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BY THE COMPTROLLER GENERAL

Report To The Chairman, Committee On Government Operations, House Of Representatives

OF THE UNITED STATES

FAA's Plan To Improve The Air Traffic Control System: A Step In The Right Direction But Improvements And Better Coordination Are Needed

The Federal Aviation Administration (FAA) has developed a modernization plan that describes specific improvements in facilities and equipment needed in the air traffic control system by the end of the century. Savings over the next 20 years are estimated at $25 billion. Total system costs are still being developed but FAA estimates that for the first 10 years the cost will run between $8.7 billion and $9 billion.

GAO recommends that FAA develop an integrated long-range plan addressing all aspects of the National Airspace System including use of the Nation's airspace and airports. Preliminary findings from ongoing airport and airspace reviews should be coordinated with equipment and facility decisions in the modernization plan. The modernization plan should be updated to identify priorities, subsystem costs, and interdependency of projects.

Other GAO recommendations are aimed at reducing acquisition costs of the en route replacement computers and strengthening the management and development of automation and communications systems to alleviate problems identified and satisfy the increased management demands of the new system.

UNITED STATES GENERAL ACCOUNTING OFFICE

GAO/AFMD-83-34

FEBRUARY 16, 1983

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[redacted]

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

B-206887

February 16, 1983

The Honorable Jack Brooks
Chairman, Committee on Government Operations
House of Representatives

Dear Mr. Chairman:

In accordance with your Committee's June 11, 1981, request (H. Rept. 97-137) and subsequent discussions with your office, we have completed a comprehensive review of the Federal Aviation Administration's (FAA's) planning, management, and acquisition of existing and future automated systems for air traffic control and management.

We have already issued four reports on this subject: one to the Secretary of Transportation and three to your office. In our report to the Secretary of Transportation (AFMD-82-47, Feb. 18, 1982) we advised that FAA should obtain a delegation of procurement authority for its planned acquisition of computers for air traffic control. At your request we provided you with our interim assessment of FAA's National Airspace System (NAS) plan (AFMD-82-66, Apr. 20, 1982). We then responded to the FAA Administrator's concerns about that report (GAO/AFMD-82-91, June 4, 1982). Finally, we assessed FAA's planning, management, and acquisition for administrative computer systems (GAO/RCED-83-60, Nov. 24, 1982).

In January 1982, FAA publicly announced its National Airspace System plan, with goals directly related to the concerns stated in your original request. That document identifies facility and equipment improvements that FAA believes must be made in the next 20 years. According to FAA, implementation of the entire plan will result in savings of $25 billion over this 20-year period. Costs for the first 10 years are estimated by FAA to run between $8.7 billion and $9 billion. Total system costs are being developed. In view of this significant investment and its stated objectives, we made the NAS plan a major part of our review.

This final composite report responds to your concerns about FAA's planning and management of existing and future automated systems for air traffic control. The acquisition of equipment is discussed where appropriate under each section. The objectives of our review were to

--identify current and future automation issues concerning the planning and management of existing en route and terminal area air traffic control,

--determine whether FAA's NAS modernization plan is well founded and will resolve issues and problems identified during our review, and

--determine whether selected major near-term communications projects have been properly planned, managed, and coordinated with future users.

To gain insight into FAA's planning, management, and acquisition of existing and future systems for air traffic control, we selected 7 of 20 en route centers and 10 of 186 terminal facilities for review. We also reviewed the NAS plan, discussed it with FAA officials, and analyzed its supporting documentation. A discussion of the scope and methodology used as well as a more detailed discussion of the technical issues is provided in appendixes II through VI. This letter summarizes our findings and conclusions.

CONCERNS ABOUT PLANNING AND ACQUISITION EFFORTS FOR FUTURE SYSTEMS

FAA's NAS plan is a step in the right direction toward modernizing facilities and equipment as well as toward supporting needed engineering and research. However, FAA has not yet develope a comprehensive overall agency long range plan. Also, we believe the NAS plan itself is incomplete because it does not address in an integrated manner the long range requirements of the National Airspace System. The System is made up of three major areas--airspace, airports, and the air traffic control system. The NAS plan considers only one of these--the air traffic control system facilities and equipment. FAA has begun studying the other two areas, and results will be known about 1985.

Implementation actions should be coordinated with ongoing studies

FAA recognizes that an integrated plan is desirable and believes that the results of the National Airspace Review, combined with the NAS plan, will evolve into such a plan. We would agree with this view if both efforts were being developed simultaneously or if implementation of the NAS plan were being timed to correspond with improvements developed through the National Airspace Review. However, this is not the case. The NAS plan is being implemented today and the National Airspace Review will not be completed until late 1985. Furthermore, we believe the airport plan should be considered in the development of an integrated plan.

FAA is in the process of procuring much of the computer and communications equipment it believes will be needed to operate the air traffic control system into the mid-1990s. This is risky because decisions about the amount of equipment needed, where to locate it, and the capabilities it must provide should be based on the outcome of ongoing efforts for managing the Nation's airspace and airports.

Conversely, these same equipment decisions may constrain the breadth and depth of the ongoing planning efforts. The investment in new computer and communications equipment is apt to constrain improvements in the use of airspace and airports. Under this constraint, it is unlikely that relocation or reconfiguration of centers and terminals would be recommended even if the ongoing reviews showed that to be the best use of the Nation's airspace and airports.

We are not suggesting that FAA delay implementing the NAS plan until the other ongoing studies are completed. Our purpose is to point out that there is risk associated with FAA's approach and that it would be prudent for FAA to consider how the possible outcome of ongoing studies may affect projects in the NAS plan, and vice versa. For example, at certain milestones FAA could discuss and evaluate preliminary findings of the ongoing reviews and assess their impact on implementation of projects in the NAS plan. By coordinating these two efforts, FAA could better ensure that the right equipment is procured and installed at the right location, avoid incurring additional expenses, and achieve integrated development of the National Airspace System. (See p. 13.)

NAS plan should be updated

The plan also should assign priorities to projects and clarify their predicted impact on the system as a whole. This would increase the likelihood that the plan's major goals will be met. We are concerned that because of possible budgetary constraints or engineering problems, some projects may be eliminated or some schedules altered. For example, the Mode S Data Link System, designed to improve aircraft surveillance performance and provide a computer-to-cockpit message capability, was unable to meet the basic capacity performance requirement. Also, the Traffic Alert and Collision Avoidance System, designed to warn pilots of impending collision, has not been proven effective in averting collisions and may need to be replaced by a system with significantly higher costs.

The NAS planners should assess alternatives and provide for contingencies in the event of project delays or cancellations. For example, FAA should plan to extend the existing computer system life if developmental delays or other problems are encountered with the computer replacement program. Also, officials of the Advanced Automation Office said they do not have plans for handling events that may occur during the demonstration phase such as late contractor development, or overcost but unfinished development for the computer demonstration phase. While the plan states gross estimated savings of $25 billion over the next 20 years, costs beyond the first 10 years have not been developed. Further, the plan does not identify total subsystem costs. FAA needs to calculate and provide the detailed costs of these projects for future year budgeting purposes.

Projects that are interdependent should be identified as such in the plan so that development efforts can be coordinated and goal and objectives met. For example, the consolidation of en route centers and terminals is dependent on adequate communications (radar and telecommunications), but this is not clearly shown in the plan. Changing from more than 200 en route centers and terminals to about 40 consolidated facilities requires establishing and relocating equipment, buildings, and personnel. Day-to-day air traffic control operations will need to be maintained during the changeover. Consolidation could be delayed or benefits reduced because FAA has separated these interdependent efforts. A similar situation may occur between the Mode S Data Link and the terminal computers.

Since major capital expenditures will start in 1984, we believe it is essential that the NAS plan be updated to incorporate priorities, contingencies, subsystem costs, and identification of interdependent projects. Periodic updating of the plan will increase FAA's flexibility and capability to meet future growth. (See pp. 10 - 15.)

Rejection of alternative was correct

Prior to the issuance of the NAS plan, FAA was planning to replace its existing en route computers with a conceptually different and fully automated air traffic control system. The computers were to be acquired by soliciting alternative concepts from industry. Development and demonstration of prototypes of the more promising alternatives would precede the decision to build production systems. This strategy was criticized by several congressional committees. The criticism was based on FAA's (1) inability to show that existing en route computers had the necessary capacity and reliability to last until this future system was installed, and (2) inadequate identification of its mission needs and system requirements. As a result, FAA was directed to develop alternative strategies.

One of the alternatives evaluated but rejected by FAA--upgrade of centers with the 9020A computers to 9020D computers--has been the subject of subsequent debate by several congressional committees because it appears to be the lowest cost alternative, of low technical risk, and capable of providing the needed computer capacity. We found that FAA's rejection was correct and that there were even more compelling reasons for not choosing this alternative than those identified by FAA: (1) FAA used 1977 equipment prices to cost the alternative. Prices of 5 years ago do not reliably indicate today's costs. (2) The original manufacturer of the computers does not consider restarting facilities to produce such equipment as practical and cost-effective and would do so only in response to a national emergency. In congressional hearings, FAA proposed using this as a fallback position if the computer replacement is delayed or if existing computer capacity is reached before expected. We believe FAA would do well to reconsider whether this is still a valid fallback option and try to develop other contingency options. (See pp. 15 - 16.)

Contract type for computer demonstration should be reconsidered

FAA's chosen computer modernization strategy calls for replacement of its en route center and terminal area equipment. Initially, by about 1988, the en route computers will be replaced. About 1990, as other projects are completed, the terminal equipment will be replaced or its functions consolidated into the centers. FAA has determined that the new computers must be capable of processing the existing en route software. Before deciding on the en route computer replacement, FAA will conduct a demonstration "compute-off." On a cost-plus-a-fixed-fee basis, it will fund two competing contractors to modify the existing software and demonstrate that this software can be processed on off-the-shelf equipment proposed by each contractor. Each contractor could get about $34 million to do this.

The guideline FAA is following for the computer demonstration presumes that newly developed and untried alternative concepts and solutions to agency mission needs must first be demonstrated. However, in its Request for Proposals, FAA is not soliciting alternative concepts and solutions, but has restricted the architecture and size of the off-the-shelf replacement computers. This constrains the purpose of the demonstration philosophy FAA is following. FAA has justified its need to have competing demonstrations because of the risk involved in using the existing software. However, FAA has also stated that there is a high probability that development--using the existing software--is feasible and has determined performance objectives and a schedule of completion.

We understand FAA's desire to modernize its existing en route centers with more capable and reliable computers. However, we believe the end result desired--proving that the replacement computers will process the existing modified software--can be achieved by less costly contractual methods. For example, a 1981 FAA contractor study estimated that all the software used on the center's computers could be modified to run on newer instruction-compatible computers for about $5.8 million (FAA is excluding the software modification for the display computers since they will not be replaced at this time). This cost represents a major component in the work to be completed by each contractor.

Principally, the Government employs two types of contracts, fixed-price and cost-reimbursement. In advertised procurements, some form of a firm fixed-price contract is used since the specifications are definite and competition is present. Firm fixed-price contracts place the greatest risk of performance on the contractor. FAA plans to use a firm fixed-price contract for acquiring the production replacement computers. At the other extreme, negotiated cost-reimbursement contracts such as cost-plus-a-fixed-fee place the cost or maximum performance risk on the Government, with the contractor receiving a guaranteed fee plus reimbursement for all costs. Cost-plus-a-fixed-fee contracts provide the contractor with only a minimum incentive for effective management control of costs. FAA plans to use a cost-plus-a-fixed-fee contract for the computer demonstration.

FAA has considered other procurement strategies but found them to be incompatible with its needs. We believe the information relative to defined specifications, commercial applicability, and FAA's own perception that the demonstration will be successful warrants reconsideration of the decision to use a cost-plus-a-fixed-fee contract.

According to FAA contract officials, a firm fixed-price contract was rejected because the system's specifications could not be sufficiently defined. We have surveyed the Request for Proposals and believe it amply defines the system's specifications. These officials also stated that a cost sharing contract was considered but not fully analyzed. It was deemed inappropriate because of the lack of commercial application (commercial application was interpreted as only the U. S. market). We believe use of a cost sharing contract may be appropriate because research and development funds are being used for the computer development and demonstration and the final product may have commercial value (other than in the United States). Additionally, officials of the Advanced Automation Office have pointed out that the replacement computers would be off-the-shelf (commercially available) computers and would not be modified. While they consider this approach risky, they believe the probability that one of the contractors will fail during the demonstration phase is very low. Therefore, the decision to proceed with a cost-plus-a-fixed-fee contract was made without fully assessing the advantages and costs of the other alternatives.

Before awarding the multimillion dollar demonstration contract, we believe FAA should fully analyze the appropriateness and cost/benefits of a firm fixed-price and cost-sharing contract. Since this could be done while contractors are preparing proposals, we believe it would cause little delay. The results of this analysis should be reported to the Department of Transportation Acquisition Executive for determination of most appropriate contract method before awarding the demonstration contract. We believe this determination could result in lower total acquisition costs. (See pp. 16 - 20.)

CONCERNS ABOUT MANAGEMENT OF AIR TRAFFIC CONTROL AUTOMATION AND COMMUNICATIONS

During our review of current and proposed systems, we found that the management, planning, and acquisition of en route and terminal air traffic control automation projects has not been adequate. In addition, our review of communications and navigation projects disclosed technical problems, uncoordinated implementation schedules, and questionable user acceptance of these projects.

Centralized guidance needed for automation projects

FAA has about 200 computer systems which are located at the various centers, terminals, and support facilities. Without them, control of the Nation's air traffic would be severely affected. We found that the authority, accountability, and responsibility for these automation resources are unclear. FAA's organizational structure and management approach do not provide the needed integrated planning, control, and direction we believe is necessary to ensure efficient use of air traffic control automation resources. For example, officials at the Seattle en route center said that they and 75 percent of the other centers use a local software modification that automatically produces hourly weather information. Each time FAA implements a new national software version for the centers (about every 6 months), each center using this local modification must insert and test it independently. These efforts use personnel and computer resources and could be minimized if the modification were incorporated into the national system.

We found that offices responsible for managing individual programs are not able to ensure that agencywide needs are adequately coordinated because no central management function is accountable and responsible for overall integration and direction of project management activities. We believe recent FAA efforts to realign automation engineering functions and establish a central program office for the computer replacement project will help to improve management control. However, some automation functions still need to be integrated. A fully integrated central management function would increase agencywide visibility of both current and new projects such as those in the NAS plan.

We found that FAA is experiencing delays and cost overruns in many systems and software development projects designed to implement safety and fuel efficiency improvements. For example, the feature that warns the controller when an aircraft is approaching a known obstruction, such as a mountain, is not operational at six centers that control airspace over mountainous terrain because this feature was not properly designed to meet the requirements of all centers.

In addition, as recommended by the Congress, FAA should establish a computer performance management function. Such central management would provide greater certitude in predicting when centers and terminal facilities will no longer be able to provide adequate and timely computer support to air traffic controllers. (See pp. 22 - 41.)

We found that the New York Terminal Radar Approach Control (TRACON) facility has computer problems that have delayed integration of air traffic control in the New York metropolitan airspace. The TRACON may not have sufficient computer capacity to fully support the five airports FAA originally planned for it to handle and lacks sufficient computer capacity to meet the increased traffic volume expected in future years. Also, the TRACON does not have an operational conflict-alert feature, which automatically alerts controllers when two or more aircraft are on a collision course. (See pp. 42 - 47.)

When viewed in the aggregate we believe these problems demonstrate the need for overall integration and direction of agencywide resources. While not a cure-all for the delays and cost overruns experienced, a central management function could heighten project visibility and accountability and provide guidance for considering agencywide requirements.

DEVELOPMENT PROBLEMS ASSOCIATED WITH COMMUNICATIONS PROJECTS

The projects we reviewed were the Mode S Data Link System, the Traffic Alert and Collision Avoidance and Microwave Landing Systems, and the Flight Service Station Automation Project. We found that technical problems associated with the first three indicate a need for further testing to make sure performance requirements are satisfied. In recalculating the cost/benefits of the Flight Service Station Automation Project, we found it offers no cost advantage to the Government in comparison to existing systems and that additional benefits have not been quantified.

Mode S

FAA needs to resolve a number of Mode S problems to ensure effective and efficient implementation of air-ground digital communications. Prototype testing disclosed problems with supporting equipment that prevent achievement of capacity performance requirements. Mode S acceptance by users and by the international standards organization is questionable, but is needed to maximize the benefits from FAA expenditures. Another problem is that implementation of Mode S is not timed to coincide with the installation of new air traffic control projects; this could limit planned improvements. (See pp. 48 - 51.)

Traffic Alert and Collision Avoidance System

FAA is developing the Traffic Alert and Collision Avoidance System, which is intended to serve as a backup to air traffic control. This system is aircraft-based and warns pilots of impending collision. Its effectiveness may be severely reduced by three factors: (1) unwanted or unnecessary advisories given to pilots could be disruptive, (2) pilot response to advisories may take too long, and (3) aircraft without transponders cannot be detected by the system.

FAA should demonstrate that the Traffic Alert and Collision Avoidance System can function effectively and should assess the degree of acceptance of the system by users. It should also determine with better accuracy the possible benefits and expected user costs of the system. (See pp. 51 - 55.)

Microwave Landing System

The Microwave Landing System is scheduled to replace both (1) the instrument landing system now used by civil and military aircraft, and (2) the ground controlled approach system used primarily by military aircraft. FAA needs to resolve outstanding technical problems associated with the reliability of Microwave Landing System equipment, including its Precision Distance Measuring Equipment. FAA has tested several prototypes of this equipment from two contractors. Although the test report recommended further testing to isolate the cause of a significant bias, FAA has not conducted such testing. In addition, to meet its primary objective of providing a standard civil and military method for precision approaches and landings, FAA needs to reach agreement with Defense. (See pp. 55 - 57.)

Flight Service Station Automation Project

The Flight Service Station Automation Project is intended to provide automated weather pilot briefings and graphic weather displays to flight service specialists via cathode ray tube terminals. Starting in 1984, FAA plans to introduce this automated assistance at a few locations. It plans to expand the service to more locations in the future and eventually upgrade it to allow pilots to receive weather briefings and file flight plans without a flight service specialist.

FAA needs to reevaluate the flight service station project to determine whether the aviation community will be willing and able to utilize automated services once they become available. FAA may need to retain flight specialists to directly interact with pilots who cannot use, or choose not to use, automated methods. Also, there are substantial uncertainties about the future demand for flight services. The flight service station project may not meet FAA's prime program objective, which is to reduce costs. It may, instead, actually increase costs.

We believe previous cost/benefit analyses were deficient, in part because they did not use sensitivity analysis; that is, they did not consider a range of factors. In addition, our detailed analysis and subsequent recalculation of costs and benefits disclosed some highly questionable adjustments without which the project would not have been justified by FAA's analysis. FAA needs to recompute its cost/benefit analysis to determine whether this program should be continued, delayed, or terminated. (See pp. 57 - 61.)

RECOMMENDATIONS

We recommend that the Secretary of Transportation direct the FAA Administrator to:

--Implement a comprehensive planning process for the National Airspace System (use of the Nation's airspace, airports, and the air traffic control system) that will result in a long range plan. This process should provide a mechanism to (1) define system requirements agencywide, (2) establish objectives, strategies, and priorities for these requirements, (3) coordinate preliminary or final results of ongoing reviews with implementation of the NAS plan, and (4) update the NAS plan and identify project priorities, contingencies, total and subsystem costs, and interdependencies.

--Fully analyze and evaluate the appropriateness and cost/benefits of a firm fixed-price, cost-sharing, and cost-plus-a-fixed-fee contract for the computer demonstration, and report the results of this analysis to the Department of Transportation Acquisition Executive, for determination of most appropriate contract method before awarding the demonstration contract.

--Strengthen the management of automation resources by establishing a central management function which would have the authority, responsibility, and accountability required to alleviate problems identified, and would satisfy the increased management demands of the major upgrade.

--Assess and resolve promptly the identified critical communication issues. This should include:

- Enforcement of further testing to ensure that performance requirements are satisfied for Microwave Landing System, Mode S, and Traffic Alert and Collision Avoidance System before implementation proceeds.

- Assurance of user acceptance of Mode S, Traffic Alert and Collision Avoidance System, and Flight Service Station Automation Project before proceeding with full implementation.

- Reevaluation of total costs and benefits of Traffic Alert and Collision Avoidance System before implementation.

- Reassessment of costs and benefits to Flight Service Station Automation Project users so that a decision can be made about implementing the program.

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We did not obtain agency comments on this report. Unless you release its contents earlier, we plan no further distribution of the report until 30 days from its date. At that time we will send copies to the Secretary of Transportation and the Administrator of the Federal Aviation Administration, and will make copies available to other interested parties.

Sincerely yours,

Charles A. Bowsher

Comptroller General
of the United States

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ABBREVIATIONS

ATIS	Automated Terminal Information Service
ARTS	Automated Radar Terminal System
DARC	Direct Access Radar Channel
EMSAW	En route minimum safe altitude warning
ERM	En route metering
ETABS	Electronic Tabular Display Subsystem
FAA	Federal Aviation Administration
GAO	General Accounting Office
IBM	International Business Machines Corporation
ICAO	International Civil Aviation Organization
IFF	Identify Friend or Foe
IFR	Instrument Flight Rule
MARS	Maintenance Automated Reporting System
MLS	Microwave Landing System
NAS	National Airspace System
OMB	Office of Management and Budget
PDME	Precision Distance Measuring Equipment
TCAS	Traffic Alert and Collision Avoidance System
TRACON	Terminal Radar Approach Control
TSC	Transportation Systems Center

NINETY-SEVENTH CONGRESS

Congress of the United States

House of Representatives

GOVERNMENT ACTIVITIES AND TRANSPORTATION
SUBCOMMITTEE
OF THE
COMMITTEE ON GOVERNMENT OPERATIONS

RAYBURN HOUSE OFFICE BUILDING, ROOM B-350-A-B
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September 29, 1981

Mr. Milton J. Socolar
Acting Comptroller General
U. S. General Accounting Office
441 G Street N.W.
Washington, D.C. 20548

Dear Mr. Socolar:

The Government Operations Committee's Report on Air Traffic Control Computer Failures, House Report No. 97-137, June 11, 1981, directs that GAO review FAA's planning, management, and acquisition of automated information systems for air traffic control and FAA management purposes. The report, which is based on a study by this subcommittee, also directed GAO to report its findings, conclusions, and recommendations no later than October 1982.

Since the review will encompass areas of concern to both the full committee and this subcommittee, it has been agreed that issues concerning the National Air Space Control System will be reported separately to this subcommittee, and that those concerning automated information systems, information resource management and management information systems, will be reported to the full committee.

Some of the proposed FAA systems of particular concern to the subcommittee are:

Beacon Collision Avoidance System (BCAS), Flight Service Station (FSS) Program, Discrete Address Beacon System (DABS), Microwave Landing System (MLS), Very High Frequency Omni-Range/Tactical Air Navigation System, Airport Surveillance Radar, Approach Landing System Improvements, Air Route Surveillance Radar, Low-Level Wind Shear Alerting System, Voice Switching and Control System, Electronic Tabular Display Sub-system (ETABS), the Air Traffic Control Computer Replacement Program, Air Traffic and Advisory Resolution Service (ATARS), En Route Minimum Safe Altitude Warning (EMSAW), En Route Metering (EMS), Conflict Free Clearances (CRC), Automated Flight Planning (AFP), Integrated Flow Management System (IFMS), and Threat Alert and Collision Avoidance System (TCAS).

Because of the need to ensure the air safety of the traveling public and FAA's demonstrated inability to plan and manage even the simplest of projects, I request that this subcommittee be briefed regularly so that problems needing immediate action can be called to FAA's attention and resolved or, if necessary, hearings held.

The Administrator of FAA has said that his decisions and planning will be made on a national airspace system perspective rather than on a system-by-system basis. I have heard these promises before from other administrators and FAA civil servants. Consequently, I request that your work in the areas of planning, management and acquisition be a broad system type review. I also see that a high level composite report summarizing and including information from all the other reports will be needed by this subcommittee.

We look forward to working with you and your staff on this critical review. With best wishes, I am,

Sincerely,

JOHN L. BURTON
Chairman

JLB:WDG:cm

BACKGROUND, OBJECTIVES, SCOPE, AND METHODOLOGY

The Federal Aviation Administration is responsible for ensuring the safe and efficient use of the Nation's airspace. It does this by

--controlling the use of the navigable airspace of the United States and regulating both civil and military operations in such airspace in the interest of safety and efficiency, and

--developing and operating a common system of air traffic control and navigation for both civil and military aircraft.

This responsibility is the basis for developing the overall National Airspace System. The NAS is a complex network of airports, airways, terminal control areas, and en route air traffic control systems. The network includes surveillance systems, communications, avionics, weather information services, navigation aids, and computer systems, all of which help the FAA controllers coordinate air traffic.

HOW THE NATIONAL AIRSPACE SYSTEM OPERATES

Minute-by-minute control of aircraft in the NAS is the responsibility of FAA's air traffic controllers. At the terminal facilities, controllers handle aircraft departing from and arriving at airports. Once outside the area of the terminal, aircraft flying under instrument flight rules are the responsibility of controllers at en route centers.

Aircraft flying under instrument flight rules include commercial, general aviation, and military aircraft. Upon request, FAA will also provide services to aircraft flying under visual flight rules.

Radar is used to pinpoint the location, altitude, and direction of aircraft. This radar data, along with flight plan information filed by pilots, is displayed on the controller's work station.

Shortly after takeoff, control of an aircraft is "handed off" by the terminal controller to the en route center controller for tracking. As an aircraft moves across the country, the center computer updates the flight plan and transmits it directly to computers at other appropriate centers so that the aircraft can be tracked continuously.

For aircraft moving from one controller's airspace to another within a center, or from center to center, the computer automatically generates flight data strips at the receiving center controller's work station in preparation for handoff. The data block will blink on the screen of the controller working the aircraft and also on the screen of the receiving controller. When the receiving controller accepts the handoff, the aircraft pilot is told to contact the next controller on an assigned radio frequency. As the aircraft enters the destination terminal control area, a handoff is made to the terminal controller for clearance and landing at the airport.

Level of automation in terminal areas

The four major types of systems currently installed in terminal areas are the TPX-42, the ARTS II, the ARTS III, and the ARTS IIIA.

The TPX-42 is a semiautomatic, nonprogrammable system that displays radar data. If an aircraft is equipped with an altitude encoding transponder, the altitude is also displayed. Thirty-five TPX-42 systems are in use at low activity facilities and two at support activities. The TPX-42 does not interface with other terminal or center computers.

The ARTS (Automated Radar Terminal System) II computer is programmable and performs limited automated tasks. Unlike the TPX-42, the ARTS II is capable of converting radar information into flight identification for display on the controller's work station. ARTS II computers are used at 89 facilities of low to medium activity. At some terminals, ARTS II computers can be interfaced with en route center computers for automatic exchange of information.

The highest level of automation is used at the 62 operational facilities equipped with the ARTS III/IIIA computers. FAA designates these facilities as Terminal Radar Approach Controls. In addition to performing the functions of an ARTS II, these computers predict the position of an aircraft and display the data on the controller's work station.

FAA has upgraded, or is now upgrading, the hardware and software capabilities of all ARTS III systems. The upgrade, including partial automation for the New York TRACON, will cost about $89 million. Over the next 5 years, the TPX-42 will be replaced by 37 new systems and the ARTS II will be upgraded to IIA at 89 sites. The estimated cost of this replacement and upgrade is $50 million. (See p. 29.)

Safety features and controller aids vary with equipment capabilities. The ARTS III and IIIA have a "minimum safe altitude warning" feature which automatically alerts controllers when aircraft altitude becomes low relative to the ground or to tall buildings or mountains. These computers also have a "conflict alert" feature which warns controllers when two aircraft are flying on a collision course. However, this feature is not operational at the New York TRACON or Tampa/Sarasota facility. The

TPX-42 and ARTS II currently have none of these features. FAA intends to develop and implement these features for the ARTS II and TPX-42 by 1985 and 1987, respectively.

With the exception of the TPX-42 (which is nonprogrammable), each of the terminal systems uses basic software that has been adapted to fit the individual needs of the terminals. The software programs for these terminal facilities are developed at the Atlantic City, New Jersey, Technical Center.

Level of automation in the en route centers

Four different computers forming three different hardware configurations are used in the en route centers for processing data. The IBM (International Business Machines Corporation) 9020A and 9020D computers are used for processing flight plan and radar data, while the Model 9020E and the Raytheon 730 computers are used for processing display information.

The 9020A computer has less computer processing capacity than the 9020D. During the building of the NAS, FAA replaced many of the 9020As with the larger 9020Ds because the 9020As could not handle the workload.

Some of the components in the 9020A and D can be switched in and out to provide backup in the event of a partial failure or to increase processing capacity during busy periods. Also, there is an independent backup system called direct access radar channel (DARC) which is used in the event of a total failure of the 9020s. This backup system does not duplicate all 9020 capabilities nor was it planned to. DARC is being upgraded with additional features at a cost of over $34 million.

Having three different hardware configurations necessitates using three variants of the basic NAS software. These variants are further expanded at each en route center because of local airspace characteristics and unique, locally developed software. The basic software programs for these en route computers and the DARC system are developed at the Atlantic City Technical Center.

Safety features and controller aids vary with equipment capabilities and center needs. All centers have common safety features built into the software such as the conflict alert. Not all centers activate the safety features for a number of reasons, for example: the centers decide they don't need the features, computer capacity is inadequate, and/or staff needed to adapt the features is not available. The en route minimum safe altitude system is not used at six centers because the program would have to be modified at these centers. An improved version of the en route metering (ERM II), developed to promote fuel efficiency, will not be used at any center because the program is too large to fit onto the computer. (See pp. 31 - 32.)

The en route computers are also used to train air traffic controllers; to test and debug new versions of the software programs and develop locally unique software; to develop, test, and implement new major programs for use at the various centers; to automatically record system events and controller actions; to process maintenance reporting data; and for miscellaneous administrative data processing support required by local officials.

By 1988, at an estimated cost of about $300 million, FAA plans to replace all the 9020A and 9020D computers. The 9020E and Ratheon 730 will continue to be operational until about 1990, at which time they will be replaced or eliminated.

OBJECTIVES, SCOPE, AND METHODOLOGY

House Government Operations Committee Report No. 97-137, June 11, 1981, requested that we review FAA's planning, management, and acquisition of automated systems for air traffic control and management purposes (administrative systems). In response to this request, we initiated comprehensive evaluations of FAA's automated information systems that are used to meet mission and administrative needs. In a separate report we evaluated FAA's automated systems for administrative purposes. This report deals with automated systems and communications used for air traffic control.

Our objectives were to

--identify current and future automation issues concerning the planning and management of en route and terminal area air traffic control,

--determine whether FAA's NAS modernization plan is well founded and will resolve issues and problems identified during our review, and

--determine whether selected major near-term communications projects have been properly planned, managed, and coordinated with future users.

To look at current air traffic control automation, we reviewed en route center and terminal area software and hardware development projects, and current practices and operations. We examined these projects and practices to identify any systemwide (not isolated) weaknesses that might exist.

For our analysis of en route computer reliability, we obtained computer tapes of FAA's Maintenance Automated Reporting System (MARS) data base, calendar years 1979, 1980, and 1981, for the selected en route centers. The MARS is a data collection, accumulation, and retrieval system designed to process facility system, subsystem, and equipment maintenance information for local, regional, and national use. MARS contains three major data bases that identify facilities, equipment, and periodic maintenance tasks.

The records in the MARS data base may consist of multiple records (primary and secondary) which pertain to the same action/ incident. To create our data base we included only the primary records for the central computer and the display computer systems and selected only specific components of those two systems. Selected were:

--computer elements

--storage element

--input/output control element

--disk control unit

--integrated control unit

--peripheral adapter module

--storage control unit

--system console

--tape control unit

--central processor

--input/output control

--buffer memory

--high speed filter

Because there were a great many records and coding variations between centers, we used a binary search technique to find and select components and converted the coding to FAA standards. The following table is a summary of the records that were processed for the seven en route centers.

Center	Universe size	Selected records	Sample size
Atlanta	199,564	2,997	58
Boston	136,381	1,698	58
Chicago	164,044	1,922	58
Houston	112,102	1,431	57
New York	197,665	1,975	58
San Francisco	149,110	2,500	58
Seattle	192,395	1,916	58
Total	1,151,261	14,439	405

The selected component records were then sampled using a discovery sample technique with a 95-percent confidence level for each of the seven centers. The objective of the discovery sample technique is to select, with a given probability, an unrestricted random sample which contains at least one of the characteristic (error) items being sought, based on the expectation that the projection contains a given percentage of characteristic items. Discovery sampling is a disclosure method--not an estimation method. We then printed the sample and distributed it to our field offices for manual verification against the center's official maintenance records.

To look at future automation, we reviewed 10 out of 31 projects for en route centers and terminal areas. We selected the 10 because they were significant in terms of cost, potential, or near term benefits, or were intended to provide the basis for future air traffic control. We examined these projects to identify cost, procurement methodology, and systemic weaknesses.

To accomplish our objective relating to modernization of communications, we selected 4 out of 100 communications and related projects. We selected the four because they were significant in terms of cost or potential benefits, and required coordination with national and international future user bodies. FAA estimates these four projects will cost more than $2 billion. We examined them to identify potential performance limitations, the level of acceptance by domestic and foreign users, and the full costs and benefits that might accrue by implementing, delaying, or canceling these projects.

We relied on our earlier reviews of FAA to help us identify potential deficiencies in automation and communication for further evaluation. These reviews included:

--"Status of the Federal Aviation Administration's Microwave Landing System," PSAD-78-149, October 10, 1978.

--"FAA's Program to Automate Flight Service Stations: Status and Needs," PSAD-80-1, October 31, 1979.

--"FAA Has Not Gone Far Enough With Improvements to its Planning and Acquisition Processes," PSAD-80-42, June 4, 1980.

--"How to Improve the Federal Aviation Administration's Ability to Deal With Safety Hazards," CED-80-66, February 29, 1980.

--"Computer Outages at Air Terminal Facilities and Their Correlation to Near Mid-Air Collisions," AFMD-82-43, February 16, 1982.

--"Applicability of Public Law 89-306 to FAA's Procurement of Computers for the Air Traffic Control System," AFMD-82-47, February 18, 1982.

--"Examination of the Federal Aviation Administration's Plan for the National Airspace System - Interim Report," AFMD-82-66, April 20, 1982.

--"Review of the Federal Aviation Administration's Response to Chairman Jack Brooks' Letter on the National Airspace System Plan," GAO/AFMD-82-91, June 4, 1982.

--"Greater Emphasis on Information Resource Management is Needed at the Federal Aviation Administration," GAO/RCED-83-60, November 24, 1982.

We interviewed (1) officials in the Office of the Secretary of Transportation and in FAA who were involved in planning for the proposed computer replacement and communications projects and (2) FAA staff who were operating and maintaining the NAS. We also reviewed contracts, records, reports, and related information pertaining to FAA's planning, management, and operation of the NAS. We discussed budgeting, procurement, and technical issues with staff and officials of the White House Science Council; the Senate and House Appropriations Committees; the House Committee on Science and Technology; the General Services Administration; the Office of Technology Assessment; the National Transportation Safety Board; the Air Transport Association; the International Business Machines Corporation; Sanders and Associates; the Raytheon Corporation; and the Sperry Univac Corporation. As requested by Congressman Bob Whittaker, we briefed his staff on automation issues related to delays in implementing the computerized air traffic control system at the New York Terminal Radar Control facility. Also, at his request, we briefed Congressman Elliott Levitas' staff on FAA's computer modernization plans.

Our work was conducted at the Department of Transportation and FAA headquarters in Washington, D.C.; the FAA Technical Center in Atlantic City; the Mike Monroney Aeronautical Center in Oklahoma City; 8 of 10 FAA regional offices; 7 of 20 en route centers; and 10 of over 180 terminal facilities.

Our review was performed in accordance with generally accepted government audit standards except that we did not obtain agency comments on our findings, conclusions, and recommendations.

CONCERNS ABOUT PLANNING AND ACQUISITION EFFORTS FOR FUTURE SYSTEMS

FAA's NAS plan deals with facilities and equipment as well as with supporting research and development. We believe the plan is a step in the right direction toward overhauling the air traffic control system. However, it should not be viewed as a comprehensive plan which addresses the three major areas of the National Airspace System--airspace, airports, and the air traffic control system--in an integrated manner. FAA recognizes this and has additional planning efforts underway which are expected to be completed by late 1985. Because certain actions in the plan such as en route computer replacement must go forward at this time, FAA cannot be expected to wait for the results of the other studies before proceeding with implementation of the NAS plan. However, we believe FAA could minimize some of the risks associated with this approach by discussing and coordinating, at specified milestones, the preliminary findings of the ongoing reviews and assess their impact on implementation of projects in the NAS plan. Also, we believe the plan should:

--Assign priorities to the projects and clarify their predicted impact on the system as a whole.

--Assess alternatives and provide contingencies in the event of project delays.

--Identify total subsystem costs for future year budgeting purposes.

--Allow for inclusion of improvements identified by ongoing reviews of the National Airspace System and airports.

--Identify the interdependencies of all NAS plan projects to include those projects that are not in the plan but that interface with the plan's projects.

Some congressional committees and others have been concerned that FAA rejected a less costly alternative for its en route computer replacement program. We believe this alternative should have been rejected and found even more compelling reasons for rejection than those identified by FAA.

With regard to FAA's proposed demonstration of the replacement computers, we believe other alternatives exist that should be considered by FAA to validate that the new computer can process existing software.

OVERVIEW OF THE NATIONAL AIRSPACE SYSTEM PLAN

On January 28, 1982, the FAA released its National Airspace System plan. This document spells out the improvements in facilities and equipment that FAA believes must be made in the next

20 years to meet the projected needs and demands of aviation safety. Costs for the first 10 years are estimated by FAA to be about $8.7 billion to $9 billion.

As part of its planning for the National Airspace System, FAA made certain decisions. These include

--continuation of a fundamentally ground-based air traffic control system,

--implementation of an independent airborne traffic alert and collision avoidance system,

--implementation of the highest level of air traffic control automation,

--continuation of previously funded near term automation enhancement to terminal and en route areas, and

--eventual replacement of the Instrument Landing System by the Microwave Landing System.

With implementation of the plan, FAA intends to consolidate facilities, starting with the closing of en route traffic control centers in the mid-eighties. According to FAA, the newer technology will permit even greater future consolidation, from today's more than 200 air traffic control facilities to approximately 60 or even 40 by the year 2000.

Among the 97 individual projects described in the NAS plan, the most significant acquisitions include

--near term replacement of the present air traffic control computers,

--automation of the flight service stations to permit direct pilot access to more timely weather information, and

--development of new radar, communications, and landing systems.

THE NAS PLAN NEEDS TO IDENTIFY SYSTEM PRIORITIES, ALTERNATIVES, AND SUBSYSTEM COSTS

The plan identifies 97 facilities and equipment projects to be completed over the next 20 years. By 1994, FAA hopes to have completed its air traffic control computer modernization program. More than 30 time-sensitive and interdependent projects must be successfully developed and implemented if this goal is to be met. We believe such an ambitious schedule requires identification of project priorities, careful planning of alternatives (including contingencies), clearly defined project interdependencies, and description of planned activities.

We are concerned that the plan does not identify priorities for projects necessary to achieve the plan's goals. If, because of possible budgetary constraints or engineering problems, a project is eliminated or schedules altered, the plan should make it clear what impact this would have on the system as a whole. Also, the plan should specify how or which projects could be eliminated or rescheduled so that major goals are achieved. For example, the plan gives developmental flow diagrams for each level of the system. We believe the diagrams should include critical paths; their relationship to the goals of safety, capacity, and productivity; and critical project interdependencies.

An example of the need to plan for contingencies is FAA's Advanced Automation Program. This program involves two major procurements: (1) the replacement computers and (2) new software and controller sector suites. FAA's acquisition strategy is to select two competitors for each of these procurements. Thus, for just this one program, FAA must manage four contractors (possibly some subcontractors as well), coordinating work and development and keeping on schedule. FAA should develop a contingency strategy for extending the existing computers' system life if delays are encountered during these two major procurements.

Total costs to implement the NAS plan have not been fully determined by FAA. Costs for the first 10 years are estimated by FAA to run between $8.7 billion and $9 billion. Congressional approval has been requested to start implementation of the NAS plan; however, subsystem costs are yet to be identified. The House Committee on Appropriations has voiced its concern about the lack of cost justification in the 1983 Department of Transportation and Related Agencies Appropriations Bill (H.R. 97-783). The Committee indicated it was not committed to funding the entire NAS plan. Further, the Committee said it expected FAA to provide detailed justification in future years' budgets for replacing terminal services computers, the sector suite program, and other programs in the NAS plan.

NAS PLAN SHOULD BE UPDATED

Since major expenditures will soon be occurring, FAA needs to assure itself that acquisition decisions are adequately coordinated with other air traffic control activities and projects so that user and operational needs are not unnecessarily constrained. We believe that coordinating the plan's projects, assigning priorities to projects, assessing alternatives and developing contingency plans, and identifying interdependencies of systems will provide this assurance.

FAA has already identified 31 en route and terminal automation projects in the plan. Funding during fiscal 1983 through 1985 for 24 of the projects is as follows:

Fiscal year	En route automation projects	Terminal automation projects
	---------(millions)---------	
1983	$116.1	$ 62.0
1984	834.4	126.1
1985	152.2	67.4

As of December 1982, costs by project and by fiscal year after fiscal 1985 could not be provided. We believe these costs should be developed as early as possible and that updating of the plan is essential. This will increase FAA's flexibility and capability to meet future growth.

PRELIMINARY FINDINGS OF ONGOING REVIEWS SHOULD BE COORDINATED WITH IMPLEMENTATION OF THE NAS PLAN

We believe comprehensive long-range planning is a recognized way to (1) achieve efficient and effective use of resources, (2) ensure that these resources support agency missions and objectives, and (3) commit top management to action. The lack of long-range planning has been of concern to congressional committees monitoring FAA activities.

FAA has not yet developed a comprehensive overall agency long-range plan. The National Airspace System is made up of airports, the air traffic control system, and airspace. We believe the NAS plan is a significant effort to chart future evolution of the air traffic control system, but it addresses only part of the whole National Airspace System--the air traffic control system facilities and equipment and supporting research and development.

To do comprehensive long-range planning we believe all three parts should be addressed so that the National Airspace System will develop in an integrated manner. FAA has begun studying both of the other parts. The National Airspace Review, a study of the operational uses of the Nation's airspace, is expected to be completed near the end of 1985. FAA expects that the National Airport System Plan will not be completed for at least 2 more years. By issuing a plan for modernization of facilities and equipment without first knowing how the results of the other two plans will affect these decisions, we believe FAA risks limiting needed improvements in use of facilities and equipment because of large investments that will have already been made. We have previously reported on FAA's need for comprehensive planning for aviation safety. 1/ That report identifies the key elements of a comprehensive planning process which we believe are also applicable to the National Airspace System planning process.

FAA estimates that costs for the first 10 years of the NAS plan will run about $8.7 billion to $9 billion. This includes buildings, landing and communications systems, and the computer modernization program. At congressional hearings, FAA has stated that the equipment decisions in the NAS plan incorporate sufficient flexibility to accommodate changes recommended by the National Airspace Review but did not explain how this would be done. We are concerned that the multibillion-dollar equipment and facility decisions being made now may limit the degree of improvement recommended by the National Airspace Review. Consequently, instead of the operational use of airspace driving the equipment needs, the opposite may be true. Newly established facilities and equipment could drive and limit improvements sought by the airspace review and airport plan.

We are not suggesting that FAA delay implementing the NAS plan pending the results of the other ongoing studies. Our purpose is to point out that there is risk associated with FAA's approach and that we believe it would be prudent for FAA to consider how the possible outcome of ongoing studies may affect projects in the NAS plan, and vice versa. For example, at certain milestones FAA could discuss and evaluate preliminary findings of the ongoing reviews and assess their impact on the implementation of projects in the NAS plan. By coordinating these two efforts, FAA could ensure that the right equipment is procured and installed at the right location, avoid incurring additional expenses, and achieve integrated development of the National Airspace System.

INTERDEPENDENCIES OF SYSTEMS AND PROJECTS NEED TO BE IDENTIFIED

We believe the NAS plan should identify what projects are interdependent so that development efforts can be coordinated and goals and objectives met. One of the objectives in the plan is to consolidate en route and terminal facilities, with most hardware and software elements identical. FAA hopes to achieve substantial productivity gains and reduce costs by consolidating its more than 200 centers and terminals to 40. Since issuance of the plan FAA has introduced a different concept for consolidation: the Area Control Facility. Under this concept, both the centers and the terminals would be consolidated in one move rather than in two. The Area Control Facilities would maintain control of both terminal arrival/departure and/or en route air traffic.

1/"How to Improve the Federal Aviation Administration's Ability to Deal With Safety Hazards," CED-80-66, Feb. 29, 1980.

Most control towers at airports would continue to operate, but staff would be reduced from current levels. About 60-70 percent of the staff would be transferred to an Area Control Facility. According to FAA, the goal is to lessen operational costs by reducing the number of manned facilities and improving productivity.

FAA's consolidation project is dependent on adequate communications (radar and telecommunications) for controlling air traffic from consolidated centers. Communications are needed to link radar sites to the new centers. However, FAA has separated consolidation of air traffic control centers and terminals from equipment replacement proposals (such as replacement of the en route computer and communications). These are interdependent actions. We believe FAA should identify the projects--including those not in the plan--that are interdependent so that they can be developed in a coordinated manner.

MORE COMPELLING REASONS WHY FAA'S REJECTION OF 9020A to D ALTERNATIVE WAS APPROPRIATE

In response to House Report 98-1400 1/ recommendations to review alternatives to en route computer replacement, FAA provided the Congress a study of its analysis of options and its near and far term solutions. The options in the study address the House Report's recommendations and no single option includes the selected approach for en route computer replacement stated in the NAS plan. One of the near term solutions describes the upgrading of centers with IBM 9020A computers to 9020D computers as (1) cost effective, (2) entailing minimum risk, and (3) capable of providing sufficient capacity until a long term solution can be implemented. FAA rejected the 9020A to 9020D alternative because:

--Reliability would not be improved since 1960 vintage technology would still be used.

--Problems of parts availability and high maintenance costs would not be resolved.

--Functional improvements such as direct/fuel efficient route planning and automated en route air traffic control could not be processed due to 9020D limitations.

We found that FAA's analysis of this option was based on incomplete and outdated information. The 9020 series computers, manufactured by IBM for FAA in the late 1960s, introduced a new era in automated air traffic control. Because IBM officials have the institutional knowledge needed to build the 9020, we discussed

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1/"Making Appropriations for the Department of Transportation and Related Agencies," 96th Congress, Sept. 25, 1980.

this alternative with them. They told us that while such an upgrade is technically possible, it would not be practical. IBM said it would have to reestablish its engineering and production facilities to upgrade 9020As to Ds and would do so only in response to a national emergency.

We also reviewed FAA's methodology for determining the cost of this alternative and found that in developing its cost estimate, FAA used pricing data obtained through informal discussions with IBM in 1980. This data reflected the price of the new IBM 9020s which were last available in 1977. We believe, therefore, that FAA's $64 million figure is no indication of actual costs were FAA to proceed.

The impracticality of the 9020A to 9020D solution also affects FAA's plans to use it as a fallback option if computer replacement efforts are delayed. In hearings before the House Committee on Appropriations, FAA stated that the 9020A to 9020D option still could be exercised in case of delays to the computer replacement program. Since IBM considers the upgrade impractical, it is highly unlikely that such a contingency plan could be implemented.

FAA SHOULD CONSIDER ALTERNATIVES FOR PROCURING AND DEMONSTRATING THE REPLACEMENT COMPUTERS

FAA has taken several actions to facilitate its computer replacement effort. In early 1981, FAA opened the Technical Center Library to all parties seeking technical information and background on the IBM 9020 computers. On December 7, 1981, the Secretary of Transportation authorized FAA to include in the computer replacement contracts a clause under which the United States will indemnify or "hold harmless contractors and subcontractors for losses arising out of 'the use, operation or malfunction or failure of any hardware or software for losses in excess of $500 million per single occurrence' provided under such contracts." As a result, vendors who previously were unwilling to propose a new system to FAA because of the risk of financial loss are now prospective bidders. After publicly announcing in 1982 that the en route computer would be replaced, FAA offered to sell the current software to all interested parties at a cost of $3400. In July 1982, at the Houston center, FAA provided one week of briefings and discussion to interested vendors on center and 9020 operations--hardware and software.

FAA's chosen computer modernization strategy calls for replacement of its en route center and terminal area equipment. Initially, about 1988, the en route computers will be replaced. About 1990, as other projects are completed, the terminal equipment will be replaced or its functions consolidated into the centers. FAA will, on a cost-plus-a-fixed-fee basis, fund two competing contractors to modify the existing software and demonstrate that this software can be processed on the computer proposed by each contractor. FAA has determined that the new computers must be capable of processing the existing en route software and will conduct a demonstration "compute-off." We believe FAA should consider other contractual alternatives to using the cost-plus-a-fixed-fee approach such as firm fixed-price or cost-sharing contracts. Either of these alternatives would permit the vendor to share the risk and benefits associated with development.

Computer modernization strategy

FAA's chosen computer modernization strategy calls for the evolutionary replacement of en route and terminal area equipment. Current en route computers will be replaced about 1988 by computers capable of processing the existing software. FAA calls these replacement computers host computers. The estimated total cost of this program is about $300 million. Next, between 1988-1994 additional hardware and software will be installed for the Advanced Automation System. This will entail (1) upgrading or replacing the host computers, (2) replacing existing controller displays at en route and terminal areas with newly developed sector suites, (3) redesigning the existing software to permit increased use of automation in air traffic control such as automatic generation of aircraft clearances, and (4) consolidating en route and terminal area control functions. Acquisition of these improvements will be managed by the newly established Advanced Automation Program Office. Total cost of the entire computer modernization program is estimated by FAA at $3.4 billion.

In its determinations for replacing the computers, FAA's prime consideration was that the computers must be able to process the existing software. FAA recognizes that the requirement for instruction compatibility could reduce the competition because few vendors have instruction-compatible equipment of the size needed. FAA believes that this disadvantage is outweighed by the lower risk inherent in the chosen solution. Although alternative approaches such as total hardware and software replacement were considered, FAA rejected these because they were determined to be risky and incapable of meeting FAA's replacement date. FAA does not believe competition would be enhanced for this project if the software compatible requirement were dropped. This is because FAA does not believe anyone could develop a system within the 21-month period allowed with other than an instruction-compatible computer. (The 21-month period is FAA's estimate of the time needed to develop or convert the software and demonstrate it on the proposed computer.) Officials of the Advanced Automation Office stated that the current software is the driving force and the means to the end--acquiring computers to run it--and only by continuing to use it can FAA have confidence that the replacement computer will continue to safely support air travel.

Two-phase procurement is planned

The replacement hardware, which does not include replacement of the display computers (Raytheon 730 and IBM 9020E), must be capable of processing the existing en route software. The procurement will be performed in two phases.

In the first phase, FAA will fund, on a cost-plus-a-fixed-fee contractual basis, two contractors to modify the NAS software and demonstrate that this software can be processed on off-the-shelf equipment proposed by the contractor as replacement for existing computers. Total estimated contractual cost for the demonstration is $68 million. During this 21-month phase, each contractor will perform FAA-monitored tests at the Technical Center. Upon completion of testing, one contractor will be selected to deliver production systems.

In the second phase, FAA plans to install about 24 systems. These will be located at 18 to 20 en route centers, the FAA Academy, and one each to the two follow-on system contractors. 1/ As an option, one may be installed at the Technical Center. FAA estimates that all 24 systems, each built around two off-the-shelf instruction-compatible processors, will cost about $238 million.

Compute-off demonstrations are sometimes appropriate

Compute-off demonstrations are appropriate when major Government acquisitions entail a high degree of risk due to innovative concepts or risky and costly conversion. The Government reduces the risk to contractors by funding the demonstrations. Such compute-off demonstrations are appropriate in procurements conducted under Office of Management and Budget (OMB) Circular A-109 guidelines.

The philosophy of OMB A-109 is to present agency mission needs (rather than specific solutions to needs), to encourage interest, innovation, and competition among potential contractors. A-109 places emphasis on generating alternative solutions while controlling risks and costs through parallel development, demonstrations, and tests. The method has been used for developing weapons systems and other major system acquisitions.

FAA's use of the compute-off will result in duplicative software efforts

In its Request for Proposals, FAA has restricted the architecture and size of the replacement computers and specified that processors must be available "off the shelf." These constraints restrict achievement of the benefits of the demonstration philosophy. Also, FAA's $68 million compute-off will result in duplicative software efforts--one will not be used. The compute-off will demonstrate that two contractors can modify existing software programs

1/Two system contractors will be provided the replacement computers as Government-furnished equipment for designing the Advanced Computer System. The contractors will redesign the software and develop new controller workstations called sector suites. FAA estimates that development and production of the Advanced Computer System will cost about $2 billion.

so that they can be processed on the type of instruction-compatible equipment each proposes. In an October 1981 study on the technical issues of using instruction-compatible computers to replace existing en route 9020s, a contractor stated that the software could be modified for about $5.8 million. We believe that because of the architecture and size restrictions and the instruction compatibility requirement, the software modified by the two contractors will be mostly similar. Only one of these packages will be used at the operational sites.

Alternatives were considered by FAA for demonstrating the computer

FAA contract officials said they considered other contractual alternatives besides the cost-plus-a-fixed-fee method but found them to be incompatible with FAA needs. Alternatives included (1) a firm fixed-price contract and (2) cost sharing arrangements. A firm fixed-price contract was rejected because the system's specifications could not be sufficiently defined. These officials also stated that use of a cost-sharing contract was considered but not fully analyzed. It was deemed inappropriate because of the lack of commercial application of the product developed (commercial application was interpreted as only the U.S. market).

FAA should reconsider contractual alternatives

We agree that a demonstration to validate contractor performance may be warranted as a desirable feature. However, we believe that information regarding (1) the absence of a need to demonstrate alternative concepts and solutions, (2) defined specifications, (3) commercial applicability, and (4) FAA's own perception that the demonstration will be successful, warrants reconsideration of contractual alternatives.

Current demonstration requirements will provide two solutions that may be very similar in approach, since both will be based on instruction-compatible equipment processing the existing software. The guideline FAA is following for its software modification and computer demonstration is intended and used for demonstrating newly developed and untried alternative concepts and solutions to agency mission needs. FAA is not seeking alternative concepts and solutions for computer replacement (in its Request for Proposals FAA has restricted the computer architecture and speed of the replacement computers).

FAA contracting officials said that a firm fixed-price contract was rejected because the system's specifications could not be sufficiently defined. We have surveyed FAA's Request for Proposals for the computer demonstration and believe it amply defines the system's specifications.

Federal procurement regulations state that the cost-plus-a-fixed-fee contract is inappropriate once preliminary exploration and studies have indicated a high degree of probability that the development is feasible, and the Government generally has determined its desired performance objectives and schedule of completion. An official of the Advanced Automation Office stated that the risk of contractors not meeting FAA's demonstration requirements is low. Therefore, we believe the cost-plus-a-fixed fee contract may not be appropriate for the demonstration contract.

Federal procurement regulations state that cost-sharing contracts are suitable for those procurements covering production or research projects that have potential mutual benefit to the Government and the contractor. An illustration provided in the regulations of when a cost-sharing contract would be desirable is that of research and development work when the results of the contract could have commercial benefit to the contractor. FAA contracting officials said that a cost-sharing contract was considered but not fully analyzed. It was deemed inappropriate because of the lack of commercial application. We believe the experience gained in the demonstration would benefit a contractor by increasing its competitiveness regarding the Advanced Automation System and foreign civilian air traffic control systems as well. Therefore, we believe cost sharing may be more appropriate than the cost-plus-a-fixed-fee approach. Also, contractor demonstrations funded under a cost-plus-a-fixed-fee contract are appropriate if the level of effort required is unknown, but this is not the case.

We believe that, before awarding the demonstration contract, FAA should fully analyze and evaluate the appropriateness and cost/benefits of a firm fixed-price contract and a cost-sharing contract for the computer demonstration. Since this could be done while contractors are preparing proposals, we believe it would cause little delay. The results of this analysis should be reported to the Department of Transportation Acquisition Executive for determination of most appropriate method before officiating the demonstration contract. We believe this assessment could result in lower acquisition costs.

CONCLUSIONS

FAA's efforts to develop the NAS plan are a commendable first step. However, FAA needs to develop a comprehensive long range plan and to identify priorities, alternatives and contingencies, interdependencies, and subsystem costs for specific projects in the NAS plan. This is needed for congressional program approval as well as for FAA purposes. Also, the preliminary results of other ongoing reviews should be coordinated with implementation of the NAS plan. We believe this would reduce the risk of limiting improvements in use of the airspace, airports, and the air traffic control system.

We believe the use of a cost-plus-a-fixed-fee contract for demonstrating that new computers will process the existing software is too costly. FAA should consider a less costly type of contractual approach for its computer demonstration.

RECOMMENDATIONS

We recommend that the Secretary of Transportation direct the FAA Administrator to:

--Implement a comprehensive planning process for the National Airspace System (use of the Nation's airspace, airports, and the air traffic control system) that will result in a long range plan. This process should provide a mechanism to (1) define system requirements agencywide, (2) establish objectives, strategies, and priorities for these requirements, (3) coordinate preliminary or final results of ongoing reviews with implementation of the NAS plan, and (4) update the NAS plan and identify project priorities, contingencies, total and subsystem costs, and interdependencies.

--Fully analyze and evaluate the appropriateness and cost/benefits of a firm fixed-price, cost-sharing, and cost-plus-a-fixed-fee contract for the computer demonstration, and report the results of this analysis to the Department of Transportation Acquisition Executive, for determination of the most appropriate contract method before awarding the demonstration contract.

FAA NEEDS TO IMPROVE THE MANAGEMENT OF ITS AUTOMATION RESOURCES

The National Airspace System is dependent upon computers for its operation. Without them, control of the Nation's air traffic would be severely affected. We found that FAA's organizational structure and management approach do not provide the centralized oversight, planning, control, and direction we believe is necessary to ensure that air traffic control automation resources are efficiently and effectively used. Offices that are responsible for managing individual programs are not able to ensure that agencywide needs are adequately coordinated. FAA has experienced delays and cost overruns in many system and software development projects because of inadequate management control and oversight. Many of these projects were designed to improve safety and fuel efficiency.

Many of these problems appear to be isolated, but when viewed as a whole they demonstrate the need for more oversight and control. While not a cure-all for the delays and cost-overruns experienced, we believe centralized management could increase oversight and control and improve program accountability.

FAA has recently focused greater attention on the management of computer resources but has not adopted the centralized management concept for all its automation resources. FAA has reorganized to provide greater centralized management control over its Advanced Automation Program under one organization. It also issued a new operating order which, if successfully implemented, could result in better control over major acquisitions and increased accountability of the project officers. We view these management initiatives as a step in the right direction and provide several recommendations for improvement to further what has already been started.

Although FAA's air traffic control system relies heavily on computers, it does not have a functional organization with responsibility for measuring the efficiency and performance of its computers. This had been previously recommended in House Report 98-1400. We believe that as part of its efforts to revitalize management, FAA needs a comprehensive organization to improve its ability to acquire, manage, and use computer resources efficiently and effectively and provide management with timely performance information.

AUTHORITY AND ACCOUNTABILITY UNCLEAR

Under FAA's management philosophy, the authority and accountability for managing automation resources are divided among four different organizations. These are the Air Traffic Service, the Airway Facilities Service, the Systems Research and Development Service, and the Advanced Automation Program Office. The duties and responsibilities for development, operation, maintenance, and acquisition of software and hardware are therefore dispersed and relegated to lower level units, and sometimes duplicated.

The four organizations do not have line authority over automation staff and resources located in regional offices, en route centers, and terminal facilities. This is because the management structure was established at a time when FAA was implementing the initial stages of air traffic automation (early 1970). However, today's automation priorities focus on routine day-to-day hardware and software maintenance of the established system, and management directives have not been updated to reflect this change. Currently, each center or facility can decide to implement local software changes. This sometimes occurs at the expense of efficient use of resources. For example, officials at the Seattle en route center said that they and 75 percent of the other centers use a local software modification that automatically produces hourly weather information. Each time FAA nationally implements a new version of the software for the centers (about every 6 months), each center using this local modification must insert and test it independently. These efforts use personnel and computer resources and could be minimized if the modification were incorporated into the national system.

Historically, FAA's management philosophy has been to permit Services and Offices to independently manage automation resources such as computers and personnel with little or no central direction. Although these decentralized activities provide air traffic control automation support where the users are located, they provide no assurance that FAA-wide air traffic control automation needs are met. Differing management styles and techniques are focused on local needs with no adequate assessment and consideration of FAA-wide requirements.

The following table illustrates the decentralized management approach used for several air traffic control automation projects. Although orders specify that system development projects are to be the sole responsibility of the Systems Research and Development Service, the operational services also lead development projects--such as the retrofit of ARTS IIIA software (Air Traffic Service) and the direct access radar channel (DARC) enhancement project (Airway Facilities Service). System acquisition, which was the sole responsibility of the Airway Facilities Service, is now also included in the duties of the Advanced Automation Office. Although maintenance of the operational software is the responsibility of the Air Traffic Service, all DARC software development and maintenance is handled by the Airway Facilities Service. Because of a shortage of personnel at FAA's Technical Center, software maintenance for Tampa/Sarasota ARTS is performed by local personnel who report to regional management. The Air Traffic Service is retrofitting the nationally used ARTS IIIA software because their operational needs were not properly identified when the original specifications were developed by the Airway Facilities Service. (See the table on page 24.)

DISPERSION OF ATC AUTOMATION FUNCTIONS AND PROJECT RESPONSIBILITIES

IN THE FEDERAL AVIATION ADMINISTRATION

	Operational Services								Nonoperational Organizations	
	Air Traffic Service (ATS)				Airway Facilities Service (AFS)					
Function	Headquarters	Technical center	Region	Center/ facility	Headquarters	Technical center	Region	Center/ facility	System Research and Development Service (SRDS)	Advanced Automation Program Office
Systems development		Retrofit of ARTS IIIA, NY TRACON and conflict alert software			TPX-42 replacement, DARC enhancement, FDIO				ETABS, Tampa/ Sarasota, enhanced conflict alert software	
Systems acquisition					All ATC systems less computer replacement					Computer replacement
Hardware maintenance								All ATC hardware		
Analysis of hardware reliability					National Performance Reporting System	Maintenance Automated Reporting System				
Analysis of computer utilization	Impact of resectorization on en route computers	Audits at Memphis and Houston centers				Display computer utilization			Congressionally directed study to determine en route computer saturation	
Software maintenance		En route and terminal operational programs		Tampa/ Sarasota operational programs		En route and terminal functional programs and DARC software		Tampa/ Sarasota functional programs		
Approval of local software modifications	Modifications to operational programs (national impact)		Modifications to operational programs (local impact)			Modifications to functional programs				
Testing new software versions		En route and terminal operational programs		En route and terminal operational programs		En route and terminal functional programs		En route and terminal functional programs		

APPENDIX IV

FAA has taken an initial step toward integrating some computer modernization efforts under one organization. For its $3.4 billion computer modernization program FAA has established the Advanced Automation Program Office. The program manager responsible for acquiring, testing, and implementing this system reports to the Administrator. The program manager approach is intended to integrate system development, focus attention on resolving problems, and centralize direction and authority for specific projects.

Furthermore, FAA has also realigned its automation engineering functions. Most of these functions, formerly performed by the Airway Facilities Service and the Systems Research and Development Service, are being combined into a newly created Program Engineering and Maintenance Service. To preserve the continuity of essential operations the current organizations will continue to perform their assigned functions, but they will do so within the new organizational structure and with the same personnel. Air Traffic Service automation responsibilities were unchanged and were not integrated.

We believe that combining the engineering functions of Systems Research and Development with those of Airway Facilities Service and creating the Advanced Automation Office will improve the use of engineering resources for development and provide better management of the computer replacement. However, this realignment does little to alleviate the need for central direction and leadership, since three separate offices remain independently responsible for automation.

INCREASED MANAGEMENT CONTROL NEEDED OVER SYSTEMS AND SOFTWARE DEVELOPMENT

Many automation projects being developed by FAA's lower level units are experiencing delays and cost overruns. We believe these problems have NAS-wide impact because the projects are designed to improve safety and productivity at the en route centers and terminal areas nationally; they are not isolated projects.

Numerous management and technical problems delay implementation of programs

The following examples illustrate the problems FAA has encountered over the past several years in completing systems projects and developing the software needed to run the systems. We believe the magnitude and complexity of these problems demonstrate a need for greater oversight and control. Also, a more centralized management approach may help correct these problems and reduce recurrences.

--Development and testing of the Electronic Tabular Display Subsystem (ETABS) is more than 2 years late and more than $5 million over cost. (Systems Research and Development Service project)

--The digital features of the Tampa/Sarasota ARTS system were not fully commissioned until 3 years after the equipment was installed. (Portions of this development project are divided among Systems Research and Development Service, Airway Facilities Service, and Air Traffic Service.)

--Software development problems have delayed full use of the ARTS IIIA hardware at larger sites until late 1984. (Air Traffic Service project)

--Installation of ARTS IIA computers at medium density terminals, estimated to cost $12 million, is proceeding without FAA having formalized system and user needs. (Airway Facilities Service project)

--Replacement of the TPX-42 system, estimated to cost $37 million, is proceeding without FAA having identified user and operational requirements. (Airway Facilities Service project)

--Testing of a prototype Automated Terminal Information Service system was suspended due to Air Traffic Service's concern that controller functions would be impaired. (Systems Research and Development Service project)

Electronic Tabular Display Subsystem is late and over cost

Recognizing that controller productivity should be improved, the Systems Research and Development Service developed a concept called the Electronic Tabular Display Subsystem. The subsystem was envisioned to be a flight data presentation located at en route controller positions, and would replace the currently used flight progress strips. By automating some of the controller's manual and verbal tasks, it could reduce the controller's workload.

The $2.6 million contract called for the delivery of an engineering model by January 1980. Eight months into the contract, a cost overrun proposal was submitted by the contractor. It advised FAA that the cost to the Government had risen by over one million dollars, the schedule had slipped 6 months, and the overrun was due to design changes and incomplete and changing FAA specification requirements. For example, the contractor stated that the complexity of the task had been underestimated by all parties and that the total number of lines of software code had increased by more than 300 percent. Subsequently, three other cost overrun proposals totaling $4.6 million were submitted and contractually incorporated. The prototype ETABS equipment was delivered in May 1982, more than 2 years later than originally specified. Because of these overruns, a planned analysis of controller productivity improvements resulting from the use of ETABS was canceled.

Originally planned as the forerunner of a production system, ETABS has been relegated to providing technical input to the design of the future sector suite, an automated controller workstation. Although ETABS is less complex than sector suite, it is conceptually similar in that controller productivity is presumed to increase due to automation of manual functions. Therefore, because controller productivity is a goal of the NAS plan, FAA should resume the planned analysis to determine if such productivity gains are possible and cost effective. The project was managed mainly at the branch level within the Systems Research and Development Service.

Lack of management attention affects Tampa/Sarasota development efforts

The Tampa/Sarasota project was a developmental effort designed to demonstrate the operational feasibility of digitizing 1/ remote radar data and transmitting it to the Tampa TRACON and to control towers located at Sarasota, Tampa, St. Petersburg, and Mac Dill Air Force Base. Because the project stemmed from a development effort managed by the Systems Research and Development Service, regional and facility personnel felt that it did not receive full attention from the operational services (Air Traffic Service and Airway Facilities Service). (See p. 23 for discussion on responsibilities for system development projects.) We believe this has increased costs and delayed timely testing and full commissioning of the system.

FAA Southern Region and Tampa personnel believe efforts to use the system operationally were delayed because the Air Traffic and Airway Facilities Services in headquarters felt the project was unique and would produce little benefit that could be applied nationwide. Headquarters personnel from both Services have stated that they are not responsible for delays in the full commissioning of the TRACON. They claim that many of the problems cited by the facility as obstacles to resumption of operational tests could have been resolved earlier had the facility not overly sensitized the calibration of some of the equipment used.

Originally estimated at $4 million, the automation costs have increased to more than $11 million. Additional costs will be incurred later for replacement of computer equipment and controller displays that have been identified as maintenance liabilities.

Following hardware installation in 1977, the basic system was partially commissioned in May 1979. Only those functions

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1/Radar information is usually sent to an ARTS computer by microwave transmission. By converting the data at the radar site to digital form, the information can be transmitted at less cost over telephone lines.

performed by the previous system were available. The digital features of the system were working but needed to be fully tested using live air traffic.

Tampa personnel attempted to conduct an operational evaluation of the digital portion of the system on several occasions starting in January 1980. Operational tests were either terminated during testing or were canceled due to hardware and software problems. Following successful completion of tests in August 1982, the Tampa/Sarasota TRACON was officially declared fully operational in September 1982.

FAA Southern Region and tower personnel believe that while developmental problems have occurred, the Tampa/Sarasota project deserves the attention and support of the Air Traffic and Airway Facilities Services, especially since the project has demonstrated that radar signals and other information can be transmitted in digital form to remote locations. They believe that this capability may preclude the need for installing individual computers at low and medium activity facilities. Also, that the proposed consolidation of terminal and en route functions into one facility may benefit from the experience gained and reduce communication costs.

ARTS IIIA software is not fully operational

After unsuccessful attempts to operationally install the ARTS IIIA software at the Jacksonville, Florida, and Denver, Colorado, facilities, the Air Traffic Service initiated an extensive in-house analysis. Following analysis of the executive program, which supervises computer operations and software, the Air Traffic Service concluded that the Univac-developed software was designed improperly because it did not incorporate any program or data protection schemes to prevent access, destruction, or modification of data used by another program. Such protection is necessary.

Air Traffic Service software programmer personnel have redesigned the program and believe they have corrected this problem. However, another modification of the executive program will be needed for sites with more than 10 displays. The Air Traffic Service plans to perform this task using in-house personnel resources, and estimates it will take a year to complete.

Only those ARTS IIIA sites with fewer than 10 displays are installing the new software. We found that only 5 of 62 sites are operating using the ARTS IIIA software. According to the latest estimate, large terminal areas such as Washington, D.C., Atlanta, and Chicago will not receive full ARTS IIIA capability until late 1984.

<u>Acquisition of lower density terminal computers is hindered by lack of user requirements</u>

FAA officials have stated that computer equipment installed at lower density terminals needs to be replaced because the safety features of computers installed at busier terminals cannot be performed at less busy ones. FAA believes this to be a less costly alternative than installing ARTS III type computers at these lower density sites. These features are conflict alert and minimum safe altitude warning. Two acquisition activities have been initiated, namely the upgrade of 89 ARTS II sites and the replacement of 37 TPX-42 semiautomatic systems.

The upgrade of the ARTS II computers to ARTS IIA capability involves three organizations: the Systems Research and Development Service, the Airway Facilities Service, and the Air Traffic Service. The Systems Service is responsible for developing the initial hardware and software systems. The Facilities Service will procure production equipment to replace the existing processor with a more powerful version. The Traffic Service is responsible for identifying its operational needs and implementing the system procured.

We found that the Traffic Service has not formalized its system workload requirement. This has hindered the developmental efforts of the Systems Service and the procurement activities of the Facilities Service. Development of ARTS IIA software is proceeding despite unanswered requests for more definitive workload requirements from the Traffic Service. In a memorandum to the Traffic Service, the Systems Service stated:

> "Although we agree in principle with the need for this demonstration [of the ARTS IIA tracker], it will only answer the question of actual ARTS-IIA system capacity. The question of what capacity is required will not be addressed by this demonstration. It is imperative that capacity requirements be determined before the ARTS IIA system is fully developed."

The Facilities Service is responsible for developing ARTS IIA specifications and related procurement activities. The absence of formalized Traffic Service requirements has delayed the development of the justification for the $12 million upgrade. Similar problems are occurring with the $37 million TPX-42 enhancement program. As in the case of ARTS IIA, no acquisition paper has been developed because the Traffic Service has yet to identify its operational needs. Consequently, these problems may delay the development and implementation of conflict alert and minimum safe altitude warning--features that FAA states are needed to improve safety at low density airports.

Testing of prototype delayed due to incompatibility with operational environment

Currently, major airports are equipped with an Automated Terminal Information Service (ATIS) system which is used to provide airport operational data--including some weather data--to arriving and departing pilots. The present system consists of a magnetic tape loop on which controllers record the ATIS message. The system suffers from a number of shortcomings:

--Poor equipment reliability.

--Unclear speech.

--Infrequent data updates, particularly during bad weather. (During adverse weather conditions, when the service is most needed by pilots, controllers are most needed at their work stations and cannot leave them to record an ATIS message.)

Recognizing these shortcomings, the Systems Research and Development Service asked the Transportation Systems Center (TSC) to develop a computer-generated ATIS system. 1/

This computer-generated ATIS was to be solid-state, able to acquire airport visibility information automatically and to output a voice message using stored speech encoding techniques--all without human intervention. At the same time, it must still be able to input special controller messages. Since the system would use a standard computer voice throughout the country, misunderstanding by pilots would be minimized. Pilots could receive timely transmission of airport information in bad weather without controllers leaving their scopes.

TSC designed and built a prototype, which was installed at the Greater Buffalo International Airport. However, the operational test was suspended. TSC project personnel assigned to ATIS stated several reasons why the project did not go well:

--FAA project managers changed four times and each manager had a different concept about what the project goals should be.

--The Air Traffic Service was reluctant to use such a system because controllers would not know what pilots were hearing over the ATIS system.

--ATIS did not fit into the controllers' normal method of operation.

1/TSC is a multimodal research, analysis, and development organization located in the Research and Special Programs Administration, Department of Transportation, Cambridge, Mass. Through intra-agency agreements, FAA has used TSC to perform various projects related to air traffic control.

--Coordination of requirements with other Services was limited.

The following example illustrates one situation: If winds shift, the controller may not change runway configuration because it is a slow and difficult process to turn incoming traffic around to another approach. Rather, the controller will keep close-in traffic on the same approach unless conditions become dangerous. The controllers can do this freely now because pilots do not have up-to-date information. With ATIS, however, pilots would be aware of wind shifts and could question controller judgments relative to runway approaches.

A TSC official stated that the frequent change in project managers for the ATIS project was not unique and that whenever a project is proposed, requirements given are only those of the sponsoring element. Any coordination or identification of user requirements is the responsibility of the project manager. We believe placing this responsibility at such a low level cannot ensure agencywide coverage. It appears that the Air Traffic Service was not fully aware of the operational impact of the ATIS prototype until it was built and installed.

The Automated Terminal Information Service system is only one example of the lack of coordination among FAA organizational elements. We did not review all FAA efforts relative to weather information, so can make no judgment on whether ATIS could have provided a more cost effective service than others FAA is developing.

<u>Software development problems delay safety and fuel efficiency features</u>

Over the past several years, a number of major safety and fuel efficiency enhancements have been developed for the NAS software. We found the following:

--The en route minimum safe altitude warning (EMSAW), which tells the controller when aircraft are approaching a known obstruction such as a mountain, is not operational at all centers because the software program was inadequately designed. (Portions of this project are divided between Systems Research and Development Service and Air Traffic Service.)

--The en route metering (ERM) feature for controlling the movement of aircraft and promoting fuel conservation cannot be used because the software program is too large to fit onto the computer. (Developmental work was performed by the Systems Research and Development Service and operational implementation will be performed by the Air Traffic Service.)

--The terminal conflict alert feature is causing false alerts in some locations and must be redesigned. (Systems Research and Development Service project)

EMSAW does not operate at six en route centers that control airspace over mountainous terrain because the software program was inadequately designed. To operate the system at these centers, significant software modification will be needed to incorporate the data describing airspace covered by these centers into the program.

The ERM software has undergone two developmental efforts by the Systems Research and Development Service since 1975. The second effort was intended to correct problems encountered with the first. The first version did not permit metering the movement of aircraft for fuel efficiency between centers; some had features that were usable only at the center that developed them. The second version, called ERM II, has been completed and is undergoing testing and review by the Air Traffic Service. According to the NAS plan, because of the ERM II's ability to improve fuel efficiency and because the current en route computers have sufficient capacity, implementation is scheduled in 1983. However, we found that it cannot be installed because it is too large--existing computer capacity is not adequate, and new computers are not expected to be operational until 1988. This problem is significant because fuel efficiency benefits are being used to justify some of the large cost savings in the NAS plan and could permit important fuel savings today.

Several problems with the terminal conflict alert feature were identified shortly after its operational implementation in basic ARTS III systems and have led to a major enhancement effort. In particular, as in the case of the Minneapolis ARTS III facility, nuisance alerts were generated during visual flights and when visual approaches were conducted on parallel runways. In his May 1, 1978, letter to the Great Lakes Region, the Minneapolis tower chief stated that conflict alert problems caused controller complacency because the program has shouted "wolf" so many times. Nuisance alarms were so frequent in the Dallas/Fort Worth ARTS III that FAA disabled the two-radar conflict alert function. In other words, if two aircraft were being tracked on two separate radars, the conflict alert feature would have sounded; now it is inoperative. Conflict alert at the Los Angeles TRACON is similarly inhibited. Other reported false alerts in metropolitan areas include those generated by traffic patrol planes and helicopters. These aircraft operate directly under terminal flight patterns and generate continuous alerts. Special codes have been used to inhibit these alerts.

In July 1981, at the request of the Air Traffic Service, the Systems Research Development Service initiated efforts to enhance the performance of conflict alert for the newer ARTS IIIAs by reducing nuisance alerts. It also agreed to develop a method to detect and control aircraft identification errors in dual radar systems. These efforts have been delayed because of the problems experienced by the Air Traffic Service in implementing the ARTS IIIA software program.

RECENT FAA EFFORTS IMPROVE MANAGEMENT OVERSIGHT BUT ADDITIONAL STEPS ARE NEEDED

During our review we noted that in August 1982 FAA published a new order on major systems acquisition procedures. This order establishes many needed project controls and strengthens accountability. The order also establishes criteria for identifying which systems are major.

Specifically, an acquisition is reviewed by the Aviation System Acquisition Review Committee (chaired by the Administrator) for possible acceptance as a major acquisition when it (1) exceeds certain dollar thresholds 1/ or (2) is so unusually critical, visible, or risky as to warrant the special attention required by the FAA order. This process also identifies certain major systems acquisitions and designates them for special attention and reporting to the Administrator. Otherwise, project managers report to the cognizant Associate Administrator. The following table shows the major systems acquisitions programs as of January 11, 1983 (those with asterisks have been designated for reporting to the Administrator).

MAJOR SYSTEMS ACQUISITIONS

	Cost (millions)	Priority	Visi-bility	Risk
*Advanced Automation Program	$3,400	High	High	Medium
*Microwave Landing System	1,029	Medium	High	Low
*Mode S/Data Link	475	High	High	Low
*Airport Surveillance Radar	371	High	Low	Low
Air Route Surveillance Radar	317	High	Low	Low
*Flight Service Stations	305	Medium	Medium	Medium
*Automated Weather Observing System	161	Medium	Medium	Low
Voice Switching Communications System	141	High	Low	Low
*Traffic Alert and Collision Avoidance System	20	Medium	High	Medium

Note: Asterisks identify systems designated for reporting to the Administrator. Costs are based on the Jan. 1982 NAS plan (1981 dollars) and planned support for fiscal 1983 - 1991.

1/Department of Transportation Order 4200.14A specifies $150 million total estimated cost or $25 million in research and development cost.

We believe the systems and software development projects we reviewed and have previously discussed constitute significant budget investments, are critical in nature, and carry significant risk. For example, the hardware costs for upgrading the TPX-42 computers are estimated to be $37 million and, as we discussed, there are problems in defining the needed computer capacity requirements.

We believe the management procedures established for major systems acquisition could, under the direction and leadership of a central management function, improve the management and control of the projects we reviewed.

Management practices may hinder new projects

Successful day-to-day operation of modern automation resources requires management attention and oversight. This includes adequate system and software development and testing, well defined requirements, standard software with good control over changes, uniform procedures for resolving problems, accounting for operations and maintenance costs, and postevaluation of enhancements. We are concerned that past system and software management practices may hinder FAA's successful implementation and operation of new projects such as the $3.4 billion computer modernization program. This concern is based on our review of how the various services carry out these required tasks. We found that:

--FAA does not have an overall system and software testing philosophy and plan. Separate organizations for Air Traffic Service, Airway Facilities Service, and Systems Research and Development Service located at the Technical Center in Atlantic City perform separate tests, with each developing and using its own test procedures. Test results are not coordinated with those of other programs to determine the impact of one on the other. This is troublesome because, while some systems and software operate well independently, problems may arise when they become part of the whole system or affect changes being made by one of the other Services. Because of equipment limitations in each of the test laboratories and the inability to simulate all local center and terminal conditions, the Services perform final testing of each new software version in the field. For en route systems, this means testing at three en route centers because there are three different equipment configurations. System and software testing for terminal areas is also dispersed because of the various ARTS III and IIIA equipment variations. Software developed by contract is often tested using vendor-supplied conditions instead of those developed by FAA and derived from user requirements. Consequently, the software meets the vendor's test but not necessarily the user's needs.

--Contractually developed software has been accepted despite known operational shortcomings. Although vendors provide software that meets contractual requirements, evolving operational needs and ill-defined requirements cause extensive and time-consuming retrofitting. The Air Traffic Service redevelopment of UNIVAC-provided software to add conflict alert features to the ARTS IIIA computers and at the New York TRACON illustrates this problem.

--System and software configuration has not been adequately controlled. Control and approval of changes to the NAS software should maintain standardization at all centers and facilities. However, some centers have exceeded the total number of local software changes allowed and their system is not standard. This results in a cascading effect, causing centers and terminals to make multiple changes when a new version of the software is released to the field. We believe such practices increase the risk that the new computers may not be able to replicate the 9020s they will replace. If past practices are continued, it is possible that the software version used in 1983-84 as the basis for testing and selecting the new computers could change significantly before the computers are finally installed in 1985-87. Consequently, it may be that the new computers will be unable to process the changed software without modification. We believe that, with due consideration for safety, FAA needs to strengthen configuration management controls.

--Planning and scheduling of major software modifications have been hindered by FAA's "fire-fighting" method of correcting field problems individually as they occur. This practice also causes duplicative effort as different centers unknowingly try to resolve the same problem. Problems should be elevated to a national level for determination and solution. Then common problems can be identified and solved more efficiently.

--FAA does not monitor total costs associated with a given system development or software maintenance project. We believe productivity, quality, and performance data should be tracked and a postevaluation of cost/benefits made to assess if objectives and goals are met.

COMPUTER PERFORMANCE MANAGEMENT FUNCTION NEEDED TO HELP MANAGE, ACQUIRE, AND USE COMPUTER RESOURCES

Although FAA's air traffic control system relies heavily on computers, it does not have a computer performance management function with the responsibility for measuring and determining the efficiency and performance of its computers. Such a management function was recommended in House Report 98-1400. FAA's planned installation of replacement computers does not preclude the necessity for such a function.

Computer performance monitoring is essential

As part of its efforts to revitalize management, FAA needs to implement a computer performance management function that is responsible for measuring the efficiency and effectiveness of computer operations at all en route centers and terminal facilities. Such an organization would enable FAA to

--collect, analyze, and report system data for identifying nationwide performance trends;

--identify potential problem areas, system limitations, and software inefficiencies;

--make system life projections of reliability and capacity based on validated user needs;

--develop cost data on operations and maintenance to determine cost effectiveness of the system; and

--provide top management with timely information comparing actual performance with planned objectives.

In its response to House Report 98-1400, which recommended that improvements be made in en route computer operations, FAA stated that it was establishing (1) a joint Air Traffic Service and Airway Facilities Service Performance Improvement Program, and (2) a system evaluation staff at some time in the future.

In line with these actions, biweekly meetings are being held between the Air Traffic and Airway Facilities Services at many of the sites we visited. However, the issues of computer capacity, reliability, and performance are still inadequately addressed for reasons discussed below. And no national oversight of computer performance problems is being maintained to determine overall trends.

In the absence of a formally designated entity, the analysis of computer utilization at en route centers is performed by the three separate Services. The Air Traffic Service is collecting data to determine peak computer use at all centers, while similar analysis is being conducted by the Airway Facilities Service on the en route display computers. The Systems Research and Development Service provides the basic analysis used by FAA in determining en route center computer use. We believe these individual efforts should be integrated to provide the total systems perspective required.

As we discuss in the following sections, FAA does not know the capacities of the various en route and terminal computer systems and is unable to adequately predict system behavior or identify potential bottlenecks because there is no computer performance measurement function. The computer modernization program is an additional reason for the establishment of such a function. Any delays in installing replacement equipment will require current systems to operate longer than anticipated and could result in decreased services due to capacity shortages. It is possible that even the new computers could eventually experience capacity problems if comprehensive management controls are not instituted.

En route computer system reliability is undetermined

We reviewed the information available at FAA headquarters, the en route centers, and the Technical Center on equipment reliability. We learned FAA did not analyze information on a national level to assess computer reliability and to make trend analyses. This is because FAA has been unable to develop and implement a computerized system capable of recording and reporting all maintenance actions, which could be used for such predictions. Previous attempts to implement such a system failed because of poor planning, high cost, and limited access by the users to the data base. The Airway Facilities Service is currently attempting to develop such a reporting system using in-house hardware, software, and personnel.

In our discussions with officials at the en route centers, we found that they think the computers are reliable. They believe that reliability has improved significantly over the last few years. However, we found little documentation to support their belief. At the Technical Center we found that hardware reliability analysis, a responsibility of the Airway Facilities Service, was directed toward solving immediate failures, and little effort was being made to determine trends and assess long term reliability.

Consequently, we constructed a data base to determine the reliability of the en route computers. From FAA-provided computer tapes, which contained approximately 1.2 million records, we identified about 14,000 recorded computer and associated equipment failures. The period covered was 1979 through 1981. At the centers and terminals we compared selected records with official maintenance log entries. Our analysis and review showed the following:

--FAA criteria for determining a reportable outage is not uniformly applied at all centers and many outages go unrecorded.

--Equipment outages recorded in the maintenance log by the maintenance technician are not always reported for inclusion on the computer tapes.

--We found that because the Seattle center erroneously used nondescriptive codes to record outages in the maintenance log, no computer equipment outages were reported for the entire 3-year period. 1/

These problems prevented us from establishing any conclusive opinion on computer reliability. Using another approach, we attempted to analyze maintenance cost to determine computer reliability. A trend in rising hardware maintenance costs could indicate decreasing reliability. We found that actual hardware maintenance costs for the en route computer system are not available. We believe this is one reason why two FAA responses to congressional inquiries on this subject produced inconsistent estimates. 2/

A December 1980 contractor study, completed at a cost of more than $50,000, is the only formal documentation on en route computer system reliability. The contractor reached the following conclusions:

--The limited description codes used to describe maintenance actions were inadequate for the wide range of system problems.

--Although certain components and subsystems have shown signs of deterioration with age, there appears to be no evidence to indicate that system reliability of the 9020 is deteriorating or that it will be maintainable only at an excessively high cost.

These conclusions were based on interviews with center personnel because the contractor believed the maintenance records offered an inadequate description of system problems.

In discussing symptoms of reduced reliability in the study, the contractor stated:

"While reduced availability, reduced reliability, lower productivity, and increases in maintenance time and costs may indeed be symptoms of 9020 system aging, these signs"

1/FAA has acknowledged this particular problem and claims to have taken corrective action.

2/FAA's response to a March 23, 1982, inquiry by Congressman Elliott Levitas on the annual cost to maintain the software and hardware of the current air traffic control system was $119.5 million. In response to the same question, while appearing before the House Committee on Appropriations on April 21, 1982, the Director of the Airways Facilities Service stated that fiscal 1982 costs were $140.6 million.

"are not the exclusive results of a hardware aging process. Poor maintenance, a deterioration in the quality of the environment, low-quality parts, and even badly written software could all produce symptoms that, if care were not taken, could be incorrectly interpreted as signs of hardware aging."

Regarding the use of parts analysis as a determinant of physical life, the contractor said:

"If parts tracking, with potential aging in mind, is desired, now is the time to start the planning and implementation processes. While such a tracking system may not affect the lifetime of the 9020 system, it should carry over to the replacement system."

We learned that the greatest concern expressed by center personel was not reliability or spare parts but the availability of trained maintenance technicians through the 1980s. For example, at the Houston and Boston centers, officials predict that approximately 50 percent of current maintenance staff will be lost to retirement by 1986 and 1990, respectively. Compounding this problem is the apparent decline in hiring and training of new technicians and FAA's projected reduction in maintenance staffing levels.

En route computer capacity

FAA has concluded that several en route centers will have computer capacity problems in the mid-to-late 1980s. This conclusion is based on FAA's assessment of central processor utilization of the computers at these centers. We believe other factors will affect computer capacity besides central processor utilization. These include the computer's data channels, the main memory, and the input/output devices such as controller keyboards, printers, and mass storage devices. Consequently, we believe FAA may experience computer capacity problems sooner than it expects because some centers with the 9020D computers are already at or near unacceptable channel utilization levels.

To project future computer capacity requirements for system life and to identify limiting resources, FAA correlated central processor use of the 9020A and 9020D computers with aircraft traffic at each of the centers. The central processor was identified as the most critical factor affecting capacity at centers with the smaller 9020A computer. Analysis showed that the 9020As would run out of computer capacity in the late 1980s. The 9020D was not considered to have near-term capacity limitations.

We believe these conclusions are not indicative of the overall system capacity requirement and system life because FAA did not consider the effects that computer channel utilization has on the larger 9020D computer.

The most critical limiting resource in any computer system is that computer resource which reaches its maximum utilization level first. For the 9020A computer, that resource is the central processor. On the other hand, channel utilization has been shown to be the most critical factor affecting capacity at the centers with the 9020D computer.

FAA has determined that significant response time delays (a critical factor in air traffic control) occur when central processor utilization exceeds 80 percent, or when channel utilization exceeds 45 percent. FAA has determined that response times become unacceptably long when channel use approaches 60 percent.

Since FAA's weekly system utilization reports did not include channel activity, we constructed the following table. On the 9020D, FAA has found the percentage of channel use to be approximately the same as central processor use. Therefore, although the table was constructed using central processor utilization, the figures also represent approximate channel utilization.

The table shows the number of weeks in fiscal 1982 during which central processor utilization of the larger 9020D computer exceeded certain levels at least once during the week (meaning that channel usage was also at about the same high level).

En route center	Number of weeks: Reported	Number of weeks: 45% or more	Number of weeks: 60% or more
Atlanta	52	48	--
Chicago	26	8	4
Cleveland	41	41	7
Ft. Worth	47	45	10
Indianapolis	24	5	1
Jacksonville	38	19	2
Kansas City	44	14	--
Los Angeles	39	11	--
New York	52	9	--
Washington, D.C.	46	41	1

From this table we conclude that all centers may have experienced delayed response times because the channels were at or above the 45-percent level. Channel utilization was higher most frequently at the Atlanta, Cleveland, Fort Worth, and Washington, D.C. centers. These centers reported at least one instance of reaching or exceeding the 45-percent level for almost every week of the period covered. Also, six centers experienced at least one instance of channel saturation during the reporting period. The Fort Worth center had the largest number of occurrences of higher channel utilization and reached the 60-percent level at least 10 times.

FAA has developed procedures to free up computer capacity under these and other capacity limiting conditions. These include sequentially removing or reducing nonessential functions and/or restricting or eliminating the use of certain air traffic controller computer aids and functions. We believe these actions do not address the real problem. In our view, at best they are only a temporary solution to FAA's computer capacity problems.

CONCLUSIONS

FAA's recent initiatives have increased the degree of control and oversight over some of its current major projects. However, FAA's organizational structure and management approach do not provide for central planning, control, and direction of all air traffic control automation resources. We believe a more centralized approach would provide the increased oversight and control needed given the magnitude and complexity of the problems experienced. A central management function with oversight and control of offices responsible for managing individual programs could provide the guidance needed to ensure overall integration and direction of FAA's many system and software development projects. While not a cure-all, we believe a central management function could heighten project visibility and accountability, and reduce delay and cost overruns.

FAA needs to more closely monitor the performance of its automated systems and should, as recommended by the Congress, establish a computer performance management function to do this. Such a function could better ensure that the existing system usage does not exceed acceptable capacity levels and that computer reliability does not fall below acceptable levels. Also, FAA's planned replacement computers, which are more technically complex, would have the benefit of this function because reliability and capacity would be monitored; operations and maintenance costs collected and analyzed; potential problems, systems limitations and software inefficiencies identified; and actual performance could be compared with planned objectives for top management analysis and decisions.

RECOMMENDATIONS

We recommend that the Secretary of Transportation direct the FAA Administrator to:

--Strengthen the management of automation resources by establishing a central management function which would have the authority, responsibility, and accountability required to alleviate problems identified, and would satisfy the increased management demands of the major upgrade.

COMPUTER CAPACITY AND SOFTWARE PROBLEMS

DELAY NEEDED NEW YORK TRACON IMPROVEMENTS

The New York Terminal Radar Approach Control system has problems that carry over into FAA's plans for implementing the enhanced ARTS. The TRACON computer provides service to only four of the five airports it was planned to serve. This has delayed the safety and efficiency improvements that were to be derived from integrated control of air traffic in the New York metropolitan area.

Because of unsuccessful in-house and contractor software development, the TRACON still does not have an operational conflict alert feature that will automatically alert controllers when two or more aircraft are on a collision course. Furthermore, the TRACON computer lacks expansion capability. We believe this will restrict its ability to handle the increased traffic expected in future years and may result in additional procurements or efforts to optimize software. These problems could have been avoided by better planning, management oversight, and more clearly defined requirements.

BACKGROUND OF THE NEW YORK TRACON

The New York Common Instrument Flight Rule Room (Common IFR), commissioned in September 1968, was an interim solution to serious terminal control problems in the New York metropolitan area. In 1976, FAA contracted with the Univac Corporation for an ARTS IIIA based system to replace New York's interim Common IFR. FAA also decided to move air traffic control operations from Kennedy airport to new facilities in Westbury, New York. Construction was completed in 1978 and computer equipment was installed in 1979. Initial facility, automation equipment, and communications costs were about $25 million. Total costs through 1982 are about $28 million. FAA planned to configure the ARTS IIIA to accept four radar inputs and control air traffic at 3 major and 2 medium airports and 25 smaller ones, but the system was commissioned in January 1981 as only a two-radar, three-airport TRACON. Although the software used at the New York TRACON is unique to that facility, much of the design logic is similar to that at other ARTS IIIA sites.

The following table identifies the category and location of the airports included in the original concept.

Category	Location
Major airports	John F. Kennedy La Guardia Newark
Medium airports	Westchester MacArthur-Islip
Smaller airports	25 satellite airports

Original plans included a switching capability which would enable each controller to display data from a second radar in the event of a radar failure. Also, the system was to be modularly expandable to accommodate future automation and air traffic growth. As discussed below, these plans were not achieved.

SHORTAGE OF COMPUTER CAPACITY DELAYS BENEFITS OF INTEGRATED AIR TRAFFIC CONTROL

We found that FAA did not adequately define system requirements or the computer capacity needed to operate a five-airport system. Also, FAA proceeded with implementation of the TRACON even though a study showed that addition of other functions such as conflict alert would cause the computer to exceed its capacity by 1982--1 year after becoming operational. As a result, the full benefits of improved safety and efficiency to be derived through integrated control of air traffic in the New York metropolitan area are not being realized. The TRACON's inability to serve all airports necessitated the interim installation of a less capable ARTS II computer at the Westchester airport.

Computer capacity may cause future problems

As early as July 1978, 2 years before commissioning, FAA was aware that capacity problems would limit future software expansion, the development of conflict alert, and the tracking of all aircraft. Also, that new computer hardware would be needed when all radars became operational. We found no evidence that FAA evaluated ways to solve this problem before the system was installed.

Between 1979 and 1982, Univac provided seven reports detailing various proposals to increase capacity. Univac told FAA that there was a capacity problem and that ways should be developed to resolve it. Also, Univac suggested 17 capacity expansion alternatives. FAA told us that Univac's proposals to increase memory capacity were unacceptable because they required internal changes to the system.

The Airway Facilities Service also developed an alternative which could be done in-house. This would have doubled capacity at an estimated cost of $580,000. Officials from the Air Traffic Service said they did not implement this proposal because it involved significant software changes.

No assessment or cost effectiveness study was done on either the Univac or in-house alternatives. FAA later approved a Univac-proposed hardware modification for one additional module of memory at a cost of $600,000.

The possibility of computer capacity problems was also raised in a June 1980 report prepared by another contractor. This study disclosed that if the processing capacity limitation was not overcome, it would constrain growth at metropolitan air traffic facilities such as those at New York and Chicago. Specific findings were:

--Processing capacity for the New York TRACON appears to only marginally meet air traffic demands expected in 1984 and later.

--Computer memory saturation is expected in 1982 at the New York TRACON with the implementation of conflict alert.

--Large increases in processor and memory are required for adding new functions such as conflict alert.

We could find no evidence that FAA addressed the problems outlined in the contractor's report.

Interim ARTS II system installed at Westchester County Airport

We found that FAA installed an ARTS II system at Westchester County Airport on an interim basis because of the TRACON's inability to serve this airport as planned.

The system, installed in August 1981 at an estimated cost of $300,000, provides aircraft identification and altitude data in much the same manner as the ARTS IIIA. However, it does not have the capability to warn controllers of aircraft flying below established safe altitudes and cannot predict an aircraft's flight path.

We believe use of the ARTS II indefinitely delays full implementation of an integrated control system in the New York metropolitan area. The efficiency and effectiveness benefits of an integrated TRACON will not be fully realized until the five-airport system is fully operational. FAA has no definite date for a four-radar and five-airport TRACON capability.

HARDWARE AND SOFTWARE MAY LIMIT TRACON'S ABILITY TO HANDLE EXPECTED GROWTH IN AIR TRAFFIC

We found that although the purchased four-radar, five-airport system and the software met design specifications and were tested, they were not used. Instead, because of memory size limitations, FAA retrofitted the original software by reducing its scope so that a new function called conflict alert could be added when it was developed. In addition, inadequate hardware design specifications resulted in a nonexpandable system that was known to have insufficient capacity.

Software met design specifications but was not used

As part of the original 1976 contract, FAA procured a four-radar, five-airport software program from Univac for use at the TRACON at a cost of $429,704. This software was tested and accepted by FAA in November 1979. It was not used because air traffic requirements were upgraded between 1976 and 1979 and the system did not have conflict alert.

In 1980, another contractor and FAA Technical Center personnel began work to add conflict alert. After expenditures of over $580,000, the contractor-developed software could not be used. Only recently, after extensive redevelopment by Technical Center personnel of the Air Traffic Service, was conflict alert added to the TRACON software. As of November 1982, it is still being tested and the date it will become operationally usable to the air traffic controllers is uncertain.

Design specifications limit TRACON functions

We found that FAA's design specifications did not adequately define expansion capability and the amount of reserve capacity to be provided. Insufficient capacity has kept the TRACON from operating as planned; it has also caused numerous software changes, with more continuing to be made. FAA's design specifications for computer expansion and capacity for growth could not be measured because they stated no criteria. They simply said the ARTS IIIA system was to provide the capability for further

--modular expansion of hardware and software, and

--functional growth with increased capacity.

Univac claimed the primary advantage of the ARTS IIIA system was its modular design. This feature allowed for expansion at minimal cost by adding memory modules to the existing system.

The ARTS IIIA system procured for the TRACON contained the maximum configuration of 15 memory modules for processing plus a sixteenth for the Reconfiguration Fault Detection Unit. Univac delivered the system, as specified, but because FAA did not adequately define system requirements, the system has limited expansion and capacity. Univac satisfied:

--The excess capacity specification because only 227,000 of the 229,000 words of memory were used by the four-sensor software program--2,000 words of excess capacity.

--The hardware and software expansion specification because no definition of such expansion was provided. The amount of unused memory in the system Univac supplied allowed the hookup of an additional printer or display, but not the addition of another processor memory module.

Consequently, the TRACON has no modular capacity growth. We believe that the inability to expand the computer capacity of the ARTS IIIA will severely limit the TRACON's ability to handle the FAA-projected growth in air traffic. Regional and TRACON officials believe that the solution probably is to replace the ARTS IIIA, place additional ARTS IIs at the larger airports, limit air traffic, or eliminate planned enhancements such as Metering and Spacing, Mode S, and Terminal Information Processing System.

Software approaches computer capacity limits of ARTS IIIA

To incorporate the conflict alert feature, FAA has redesigned its three-radar, four-airport software program. We found that this effort incorporates the conflict alert capability, but the program consumes almost all available memory in the ARTS IIIA computer. Our review of the FAA's efforts to develop this software program disclosed that the design and modification were done without knowledge of memory requirements or of whether the resulting software would fit into available memory.

Specific program size was unknown during the design

To ensure efficient use of computer resources, an FAA order requires that a costing and sizing study be prepared for system updates and program inprovements, showing

--the amount of increase or decrease in computer memory;

--design, programming, testing, and documentation costs; and

--the interface impact between the ARTS and en route centers.

We found that no formal study had been prepared for this latest software program redesign and redevelopment effort.

Because of the uncertainty about whether the software would fit on the TRACON's computer, plans were drawn up for how FAA could "buy back" computer capacity. FAA considered increasing the capacity of the system by requiring the "tracking of radar-only targets" 1/ to be initiated manually by the controller rather than automatically by the computer. Another possibility was to

1/Tracking is an automated process by which the computer predicts the position of aircraft through intermittent radar or beacon returns. The tracking capability allows the association of alphanumeric datatags and presents a smoother, more realistic display of aircraft path and positions.

configure the Reconfiguration and Fault Detection Unit so that more computer memory could be accessed by the computer for processing. This would limit the function of the unit.

We found that even after redesign and testing at the Atlantic City Technical Center, FAA did not know if the software would fit the TRACON ARTS IIIA. Not until the software was implemented at the TRACON did FAA learn the true capacity of this version. It uses 14 of the 15 available memory modules.

We asked FAA officials why the additional capability did not require more memory than the version it replaced. We were told that the conflict alert feature was not as large as expected (exact size to be determined) and that program redesign eliminated inefficiencies in memory usage. Since actual memory requirements were not known during software development, we conclude that FAA was fortunate to have it fit within the system's memory constraints. We believe this trial and error approach has no place in the development of software as critical as that for the Nation's air traffic control system.

CONCLUSIONS

FAA has not been able to achieve the full benefits of improved safety and efficiency that were to be derived from the integrated control of air traffic in the New York metropolitan area. Because costly in-house and contractor software development efforts failed to produce a fully usable software package to meet current requirements, the TRACON does not have an operational conflict alert capability. The computer's inadequate expansion capability will severely limit the TRACON's ability to handle the projected growth in air traffic and may result in additional procurements. We believe that better defined requirements and increased project oversight by FAA could have prevented many of the TRACON's current deficiencies. As discussed in appendix IV we believe a central management function to coordinate and manage all facets of air traffic control automation would have minimized the impact of this problem.

CONCERNS ABOUT PLANNING, MANAGEMENT, AND COORDINATION

OF SELECTED COMMUNICATIONS PROJECTS

The projects we reviewed were the Mode S Data Link System, the Traffic Alert and Collision Avoidance System, the Microwave Landing System, and the Flight Service Station Automation Project. We found that technical problems associated with Mode S Data Link, Traffic Alert and Collision Avoidance, and Microwave Landing Systems call for further testing to make sure performance requirements are satisfied. Also, implementation of Mode S is not timed with new air traffic control projects; this could limit planned improvements. We found the degree of user acceptance for these systems uncertain. Poor user acceptance could result in reduced system benefits. Furthermore, in recalculating the cost/ benefits of the Flight Service Station Automation Project, we found it offers no cost advantage to the Government in comparison to existing systems.

FAA NEEDS TO RESOLVE MODE S PROBLEMS

FAA needs to resolve a number of Mode S problems to ensure effective and efficient implementation of air-ground digital communications. Prototype testing disclosed problems with supporting equipment that prevented achievement of performance requirements. Mode S acceptance by users and the international standards organization is questionable but is needed to maximize the benefits from FAA expenditures. In addition, users will receive limited benefits under the current implementation plan for an undetermined period of time.

Mode S is the advanced air traffic control air-ground digital communication system scheduled to replace the current Radar Beacon System starting in 1987. Formerly called Discrete Address Beacon System, Mode S is the internationally accepted name for this secondary surveillance system with data link capabilities. With Mode S, FAA intends to improve surveillance performance, accuracy, and reliability. According to FAA's December 1981 "National Airspace System Plan," Mode S equipment will provide more accurate aircraft surveillance information, a computer-to-cockpit message capability for weather, air traffic control clearances, and other air traffic control information via the Mode S data link. The plan also states that in 1990, Mode S data link will be provided above 12,500 feet and Mode S transponders will be required for aircraft operating above this altitude. Below this altitude, Mode S will be optional avionic equipment.

The FAA has already spent $64.5 million though fiscal 1982 on Mode S development and plans an additional $54 million in fiscal 1983 through 1991 for further Mode S research and development.

FAA plans to begin procurement of 137 Mode S sensors in fiscal 1983 and to complete installation by 1990. The sensors are expected to provide complete coverage at 12,500 feet and above for en route areas and for approaching the surface of qualifying airports. However, about 72 percent of the general aviation fleet cannot fly above 12,500 feet. These planes would receive only partial coverage and intermittent Mode S services until an additional 60 sensors are procured to bring complete coverage down to 6,000 feet. FAA plans to have coverage down to 6,000 feet by the year 2000. It is requesting $231.8 million for fiscal 1983 through 1985 for Mode S production and installation. 1/

FAA anticipates that Mode S transponders will be in widespread use by 1990. We estimate it will cost civil (commercial and general) aviation users $2.9 billion to equip with Mode S transponders over a 20-year period based on 100-percent adoption. We used FAA estimates that Mode S transponders will cost $36,000 and $3,000 (1982 dollars) for commercial and general aviation aircraft, respectively.

Performance problems disclosed during testing

The prototype Mode S sensor was unable to satisfy a basic performance requirement for future traffic projections during testing because it failed to interrogate 400 aircraft in a given area and to transmit and receive longer messages from 50 of them. The contractor responsible for the prototype has not been able to correct this problem and attributes it to inadequate computer processing capability. The contractor stated that in order to meet the 400-aircraft requirement, it would have to start from scratch and design a new software package as well as build a new hardware processor. Although FAA is reexamining its requirements for sensor capacities, it plans to issue a Request for Proposals for 250-, 400-, and 700-capacity sensors. These capacity levels correspond to current FAA projections of various airspace densities through 1995. For example, in high density airspaces such as Chicago and Los Angeles, FAA anticipates the need for two 400-capacity sensors at each location. Each sensor would assume the total workload for short periods in the event of a sensor failure. Despite not having a successful Mode S prototype, project officials claim that production can be started because current hardware technology and new software can satisfy performance requirements. We believe there is a need for further prototyping, including testing, prior to procurement to demonstrate Mode S ability to satisfy established requirements.

1/This is not the total cost of Mode S implementation. Additional funds will be needed in later years for production and installation.

Mode S acceptability is questionable

Mode S acceptability by domestic users and the international standards organization, which is important to FAA in supporting gateway facilities, is questionable. The NAS plan makes Mode S transponders mandatory on all aircraft operating over 12,500 feet, starting in 1990. Department of Defense representatives told us this date will not allow Defense sufficient time to efficiently and economically equip its aircraft with Mode S transponders. Also, this requirement will force users to procure Mode S transponders when only limited data link services are available. The International Civil Aviation Organization (ICAO) has not yet approved Mode S as designed.

Defense officials have expressed concern over FAA's early requirement for Mode S transponders. Many military aircraft will not receive new advanced IFF (Identify Friend or Foe) avionic boxes incorporating Mode S transponders before 1990. Therefore, getting Mode S into these aircraft at a reasonable cost is an important concern. Defense is interested in a gradual phasein of Mode S to allow a cost effective replacement of current IFF avionics.

The major benefit of Mode S to the aviation community is the data link and the services it can provide, such as allowing pilots to change flight plans and update weather information while airborne. FAA has established a working group to identify services for Mode S use and assess their potential benefits. Only two data link packages, offering few defined services, are under consideration. Unless a significant percentage of general aviation aircraft which account for 90 percent of air traffic, are equipped with Mode S transponders, FAA will not realize the full benefits of Mode S: improved secondary surveillance performance and transmission of air traffic control and weather data independent of controllers. FAA's ability to get general aviation to equip planes with Mode S may be the factor that determines whether FAA can successfully change from the Radar Beacon System to Mode S. If general aviation accepts Mode S in large numbers, FAA will be able to reduce its need for air traffic controllers.

Mode S is undergoing study by the International Civil Aviation Organization. This is an international organization of 149 member countries which establishes international standards for flight procedures and aviation equipment specifications. The member countries span the political and economic spectrum; they include Argentina, Peoples Republic of China, Czechoslovak Socialist Republic, Iran, Iraq, Saudi Arabia, and the Union of Soviet Socialist Republics. Each member country must comply with international standards at its gateway facilities.

FAA plans to implement Mode S before its international use is approved by ICAO. Approval of Mode S as an international standard may take from 2 to 5 years, but FAA will begin committing funds for Mode S production and installation in fiscal 1983. FAA believes ICAO will approve its Mode S signal format for international use because most industrialized countries have accepted the U.S. specifications. In our opinion, FAA is taking a risk in producing Mode S equipment before the Mode S signal format has gained international approval. If another signal format is approved by ICAO, substantial modifications could be necessary to Mode S ground systems and avionics. This could cost FAA and users millions of dollars.

Reduced benefits
under current implementation plan

Mode S benefits will be reduced during an undetermined interim period beginning in 1985 while it functions with the current automated radar terminal systems--ARTS. FAA plans to study the upgrading of the existing ARTS and ultimately replace them under the "Sector Suite and Software Redesign Project" (see p. 17) to effectively utilize the full data link capability of Mode S.

The current ARTS were not designed to function with Mode S. To overcome this, Mode S messages sent from the sensors will be converted to look like the messages received from the current beacon systems. The increased positional accuracy of the Mode S information will be lost after this conversion, as will the computer-to-cockpit capability. FAA plans to award a contract to study the feasibility of upgrading ARTS to interface with Mode S, thereby taking earlier advantage of the more accurate surveillance data and data link capability. If the upgrades are cost effective, the contractor selected will design and develop this software interface by 1987. However, if the ARTS upgrades are not determined to be cost effective, FAA will not fully utilize procured Mode S equipment until the new sector suites become operational. The sector suites are scheduled for delivery from 1988 to 1991. If delivery is delayed, reduced FAA and user benefits will be extended even longer. This could contribute to lower user acceptance, which is discussed in a preceding section.

TCAS SAFETY, ACCEPTANCE, AND BENEFITS
SHOULD BE CONFIRMED

FAA should demonstrate that the Traffic Alert and Collision Avoidance System (TCAS) can function effectively and should assess the degree of acceptance of this system by users. In addition, the possible benefits and expected user costs of TCAS should be determined with better precision.

FAA has made several earlier attempts and spent millions of dollars to develop collision avoidance systems. More recently, FAA was developing a ground based collision avoidance system called Automatic Traffic Advisory and Resolution Service--for high aircraft density airspace--and an aircraft based Beacon Collision Avoidance System--for medium and low aircraft density airspace. On June 23, 1981, the FAA Administrator announced his decision to proceed with TCAS.

TCAS is aircraft based and warns pilots of impending collision. Intended to back up the air traffic control system, its operation is completely independent. It handles high, medium, and low density airspace. TCAS helps to resolve some earlier problems, including the excessive FAA implementation cost of the Automatic Traffic Advisory and Resolution Service system.

The objective of TCAS is to provide a range of collision avoidance equipment alternatives to airspace users. It is designed to meet two minimum capabilities: TCAS I, for general aviation, provides proximity warning to pilots when other aircraft are nearby. TCAS II, for air carriers, informs a pilot of an intruding aircraft's position and gives a resolution (maneuver) advisory if the other aircraft represents a collision threat. Mode S transponders are integral components of TCAS operation.

Through fiscal 1981, FAA has spent $64 million to develop and test various collison avoidance systems. It expects to spend another $29 million for fiscal 1982 through 1986 to complete development, testing, and evaluation of TCAS equipment and to publish appropriate standards and guidelines. FAA costs are minor compared to user costs. Based on FAA's aircraft population growth projections, assuming 100-percent adoption of Mode S for all aircraft and 100-percent air carrier and 50-percent general aviation adoption of TCAS, we estimate that users would incur $7.1 billion (1982 dollars) in costs over 20 years. This is based on FAA's estimate of $66,000 and $3,800 (1982 dollars) to equip commercial and general aviation aircraft, respectively.

Limitations to system effectiveness

TCAS effectiveness as a backup to air traffic control could be severely reduced by three factors--(1) unwanted or unnecessary advisories given to pilots could be disruptive; (2) pilot response time to advisories may be too long; and (3) aircraft without transponders, which will frequently be operating in the same vicinity as the TCAS-equipped aircraft, cannot be detected by TCAS.

Terminal area aircraft densities increase the likelihood of collisions. A passive avoidance system, which does not interrogate other aircraft transponders and was originally planned for TCAS I, has proven to be ineffective in terminal areas. New methods are being examined. FAA's testing of TCAS II has been pursued by FAA for only a year. TCAS II should work when the air traffic control system--because of human error or mechanical failure--does not detect a pending collision. Since TCAS cannot determine controllers' intentions, aircraft in the same general vicinity that are climbing, descending, or turning toward one another will generate a TCAS maneuver advisory. Recent tests showed that in low and medium densities unnecessary maneuver advisories, which could be disruptive to pilots, were generated when other aircraft were in the vicinity.

The possibility exists that the number of maneuver advisories will increase as aircraft densities increase. Although FAA did not calculate airspace densities during TCAS II flight testing, the project official estimated the maximum airspace density encountered during testing to be 31 aircraft within a radius of 10 nautical miles. FAA has scheduled additional TCAS II flight tests. However, a TCAS program objective is for the system to work in airspace densities up to 90 aircraft within 10 nautical miles through the 1990s and in densities of 120 aircraft after the year 2000. These requirements were derived from FAA projections of aircraft densities for the Los Angeles basin airspace. FAA believes this airspace will continue to have the greatest density in the Nation.

The adequacy of time allowed for pilot response to resolution advisories still has to be proven. FAA has built "densensitization" into the TCAS II logic to reduce unwanted resolution advisories in terminal areas. Densensitization reduces protection response time as aircraft reach lower altitudes. For example, aircraft flying below 2,500 feet have only 20 seconds or less from the time of the resolution advisory until potential impact. Even though FAA recognizes it is trading protection time for fewer unwanted alarms, it believes that a vertical escape maneuver of 1500 feet per minute or greater is acceptable. This maneuver requires a prompt and positive response by pilots because delays of ten seconds or more would not leave sufficient execution time for many commercial airliners. Pilots need time to execute the maneuver advisory and achieve needed altitude separation, plus an allowance for errors in aircraft altitude reporting equipment. Actual test flights have shown that pilots often do not promptly respond to advisories. Instead, they first visually search for the intruder. This could thwart the objective of TCAS.

TCAS effectiveness and safety still needs to be determined when units are operating in airspace where transponders are not required. Terminal areas where transponders (currently Radar Beacon Systems) are not required to account for most errors that could lead to collisions. According to FAA, about half of all scheduled air carrier landings and departures occur in terminal areas where general aviation aircraft can also operate without having either a transponder or altitude encoder. FAA estimates that about 39 percent of general aviation aircraft do not have transponders and about 72 percent do not have altitude encoders. Statistics show that these rates vary significantly from one State to another. Failure to require transponders and altitude encoders in more terminal areas will make TCAS less effective because TCAS I and II cannot detect aircraft without transponders, nor can TCAS II give resolution advisories if other aircraft are without altitude encoders.

National and international acceptance is questionable

FAA needs a better understanding of community support for TCAS. According to the FAA Administrator there are no present plans to require TCAS on aircraft. Therefore, the demand for TCAS will probably be based on perceived need in relation to cost, since FAA has not quantified the benefits. While industry officials basically support FAA's research and development activities in collision avoidance, the airlines, the general aviation owners, the military, and the International Civil Aviation Organization appear less than certain about plans to implement TCAS.

Although FAA has not quantified the benefits of TCAS, its position is that if the system can prevent a single midair collision between two wide-body aircraft, the system cost to the user is justified. According to a preliminary cost analysis, FAA estimated that more than half a billion dollars would represent a reasonable estimate of the cost of such a catastrophe. According to an FAA preliminary cost analysis, user cost to implement Mode S and TCAS, based on 100-percent Mode S adoption and 100-percent air carrier and 50-percent general aviation TCAS adoption, would be $3.5 billion over 20 years. This figure represents a $2.4 billion cost for Mode S and TCAS over the present Radar Beacon transponders cost.

FAA's cost estimates for Mode S and TCAS do not include military and system life replacement costs. According to the Air Force traffic control program officer, Defense has not developed any firm cost figures to acquire and install Mode S and TCAS. However, depending on the types of units to be installed on various aircraft, these systems could cost the military up to several billions of dollars. Including a 15-year system life replacement cost, and $2 billion for military costs, we estimate user costs for Mode S and TCAS to be $7.1 billion (1982 dollars) over 20 years.

Since TCAS is an optional, airborne, user acquired system, its costs and implementation schedule do not directly affect air traffic control operations. The user determines when and if the system will be acquired. However, for the concept to be successful, large user investments are necessary. Users, therefore, must be convinced that the benefits to be received from the system are greater than the costs.

FAA expects air carriers to voluntarily equip planes with TCAS. The airlines, however, support a less costly collision avoidance system, but they have proposed no alternatives to TCAS. The Air Transport Association, which represents the major air carriers, has not fully accepted TCAS II requirements. Airlines are concerned that the additional cost to implement TCAS II compared to a less complex system may not be justified. Some unofficial estimates for TCAS II implementation are as high as $80,000 to $90,000 per aircraft. According to Air Transport Association officials, preliminary indications are that the airlines do not believe the benefits from a collision avoidance system are worth this high a price.

FAA has done very little to assess the interest of the general aviation community in investing in collision avoidance. The proposed passive concept originally planned for TCAS I, which is estimated to cost from $2,500 to $3,500, is an ineffective system according to FAA. Therefore, additional upgrades or a change to an active system which interrogates other aircraft transponders in its vicinity can be expected to significantly increase FAA's original cost estimates. Such increases may make the system less attractive to general aviation--which accounts for 99 percent of the U.S. civil air fleet, about 90 percent of all air traffic, and 84 percent of civil operations at FAA tower airports. Availability of an effective TCAS I is one of the incentives FAA can use to encourage general aviation owners to acquire Mode S, which we discussed earlier.

The Defense Department has not developed a policy statement concerning plans to acquire TCAS once the systems are available. The Air Force representative to the Aircraft Separation Assurance Program stated that the military is most concerned about midair collision when aircraft fly close to one another during refueling missions and formation flying. TCAS would not be able to reduce the collision risk in either of these situations. General aviation represents the other greatest collision threat to military aircraft. FAA data show that midair near collisions between military and general aviation account for about 32 percent of all midair near collision reports. The probability, however, of general aviation aircraft not being equipped to allow detection is much higher than with other aircraft.

According to the FAA timetable, TCAS II should start production in 1984. FAA and other officials doubt that ICAO standardization of Mode S can be achieved before 1984. The ICAO committee working on Mode S will not begin work on collision avoidance standards until it has finished with Mode S. TCAS and Mode S project managers have stated that much of the groundwork for obtaining agreement on the U.S. specifications for TCAS and Mode S has been accomplished, since most of the industrialized countries have accepted the U.S. specifications. There are, however, other existing collision avoidance systems that could be adopted by ICAO's 149 members. In addition, the long projected time frame for the ICAO standardization process adds significantly to the risk that new technology will make TCAS obsolete before standardization occurs.

MLS PROGRAM NEEDS TO RESOLVE PROBLEMS AND REACH AGREEMENT

FAA needs to resolve outstanding technical problems associated with the reliability of Microwave Landing System (MLS) equipment, including the Precision Distance Measuring Equipment (PDME), and reach agreements with other organizations to achieve acceptability.

MLS will replace the Instrument Landing System now used by civil and military aircraft and the Ground Controlled Approach System used primarily by military aircraft. MLS provides aircraft azimuth (course or direction), angle (glide slope), and range (distances between an aircraft and the MLS equipment located near airport runways). Azimuth and angle information is provided through the Time Reference Scanning Beam component, while range is calculated by the PDME component.

MLS is expected to provide greater flexibility of air traffic procedures by allowing curved and segmented approach paths; these increase safety and reduce noise levels. Also, MLS is expected to improve short field operations by short and/or vertical takeoff and landing aircraft. It is intended to meet the full range of user operational requirements through this century and beyond. FAA estimates program costs will be $1.1 billion for procurement of ground equipment starting in 1983. Civil aviation is expected to spend $900 million for avionic equipment. Defense has not yet formalized an MLS program.

Technical problems need resolution

Uninterrupted MLS service cannot be assured under present plans. Also, technical problems with the PDME component were disclosed during testing.

FAA plans to use Remote Maintenance Monitors to control a variety of MLS equipment functions. In reviewing MLS specifications, the Department of the Army identified a major technical concern--MLS susceptibility to inadvertent or deliberate sabotage. Remote Maintenance Monitors use electronic signals to turn on and off (reset) MLS equipment. Inadvertent signals from two-way radios, electronic garage door openers, and the like could change the function of MLS equipment. The function could also be changed intentionally through sabotage by persons attempting to damage the United States, FAA, the military, or the airlines. The use of a properly secured password was proposed by the Army to remove this risk. FAA has not decided what action, if any, it will take.

FAA has tested several prototypes of PDME from two contractors, with differing results. One contractor's prototype displayed significant bias, ranging from 10 to 295 feet, that could not be isolated by the contractor's engineers. PDME should be accurate to within 100 feet. This degree of precision is sufficient for safe landings under zero visibility. A consistent bias that does not vary over time can be corrected simply by compensating for the known value of the bias; it then does not affect the precision of the resulting estimates. FAA's evaluation report on these prototypes recommended further testing to isolate the cause of the significant bias, but no further testing was conducted or is planned according to FAA's program manager. The prototypes from the other contractor displayed no significant bias during testing. We believe there is no assurance that this bias will not occur in another contractor's production models without determining the source of the bias in the one prototype.

Agreements needed with other organizations

FAA needs to reach agreement with the Defense Department on MLS in order to meet its primary objective of providing a standard civil and military method for precision approaches and landings.

A primary MLS objective is to provide a standard civil and military method for precision approaches. The military needs a tactical landing system for adverse combat conditions overseas and for domestic disasters and other emergencies here. This equipment should be compatible with FAA equipment to efficiently minimize the need for dual or multipurpose receivers on military aircraft which frequently use civilian air facilities. To achieve this objective, FAA and Defense must agree on all specifications and procedures needed for interoperability and compatibility prior to production. Such agreement had not been achieved by July 1982.

FAA and Defense have been discussing MLS for several years but significant issues are still unresolved. In June 1982, Defense stated its desire that 15 channels be dedicated exclusively for military use. Although requirements have not been analyzed to calculate its real need for dedicated channels, Defense proposed a set-aside of 15 channels. Defense officials responsible for coordinating with FAA feel that 15 channels will meet their actual operating requirements.

Since only about 100 channels are available, FAA officials told us they anticipate a possible shortage of channels during the MLS equipment life cycle if they permanently relinquish as many as 15 channels. FAA bases this conclusion on its official forecasts which state that air traffic will more than double over the next 25 years. FAA and Defense did not begin active discussions on this important issue until July 1982. We believe it should have been resolved earlier because it directly affects a major MLS program objective--to meet operational requirements through the end of this century and beyond.

FLIGHT SERVICE STATION AUTOMATION PROJECT NEEDS TO BE REEVALUATED

FAA needs to reevaluate the Flight Service Station Automation Project for two reasons. First, to be effective and reduce costs, the aviation community must be willing and able to utilize automated services once they become available, but FAA has not yet demonstrated this willingness. Secondly, because of the large initial expenditures for this project, the need to maintain flight specialists to directly interact with pilots who cannot or choose not to use automated methods, and the uncertainties about levels of future demand for flight services, the Flight Service Station project may not meet FAA's prime program objective to reduce costs. It may, instead, actually increase costs.

The Flight Service Station Automation Project is intended to provide automated weather pilot briefings and graphic weather display to flight service specialists via cathode ray tube (CRT) terminals. FAA plans to introduce this automated assistance starting in 1984 at a few locations. It would expand the service to more locations in the future and eventually upgrade it to allow pilots to receive weather briefings and to file flight plans without a flight service specialist.

More than 4,500 flight specialists, or roughly 10 percent of FAA's total workforce, now manually provide flight services to the aviation community. The total annual operating costs exceed $100 million. FAA's prime objective for the Flight Service Station project is to reduce costs, particularly personnel costs, through automation.

FAA plans to produce equipment for 61 automated flight service stations, consolidating its approximately 300 current facilities. It estimates the cost at $495 million--$170 million from fiscal 1977 through 1982 for research and development, and $325 million from fiscal 1983 to 1987 for facilities and equipment, research and development, and installation, but not operations or maintenance.

<u>User acceptance is uncertain</u>

FAA should assess the degree of acceptance among general aviation pilots of the automated flight services it plans to offer. The success of the program and its cost impact on the Government depends on such acceptance.

These planned automated services will require pilots to use either computer terminals with ordinary telephone lines or touch-tone telephones. A direct user access terminal costs a few hundred dollars. Using a touch-tone telephone, approximately 100 keystrokes are required to enter flight plans. FAA has not evaluated pilot willingness to purchase terminals or enter a flight plan with a touch-tone telephone, but estimates that by 1995, 80 percent of weather briefings and 85 percent of flight plans will be filed directly by pilots without the assistance of flight service specialists.

We believe that commercial airline companies and the Department of Defense either already own or will acquire access terminals to enter data for their limited use of the system. The major unknown is system acceptance by general aviation, which accounts for 90 percent of all air traffic.

FAA's program manager stated that the only study of user acceptance of automated flight services was conducted by FAA in 1976. The study showed generally positive reaction to automated flight services; however, FAA was unable to provide the detailed statistics it used to make this assessment. The study notes that the participants were primarily engineers and computer programmers--individuals already comfortable with computer systems. This gives the study an unknown bias because there is no assurance that the group tested would fairly represent general aviation. In addition, the study did not measure general aviation users' willingness to purchase computer terminals or use touch-tone telephones. Later studies in 1979 and 1980 dealt primarily with the usefulness of data provided by the Flight Service Station project. In our opinion, they do not satisfactorily demonstrate pilot acceptance of automated services.

The other aspect of acceptance is pilot perception of the quality of weather information furnished by the system. Here again, the emphasis is on general aviation. We believe that general aviation pilots can reach decisions when weather conditions are excellent or very poor. However, between such extremes lies a considerable amount of uncertainty wherein an unknown number of pilots will wish to speak with a flight specialist to get an expert opinion. As the number of calls to flight specialists increases, system efficiency will decrease because calls must be answered promptly to ensure the safety of aircraft since weather conditions are subject to rapid change.

In our opinion, this unknown acceptance of reliability could heavily affect the expected cost benefits that are discussed in the following section.

Need to recompute costs/benefits

FAA needs to recompute its cost/benefit analysis for the Flight Service Station Automation Project to determine if this program should be continued, delayed, or terminated. Earlier cost/benefit analyses were deficient because they did not consider a range of variable factors. In addition, our detailed analysis and subsequent recalculation of costs and benefits disclosed some highly questionable adjustments without which the project would not have been justified by FAA's analysis.

FAA initially conducted a cost/benefit analysis for the flight services project in 1978, in connection with the project's master plan. This study concluded that FAA could save $1.5 billion in operational costs through 1995, but less than $300 million after the discounting required by OMB. The study relied on critical assumptions that could vary substantially. These assumptions concern

--the rate of utilization by general aviation pilots of flight services, and

--the growth in demand for flight services.

The study did not show a range of results based on differing assumptions for these variable factors.

Our analysis of FAA's study disclosed two highly questionable adjustments which gave a significant cost advantage to FAA's automated alternative. FAA had estimated that with the current manual system, operational costs would increase approximately 20 percent more than the projected demand increase for flight services during the second year of the research and development phase. Since this increase became the basis for future year projections, the overstatement of cost was reflected throughout the balance of FAA's analysis. In addition, continuing manual system expenses were held constant when costing automated alternatives, despite projected dedemand increases, until initial automated operations were planned to begin. We recalculated the discounted costs of the Flight Service Station project without these adjustments through 1995, using several different rates for user acceptance and growth in demand. 1/ Our results are shown below.

Comparison of Discounted Costs
For Flight Services

	Annual demand growth			
	Zero	One percent	Three percent	Five percent
	Cost to the Government			
	(millions)			
No automation (using current manual system)	$1,128	$1,190	$1,332	$1,503
Automation (Using Flight Service Stations)				
Acceptance rate (percent)				
80	1,460	1,497	1,581	1,676 a/
60	1,509	1,552	1,639	1,765
40	1,557	1,606	1,720	1,853
20	1,604	1,660	1,788	1,941

a/Closely approximates assumptions used by FAA.

1/Our recalculation used OMB Circular A-94 discounting rates for consistency with FAA. However, the prescribed 10% rate for discounting is arbitrary. If 10% is too high a rate, the economic impact of discounting has been overestimated. If it is low, the impact of discounting has been underestimated.

A comparison of our recalculated costs for both the present system and the Flight Service Station system shows that the latter offers no cost advantage to the Government.

FAA updated its cost/benefit analysis in October 1979, using its 1978 study results to reflect changes in its plans to consolidate flight service stations. Several minor (unsigned) papers prepared in the summer of 1981 attempted to evaluate reductions in predicted demand for flight services but did not address discounted costs. Because these updates were based on the initial analysis, the same problems exist in these later analyses. None of the analyses quantified benefits of automation such as service improvements or assessed user costs of system implementation.

We believe that general economic conditions and the air traffic controllers' job action affected demand for flight services. For example, the demand actually decreased more than 3 percent from fiscal 1978 to 1981, rather than increasing 15 percent as FAA had assumed in its initial cost/benefit analysis. If FAA had computed costs for a range of growth rates and user acceptance rates, the program's benefits or lack thereof would be clearer. Use of a single point estimate when there are critical variable factors is an error that limits meaningful evaluation of results for managerial decisions.

CONCLUSIONS

Testing disclosed technical problems associated with Mode S, the Traffic Alert and Collision Avoidance System, and Microwave Landing System that require resolution, including further testing, before full implementation. User acceptance for Mode S, TCAS, and the Flight Service Station Automation Project needs to be assessed to ensure successful system implementation for safety and cost considerations of FAA and users. FAA's successful implementation of these programs depends, to a large extent, on a high degree of user acceptance. Without it, FAA may not gain significant short term or possibly long term benefits from its investments and those made by users.

RECOMMENDATIONS

We recommend that the Secretary of Transportation direct the FAA Administrator to:

--Assess and resolve promptly the identified critical communication issues. This should include:

- Enforcement of further testing to ensure that performance requirements are satisfied for Microwave Landing System, Mode S, and Traffic Alert and Collision Avoidance System before implementation proceeds.

- Assurance of user acceptance of Mode S, Traffic Alert and Collision Avoidance System, and Flight Service Station Automation Project before proceeding with full implementation.
- Reevaluation of total costs and benefits of the Traffic Alert and Collision Avoidance System before implementation.
- Reassessment of costs and benefits to Flight Service Station Automation Project users so that a decision can be made about implementing the program.

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