recommended in our February 1988 report that FAA postpone further reductions in the flight service specialist work force until after the flight service stations are closed and performance standards and staffing levels can be developed for the automated stations.

[5]Aviation Safety: Serious Problems Concerning the Air Traffic Control Work Force (GAO/RCED-86-21, Mar. 6, 1986).

NAS Plan Delays Contributed to Unappropriated Trust Fund Balance

According to FAA, at the end of fiscal year 1987, the Airport and Airway Trust Fund's unappropriated balance—the difference between revenues available and amounts appropriated—reached $7.2 billion, up from $5.9 billion at the end of fiscal year 1986. Part of the balance results from appropriations for ATC facilities and equipment reaching only $4.7 billion since 1982, compared with the 5-year authorization of $6.3 billion. The primary reason that appropriations have not more closely approached fund authorization is that NAS Plan projects have been delayed an average of 3 years (see ch. 2). Thus, many projects that were scheduled to be in production before the 5-year authorization period ended are still in development phases. Fund expenditures are not as high in these phases as in production.

Additional delays in NAS Plan projects, however, will not increase the size of the trust fund's unappropriated balance in the same way they have in the past. This is because of the trigger mechanism that was added to the 1987 Airport and Airway Fund reauthorization legislation. (See ch. 1). This mechanism will reduce fund revenues during a fiscal year if fund appropriations during the prior 2 years are less than 85 percent of authorized amounts.

Demand for Air Travel Puts Pressure on ATC System Modernization

After airline deregulation, the average fares in the air travel industry declined significantly. As a result, many more people can afford to fly. The domestic passenger load has increased from 278 million in 1978 to 415 million in 1986, or by 50 percent. However, according to DOT, the quality of airline service has deteriorated in that same period. The number of consumer complaints to the Department about airline service went from almost 13,000 in 1986 to about 45,000 in 1987, or an increase of 246 percent. Many of these complaints involve areas such as baggage handling, meal service, and flight schedules, and they concern airlines more than FAA. However, a significant number of complaints are directed at delayed flights, many of which result from the current ATC system's limited ability to accommodate the rapid increase in air travel.

FAA believes that it will be able to meet the growing needs of air travel by modernizing its ATC facilities and equipment. However, major NAS Plan acquisitions have been from 6 months to 5 years behind schedule, while the plan's critical period of system integration and installation has yet to occur. NAS Plan delays have postponed almost $47 billion in anticipated benefits to users of the ATC system. As estimated by FAA, these benefits will include $33 billion in reduced airline schedule delays. They also include almost $14 billion in fuel efficiencies that are expected to

result from allowing airlines to fly routes preferred by pilots rather than routes assigned by air traffic controllers.

Planning Issues Critical to NAS Plan Success

DOT and FAA have made some progress toward addressing the problems described in the preceding chapter. However, we believe that additional improvements to FAA's planning process, some of which are underway, are necessary to maximize FAA's success in implementing the NAS Plan. In particular, improvements are needed in FAA's

- benefit-cost methodology for justifying major systems;
- operational test and evaluation policy; and
- efforts to develop a long-range, integrated plan that coordinates the three National Airspace System components of airspace, airports, and air traffic control with expected controller and maintenance work force levels and skills.

FAA's Benefit-Cost Methodology Is an Inadequate Planning Tool

As a planning tool, FAA's methodology for conducting benefit-cost studies is inadequate. By using questionable means of assigning values to such variables as passenger time, safety, and productivity benefits, FAA has produced overly optimistic benefit levels for several projects and for the NAS Plan as a whole. These inaccurate benefits impair decisionmakers' ability to plan and manage the deployment of the NAS Plan. For example, as we reported in December 1986, eliminating questionable estimates of passenger time savings benefits could reduce the procurement quantity from 30 to 26 airport ground radars, saving about $10 million.[1]

In addition, proper benefit-cost analyses would permit both FAA and the Congress to better select the best system concepts with which to meet the future requirements of the National Airspace System. In this regard, we testified in March 1988 that in evaluating alternative concepts for implementing AAS, FAA had at that time not fully analyzed or properly compared several facility consolidation options.[2] We said that FAA needed to do this to determine whether its chosen alternative was the best and to verify its assumption that consolidating many small facilities into a few large centers would yield greater cost savings than minimal consolidations. Moreover, the contract that FAA had planned to award in July 1988 for this project would not have been flexible enough to acquire the amount and types of equipment needed to support a nonconsolidation alternative, if that alternative subsequently proves most

[1] Airport Radar Acquisition: FAA's Procurement of Airport Surface Detection Equipment (GAO/RCED-87-18, Dec. 17, 1986).

[2] Federal Aviation Administration's Advanced Automation System Investment (GAO/T-IMTEC-88-2, Mar. 31, 1988).

desirable. Thus, FAA would have been locking itself into an approach that precluded nonconsolidation without first having properly considered the feasibility and efficiency of this approach.

In the meantime, however, FAA amended its request for proposals to provide the flexibility to acquire the equipment needed if it decides not to consolidate facilities. The AAS contract, awarded on July 25, 1988, now has this flexibility.

Despite ongoing unused balances in the Airport and Airway Trust Fund, funding decisions should be scrutinized more closely and benefit-cost analysis should be an important planning and management tool.

FAA Projects NAS Plan Benefits of $66 Billion

According to the 1987 NAS Plan, the net benefit estimates of the NAS projects total $66.2 billion. This total consists of three basic categories: (1) $46.6 billion in user benefits, (2) $24.4 billion in savings to FAA, and (3) $4.8 billion in safety benefits. (The total reflects a deduction derived statistically by FAA of $9.6 billion from gross benefits because of uncertainties in the three basic benefit categories.) Table 4.1 shows FAA's breakdown of benefits supporting the figures in the 1987 NAS Plan.

Table 4.1: Breakdown of Nas Plan Benefits

(1981 Dollars in Billions)

Type of benefit	Net benefit estimates	Subtotal for benefit category
Users' efficiency benefits		
Meet user demand efficiently		
Reduce delays	$32.8	
Provide user preferred routes	13.8	
Subtotal		**$46.6**
FAA's efficiency benefits		
Maintain operations cost at 1980 level		
Double air traffic productivity	10.7	
Reduce technician staff	8.7	
Lower nonlabor cost	5.0	
Subtotal		**24.4**
Safety		
Reduce risks of accidents/collisions	4.8	
Subtotal		**4.8**
Total		**$75.8**
Less uncertainty adjustment		(9.6)
Net total benefits		**$66.2**

The SEIC estimated 1987 user benefits by updating the level of user benefits in the 1986 NAS Plan. (User benefits were first calculated in the 1986 NAS Plan.) User benefits are based on passenger and airliner time and cost savings and safety benefits for 10 NAS Plan projects. The contractor used the individual benefit-cost analyses for these 10 projects, although some of the studies date back to 1978. These estimates were updated to adjust for changes in implementation schedules and aviation activity forecasts that have occurred since then.

NAS Plan User and Safety Benefits Could Be Lower Than FAA's "Most Likely Benefit" Estimate

In our opinion, the $66 billion in total benefits—user efficiency, FAA efficiency, and safety—that FAA presents in its 1987 NAS Plan update represents an overly optimistic picture of the plan's value. Actual plan benefits could vary significantly. For example, the SEIC estimates that user efficiency plus safety benefits of $51.4 billion could range from $14 billion to $57.9 billion. Moreover, while the extremes of this range are important by themselves, the assumptions the SEIC used to arrive at them are not discussed in the NAS Plan itself and thus are not available to readers and reviewers of the plan.

In providing comments on the accuracy of the information in this report, FAA officials noted that the 1987 NAS Plan update reported user efficiency and safety benefits of $41.8 billion, instead of the SEIC's $51.4 billion estimate, with a 50-percent probability of this lower estimate being higher (and a 50-percent probability of it being lower) than the true value of ultimate efficiency benefits. To arrive at the lower estimate, however, FAA inappropriately combined adjusted and unadjusted figures. Specifically, FAA officials reduced the $51.4 billion "most likely" estimate—a number already adjusted by the SEIC for uncertainty—by the full uncertainty adjustment (see table 4.1) of $9.6 billion (51.4 - 9.6 = 41.8). After this over-adjustment for uncertainty, the 1987 NAS Plan combines the $41.8 billion with an unadjusted estimate of $24.4 billion (see table 4.1) for FAA efficiency benefits to arrive at the same total benefits as does the SEIC: $66.2 billion. Thus, not only are some important benefit-cost assumptions and quantitative results omitted from the plan's presentation, the underlying basis for some of those that are presented is also questionable.

In performing benefit-cost analyses, the SEIC uses data provided by FAA concerning project schedules, aviation activity forecasts, initial estimates of each project's benefits, and passenger time savings.[3] As part of these analyses, the SEIC also measures the sensitivity of the NAS Plan's benefits to changes in various "uncertainty factors" such as system effectiveness (e.g., the number of flights that may benefit from any given project), reprogramming (to account for potential project delays), equipage rate (the extent to which aircraft becomes equipped with the necessary supporting avionics), and other factors (such as ranges in operations and maintenance or fuel cost savings). Measuring the plan's sensitivity to these factors produces the range of benefits shown in table 4.2.

[3]FAA is currently reviewing the results of two studies of several economic parameters, including the value of passenger time intervals of less than 15 minutes and the dollar value for passenger time savings that it used in benefit-cost analyses. FAA expects to use the results of these studies in updating its benefit-cost analyses near the first of fiscal year 1989.

Table 4.2: Estimates of Low and High User and Safety Benefits

(1981 dollars in billions)

	Low estimate	High estimate
Most likely benefit	$51.40[a]	$51.40[a]
Adjustment factor less or plus:		
Passenger time savings	(7.80)	0.20
Aviation activity forecast	(4.90)	4.10
System effectiveness	(12.10)	0.90
Reprogramming	(1.40)	0.06
Equipage rate	(0.40)	0.05
Other	(10.80)	1.20
Lowest user benefit level	**$14.00**	
Highest user benefit level		$57.91

[a]This value is the sum of $46.6 billion in estimated user efficiency benefits and $4.8 billion in estimated safety benefits as shown in table 4.1.

Using the low end of each of these uncertainty factors and deriving a worst case by cumulating their effects lowers the total user benefits from $51.4 to $14 billion. On the other hand, using the high end of the uncertainty factors raises the total user benefits estimate to $57.9 billion. These factors' effects are shown in the uncertainty adjustments in table 4.2. We did not review the SEIC's methodology in determining each of the adjustment factors, but, according to an FAA official, these data have been shared with some congressional decisionmakers.

These adjustments and the full range of potential user benefits are not presented in the NAS Plan. An FAA official explained this by saying that the NAS Plan is not an appropriate place for detailed benefit-cost information, and presenting such detailed information would only lead to confusion. However, we believe that presenting this information in the NAS Plan would provide more accurate and balanced information concerning the full range of potential benefits.

Methodology Problems Result in Exaggerated Benefits

Because the benefit-cost analyses for several individual systems—including MLS and AAS—used unrealistic assumptions in areas such as the value of passenger time savings and the statistical value of a human life, we recommended in earlier reports on those systems that FAA change its methodology in these cases. (See app. I for list of our reports on the systems.) Even though FAA has agreed to revise individual studies and review the assumptions used in these studies, it continues to use the earlier studies as a basis for the overall NAS Plan estimate. According to

FAA, the new studies' results were not incorporated in the 1988 plan update because they had not been adequately verified.

Of the four systems mentioned above, the first three contribute over $28 billion to total NAS Plan estimated benefits. Our methodological questions about these projects' benefits focus on FAA's attributing very small amounts of time saved to several of its new NAS systems, valuing this time too highly, and placing excess value on pilots flying routes of their own choice. As noted below, we also have concerns in other areas relating to FAA's benefit-cost analysis methodology.

Passenger Time Savings of Less Than 15 Minutes Are Questionable

FAA's method of valuing time is based on a model that accumulates delays of less than 15 minutes per passenger; these savings are multiplied by an hourly value to produce the dollar savings. We, along with OMB, have questioned this methodology because the delays averaged less than 1 minute per take-off or landing. Determining what constitutes a meaningful period of time is somewhat arbitrary and likely to depend on the frequency with which the time savings occur for each traveler; what is at question is the threshold below which no value should be assigned to time savings.

FAA's Estimated Value of Passenger Time Saved Is Too High

In using what we believe to be a flawed methodology, FAA places a fairly high monetary value on passenger time saved. Using the 1967 median family income of U.S. travelers as the base value and adjusting it for changes in earnings through 1985, FAA derived the value of $23.18 to represent an average hourly wage rate for air passengers. FAA applies this rate to all passengers, including children who have no wage income, and all estimated time increments saved. We believe that this methodology is flawed because the data overestimate the hourly wage earnings of individual passengers since the data are derived from total family income, not individual passenger income.[4] Another flaw is the questionable practice of applying the $23.18 wage rate to small time increments; time delay reductions of 1 minute for 60 travelers may not be as valuable as saving 1 hour for a single traveler. For time increments to be valuable, they need to be sufficiently significant for travelers to perceive that time savings have occurred and to embark on alternative activity. A third flaw stems from not making a distinction between valuing time saved in business versus nonbusiness travel.

[4]According to FAA, the most recent and accurate source of this family income data is the 1967 Census of Transportation.

User-Preferred Route Benefits From AAS May Be Too High

Some of the benefits attributed to AAS's ability to provide user-preferred routes are being realized now, years before AAS's implementation. This is contrary to FAA's assumption that no flights can be granted user-preferred routes until AAS is implemented. While FAA did not keep records of direct routes granted, we found that many requests for user-preferred routes were already being granted and that FAA was working through different procedures to increase that number. Thus, by including the benefits expected from AAS that are occurring now, independent of the new automation, FAA may be exaggerating these benefits. The current benefits should not be included as future benefits of AAS.

FAA Is Reviewing Its Use of Economic Factors in Benefit-Cost Estimates

These estimated benefits from saving passengers time and providing user-preferred routes are significant portions of the total NAS Plan estimated benefits. For example, FAA attributes $5.4 billion in NAS benefits to MLS passenger time savings and $13.8 billion to AAS's ability to provide user-preferred routes. Moreover, these kinds of benefits apply to a wide range of NAS projects—of the total $66 billion in benefits attributed to NAS, over $46 billion is a result of reducing passenger delays and providing user-preferred routes. (See table 4.1.) Because we have questioned FAA's rationale for deriving these estimates, we have recommended in the past that DOT develop improved means of measuring and valuing passenger time savings and safety benefits.

FAA has agreed with our recommendations and in August 1987 FAA initiated two studies dealing with various economic parameters including the value of air travelers' time, the statistical value of a human life, and the costs of aviation injuries. Although one of the studies is complete, its results have not been officially approved and, therefore, are not being used to update existing benefit-cost studies. FAA expects a draft of the second study to be complete near the beginning of fiscal year 1989, but its results would still need to be coordinated throughout FAA before they could be useful in benefit-cost analysis. Therefore, while FAA claims that its new studies justify using small time increments and a wage rate even higher than the current $23.18 value, we are unable to comment on the validity of these results until the studies are complete and available for review.

Automated Weather Observing System Benefits Are Questionable

Our review of the benefit-cost analysis for the Automated Weather Observing System (AWOS) showed a deficiency of benefits compared with costs.[5] Because the system FAA intended to purchase did not meet all of its operational requirements, FAA planned to supplement the system with human weather observers until the requirements could be met. Subsequent adjustments to the benefit-cost analysis calling for more current data and supplementary weather observers showed that the system's benefits did not exceed its costs at commercial airports. Although FAA has now delayed the program to ensure that it meets operational requirements and also plans to restudy system costs and benefits in 1988, the initial analysis of AWOS benefits still supports $900 million of benefits in the 1987 NAS Plan.

Air Traffic Productivity Benefits Are Not Realistic

One of the NAS Plan's primary benefits is the air traffic productivity gain that the new systems should provide FAA. Changes in productivity, as defined by FAA for use in this context, are shown in terms of increases in the number of operations—aircraft arrivals and departures—per controller over a period of time. Using this definition of productivity, FAA states that, of the total $66.2 billion in benefits attributed to NAS Plan projects, $19.4 billion are due to "productivity gains" by air traffic controllers and reductions in the technician staff. (See table 4.1.) However, these benefits may be overestimated because at least some of these productivity gains are attributable to events such as the controller strike of 7 years ago, an event unrelated to the new technology brought by the NAS Plan projects. In addition, FAA may not be able to decrease staffing as quickly as it anticipates because of delays in system development. Thus, delayed increases in productivity would, by FAA's definition, make remaining benefits uncertain.

Because the NAS Plan was issued before the strike, FAA uses pre-strike staffing and operations figures as the baseline for measuring productivity improvements. According to the 1987 NAS Plan update, NAS projects were to increase levels of productivity and air traffic personnel at the air route traffic control centers, as shown in table 4.3.

[5] Installation of Automated Weather Observing Systems By FAA At Commercial Airports Is Not Justified (GAO/RCED-85-78, July 29, 1985).

Table 4.3: Air Traffic Productivity, 1981-2000

	1981	1985	1990	2000
Operations (millions)	27.3	32.7	38.7	47.2
Air traffic personnel	10,300	9,125	9,990	12,520
Productivity (operations per person)	2,650	3,584	3,874	3,743

Note: Figures include both terminal and en route equivalent positions

However, in 1982, the year after the air traffic controller strike, the personnel level fell to 7,989; the operations level increased to 27.8 million; and the productivity level relating the two rose to 3,480. Some of the productivity increase could be attributed to FAA's implementation of the Traffic Management System, a system that has enabled FAA to balance the traffic flow across the country with the ATC system's capacity at that instant in time.

Because many NAS projects have been delayed, their associated productivity benefits have also been delayed. Although the 1987 NAS Plan shows air traffic controller staffing increasing from 9,125 in 1985 to 9,990 by 1990, and to 12,520 by 2000, FAA's actual fiscal year 1989 estimate is for 10,100 air traffic controller positions. This reflects the fact that most of the productivity-improving projects are not scheduled for implementation until the mid-1990s.

No consensus exists within FAA regarding the level of staffing reductions that the various NAS projects will permit. FAA's Air Traffic Operations Service, which is responsible for managing the agency's air traffic controllers, believes that virtually all "position savings" as now stated are grossly overstated. In addition, because of an unavoidable overlap of old and new systems and equipment, the service believes that it could need additional personnel before the NAS Plan is completed.

FAA Did Not Follow Disciplined Acquisition Approach

OMB guidance on major system acquisitions, OMB Circular A-109, was developed to help agencies avoid potential development problems by preventing premature commitments to full-scale development and production and establishing key decision points at which the agency head could make "go/no go" decisions. None of the 12 major systems in the NAS Plan was reviewed by DOT at either of the first two key decision points, and five projects proceeded directly to production. FAA's acquisition process often combined both system development and production, a practice contrary to OMB guidance that resulted in excessive risk to

schedules and costs. Although FAA has made some changes to its acquisition process, further changes are needed in FAA's operational test and evaluation policy. In particular, FAA needs to institute adequate testing to better ensure that production will not begin on a system design that subsequently will need costly revision and will experience delays. Needed changes include operational testing by an independent organization.

FAA Process Differed From OMB Guidance

Unlike OMB's recommended four-phased system acquisition process (see ch. 3 and app. II), FAA normally used a two-phased process to accomplish the same set of acquisition activities. FAA's two phases leading to project implementation were the following:

- The requirements phase is the initial acquisition phase, which lasts until a development and production contract is signed with a contractor. During this phase, design concepts are explored, engineering models of the competing concepts might be developed and tested, and technical specifications are written.
- The development and production phase is the period during which the system is designed from the technical specifications, the design is reviewed and approved, and the system is subsequently produced and tested.

During development of NAS Plan systems, FAA often combined development activities with full production. In doing so, FAA approved production contract awards before completing development activities and testing system performance. In cases where this happened, the key decision point at which production is either approved or disapproved occurred after the development/production contract had been signed. As a result, the Secretary of Transportation did not conduct an important formal review of test results, mission need, and project objectives before FAA committed significant resources to a contractor for production.

Operational test and evaluation is the primary means of ensuring that newly developed systems perform properly, and such testing can be invaluable in identifying ineffective or unreliable systems before they are produced. Beginning production before demonstrating that the system performs effectively in a realistic operational environment increases risks that significant and costly changes could be required to correct problems in equipment that is already produced and possibly deployed. In extreme situations, FAA would risk deploying systems that might not adequately perform portions of their missions.

DOT officials acknowledge the benefits of the Circular A-109 process in improving the planning and discipline of the Department's major systems acquisitions. However, they also recognize FAA's need to be responsive to the realities of the user-intensive, high-technology, safety-critical acquisitions of the NAS Plan. In discussing this issue with us, they stressed their belief that strict adherence to the OMB guidance will not solve all the problems FAA has encountered in implementing the NAS Plan nor will it address the public clamor for expedient modernization of the air traffic control system.

FAA Underestimated NAS Plan Projects' Need for Research and Development

FAA significantly underestimated the complexity and risks involved in acquiring the major NAS Plan projects. According to FAA officials, their belief that the projects involved only limited system development and few risks led to decisions to accelerate the acquisition process by bypassing the first two or three key decision points recommended by OMB. In many cases, FAA incurred additional risks by combining development and production phases. As a consequence, adequate demonstration of system performance before committing to production was precluded.

FAA officials initially believed that mission needs could be satisfied with off-the-shelf technology. Thus, Circular A-109's third phase—Demonstrating Alternative Design Concepts—was omitted from FAA's acquisition process. FAA's optimism was later shown to be unfounded, as many projects required extensive development of advanced and sometimes state-of-the-art technology. For example, in a fiscal year 1987 research, engineering, and development funding summary, FAA identified 24 NAS Plan projects, 10 of which were major system acquisitions, that will require a total of over $1 billion in research, engineering, and development costs over the 12-fiscal year period 1982-1993. While the AAS and related efforts account for $600 million of these costs, most of the remaining $400 million was spread over several major systems, including the Host Computer, VSCS, Central Weather Processor, FSAS, Mode S, and TDWR. Even this amount, however, understates the total development costs actually incurred because development efforts were also conducted using facility and equipment funds—an account separate from the research and development account. We believe that the magnitude of these research and development expenditures shows that (1) the projects were not low risk as FAA initially believed, (2) many unknowns existed regarding their design concepts, and (3) FAA's acquisition process should have more closely approximated the disciplined approach recommended by OMB. Further, had FAA more closely followed OMB guidance, the complexity of the system development effort would have been

understood earlier, thus enabling FAA to reduce the extent to which development problems occurred.

Improvements Are Needed Despite Changes to the Acquisition Process

Although in July 1985 FAA updated its policy for acquiring major systems to be more in line with Circular A-109, by 1987 none of the then 11 major systems had been submitted for approval at either of the first two key decision points called for by OMB.[6] (See ch. 2 for table containing the current 12 major systems.) In addition, 5 of the 11 major systems had proceeded directly to the final production phase without having DOT top management formally review their mission need, design concept, or system test results as required by Circular A-109. Thus, because we found that FAA's acquisition practices did not follow OMB's guidance, we recommended in 1987 that (1) current projects be subjected to operational testing before production and (2) future projects receive the level of management review prescribed by OMB Circular A-109.

DOT responded to our 1987 report by stating that it is firmly committed to operational test and evaluation of all major systems acquisitions, where practicable, before they enter the full production phase. DOT assured us that projects will be sufficiently justified, developed, and documented before receiving approval to proceed. In addition, FAA has recently corrected some deficiencies in its acquisition process by issuing its first standard operating procedures, establishing test and evaluation policies and criteria, and taking other actions to improve internal management controls. Moreover, DOT Order 4200.14B, "Major System Acquisitions," is currently being revised. According to Department officials, the new order will address many of our concerns with FAA's implementation of the Circular A-109 process, especially in the areas of acquisition planning and adequately defining what must be accomplished at each step.

Our current evaluation shows that FAA does plan to conduct operational test and evaluation on all six major system acquisitions that have yet to enter production. These systems are the

- Terminal Doppler Weather Radar,
- Automated Weather Observing System,
- Voice Switching and Control System,
- Central Weather Processor,
- Advanced Automation System, and

[6] Aviation Acquisition: Improved Process Needs to be Followed (GAO/RCED-87-8, Mar. 26, 1987).

- Air Route Surveillance Radar.

In discussing this issue with us, DOT officials recognized the problems inherent in combining development and production activities. They said that in developing AAS, DOT tried to address these problems. Specifically, the Department gave FAA the authority to award the acquisition phase contract, but required FAA to obtain the Deputy Secretary's concurrence before committing each segment of AAS to full production. In doing so, FAA must brief the Deputy Secretary on the results of operational testing before this approval will be given.

Operational Testing Should Be Conducted Independently

FAA's current plans, if carried out, represent a significant improvement in FAA's acquisition process. However, FAA's acquisition policy still does not call for operational tests and evaluations to be conducted independent of the developing and using organizations.

OMB Circular A-109 recommends that operational test and evaluation be conducted independent of the developing and using organizations. Independence has long been a recognized principle of effective test programs. For example, the Army, Navy, and Air Force have had independent testing organizations since 1971. Independence is important because contractors, developers, and users may have goals, such as meeting cost and schedule commitments, which conflict with thorough testing. To avoid this real or apparent conflict and ensure that systems are operationally suitable and effective, the test organization needs to be responsible for managing operational tests and reporting test results and its independent evaluation of the system's ability to perform its mission.

In 1976, we recommended that FAA establish an operational testing capability independent of the developing organization. We pointed out then that FAA's test facility, located at Pomona, New Jersey, reported to the organization responsible for developing systems and thus was not independent. We also said that the testing organization rather than the developing organization should

- set the test objectives and evaluation criteria,
- control test funding,
- conduct the tests,
- modify test plans and specifications, and
- review and approve test reports.

FAA still conducts much of its systems testing at its Pomona facility—now called the Technical Center. The Technical Center also reports to the developing organization, and, as in 1976, it still is not responsible for conducting system tests. In December 1986, the developing organization issued a new test and evaluation policy which assigns the program manager overall responsibility for all test phases, including operational testing. As a result, the program manager, subject to approval of the developing organization, decides which tests will be conducted, supervises and controls the tests, and controls the resources applied to conduct the tests—including Technical Center resources. This means that the testing lacks the needed degree of independence because the project manager's concerns about meeting cost and schedule milestones could conflict with the need to conduct thorough operational tests. On one hand, the project manager is striving for a system that functions correctly. On the other hand, the project manager must field the system on time and within budget.

FAA did establish in 1986 an Operational Test and Evaluation staff, reporting to FAA's Office of Science and Technology, which is independent of the developing and using organizations. This staff is responsible for providing independent assessments of the operational readiness of major systems to the FAA Administrator before commitments are made to full production. However, this organization does not control the application of test resources nor the content or conduct of the tests. Operational testing remains the responsibility of the project manager and the developing organization.

Continued Emphasis Needed to Coordinate Planning for All Facets of National Airspace System

In addition to the NAS Plan, FAA has several other formal plans to improve or change certain aspects of the National Airspace System. The plans are aimed at one of the NAS's three separate but interdependent components—airspace, air traffic control, and airports—each of which significantly affects the safety and capacity of the ATC system. Changes in one component's capacity require corresponding adjustments to the other components. For example, while a new airport in Denver will enhance airport capacity, new ATC systems such as radars and computers will also be required, along with appropriate changes in airspace, routes, and flight procedures.

FAA recognizes the importance of this agencywide coordination of the three components and the long-range planning that should accompany the process. In 1986 FAA documented this recognition in a revised agencywide planning directive. Although steps have been taken toward

implementing the revised policy, several senior FAA officials involved in the planning function believe that these steps could be more substantive.[7]

While current progress should be accelerated, we believe that FAA is making more progress in developing long-range planning for the agency than it did in the late 1970s and early 1980s. This is based on several current FAA actions, among which are the revised planning directive, subsequent development of an agencywide planning process, and the recent establishment of an Associate Administrator for Advanced Design and Management Control. These actions stem from FAA's recognition that planning and coordination are necessary for modernizing the National Airspace System.

Broad Recognition of Need for Improved Coordination Among Several Agencywide Plans

Recognizing the need for coordination, several groups have called for improvements in the status quo. The President's Aviation Safety Commission, in its April 1988 report, calls for a greater effort to integrate the NAS Plan with the National Plan of Integrated Airport Systems. The report states that the airport plan, as it is currently developed, bears no relation to the investment and policy program outlined in the NAS Plan. The Commission believes that FAA should target the planning efforts to develop an "integrated" airport system to assist those airport facilities experiencing the greatest congestion or capacity constraints. Without such efforts, it remains unclear whether capacity enhancements under the NAS Plan will be realized, the Commission said.

The legislative branch's Office of Technology Assessment also has called for an agencywide comprehensive planning capability that would include participation by all major FAA programs in setting long-term safety goals and budget priorities to achieve them. With firm and consistent top-level guidance, FAA could ease conflicts between and among the Associate Administrators and Regional Office Directors, according to the technology assessment office. Such conflict jeopardizes the efficient operation and use of the National Airspace System and could, therefore, have an effect on the safety of air traffic control. Since the Office of Technology Assessment issued its report, FAA has instituted several organizational changes, including creating a more direct management

[7]In discussing FAA's progress in this area, we spoke with several FAA officials responsible in various planning functions: National Planning Division Director, Office of Airport Planning and Programming; Deputy Associate Administrator for Policy and International Aviation; Acting Deputy Director of Aviation Policy and Plans; Director, Airport Capacity Program Office; and Deputy Associate Administrator for Advanced Design and Management Control.

chain between headquarters and the regional offices and establishing four executive directors to provide more top management overview of FAA operations. Because these changes have been in effect for only a few months, it is too soon to determine whether they will have a positive effect on FAA's ability to conduct agencywide long-range planning.

The Congress, in its reauthorization of the Airport and Airway Improvement Act of 1982, recognized the need for FAA to do long- range planning. The act authorized the Secretary of Transportation to conduct a study for the purpose of developing an overall airport system plan through the year 2010 to ensure the long-term availability of adequate airport system capacity. It also mandated FAA to take a national systems approach to planning for airport development and capacity enhancement. The Congress stated that ". . . as the FAA proceeds with the implementation of the National Airspace System plan, it is vital to the public interest that it be fully coordinated with the implementation strategy of the National Plan of Integrated Airport Systems."[8]

Other Agencywide Plans Related to Air Traffic Control

In addition to the NAS Plan, other major FAA plans relate to the National Airspace System. These plans focus primarily on methods to improve capacity through airport development and airspace procedures. They are FAA's

- Plan for Research, Engineering, and Development (RE&D), which describes activities designed to improve the safety, capacity, and efficiency of the NAS and includes the RE&D of systems and equipment that may eventually be incorporated in the NAS Plan;
- National Plan of Integrated Airport Systems (NPIAS), which biennially presents airport development proposals by state and local governments and the private sector, and contains the 10-year requirements for airport development and capital needs; and
- Airport Capacity Enhancement Plan, which describes ways to increase the capacity and utilization of airports and to alleviate current and projected aircraft operating delays in the airport system. While not considered a major plan by FAA, we include it here because of its relationship to the NAS Plan.

FAA's National Airspace Review Enhancement (NARE) effort to improve the safe and efficient use of the nation's airspace is also a relevant planning tool. While not a plan per se, the NARE has had significant impact on

[8]Congressional Record, U.S. House of Representatives, Dec. 15, 1987, p. H 11491.

the implementation of the NAS Plan. Under the direction of an Executive Steering Committee—chaired by the Deputy Administrator of FAA, with members from FAA, Defense, and a cross section of aviation organizations—the NARE reviewed the airspace, procedural, and regulatory aspects of scheduled improvements envisioned under the NAS Plan. This review resulted in many recommendations to enable a smooth transition into the next generation NAS and an accelerated realization of benefits. Many of the recommendations have already been incorporated into the NAS Plan.

FAA Recently Revised Agencywide Directive

Recognizing the need to integrate and coordinate its various planning efforts, FAA has undertaken several comprehensive planning efforts in recent years, culminating in the October 1986 revision of its agencywide planning directive, Planning and Resource Allocation (Order 1800.13C). The revised directive requires new, comprehensive methods to allocate agency resources within a framework of planning, multiyear programming, and budgeting. This is FAA's first attempt at coordinating top-level management across several programs since 1976 and, as such, is a wide-ranging effort to develop a planning philosophy for the agency. The planning directive provides a structure for top-level strategic guidance as well as an emphasis on developing coordinated plans at the program level that would achieve FAA goals and objectives. The directive's key planning objectives include

- incorporating agency goals and objectives into the planning process,
- ensuring that the various individual FAA planning efforts are consistent and coordinated,
- enhancing internal communications by exchanging planning information,
- ensuring human resource considerations in agency planning activities, and
- providing a planning structure consistent with the FAA budgetary process.

Pursuant to the directive, FAA established a Board of Advisors to oversee planning activities. All the Associate Administrators and three of the nine Regional Directors serve as Board Members. It also empowered the Board to allocate resources to this planning endeavor and designated FAA's Office for Policy, Planning, and International Aviation to coordinate this process and work with the Board of Advisors and their support teams to direct and oversee FAA's strategic planning activities.

FAA also has identified a stronger need for planning by recently establishing an Associate Administrator for Advanced Design And Management Control. The office will not take over the overall agency planning functions of the Office of Policy, Planning, and International Aviation. Instead, its purpose is to plan for the next set of air traffic control system improvements, determine an appropriate strategy for investing in future technology, and make greater use of operations research in FAA decision-making. For example, the new office plans to bring an integrated, in-house operations research capability to FAA's planning function. The new office has set both short-term and long-term goals and plans to work with the other staff and program offices to ensure coordination.

FAA's Long-Range Planning Needs Further Improvement

We have questioned FAA's long-range planning efforts in the past. For example, in 1980 we found that not having an agencywide comprehensive planning process forced FAA to rely on its budgetary process to fulfill its planning responsibilities. Without a longer-term focus, FAA had no choice but to rely heavily on identifying equipment that was needed at the moment rather than on required operational capabilities needed over a longer period. We concluded that FAA was not making effective use of its resources. Three years later, we again stressed the need for comprehensive long-range planning and said that the process should provide a mechanism to (1) coordinate preliminary or final results of ongoing reviews with implementation of the NAS Plan and (2) update the NAS Plan and identify project priorities, contingencies, total and subsystem costs, and points of interdependence.[9] This is important given the many plans the agency has and their interdependent relationships.

We recognize that FAA is not without coordination; for example, airspace changes have been incorporated into the NAS Plan via the NARE, and some advanced facilities and equipment planning has been accomplished for the proposed new Denver Airport. Moreover, the progress made on implementing the new directive, although not complete, includes the Board of Advisors concurring with the need for (1) a strong "top-down" component, (2) a mechanism to make the transition from a strategic plan to the program plans, (3) linking planning to the budget process, and (4) involving the Administrator.

[9]FAA's Plan to Improve the Air Traffic Control System: A Step in the Right Direction But Improvements and Better Coordination Are Needed (GAO/AFMD-83-84, Feb. 16, 1983).

In addition, in accordance with the goals and objectives of the directive, FAA's top management plans to institutionalize a planning process by developing objectives for the agency, evaluating strategic alternatives and their impact, and providing agencywide direction. The importance of this planning process is that it should force the Associate Administrators and Directors to communicate their long-term goals and work with each other to ensure fruition of those goals. This process should also solidify the commitment to plan for the future. This commitment will be reflected in the major FAA plans, according to senior FAA officials. Further, the process will include a mechanism to incorporate the suggestions of the aviation industry. The Administrator also has obtained support for and concurrence with this strategic planning effort from the Secretary of Transportation.

However, beyond the Board of Advisors concurring on the above items, FAA officials involved in various aspects of planning as well as an official from FAA's new Office of Advanced Design and Management Control could point to few concrete actions taken under the revised policy. Thus far, the Board has not finalized FAA's strategic planning process. However, it plans to have the agency's first strategic plan complete by December 1988. As for integration and coordination of the plans relating to the National Airspace System, these officials gave several reasons why it has not been more substantive. These include (1) the plans' varying approaches to solving aviation problems, (2) higher priority resource needs, (3) lack of communication among the responsible FAA units, and (4) incompatible databases.

The plans each have somewhat varying perspectives and different means of addressing concerns of National Airspace System users. For example, the NAS Plan is managing the modernization of the nation's air traffic control system by investing in capital equipment and new technology; the airport plan compiles costs and descriptions of airport projects being undertaken over the next 10 years by the private sector; and the airport capacity enhancement identifies the capacity and delay problem and describes current solutions in terms of airspace, airport, and aircraft improvements.

One reason for the different perspectives is that these plans are driven by differing agency missions. The NAS Plan concentrates on the air traffic control component; the NPIAS is a compilation of all airport development in the country, but the development itself is primarily a private sector responsibility; and the capacity plan provides a more focused perspective on ways to reduce delays and increase capacity. Unlike the NAS

Plan or the NPIAS, the capacity plan discusses major airports and air traffic control systems that have existing or potential congestion problems.

In the past, higher priority resource needs have also hindered FAA's planning efforts. For example, the 1981 air traffic controllers' strike and subsequent firing of about 9,800 full performance controllers required FAA during the early 1980s to redirect its resources from planning and other areas to maintaining day-to-day safety in the skies. FAA still feels the effects of this strike as it struggles to raise the number of its full performance controllers to earlier levels.

Ineffective communication among the program offices is another obstacle officials cite as impeding consistent coordination among the plans. The program offices do not meet regularly to discuss planning objectives and strategies. Therefore, the work of one office may not be incorporated in another office's plan. For example, current activities in airport development—such as the proposed airport in Denver and other cities—were not included in the NAS Plan until the most recent update in June 1988.

Further, the responsible program offices do not have compatible databases; thus, they are less inclined to share information that could have a significant impact on the effectiveness of the implementation of the plans. Also, because the program offices may use different modeling techniques in their analyses, their results may not be easily transferable or useful to offices not using the same model.

Revised Directive's Effectiveness Tied to Top Management Support

Because a central theme of these plans is to increase aviation efficiency by increasing capacity without sacrificing passenger safety, security, or convenience, FAA needs to coordinate changes in all three National Airspace System components. Each component cannot be treated as an isolated entity. The NAS Plan, though the largest and most visible of all FAA plans, will not singlehandedly modernize the NAS through implementation of new technology. Limitations exist in the amount of increased capacity that can be provided by installing new radars and computers. Moreover, FAA has acknowledged that the largest gains in capacity are made not by applying technology, but through the construction of new airports or new pavements at existing airports. Therefore, the lack of effective coordination of the plans would impede FAA's efforts to modernize.

Although progress to date under the revised planning directive has been limited, with adequate management support the new policy should help FAA coordinate and integrate these plans. Because the order is agency-wide and mandated by FAA's top management, it is a means of cutting across all the program areas, tying together related areas, and eliminating redundant efforts. However, the continued support of the Administrator and the Secretary of Transportation will be necessary to give this long-range planning effort the visibility and priority it deserves. In addition to this support, FAA now needs to ensure that this top-level planning effort is adequately tied to the individual plans. According to FAA officials, another agencywide plan is in preparation at this time—the integrated National Airspace System Human Resources Management Plan. If this plan fulfills its objective of coordinating the personnel needs of the three NAS components, it will fill a critical need in FAA's overall long-range planning.

Summary, Conclusions, and Recommendations

Since 1983, the total estimated cost to modernize the air traffic control system has increased substantially and the schedule to complete deployment has been extended into the 21st century. Moreover, the potential exists for additional change in the future. Therefore, FAA needs to revise the NAS Plan in a larger sense than annual updates allow so that the plan, as it has now evolved, can reflect new costs and schedules that were not envisioned 6 years ago. Until now, FAA has been hindered in presenting the best information in its NAS Plan because of problems in the areas of benefit-cost methodology, operational testing policy, and implementing long-range planning policy. However, once certain changes now underway are implemented, FAA's information on project benefits and schedules and how the NAS Plan relates to other planning efforts should be sufficient to allow appropriate revisions to be made to the plan.

Significant Changes to the NAS Plan Make Revision Necessary

The NAS Plan for air traffic control modernization that FAA issued in December 1981 was based on the aviation community's projected needs identified in the 1980-81 time period. ATC modernization's needs have changed in many ways since that time. Change was not unexpected; the magnitude of that change, however, could not have been foreseen. Moreover, the change is affecting the three primary measures of the NAS Plan's status: cost, schedule, and performance. The change is accompanied by a need for improved long-range planning.

Cost Changes

As discussed in chapter 2, we believe the appropriations needed to modernize the air traffic control system will be about twice the amount FAA estimated in 1983—increasing from $11.7 billion in 1983 to our current estimate of $25 billion. Reasons for this increase include the costs of making needed engineering changes and FAA's adding new projects—some major ones such as the Terminal Doppler Weather Radar—to the basic plan. These reasons will continue to account for cost increases over the life of the NAS Plan. Thus, because FAA is, at most, only one-third through the plan (if FAA's current assumption of a 20-year life proves correct), additional cost increases can be expected over the next decade. Furthermore, because the NAS Plan does not contain estimates of the expected annual costs for each project, the full cost of ATC modernization cannot be assessed by those responsible for making funding decisions and trade-offs if necessary. Consequently, the adequacy of Airport and Airway Trust Fund revenues to finance continued modernization cannot readily be determined.

Schedule Changes

Schedules for completing the plan's projects have been extended an average of 3 years. This has been caused primarily by technical problems and FAA's inadequate definition of operational and quantity requirements for some of its major systems. This, in turn, was due to FAA's lack of experience in acquiring large-scale systems involving the development of complex hardware and software.

Schedule delays are particularly troublesome because of the ramifications they have in other areas of FAA and on other aspects of the plan. For example, delaying a project's implementation means that the expected benefits of that project—both to FAA and to airspace users—also are delayed. Further, expectations of a reduced maintenance work force cannot be properly factored into firm plans. In the meantime, costs continue to be incurred. This alters the sometimes delicate balance between benefits and costs that FAA initially used to justify the project. Therefore, because delays have been widespread in the NAS Plan, the cost effectiveness of projects not yet completed should be reassessed and those whose benefits exceed costs only marginally or not at all should be further reviewed for whether they still contribute as intended to the overall improvement of ATC services.

Performance or Scope Changes

The scope of the modernization effort as a whole also has changed in the sense that projects have been and will be added to the initial 1981 plan. Depending on degree, this constitutes a change in the expected performance of the modernized ATC system. Also, specific projects have had requirements added to their system specifications to improve the system's performance. As with changes in cost and schedule, performance and scope enhancements are expected in an effort that is responsive to technological opportunities and the changing needs of its beneficiaries—FAA and the other members of the aviation community. For example, to relieve congestion around the country, ways of increasing many airports' capacity are being considered, and for the first time since 1974, entirely new international airports are on the drawing boards, including one in the Denver, Colorado, area.

On the other hand, "down-scoping" also could be appropriate. In other words, as FAA refines its benefit-cost methodology, projects whose benefits no longer exceed costs can be culled from the NAS Plan. Or, as aviation forecasts change, appropriate changes to NAS Plan project mix and substance can be made. For example, the decrease in general aviation activity, against 1981 forecasts, reduced the need for weather information services provided to this sector of the aviation community by FAA's

flight service stations. In response to this trend and for other reasons, FAA has reduced the scope of its flight service program by reducing the number of flight service station employees in 1988 to 4,023 from 4,505 in 1981, a decline of 12 percent.

Thus, the NAS Plan as it was developed in 1981 no longer represents the complete scope of today's ATC modernization. While the plan has evolved to accommodate some new projects and changes to existing ones, it still does not incorporate many projects necesary for full modernization. Therefore, decisionmakers do not have all of the information they need to make comparisons among projects and allocate funds appropriately.

Need for Improved Long-Range Planning

As these changes to the NAS Plan have been occurring, several organizations—the Congress, the President's Aviation Safety Commission, and the Office of Technology Assessment—have concluded that an area in which FAA needs to improve is its long-range planning and coordination of major planning efforts related to the National Airspace System. FAA has also concluded that improvement in this area is needed, and in October 1986 issued revised agencywide planning policy on coordinating management across several programs. An agencywide organizational change to strengthen the link between headquarters and the regions was implemented that should, in part, help address this problem. However, according to FAA officials, implementation of the new policy has been limited to concurrence by the revised policy's board of advisors on the need for several structural mechanisms within the policy. The officials conclude, therefore, that substantive progress has not been made on achieving the policy's objectives, two of which are to ensure that (1) changes to the NAS Plan are coordinated with other major agency planning efforts and (2) human resource considerations are adequately accounted for in agency planning activities. We believe that, for the revised policy to be effective in coordinating air traffic control improvements with other plans for improving airspace and airports, it will need additional support and emphasis from top management in FAA and DOT.

Obstacles to NAS Plan Accuracy

Concerns are being expressed in the Congress about the issues of NAS Plan cost, schedule, and performance. For the Congress to consider the NAS Plan's structure in an informed manner, however, FAA must be able to provide realistic cost and schedule options and reasonably accurate estimates of corresponding benefits. In addition, FAA should be able to show how any potential revisions to the NAS Plan interrelate with the airspace and airport facets of the National Airspace System. In the past,

however, three obstacles have hindered FAA's ability to accurately present NAS Plan benefits, costs, and schedules. As discussed in chapter 4, these obstacles were that

- FAA's benefit-cost methodology has not allowed the agency to develop accurate estimates of new or existing projects, especially if the estimates depended on calculating passenger-time savings benefits;
- NAS Plan project implementation schedules have been overly optimistic, partly because of FAA's inexperience in acquiring large-scale systems and its earlier policy of not operationally testing and evaluating its major systems before committing to production; and
- long-range planning to coordinate the three components of the National Airspace System—airports, airspace, and air traffic control—was limited.

We believe that with the information currently available, FAA could not develop accurate alternative implementation strategies to today's NAS Plan. For example, FAA is unable to list, in order of cost effectiveness, the 92 projects in the current facilities and equipment plan because of the many questions surrounding the agency's benefit-cost methodology. In addition, FAA cannot list projects by their ability to satisfy mission need (meet the requirements of the probable users) because it has not adequately integrated the NAS Plan with the other FAA plans that focus on airport planning, airport capacity, or airspace congestion. Finally, FAA cannot provide a realistic implementation schedule on a system-by-system basis because the schedules provided are likely to change because of FAA's omission of operational testing and evaluation of several major systems before production.

In prior reports, we have recommended corrective actions in the areas of benefit-cost methodology, operational test and evaluation, and long-range planning. Moreover, according to FAA, actions currently are underway in each of these areas designed to have the information available to revise the plan so that it will benefit the most users at the lowest cost, consistent with overall aviation safety and operational efficiency. For example, FAA has completed one study and is nearing completion of another aimed at updating and improving many of the parameters that are central to the way the agency analyzes benefits and costs of its NAS Plan projects. In addition, FAA plans to operationally test the major system acquisitions that currently are still under development before it makes a major production commitment. Although this testing still will not be performed by an organization independent of the developer, it should enable more realistic schedules to be prepared. Finally, though

getting off to a slow start, FAA has established a plan and the necessary administrative structure to coordinate its long-range plans for all aspects of the National Airspace System.

Conclusions

In 1982, the Congress approved FAA's plan for modernizing the nation's air traffic control system. In the ensuing years, however, the modernization effort has changed substantially: its scope has been enlarged by many new projects and its cost and time to complete have approximately doubled from the early $12 billion, 10-year estimate. Moreover, questions raised from the outset about the plan's cost effectiveness are even more relevant today because total costs have increased significantly. Therefore, the Congress, DOT, and FAA would benefit from a revised NAS Plan, one that would better reflect (1) accurate costs and schedules of the plan as a whole, as well as of specific projects, and (2) current and future priorities based on the best information available regarding expected changes in airspace and airport needs.

Improved information on future plan schedule, cost, and scope will be necessary if FAA is to make such revisions. These improvements in information will likely come about through FAA's progress in (1) making needed improvements to its benefit-cost methodology, (2) implementing guidance issued by OMB that would minimize schedule risks for the NAS Plan's major systems, and (3) establishing the administrative framework necessary to implement a long-range planning process that would better relate the NAS Plan to other FAA plans for airport development, airspace changes, and work force considerations.

Recommendations

In addition to following through on recommendations we have made in the past regarding FAA's benefit-cost methodology and operational testing policy, we recommend that the Secretary direct the Administrator, FAA, to revise the ATC modernization plan by

- identifying all needed projects and their associated benefits, costs, and schedules so that relative priorities can be set on the basis of benefit-cost ratios, mission need, or safety considerations and
- reflecting in project schedules and quantity requirements the results of other agencywide plans for airspace changes, airport development, and human resource management.

Views of Agency Officials

As requested, GAO did not obtain official written comments on a draft of this report. However, GAO made the contents of a draft of this report available to responsible FAA and DOT officials who provided their individual but informal views on the draft. These views are incorporated throughout the report as appropriate. In particular, officials noted that the NAS Plan was revised in August 1988, after our audit work had terminated. On the basis of our review of the new plan, however, we believe that our conclusions and recommendations as stated in this report are still valid.

Among the officials' comments were two that directly opposed two of our principal conclusions. First, officials disagree that the NAS Plan cost has increased from FAA's current estimate of $15.8 billion to our estimate of $25 billion. Instead they believe that, while FAA may spend the higher amount on capital improvements to the air traffic control system, the added investment should not be considered part of the NAS Plan. We disagree with this method of accounting for modernization expenditures and believe that modernization and the NAS Plan should not be treated separately; one does not stop while the other continues. By denying that increasing modernization costs are not part of the NAS Plan, FAA is masking the true costs of the overall effort.

Second, officials do not believe that all major systems should adhere to the guidance contained in Circular A-109. They commented that blaming delays on not following the circular's recommendations is an oversimplification. We agree that it is not the letter of Circular A-109 itself that needs to be followed, rather it is the philosophy of minimizing the risks inherent in acquiring complex and costly systems that FAA needs to more fully adopt. In view of FAA's lack of experience in acquiring major systems, the agency should have been more attentive, rather than less, to reducing cost, schedule, and performance risks by demonstrating and validating system concepts, design, and performance at the end of each development phase. We believe that FAA's intention to now operationally test and evaluate the remaining major system acquisitions before committing to their production indicates the agency's awareness of the need to minimize the risks of acquiring costly and complex systems.

Listing of Recent GAO Reports and Testimony Related to FAA's National Airspace System Plan

Date Issued	Title	GAO Number
Reports		
07/29/88	Air Traffic Control: Efforts to Expand the New York Terminal Area Automation System	IMTEC-88-29
05/26/88	Microwave Landing Systems: No Additional Procurement Unless Benefits Are Proven	RCED-88-118
02/08/88	Aviation Services: Automation and Consolidation of Flight Service Stations	RCED-88-77
01/06/88	FAA Technical Center: Mission and Role in National Airspace System Plan Implementation	IMTEC-88-6BR
12/22/87	Air Traffic Control: FAA Should Avoid Duplication in Procuring a Traffic Management System	IMTEC-88-8
10/23/87	FAA Staffing: FAA's Definition of Its Controller Work Force Should Be Revised	RCED-88-14
09/29/87	Aviation Weather: Status of FAA's New Hazardous Weather Detection and Dissemination Systems	RCED-87-208
03/26/87	Aviation Acquisition: Improved Process Needs to Be Followed	RCED-87-8
12/17/86	Airport Radar Acquisition: FAA's Procurement of Airport Surface Detection Equipment	RCED-87-18
07/08/86	Air Traffic Control: FAA's Advanced Automation System Acquisition Strategy Is Risky	IMTEC-86-24
07/03/86	Air Traffic Control: Status of FAA's Host Computer Project and Related Software Enhancements	IMTEC-86-25BR
06/06/86	Aviation Weather Briefings: FAA Should Buy Direct User Access Terminal Systems, Not Develop Them	RCED-86-173
05/21/86	Aviation Funding: Options Available for Reducing the Aviation Trust Fund Balance	RCED-86-124BR
04/22/86	Aviation Weather: FAA System for Disseminating Severe Weather Warnings to Pilots	RCED-86-152BR
03/06/86	Aviation Staffing: Serious Problems Concerning the Air Traffic Control Work Force	RCED-86-121
07/29/85	Aviation Weather: Installation of Automated Weather Observing Systems by FAA at Commercial Airports Is Not Justified	RCED-85-78
06/17/85	GAO Questions Key Aspects of FAA's Plans to Acquire the Multi-Billion Dollar Advanced Automation System and Related Programs	IMTEC-85-11
06/06/85	Federal Aviation Administration's Host Computer: More Realistic Performance Tests Needed Before Production Begins	IMTEC-85-10
04/04/85	FAA Could Improve Overall Aviation Safety and Reduce Costs Associated with Airport Instrument Landing Systems	RCED-85-24
02/16/83	FAA's Plan to Improve the Air Traffic Control System: A Step in the Right Direction But Improvements and Better Coordination Are Needed	AFMD-83-34

(continued)

Date Issued	Title	GAO Number
Testimony		
06/02/88	Issues Related to an Independent FAA. Subcommittee on Aviation, House Committee on Public Works and Transportation	RCED-T-88-45
04/12/88	FAA Appropriation Issues. Subcommittee on Transportation, Senate Committee on Appropriations	RCED-T-88-32
04/12/88	FAA's Advanced Automation System Investment. Subcommittee on Transportation, Senate Committee on Appropriations	IMTEC-T-88-3
11/18/87	FAA's Air Traffic Controller Staffing Standards. Subcommittee on Investigations and Oversight, House Committee on Public Works and Transportation.	RCED-T-88-8
05/08/87	Effects of Delays in FAA's NAS Plan. Subcommittee on Transportation, Senate Committee on Appropriations	RCED-T-87-23
05/08/87	FAA's Acquisition of the Advanced Automation System. Subcommittee on Transportation, Senate Committee on Appropriations	IMTEC-T-87-6

OMB Circular A-109 Recommends Structured Approach

In 1976, OMB issued a policy for all executive agencies to follow in managing their acquisitions of major systems—OMB Circular A-109. The circular is designed to minimize potential problems with the development and procurement of complex major systems by increasing top management's awareness of the technical, operational, and economic risks associated with the systems. The acquisition framework and policy established by A-109 is intended to reduce the potential for cost growth, schedule delays, and performance deficiencies, and avoid the premature commitment of major systems to production.

In accordance with OMB Circular A-109, agency heads are to reevaluate major projects at four critical points in the acquisition process in terms of cost, schedule, and performance, and reaffirm the need for the projects at each decision point. At each of the four key decision points, agency heads are to decide whether the projects are ready to move to the next phase in the acquisition process.

Acquisition Phases

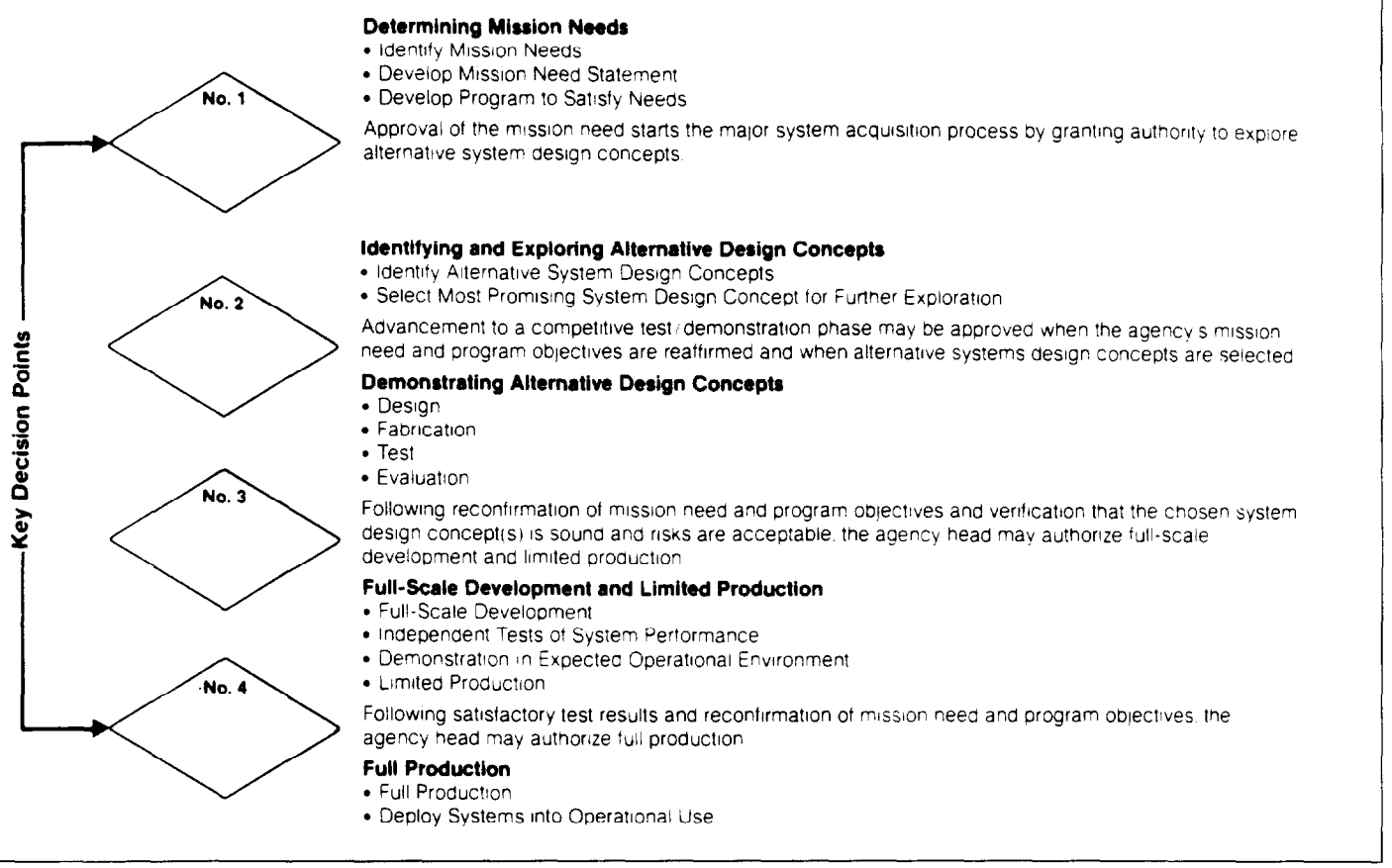
The acquisition of major systems begins with the identification of a mission need. OMB considers that determining mission need is the most important part of the acquisition process. The thinking and planning involved in the phase affects the character, quality, and, ultimately, the cost of the major system which is procured.

Following the determination of mission needs, the A-109 acquisition process continues with four additional phases where passage from one phase to the next is decided by the agency head. The five acquisition phases are: (1) determination of mission needs, (2) identification and exploration of alternative design concepts, (3) demonstration of alternative design concepts, (4) full-scale development and limited production, and (5) full production and are illustrated in figure II.1.

Identification and Exploration of Alternative Design Concepts

This initial phase of the A-109 acquisition process occurs when alternative system design concepts are solicited from a broad base of qualified firms. These firms submit their concepts to fulfill the identified mission need in a form suitable for preliminary evaluation. The intent is to generate innovation and competition for the best system design to meet the mission need.

Figure II.1: Basic Major System Acquisition Review Process



Demonstration of Alternative Design Concepts

Once alternative system design concepts are selected, the project is advanced to the demonstration/test phase. Before awarding a contract for this phase, however, the agency must reaffirm its mission needs and project objectives. An agency head must decide whether to pursue alternative concepts or proceed with a single concept.

Full-Scale Development and Limited Production

Alternative system(s) can enter full-scale development, including limited production, only after the agency's mission need and program objectives have again been reaffirmed and demonstration results verify that the chosen system design concepts are sound. Agency head approval is

again required for the project to move into full-scale development and initial production.

Full Production

Agency head approval is also required for a system to enter into full production. This decision is made only after reaffirming the agency's mission need and program objectives, and satisfactorily testing system performance under expected operational conditions. Operational testing is conducted independent of the agency's development and user organizations.

An important facet of OMB Circular A-109 guidance is that the production commitment should not be made until a system's performance is tested in a realistic operational environment. The importance of following this approach was recently affirmed in the February 1986 Interim Report of the President's Blue Ribbon Commission on Defense Management. The Commission concluded that full-scale development testing of weapons systems is critical to improve system performance and that systems should not go into high-rate production without operational test results.

DOT's Implementation of OMB Circular A-109

Because FAA is an administration within DOT, the Department is ultimately responsible for approving the acquisition of major NAS plan projects. DOT has implemented OMB Circular A-109 acquisition policies through directives and memorandums which serve as the basis for the acquisition policies of its various administrations, including FAA. DOT's Order 4200.14B, dated January 6, 1983, Major Systems Acquisition Review and Approval, is the primary DOT directive implementing OMB Circular A-109. The directive designates the Deputy Secretary of Transportation as DOT's Acquisition Executive. As such, he is responsible for designating major projects and approving them at each key decision point in the acquisition process. The directive defines major systems as:

". . . that combination of elements that will function together to produce the capabilities required to fulfill a mission need. . . . Major systems acquisition programs are those programs that (1) are directed at, and are critical to, fulfilling a Departmental mission, (2) entail the allocation of relatively large resources, or (3) warrant special management attention. For the purpose of this Order, systems acquisitions which meet the requirements set forth above, or which have a total estimated acquisition cost of $150 million or more, or which have an anticipated total expenditure of $25 million or more in research and development funds shall be candidates for designation as a major system . . . ."

The Deputy Secretary fulfills his responsibility for approving the acquisition of major projects through his role as Chairman of DOT's Transportation Systems Acquisition Review Council (TSARC). Other TSARC members are the Assistant Secretaries of Transportation for Policy and International Affairs, Budget and Programs, Governmental Affairs, Administration, and Public Affairs, and the DOT General Counsel. The DOT order requires TSARC to review the acquisition of each major project at the four key decision points and, at other times, as directed by the Deputy Secretary. The reviews are to concentrate on the project's status in terms of its estimated cost, schedule, and performance requirements.

FAA's Implementation of OMB Circular A-109

FAA bases its major project acquisition process on OMB Circular A-109 and DOT Order 4200.14B. FAA Order 1810.1D, Major Systems Acquisition, dated July 13, 1985, establishes the current management policies and procedures for major project acquisitions. According to FAA officials, this directive substantially revised FAA's previous major project acquisition management process, with the intent of improving the overall efficiency of the review process between FAA and DOT.

Previously, FAA had required only certain designated major projects to receive special management attention, based on their importance to the agency. For example, the program manager was accountable directly to FAA's Administrator, independent cost and operational testing and evaluation reviews were required, and program reviews were required to be held more frequently than for nondesignated major projects. Also, FAA had an Aviation System Acquisition Review Committee (ASARC) to review each project before it was sent to TSARC.

FAA's current major project acquisition directive deleted ASARC and its review function. Individual program managers now are accountable to the NAS Program Director who, in turn, is directly accountable to the FAA Administrator for all NAS plan activities. The new process also requires that FAA now subject all major projects to the same procedures.

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