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Report to Congressional Requesters

November 1988

# AIR TRAFFIC CONTROL

# FAA Should Define the Optimal Advanced Automation System Alternative

GAO/IMTEC-89-5

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**Information Management and**
**Technology Division**

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Senator Frank R. Lautenberg
Chairman, Subcommittee
on Transportation and
Related Agencies
Committee on Appropriations
United States Senate

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

In response to requests made during meetings with your offices, we reviewed the Federal Aviation Administration's (FAA) plans to modernize air traffic control computer systems by acquiring the Advanced Automation System (AAS).[1] Although we support FAA's objective to modernize the air traffic control system, we testified in April 1987 that FAA needed to obtain additional information to enable it and the Congress to make a more informed decision about this procurement.[2] The objectives of this review were to evaluate (1) FAA actions—responding to direction from your committees—to obtain more technical information and to modify test plans before awarding the contract to buy AAS, and (2) a benefit/cost study FAA prepared in response to direction from the Conference Committee on FAA's Fiscal Year 1986 Appropriations.[3] Appendix I describes our objectives, scope, and methodology; appendix II contains background information on FAA.

Technical information is needed to provide confidence, before the production contract is awarded, that technical risks have been mitigated. We found FAA's actions to obtain additional technical information and

[1]On July 25, 1988, FAA awarded a $3.6 billion contract to International Business Machines Corporation. Hughes Aircraft Corporation protested the award. On October 28, 1988, an Administrative Law Judge at the General Services Administration's Board of Contract Appeals issued a decision upholding FAA's contract award.

[2]Federal Aviation Administration's Acquisition of the Advanced Automation System (GAO/T-IMTEC-87-4, Apr. 21, 1987).

[3]The MITRE Corporation, The Advanced Automation System: A Benefit/Cost and Risk Analysis, draft report, McLean, Va., Nov. 1987. Although the report had not been approved by the Department of Transportation when we conducted our analysis, it was subsequently approved with only minor changes.

modify test plans generally complied with your direction. Appendix III contains information about FAA's actions to obtain technical information and modify test plans.

The benefit/cost study is important to provide decisionmakers with the information needed to select the optimal system alternative. Such a study must highlight quantitative and qualitative data regarding a full range of alternatives to provide decisionmakers with a reasonable basis for their choices. However, we found flaws in the methodology used to conduct the benefit/cost study. For example, FAA did not fully analyze or properly compare a full range of alternatives to its preferred system, and our analysis indicates that it has not yet defined the optimal alternative. To illustrate, although FAA plans to close about 180 facilities and consolidate their functions at 23 large centers, it did not directly compare this alternative with one that does not consolidate facilities.

We estimate that, compared with FAA's planned approach, one nonconsolidation alternative included in the study could increase net benefits by reducing acquisition costs by over $750 million while reducing benefits by only about $200 million. Significant cost savings occur primarily because FAA would avoid spending large sums of money for items such as building expansion, communication links, and new radars, which consolidation would require. According to the study, the investment required to prepare to consolidate facilities will be about $1 billion. In recent testimony presented to your committees, we recommended that FAA amend the AAS request for proposals to allow it to acquire the equipment needed if a nonconsolidation alternative is selected; FAA has done so.[4]

We also found that FAA has not successfully controlled AAS design costs but opposes suggestions that a design-to-cost goal be adopted to help control costs.[5] FAA believes that although a design-to-cost approach might have been effective earlier in the AAS program, it is now too late to achieve the benefits of setting a design-to-cost goal. We believe, however, that costs could still increase significantly and that trade-offs to control cost increases can still be made. Further, we believe managing

[4]Federal Aviation Administration's Advanced Automation System Investment (GAO/T-IMTEC-88-2, Mar. 31, 1988; and GAO/T-IMTEC-88-3, Apr. 12, 1988).

[5]Design-to-cost is a method to control cost increases by making achievement of cost goals as important as achieving performance and schedule goals. Design-to-cost principles call for continuous analyses of trade-offs among costs, schedules, and performance requirements, and appropriate decisions to keep the program from exceeding pre-set cost goals.

the program to achieve a pre-set cost goal is an important internal control technique to ensure that FAA and Department of Transportation managers have the information needed to make timely and appropriate decisions to control cost increases.

In spite of the flaws in the benefit/cost study, we believe it is important to continue efforts to modernize the system. Under its recently awarded AAS contract, FAA can proceed to develop and test hardware and software that will be unaffected by the decision regarding facility consolidation. However, it would not be prudent to spend the estimated $1 billion for building expansions, radars, and communication links to prepare for consolidation until FAA completes a credible analysis of alternatives. FAA may also need to improve its cost control processes. Thus, we support FAA's proceeding with the contract to buy AAS, but believe FAA should (1) perform a credible analysis of a full range of reasonable and comparable system alternatives, (2) maintain its flexibility regarding consolidation alternatives by not spending money to prepare for consolidation until it completes this analysis, and (3) review the need to improve cost control processes, including setting design-to-cost goals.

## Background

AAS is being acquired to increase controller productivity, reduce operating costs, save fuel and passenger time, and allow controllers to handle anticipated air traffic increases more safely and efficiently. AAS will replace aging air traffic control computer systems with new hardware, software, and controller workstations. Improvements are expected to result primarily from (1) the use of modern equipment and (2) the development of new software functions intended to automate some controller functions and allow more aircraft to fly user-preferred, fuel-efficient routes.

FAA awarded contracts to design AAS to International Business Machines Corporation and Hughes Aircraft Company in 1984. In December 1985, the Conference Committee on FAA's Appropriations directed FAA to complete an independent benefit/cost study before requesting appropriations to award the contract to buy AAS.[6] In early 1987, FAA revised the acquisition strategy to overcome program delays and cost increases, and to respond to direction from your committees calling for FAA to reduce AAS program risks by incorporating a test phase before authorizing

[6]House Report 99-450 (Conference), dated Dec. 19, 1985, to accompany House Joint Resolution 465, Furthering Continuing Appropriations for Fiscal Year 1986.

workstation production.[7] After reviewing the changes, your committees, in separate letters dated February 27, 1987, and March 16, 1987, directed the FAA Administrator to obtain additional technical information and to further modify test plans before awarding the AAS contract. FAA made additional acquisition strategy changes, completed the required benefit/cost study, and awarded the AAS contract to International Business Machines Corporation on July 25, 1988.

## Terminal Control Facility Alternatives Not Fully Assessed

The benefit/cost study states that modernizing the air traffic control computer system is a good investment. However, our evaluation shows that the study did not fully analyze or properly compare plausible alternatives to FAA's preferred system alternative—including its plans to consolidate facilities.

The Conference Committee requested the study to demonstrate that (1) AAS is a prudent investment and (2) the selected alternative is the optimal way to achieve objectives. To ensure that the optimal alternative was defined, the Conference Committee directed FAA to evaluate a full range of alternatives for each element of the AAS program. Elements could be considered to be portions of the system or functions such as providing (1) advanced automation software, or (2) terminal-area control services. However, FAA did not separately analyze or properly compare a range of alternatives for any portion of the AAS program. Instead, it evaluated and compared alternatives as total system investments only. This approach provides information to determine whether a system is a good investment in total, but by not optimizing individual elements, the approach does not provide the information needed to select the optimal investment. To illustrate, FAA expects to achieve significant economic benefits by consolidating terminal control facilities into large centers. However, it did not fully analyze or properly compare a range of alternative terminal control facility configurations, capabilities, and locations to verify this assumption.

FAA concluded that the most cost-beneficial approach was to close about 180 terminal control facilities—which control aircraft around airports—and consolidate their functions at 23 large centers, which would control traffic both around airports and at higher altitudes. An example of consolidation would be closing the terminal control facilities at Albany, Binghamton, Buffalo, Elmira, Rochester, Rome, and Syracuse,

[7]House Report 99-696, dated July 18, 1986, and Senate Report 99-423, dated Aug. 19, 1986, Department of Transportation and Related Agencies Appropriations for Fiscal Year 1987.

New York, and transferring their functions to Nashua, New Hampshire. Similarly, the terminal control facilities at Gulfport, Jackson, and Meridian, Mississippi, would be closed and their functions moved to Memphis, Tennessee. FAA plans to close terminal control facilities beginning in 1995.

According to the benefit/cost study, the driving force behind FAA's plans to close terminal control facilities is the economies of scale that could be achieved. Economies would include reducing the number of personnel and backup equipment since there would be fewer facilities. On the other hand, the study estimates that to consolidate facilities, FAA will have to invest about $1 billion for such things as building expansion, communication links, and new radars. The study also discusses several disadvantages, including (1) increased vulnerability to losing air traffic control services in the event of fire, earthquake, or other catastrophe; (2) problems associated with relocating personnel; and (3) the need for additional controllers during transitions from the old to the new facilities. Another disadvantage, cited in a related draft study, is the likelihood of opposition to the adverse economic impact often associated with closing major federal facilities.[8]

FAA did not compare alternatives for the terminal portion that did not consolidate terminal control facilities with alternatives that did consolidate them. Using data from the study, we were able to estimate how one nonconsolidation alternative that was included in the study would affect terminal control area costs and benefits. The nonconsolidation alternative we evaluated replaces terminal equipment with modern computers and new workstations; it does not include electronically displayed flight plan information at terminal control facilities, relying instead on the current practice of using paper flight strips. The study states that all alternatives are technically feasible solutions, but the study did not include an alternative that would allow us to estimate the costs and benefits of a nonconsolidation terminal control system that includes electronically displayed flight information.

Our analysis shows that, compared with FAA's preferred approach, this terminal control alternative could increase net benefits by reducing costs to modernize facilities by over $750 million while reducing benefits by only about $200 million. Significant cost reductions occur primarily because FAA would avoid spending large sums of money to prepare to

[8]The MITRE Corporation, Evaluation of Alternative AAS ACF Configurations, draft technical report, McLean, Va., Oct. 20, 1987.

consolidate facilities. This alternative also appears to alleviate the disadvantages of consolidation, but a complete analysis would need to address other operational considerations, such as the amount of time air traffic control automation services would be unavailable because of system failures. This analysis illustrates that a proper comparison requires that terminal control alternatives be evaluated separately from other program elements.

Because the AAS contract FAA had originally planned to award would not have included the number and types of equipment needed to implement a nonconsolidation alternative, we testified earlier this year that FAA should not lock itself into an approach that precludes nonconsolidation. Subsequently, FAA amended the request for proposals to include additional equipment to implement a nonconsolidation alternative. The AAS contract now has the flexibility to allow FAA not to consolidate terminal control facilities, but FAA has not performed a credible analysis to define the optimal alternative by comparing cost and performance trade-offs among alternative system configurations, capabilities, and locations.[9] An analysis of alternatives for other portions of the system could also provide information to better define the optimal alternative, but the benefit/cost study did not separately analyze or compare alternatives for any system portion. Appendix IV contains additional information about FAA's analysis of terminal control alternatives.

## Other Benefit/Cost Study Flaws Also Exist

Our analysis also disclosed that the study used an unsound methodology to estimate AAS benefits, which included a sampling plan to measure the inefficiency of the present system that may overstate the benefits. The study data also show that the largest AAS benefit is the small amount of time saved by passengers on each flight. On the other hand, we believe the benefits could be understated because FAA, as required, used the Office of Management and Budget-approved discount rate, which is higher than the rate we use. FAA also believes safety would be improved by modernizing the system. Although the study does not quantify expected safety enhancement benefits, it does address safety improvements qualitatively.

AAS benefits largely depend on the degree to which existing and anticipated inefficiencies in the air traffic control system are reduced. New technologies are expected to reduce inefficiencies that force pilots to fly

[9]FAA has agreed to conduct an analysis of terminal control facility alternatives, but has not yet fully defined the scope or approach of the analysis.

less than optimal altitudes, speeds, and routes. As part of the study, information was collected and used to measure current system inefficiencies to project the benefits that would flow from system improvements. We found many weaknesses in the data collection form, data collector training, and other factors that raise questions about the validity of the information collected. For example, data were collected only during regular business hours, even though the air traffic control system is a 24-hour operation. No determination was made to ensure that limiting collection time in this way did not bias the results.

Also, the method used to analyze the survey data was biased and, thus, overstates the current system's inefficiency and may overstate the benefits AAS can provide. This occurred because the data collected included all categories of short fuel-inefficient flights, but did not include data for several major categories of longer, more fuel-efficient flights. The results from the sampled flights were projected to all flights, thereby overstating the amount of inefficiency in the system. The amount of resulting error cannot be calculated from the data collected.

As the study points out, the largest AAS benefit is the amount of time saved by passengers because of the more efficient flights the system makes possible. The study reports that FAA's full-consolidation alternative has costs of $3.8 billion, benefits of $7.3 billion, and yields $3.5 billion in net benefits.[10] We estimate that $4.2 billion of the expected $7.3 billion in benefits is made up of time saved by passengers because of more efficient flights. Further analysis shows that 71 percent of the $4.2 billion in passenger time savings is for small time increments—less than 15 minutes. For example, if a flight carrying 300 passengers saved 5 minutes because of AAS, the savings would be 1,500 minutes or 25 hours. Valued at $25 an hour—as FAA has done—the savings would be $625 for the flight. Totaled over the millions of flights controlled by FAA during the AAS lifetime, the estimated savings are in the billions. In a prior report we questioned the value placed on small time savings for passengers.[11]

On the other hand, we identified one factor that would tend to increase benefits of modernizing the air traffic control system. Adjusting future

[10]The numerical results used here from the benefit/cost study are risk-adjusted numbers. This follows the Conference Committee's direction to FAA to assess technical risk associated with acquiring AAS. Incorporating risk assessments reduces expected benefits and increases expected costs. The study points out that decisionmakers should use expected results reflecting risk-adjusted numbers.

[11]Air Traffic Control: FAA's Advanced Automation System Acquisition Strategy is Risky (GAO/IMTEC-86-24, July 8, 1986).

costs and benefits to their present value—called discounting—is a standard benefit/cost analysis practice. The study used a discount rate—required by the Office of Management and Budget for such analyses—of 10 percent, net of inflation. We, however, use a discount rate that reflects the cost the government pays to borrow money. Our comparable real discount rate, therefore, would be the difference between the rate the Department of the Treasury pays to borrow money for long periods of time and the expected rate of inflation. The discount rate we use—currently about 3.5 percent, net of inflation—is lower than the Office of Management and Budget rate, and would substantially increase the present value of benefits compared with the benefit/cost study.

Finally, although the study does not place a monetary value on the safety benefits that could accrue from modernizing the system, it does address potential safety improvements qualitatively. This qualitative information should also be useful to decisionmakers.

## AAS Costs Could Be Higher Than Expected

An independent cost analysis, which was also required by the Conference Committee, concluded that AAS contract costs could total $5 billion or about $1.7 billion higher than the program office estimate of $3.3 billion.[12] The Analytic Sciences Corporation prepared the independent analysis, and recommends that FAA adopt its higher cost estimate for planning and budgeting purposes because it reflects a more realistic assessment of the complexity and challenges of the AAS program.

A major difference between the independent cost analysis and the program office's cost estimate appears to be the amount of risk assumed to be associated with the AAS acquisition. The independent cost analysis was developed using cost information from other similar systems, potential vendor price estimates, and expert opinions. This cost analysis also incorporates potential cost increases due to technical problems that could occur. These costs were estimated on the basis of an analysis of risks, including risks identified by an independent AAS technical risk assessment, also requested by the Conference Committee.[13] The independent cost analysis reflects a significant potential that development problems could occur that would increase costs. The program office's cost estimate, on the other hand, assumes that few problems will occur, and

[12]The Analytic Sciences Corporation, Cost Analysis of the Advanced Automation System and Alternatives, final report, Arlington, Va., Nov. 1987.

[13]The MITRE Corporation, The Advanced Automation System: A Benefit/Cost and Risk Analysis, Volume II-Technical Risk Assessment, draft report, McLean Va., Nov. 1987.

thus costs will not increase significantly. FAA also believes that using fixed-price contract provisions for a significant portion of AAS will limit cost increases.

Although FAA is using fixed-price incentive contract provisions for a significant portion of AAS, cost increases could still occur. As we pointed out in a previous report on AAS, requirement changes to correct performance problems can lead to significant additional costs, even in fixed-price contracts.[14] Thus, if FAA decides to revise the requirements associated with items such as the new controller workstation, which are being acquired using fixed-price incentive provisions, the cost of such changes would be negotiated with the contractor in a noncompetitive environment. Also, most of the AAS software will be developed using cost-plus contract provisions. Developing the large amount of complex software required for AAS also involves risks, and if problems or delays are encountered, software costs could increase significantly.

If problems do occur, an effective cost control process would help contain cost increases. FAA, however, has not contained cost increases during the AAS design competition phase. AAS design phase contract costs increased from $247 million to about $500 million and, according to FAA, would have increased to over $600 million had FAA not reduced the contract's scope of work. Your committees expressed concern about cost increases and suggested that a design-to-cost approach might be an appropriate way to restrict additional cost growth. Design-to-cost is a method to control cost increases by making achievement of cost goals as important as achieving performance and schedule goals. Design-to-cost principles call for continuous analysis of trade-offs among costs, schedules, and performance requirements, and appropriate decisions to keep the program from exceeding pre-set cost goals.

FAA officials responded during appropriations hearings that design-to-cost principles are not practical because system contractors could eliminate critical air traffic control requirements to prevent cost increases. We found, however, that design-to-cost principles allow the government to control system requirements and contractors cannot unilaterally eliminate requirements. FAA now agrees contractors cannot eliminate requirements, but still objects to using design-to-cost principles because 1) contractors might propose changes to eliminate critical requirements that FAA would reject, and 2) although a design-to-cost approach might have been effective if implemented earlier, the system is partially

[14]GAO/IMTEC-86-24, July 8, 1986.

designed and has proceeded beyond the point where a design-to-cost approach would be effective.

We disagree that these reasons justify not adopting design-to-cost principles. First, although contractors could propose eliminating critical requirements, design-to-cost principles are intended to allow reasonable trade-offs among performance capabilities, schedules, and costs. Second, although detailed designs exist for parts of the system and preliminary designs exist for other parts, opportunities to control costs exist throughout the development process. In fact, FAA's July 1988 AAS contract specifications require the contractor to develop computer programs to analyze trade-offs among costs, schedules, and performance requirements, thus indicating that FAA believes opportunities still exist. Although FAA is requiring the contractor to develop design-to-cost information that can be used to control cost increases, FAA has not agreed to establish a pre-set design-to-cost goal that would signify FAA's commitment to make appropriate decisions to prevent cost increases.

## Conclusions

We agree that FAA needs to continue its efforts to modernize the air traffic control system by acquiring modern equipment to increase computer processing capacity and to provide additional automated functions. However, adequate information, in the form of a credible benefit/cost analysis, is still important to ensure that the government makes the optimal investment. Such an analysis would highlight technical, economic, and operational considerations and provide both quantitative and qualitative information for a full range of alternatives. We found that there were flaws in the methodology used to conduct the benefit/cost study, and that FAA has not yet defined the optimal alternative. Our analysis also indicates that FAA's plans to invest about $1 billion for building expansion, radars, and communication links to prepare for consolidation would not be prudent because this investment could well reduce its flexibility to implement a nonconsolidation alternative.

We also found that FAA has not successfully controlled AAS costs during the design phase, and that additional cost increases could occur. FAA opposes suggestions by your committees to establish design-to-cost goals to help contain cost increases. FAA believes the program has proceeded beyond the point where a design-to-cost approach would be effective. We believe costs could still increase significantly and that opportunities still exist to control cost increases. We also found that although FAA has asked the contractors to develop information to allow appropriate trade-offs to control cost increases, it is unwilling to establish a design-to-cost

goal. We believe establishing pre-set cost goals is an important internal control technique to signify a management commitment to control cost increases.

## Recommendations

To ensure that FAA completes a credible benefit/cost analysis and retains the flexibility to acquire the optimal alternative, we recommend that the Secretary of Transportation direct the FAA Administrator to

- conduct an analysis to determine the optimal terminal control alternative (1) using the data supporting the recently completed benefit/cost study and (2) comparing a full range of alternative system configurations, capabilities, and locations, and
- exclude from new contracts or extensions of existing contracts materials and services required to prepare to consolidate terminal control facilities into AAS area-control facilities until FAA determines the optimal alternative. This recommendation should not preclude FAA from modernizing facilities to perform en route functions.

To ensure effective cost control on this multi-billion dollar system acquisition, we recommend that the Secretary of Transportation review FAA's cost control processes to determine whether improvements, including establishing design-to-cost goals, should be implemented.

Our work was conducted between February and July 1988 at FAA's headquarters in Washington, D.C., and at various contractor locations in the Washington, D.C., area. The views of responsible agency and contractor officials were sought during the course of our work; we discussed our findings with them and have included their comments where appropriate. In addition, we obtained formal oral comments on a draft of this report from Department of Transportation officials. The

Department agrees that this report identifies significant issues that need to be addressed and is considering the specific actions it will take to repond to the report recommendations. We performed our work in accordance with generally accepted government auditing standards.

Daniel C. White
for Ralph V. Carlone
Director

# Contents



**Abbreviations**

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| AERA | Advanced En Route Automation |
| AAS | Advanced Automation System |
| FAA | Federal Aviation Administration |
| GAO | General Accounting Office |
| IMTEC | Information Management and Technology Division |

# Objectives, Scope, and Methodology

In response to February 1988 discussions with representatives of the House and Senate Appropriations Committees, Subcommittees on Transportation, we reviewed FAA's planned AAS investment. Our objectives were to evaluate (1) FAA's actions to obtain more technical information and to modify test plans before awarding the contract to buy AAS, and (2) a benefit/cost study FAA prepared in response to direction from the Conference Committee on FAA's Fiscal Year 1986 Appropriations. Our work was performed between February and July 1988.

To evaluate FAA actions to obtain additional technical information, we reviewed FAA and AAS contractor documents describing risk reduction activities, including demonstrations, that were undertaken to increase technical information and reduce technical risks. We interviewed FAA, International Business Machines, Hughes Aircraft, and MITRE corporation officials to obtain their opinions on the extent to which technical risks had been reduced.

To evaluate FAA's actions to modify test plans, we reviewed testing-related sections of the AAS request for proposals, and FAA test planning documents. We also discussed planned test requirements with FAA officials. Our evaluation of FAA's planned tests was limited to the extent that FAA had not fully defined detailed test requirements.

To evaluate the benefit/cost study, we reviewed a draft of the study prepared for FAA by MITRE Corporation as well as an independent cost estimate prepared by The Analytic Sciences Corporation. We reviewed documents that contained the methodology and analyses supporting the benefit/cost results, and discussed the methodology and results with the contractor analysts who performed the work and with responsible FAA personnel. We did not fully verify either the data used to generate benefit and cost estimates or the accuracy of the computer programs used to calculate benefit and cost totals. As part of our evaluation of the benefit/cost study, we also evaluated economic, operational, and technical issues associated with terminal control alternatives included in the study. We did not, however, attempt to identify the optimal terminal control alternative. Our review was limited to the extent that the computer programs used to compile and manipulate the data were structured in a way that lessened our ability to make adjustments on the basis of different assumptions or alternatives. As a result, in some instances we estimated the impact adjustments would have on the results. When we did so, we worked with the contractor analysts to develop reasonable methodologies for these estimates.

We also did not specifically evaluate the status of FAA's design phase contracts, the contractors' responses to the request for proposals, or the acquisition phase contract provisions, except to identify the planned contract's flexibility to allow FAA not to consolidate terminal control facilities.

The views of responsible agency and contractor officials were sought during the course of our work; we discussed our findings with them and have included their comments where appropriate. In addition, we obtained formal oral comments on a draft of this report from Department of Transportation officials. We conducted our review in accordance with generally accepted government auditing standards.

# Background

FAA's mission is to promote the safe, orderly, and expeditious flow of both civilian and military aircraft. Air traffic controllers maintain the necessary separations between controlled aircraft utilizing information processed by computers and displayed on video screens at controllers' workstations. Displayed information includes aircraft identity, location, altitude, speed, and direction. Additional flight information, such as the route, destination, and expected arrival time, is provided on paper "flight strips."

FAA uses three types of facilities to control aircraft—tower, terminal, and en route. About 400 airport air traffic control towers provide visual control for aircraft on the ground and prior to takeoff and landing. The 188 terminal radar approach control facilities sequence and separate aircraft arriving at or departing from airports under their control. Some of these facilities control traffic for more than one airport. Air route traffic control centers control aircraft en route between airports. Twenty of these centers are in the continental United States.

AAS is intended to allow the air traffic system to safely and efficiently accommodate expected large increases in traffic. FAA believes AAS will provide benefits to FAA and users by increasing controller productivity, saving fuel and passenger time, and reducing operating costs. AAS is planned to replace outdated computer hardware, software, and controller workstations at en route, terminal, and tower facilities. These improvements are expected to result primarily from the use of modern equipment and the development of advanced software functions to automate some controller tasks and to allow more aircraft to fly user-preferred, fuel-efficient routes. These functions—called Advanced En Route Automation (AERA)—will use sophisticated software to predict the future position of aircraft in en route airspace, check for potential conflicts, and provide controllers with alternatives to resolve predicted conflicts.

FAA concluded that the most cost-beneficial approach was to close about 180 terminal radar approach control facilities and perform their functions at 23 large centers, which will be called area control facilities. FAA plans to consolidate about 30 terminal facilities beginning in 1995, and the remaining facilities beginning in 1998. An example of consolidation is closing the terminals now at Albany, Binghamton, Buffalo, Elmira, Rochester, Rome, and Syracuse, New York, and transferring their functions to Nashua, New Hampshire. Similarly, the terminals at Gulfport, Jackson, and Meridian, Mississippi, would be closed and their functions moved to Memphis, Tennessee.

FAA is using a two-phase acquisition strategy to acquire AAS. In August 1984, FAA awarded contracts to International Business Machines Corporation and Hughes Aircraft Company to design AAS. These two contractors were competing to win a contract to develop, produce, and install AAS. FAA awarded a $3.6 billion contract, on July 25, 1988, to International Business Machines Corporation. When the design phase and costs for such things as FAA support contractors and FAA in-house personnel are included, total program costs are expected to exceed $5 billion.

FAA plans to deploy AAS, in several stages, through December 1999. First, FAA plans to deploy new controller workstations—called the Initial Sector Suite System—to en route facilities beginning in 1993. In 1995, FAA plans to deploy computer hardware and software to en route facilities to perform terminal control functions for a limited number of smaller terminal facilities. This Terminal Advanced Automation System will allow FAA to begin consolidation by closing about 30 small terminal facilities. In 1996, FAA plans to deploy the Area Control Computer Complex, consisting of additional software and some hardware to perform en route functions and allow consolidation of the remaining terminal control facilities at en route facilities. Parallel with the terminal and en route computer system deployments, FAA plans to deploy the Tower Control Computer Complex at airport tower facilities. When the terminal control facilities have been fully consolidated into the en route centers, the centers will be called area control facilities.

# Technical Information and Test Plans

Responding to direction contained in a February 27, 1987, House Appropriations Committee letter and a March 16, 1987, Senate Appropriations Committee letter, FAA (1) directed the AAS design contractors to perform risk-reduction activities, including demonstrating that their chosen hardware and software technologies will meet AAS performance requirements; (2) added tests to be completed before full controller workstation production is authorized; and (3) reviewed the need to simulate AERA functions and decided not to simulate them before awarding the contract.

Risk-reduction activities included demonstrating that such things as communications network components, software development procedures, the controller workstation, and methods to detect and recover from hardware or software failures will meet AAS requirements. To illustrate, FAA required the contractors to show that models of local communications network components could meet FAA's required response time under the maximum predicted work load. For software, the contractors were required to develop a high-level design for the workstation software using the Ada programming language. FAA checked each design to ensure that consistent definitions and procedures were applied. FAA also plans to verify that the contractors adhere to acceptable software procedures in developing other software units.

These risk-reduction activities generally corresponded to committee direction, and FAA believes the results provide increased confidence that the designs can be implemented. FAA also performed a qualitative assessment of these risk-reduction tasks and summarized the remaining technical and schedule risks associated with each contractor's design. This information was considered when the Department of Transportation selected the winning contractor. Further responding to committee direction, FAA plans to continue risk-reduction activities after contract award by requiring the contractor to submit a complete risk-management plan. This plan is to identify risks, develop risk-reduction alternatives, and continue demonstrating that hardware and software will meet performance requirements.

FAA also modified its AAS test plans to include limited workstation tests with a partial configuration of AAS terminal hardware and software before authorizing full workstation production. FAA amended the AAS request for proposals to include controls to ensure that full workstation production is not authorized until the contractor has successfully completed required tests. According to FAA, however, the final operational

test requirements documentation is not yet complete. Therefore, we were unable to fully evaluate the adequacy of FAA's test plans.

The committees were also concerned that the effectiveness of AERA software functions has not been shown. FAA reviewed the possibility of simulating the functions before contract award to demonstrate their operational suitability and benefits. FAA concluded it is not necessary or desirable to delay the AAS contract award to validate AERA's operational suitability and benefits. It believes the first set of functions—called AERA 1--does not involve significant risks and is sufficiently mature to proceed without requiring simulations. AERA 1 is intended to predict the future location of aircraft and identify potential conflicts. FAA recognizes that the second set of functions—called AERA 2—involves both technical and operational risks. Therefore, it plans to simulate these functions after contract award, but before giving the requirements to the contractor. AERA 2 is intended to provide controllers with several computer-generated resolutions to conflicts identified by the AERA 1 functions. FAA also points out that AAS does not depend on AERA for basic air traffic control functions and that AAS is needed to replace an obsolete system.

# FAA's Consolidation Plans

In December 1985, the Conference Committee on FAA's Fiscal Year 1986 Appropriations directed FAA to provide an independent benefit/cost study before requesting AAS acquisition phase funds. We evaluated the study the MITRE Corporation prepared under FAA direction. The study states that modernizing the air traffic control computer system is a good investment. Our analysis has not disclosed anything that would cause us to disagree with this conclusion. However, our evaluation shows that FAA's benefit/cost study did not fully analyze or properly compare plausible alternatives to its preferred system alternative. Our analysis indicates that FAA has not defined the optimal alternative.

The study was requested to demonstrate that (1) AAS is a prudent investment, and (2) the selected system alternative is the optimal way to achieve FAA's objectives. To ensure that FAA defines the optimal alternative, the Committee directed FAA to evaluate a full range of alternatives for each element of the AAS program. Elements could include functions such as providing (1) advanced automation software, or (2) terminal area control services. In contrast to committee direction, FAA did not fully analyze or properly compare a range of alternatives for AAS program elements. Instead, FAA evaluated and compared alternatives as total system investments. This approach provides information to determine whether a system is a good investment, but does not ensure that the optimal system is chosen. To illustrate, FAA expects to achieve significant economic benefits by consolidating terminal control facilities into large centers. According to the study, the driving force behind FAA's consolidation plans is the economies of scale that can be achieved. Economies of scale would include reducing the number of personnel and backup equipment since there would be fewer facilities. However, FAA did not fully analyze or properly compare a range of alternative terminal control facility configurations, capabilities, and locations to verify this assumption.

## Alternatives Considered

The study compares total costs, benefits, and other factors for alternative investments. It points out that the alternatives were defined to be technically feasible solutions to modernize and upgrade the air traffic control system. The alternatives were developed by varying the functional capabilities provided, the degree of terminal control facility consolidation, and the development strategy. Although the report includes seven alternatives, only four were fully analyzed.

Two of these four alternatives provided enhanced capabilities and involved consolidating terminal control facilities. FAA's currently

planned full consolidation of about 180 terminal control facilities into 23 centers showed the highest return on investment. It was estimated to cost $3.8 billion, provide $7.3 billion in total benefits, and yield $3.5 billion in net benefits. The study also points out that consolidation requires about $1 billion to be spent for such things as building expansion, communication links, and new radars. The other consolidation alternative was developed to alleviate some of the disadvantages of full consolidation, which are discussed later. This alternative would still consolidate most terminal control facilities at 22 centers, but would consolidate large terminal control facilities at 19 other locations. Thus, the terminal control facilities would be consolidated into 41 centers. This less concentrated consolidation alternative was estimated to cost $4.3 billion, provide $7.3 billion in total benefits, and yield $3 billion in net benefits. This alternative costs more primarily because additional building, power system, and communication link costs are required for consolidation at additional locations.

The two other alternatives would not consolidate any terminal facilities. The first of the two alternatives would simply replace existing equipment with modern equipment without providing any enhanced capability. It was estimated to have a net benefit of $140 million. The second alternative replaced the equipment and provided some enhanced capabilities. It had an estimated net benefit of $760 million. Neither of these alternatives, however, provided the AERA functions. Since the majority of AAS benefits come from AERA, the exclusion of AERA functions caused these two alternatives to have substantially lower net benefits. AERA benefits are also not directly affected by whether or not terminals are consolidated because AERA benefits accrue to aircraft at higher altitudes—outside terminal area airspace. We are concerned that the study does not allow a proper comparison of the benefits and costs between consolidated and nonconsolidated terminal control solutions. This is because the study only compared total benefits and total costs for these limited alternatives, and no nonconsolidation alternative was considered that included the large AERA benefits.

To estimate what impact not consolidating terminal control facilities would have on costs and benefits in the terminal area only, we looked specifically at the nonconsolidation alternative that provides enhanced terminal control capabilities. This alternative replaces terminal control facility equipment with modern computers and new workstations. It does not include electronically displayed flight plan information at terminal control facilities—relying instead on the current practice of using paper flight strips. We found that using conservative assumptions, net

benefits could increase because total costs to modernize terminal facilities would be reduced by over $750 million, while benefits would be reduced by only about $200 million, compared with FAA's preferred consolidation alternative. Significant cost reductions occur primarily because FAA would avoid spending large amounts of money on facility, communication link, radar, and other improvements needed to consolidate. We believe this analysis illustrates that a proper comparison requires that terminal control alternatives be evaluated separately from other program elements.

Both FAA and contractor officials stated that the AAS architecture is sufficiently flexible to allow a range of terminal control system configurations without affecting the large AERA benefits. For example, FAA officials pointed out that tower systems are being deployed at up to 258 airport towers, and these systems could be enhanced to provide computer processing functions for many existing terminal control facilities. In fact, the Department of Defense is considering using an enhanced AAS airport tower configuration to modernize its terminal control facilities. Where an operational need for consolidating large terminal control facilities exists—such as the Los Angeles basin, Dallas/Fort Worth, and Chicago—the AAS design also includes systems to meet these requirements.

## Disadvantages of Consolidation

According to the benefit/cost study, FAA's consolidation plans also involve disadvantages, including 1) vulnerability to catastrophic failures, 2) controller relocation and expected attrition, and 3) the need for two sets of controllers during transition. These concerns are discussed further below.

Consolidation increases vulnerability to a catastrophic failure. If an area control facility suffers a total failure, both en route and terminal control services would be interrupted in the affected airspace. Since these services are now provided at separate locations, a single facility failure does not interrupt all air traffic services. To prevent a single failure from interrupting all services, FAA plans to have area control facilities back each other up if a facility fails. The study, however, questions the operational suitability and effectiveness of these backup plans because staff at the backup facility would be unfamiliar with the airspace and may be unable to accommodate the sudden increase in controlled aircraft.

Consolidating terminals also requires many controllers to move, entailing large moving costs, possible attrition, and other hardships on the

people and communities affected by relocation. The study estimates that FAA's plan to move controllers will cost about $52 million. Another MITRE study estimates that about 15 percent of controllers told to relocate could resign or retire early. Replacing them would require training new controllers for up to several years to become fully qualified. These training costs, however, were not included in the benefit/cost study.

Finally, consolidation requires additional controllers during transition to the new facility. Controllers are needed at both the old and new facilities for up to 3 months until the new system is fully operational. After this time the additional controllers would no longer be required. The study, however, did not include costs to hire or train these controllers.

In addition, a separate contractor study concluded that the impact of facility closures and likely opposition to closures may be a major factor in the ultimate decision about consolidation. This study points out that the average terminal control facility employs 35 people, and that larger facilities employ over 70 people. According to the study, closing these facilities could adversely affect the economy of the communities where they are now located. The study also notes that the community receiving the terminal functions would benefit. The study points out that communities faced with the loss of a terminal control facility would use whatever influence was available to them to oppose the closure.

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