PART 1

The Review

EXECUTIVE SUMMARY

The National Airspace System Plan (NAS Plan) released by the Federal Aviation Administration (FAA) in January 1982 outlines the agency's most recent proposals for modernizing the facilities and equipment that make up the air traffic control (ATC) system. The plan attempts to integrate the various improvements into a single long-range program that addresses major shortcomings and reduces costs of the current system. Viewed on this high level—as a statement of policies, goals, and directions—the NAS Plan is to be commended as a significant and even bold step compared with past FAA efforts to chart the future evolution of the system.

The national airspace system is a "three-legged stool" made up of airports, the ATC system, and procedures for using the airspace. While all three need to be improved in an integrated fashion, the NAS Plan deals with only one leg—the ATC system. OTA'S assessment of the airport and ATC system found that lack of airport capacity—not ATC technology—will be the principal limit on the growth of aviation. The NAS Plan acknowledges that "capacity limitations at busy airports will be the constraining element" in the system, but it concentrates on ATC technology, and most of the proposed improvements are directed at modernization of the en route, not the terminal area, portion of the system.

FAA does intend to address the problems of airports and airspace procedures. A revised plan for airport development is to be issued later this year. FAA has also just begun a National Airspace Review (NAR), a 42-month effort that will reexamine the rules and procedures governing the use of the airspace. Still, by issuing first a plan for modernizing ATC technology, without waiting until the other efforts have more thoroughly defined needs in the area of airports and airspace procedures, FAA may be placing too much emphasis on technological solutions. This perception is reinforced by the NAS Plan itself, which gives first priority to improved technology for the en route system by the late 1980's. There is little apparent advantage in seeking to move en route traffic more expeditiously only to have it encounter delays in terminal areas, where capacity improvements are not scheduled to be made until the early 1990's.

With these reservations, the FAA plan for ATC system improvements is comprehensive. The proposed changes are technologically feasible, and they are consistent with the goals of increasing safety and productivity and accommodating future growth. Providing capacity to accommodate anticipated growth was a principal factor in developing the NAS Plan, although other factors were also involved—increased reliability, safety, productivity, and fuel savings. Still, the technological strategy and implementation schedule appear to have been driven by forecasts of aviation growth and near-term capacity problems at en route centers. FAA traffic and workload forecasts have tended to be too high in the past, however, and in some cases technological alternatives that might be equally effective or less costly than those selected by FAA appear to have been rejected because of the anticipated rate of growth in demand for ATC services. OTA'S review of the NAS Plan suggests that FAA forecasts may not be a useful guide to long-term planning and investment, and that some of these technological options may therefore warrant reexamination.

In the area of en route computer replacement, for example, some believe it would be prudent to adopt a strategy for interim steps to be taken in the 1980's that imposes no constraints on the design of the new system that will serve for the 1990's and beyond. FAA's proposed approach is to "rehost" the existing software on new computers, and then to develop new software to run on the host computers for use with the advanced sector suites to be installed by 1990. Several experts have told OTA that this approach might limit the options available in designing the new system. In their view, any interim host would have to be replaced when the new system comes on line. FAA admits this possibility, but maintains that the intent is for the host computer to serve as the basic processor for the ATC system until well into the 1990's. An alternative short-term approach would be to make selective enhancements to the present technology —i.e., upgrade the current computers in the centers where capacity problems are expected—in combination with economic or regulatory approaches to demand management, while proceeding without delay on a parallel effort to develop by 1990a totally new ATC system design that makes best use of technologies then available and that will serve until beyond the turn of the century.

As a blueprint for the modernization of the ATC system, the 1982 NAS Plan does not provide a clear sense of the priorities or dependencies among its various program elements. Nor does the plan deal explicitly with contingencies or delays caused by engineering problems or by the possible deletion of some elements due to budgetary constraints. Given the complexity and magnitude of this undertaking, FAA may have set itself an overly ambitious schedule for implementing the proposed improvements.

OTA'S review of the 1982 NAS Plan has also identified the following specific findings and issues:

- Growth. —FAA's traffic forecasts have been too high in the past and there are questions about the methodologies and assumptions underlying the projections on which the NAS Plan is based. Overestimation may have led FAA to foreclose technological options and accelerate the implementation schedule unnecessarily. It may also have led FAA to overestimate the user-fee revenues that will be available to pay for the proposed improvements.
- En *Route Computer Replacement.* —FAA's option analysis issued in January 1982 supports upgrading the 10 en route computers that face capacity problems. ' The NAS Plan, released at about the same time, calls instead for replacing the computer hardware (called rehosting the software) in all 20 centers as a part of a long-term plan to increase productivity and reliability as well as capacity. OTA does not find persuasive the reasons advanced by FAA for rejecting the previously preferred option of upgrading only selected en route centers. In addition, the choice of a host computer now may limit the options available to the contractor for the sector suite and software. OTA conferees were sharply divided in their views on this question. Some felt that the choice of a host computer now might limit future ability to benefit from a distributed computer architecture, local area networking, and new techniques in software development. Others believed that, if the host is chosen judiciously, the transition to a new system embodying these advanced and desirable features could be made without difficulty.
- *Automation.* —While the NAS Plan envisions substantial cost savings due to extensive automation, supporting analysis is not provided in the plan. This analysis is probably still in progress and may take some time to complete, but it would be useful for the interim results to be made available to assist in congressional review of the automation portions of the overall plan. In addition, there is concern on the part of some experts about the ability of human operators to participate effectively in such a highly automated system and to intervene in the event of system error or failure.
- *Satellites.* —Satellite technology has significant potential applications for communication, and eventually for surveillance and navigation. FAA does not see a role for satellites in the period covered by the NAS Plan. FAA's decision against satellites appears to have been driven by timing and present cost effectiveness, rather than technology readiness or long-term system advantages.
- *User Effects.* —A great many of the proposed ATC system improvements are directed to the needs of traffic operating under the instrument flight rules (IFR), particularly while en route at cruise altitude. These improvements will benefit FAA itself by automating functions and reducing labor costs. The principal beneficiaries among users will be air carriers and larger business aircraft. Personal general aviation (GA) users could receive improved weather information, an important benefit; but in order to obtain this benefit and other operational advantages of the new sys-

I Federal Aviation Administration, "Response to Congressional Recommendations Regarding the FM's En Route Air Traffic Control Computer System, " report to the Senate and House Appropriations Committees pursuant to Senate report 96-932, DOT/FAA/AAP-82-3, January 1982.

tern, more avionics will be required, and there would be restrictions on access to airspace by aircraft not so equipped. The Department of Defense (DOD) too, is concerned about the cost of new ATC avionics and feels that the new plan must be carefully coordinated with the military services to ensure that their mission needs and responsibilities for administration of the airspace are integrated with those of FAA.

- Cost *and Funding.* —Implementing the improvements proposed in the 1982 NAS Plan would more than double FAA's facilities and equipment budget through 1987, compared to the last 10 years. FAA has not yet released cost estimates for completing the proposed programs, but it seems likely that expenditures of like magnitude will be needed in the years beyond 1987. FAA proposes to recover 85 percent of its total budget through user fee revenues and a drawdown of the uncommitted Trust Fund balance. The user fee schedule would perpetuate the existing cross-subsidy from airline passengers and shippers of air cargo to GA. Business aviation would benefit particularly because of the extensive use these aircraft make of the IFR system. In addition, higher user fees may dampen the growth of aviation, thereby reducing the revenues expected to pay for the proposed improvements.

THE AIRPORT AND ATC SYSTEM

BACKGROUND

In December 1981, OTA completed an assessment of the airport and ATC system, with emphasis on the problem of congestion at major hubs and the feasibility, cost, and impacts of prospective improvements in ATC technology. This assessment drew on information published by FAA through 1981 and focused on three central topics:

- scenarios of future aviation growth;
- alternatives for increasing airport and terminal area capacity; and
- ATC system modifications proposed by FAA.

In January 1982, FAA issued a new NAS Plan for the modernization of the ATC system through the year 2000. The House Committee on Appropriations, Subcommittee on Transportation, which had requested the original OTA assessment, asked OTA to undertake a 3-month follow-on study to review the 1982 NAS Plan and to provide the subcommittee with the following support:

- a critique of the NAS Plan, with emphasis on changes from previous proposals;
- a delineation of technological options and alternative implementation strategies within the general framework of the Plan; and
- an analysis of issues raised by the Plan, such as benefits and costs to airspace users and the Government, and identification of questions needing further study or clarification.

The NAS Plan proposes many improvements to the ATC system—including replacement of computers, increased automation, modernization of the communication network, consolidation of ATC facilities, and upgrading navigational aids, OTA'S review focuses on the computer replacement, communications, and automation issues that are the heart of the Plan.

OTA'S response to the subcommittee's request draws on the findings of the recently completed assessment, which are outlined below, supplemented by a series of meetings with representatives of the aviation community and experts in the fields of computer and communications technology. Working Group No. 1 met on February 25, 1982, to discuss aviation growth scenarios and to examine the specific methodology and economic assumptions underlying the aviation forecasts on which FAA based the 1982 NAS Plan. Working Group No. 2 met on March 9, 1982, to discuss the specific computer and communications technologies proposed by FAA, alternative technologies that are not included in the NAS Plan, and the technical and scheduling risks involved in FAA's proposed implementation strategy. OTA also held a general conference of aviation and ATC technology experts on April 1 and 2, 1982, to discuss four major issues arising from the NAS Plan: aviation growth, proposed changes in ATC technology, effects on airspace users, and strategies for funding system improvements.

BASIC FINDINGS ON THE AIRPORT AND ATC SYSTEM

OTA'S assessment of the airport and ATC system arrived at several major findings, which have been generally confirmed by the subsequent review of the 1982 NAS Plan. Findings related to technological options are discussed later in the section entitled "Specific Technologies. " OTA findings in other areas are summarized below.

- *Congestion and delay in the system result primarily from the concentration of air traffic at a few major hub airports.* —There are over 6,000 public-use airports in the United States, of which 435 have FAA control towers. However, the 10 busiest airports handle 33 percent of all commercial operations and 47 percent of all passenger enplanements. The Nation's 60 major metropolitan areas account for 90 percent of all enplanements, 75 percent of all commercial operations, and 40 percent of all itinerant aircraft operations, including GA.

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- *There will be continued growth in the demand for ATC services through 2000, but the rate of traffic growth will be lower than in the last 20 years and probably lower than projected in FAA* aviation forecasts. —FAA forecasts have consistently overestimated traffic growth in the past, and the latest forecasts still seem too high. A number of factors suggest that the air carrier industry is already approaching its mature size and will grow slowly over the next two decades. FAA workloads will continue to increase, however, due to the continued growth of the GA sector. Between 1970 and 1980, GA traffic accounted for 72 percent of the increase in IFR tower operations and 62 percent of the increase in en route operations. GA aircraft, particularly turboprop and jet business aircraft, can be expected to generate about 65 percent of the increase in these FAA workloads between 1980 and 1990. By 1990, business aircraft will account for about half of all demand for ATC services.
- *The future growth of air traffic will aggravate congestion problems and spread them to additional airports.* —Unconstrained growth of operations at major hubs would lead to serious congestion at anywhere from 20 to 5O airports by 2000, depending on economic growth rates, compared to 5 or 10 airports before the 1981 strike. Unless there are capacity increases to relieve congestion at major hubs, there will be a redistribution of air carrier operations to "second-tier" hubs and increased diversion of GA traffic to reliever airports. Such a redistribution is already in progress as a result of market forces and FAA traffic restrictions at 22 congested hubs.
- *The principal constraint on the future growth of aviation will be the lack of airport capacity.* —Major improvements to increase capacity in congested hubs—new runways or new airports —are unlikely in the near future due to high cost, lack of land, and community resistance to airport noise. The principal opportunities for capacity expansion will come at second-tier airports and at GA and reliever airports that can accommodate traffic diverted from congested air carrier airports. However, the construction of independent, IFR-equipped "stub" runways to separate slower GA and commuter aircraft from larger jet aircraft could significantly increase the volume of traffic that can be handled at some large air carrier airports.
- *There are three basic forms of response to airport and airspace capacity problems: technological, economic, and regulatory.* —Changes in ATC technology and procedures can produce small increases in capacity by allowing airspace and runways to be utilized more efficiently. However, the major increases to be derived from technology will not be realized until advanced systems such as automated metering and spacing; microwave landing system; and wake vortex detection, prediction, or reduction are developed and deployed by the end of this decade or later. In the interim, congested airports will have to make use of demand-management alternatives—including economic measures such as peak-hour pricing and regulatory measures such as slot-allocation quotas or access restrictions—in order to shift traffic to a place or time when it can be handled more effectively.
- *All three approaches will be used, and the combination or emphasis will reflect both local conditions and a more fundamental policy decision: can the Nation continue its past practice of accommodating aviation growth wherever and whenever it occurs, regardless of the cost; or is growth to be managed and directed so as to make economical use of existing resources and capacity.*

THE 1982 NATIONAL AIRSPACE SYSTEM PLAN

GENERAL COMMENTS

The stated objectives of the 1982 NAS Plan are to achieve a significantly safer and more efficient national airspace system over the next 20 years, while constraining costs incurred by the Government and airspace users. The Plan attempts to integrate the various improvements to the ATC system into a single long-range program, while eliminating major deficiencies and costs of the current system.

Viewed on this high level—as a statement of policies, goals, and directions—the Plan is to be commended as a significant and even bold step compared to previous FAA efforts to chart a future course for the ATC system. It provides a statement of objectives and the rationale for the proposed program of system improvements. The Plan identifies capital investments needed to modernize and consolidate ATC facilities in order to meet future demand and to reduce operating and maintenance costs. The document reflects a conscious effort to provide improved services to airspace users, to promote system efficiency, and to minimize costs both to those who fly and to the FAA. This is a marked improvement over previous NAS Plans, which have tended to be little more than catalogs of proposed new equipment and engineering changes. But is is not without faults.

ADDRESSING FUTURE REQUIREMENTS

The needs of civil aviation represent what one participant in the OTA'S Conference called a "three-legged stool, " made up of airports and terminal area airspace, rules and procedures, and ATC technology. All three areas need to be addressed in a timely and coordinated manner.

The NAS Plan itself acknowledges that "capacity limitations at busy airports will be the constraining element" in the system, yet it fails to address solutions to airport capacity problems and devotes only 12 of its 450 pages to the place of airports in the NAS. A new version of FAA's National Airport System Plan is expected to be released in the fall of 1982, and there is concern that, as in the past, it will be an uncoordinated catalog of State and regional plans. FAA has programs under way to identify and evaluate techniques for increasing airport capacity, and it would be desirable for FAA to integrate its plans for future airport development with those for ATC facilities and equipment.

In cooperation with airspace users, FAA has also begun a National Airspace Review (NAR) to study possible changes in ATC procedures and flight regulations. Changes in ATC procedures (like changes in airport plans) could have a profound effect on ATC requirements, and coordination between NAR and the plan for equipment modernization is vital. NAR has just begun and will take 42 months to complete, and by then FAA may have made a commitment to many of the equipment changes outlined in the NAS Plan.

There is a recognized need for improvements in the ATC system and, given the long leadtimes involved, these improvements should be set in motion as soon as possible. As a practical matter, FAA needs a long-term modernization plan—complete with a long-term approach to funding—to ensure that the plan can be carried out. However, this requires a realistic sense of both the requirements that will be placed on the system by future growth and the opportunities that will be available in computer and telecommunication technology, as well as sufficient flexibility to exploit those opportunities in order to meet those requirements.

Because it attempts to fit all the new technological elements into a coherent system framework, the FAA considers the current NAS Plan a "blueprint" for future system evolution, indicating the steps that will be required and when they will be carried out. The Plan, however, is not a full and specific description of system development, acquisition, and deployment—nor is it really intended to be. Important details of engineering and testing for each subsystem remain to be set forth in technical documents scheduled for issue in the coming months. The Plan should thus be viewed as only the apex of a pyramid of plans and specifications for new equipment and facilities.

Within these limitations, the ATC system improvements proposed by FAA are technologically feasible and desirable with respect to safety, capacity, and productivity. Nevertheless, there are alternatives that might be equally effective and, given the uncertainties in FAA's traffic and demand forecasts, it would be prudent to adopt an implementation schedule that neither forecloses potential options nor constrains the final system design. FAA's proposed en route computer replacement program in particular has been criticized on this score. The Plan requires the coordination of many disparate projects, many involving considerable technical or schedule risks, yet it lacks a clear statement of priorities and provides no alternatives or contingencies in the event of problems, delays, or budget constraints.

PRIORITIES

While the 1982 NAS Plan states the goals that will guide the development process, it does not relate these goals to specific programs in a systematic fashion. Presumably there is a hierarchy among goals and among programs that will contribute to achieving these goals, but nowhere in the Plan are these priorities delineated. If, because of budgetary constraints or failure to meet engineering objectives, there are items that must be eliminated or schedules that must be altered, the Plan does not make clear what effects this would have on the development of the system as a whole. Nor is it made explicit how elements of the Plan could be eliminated or rescheduled in such a way that major objectives are not compromised.

A valuable feature of the Plan is material in the introductory chapter stating the rationale of the planning process and describing the steps that FAA went through to identify requirements, analyze options, and lay out a course of action. It might be hoped that FAA will carry this explanation one step further by describing the logical dependencies among elements of the Plan—i.e., an explanation of how each element supports others and how they contribute to particular objectives. The Plan is replete with development flow diagrams for each level of the system, but these charts show little more than the temporal sequence of events, the merging of development streams over time. The diagrams, and the accompanying text, do not indicate critical paths and the specific relationships to safety, capacity, and productivity.

SCHEDULE

A major shortcoming of the Plan as a planning document is that the development and deployment schedule is not tied directly to specific components of aviation growth or to the needs for particular services at certain times and places. FAA's approach seems to be to implement the entire plan as expeditiously as possible to prevent the ATC system from being overwhelmed by growing demand. However, as FAA's own forecasts indicate, growth is expected to occur at different rates in different regions and among user groups. This pattern of growth may impose requirements not addressed by the NAS Plan.

For example, the Plan states that the major factor constraining the future growth of aviation will be the lack of capacity at major airports. Yet, the first part of the ATC system scheduled for modernization and increased capacity to handle traffic is the en route system. Terminal area improvements, some of which could ease airport capacity constraints, are not planned for installation until the 1990's. Giving priority to improvements that would increase the throughput of en route centers does not seem entirely consistent with the forecasts of where the capacity of the system will be most severely limited. There is little apparent advantage in moving en route traffic more expeditiously only to have it encounter delays in terminal areas where capacity improvements are not scheduled to be made until the early 1990's.

FAA has also set itself a complex task of system development and deployment—more complex than any it has attempted before—and there is room for doubt about the prospects of keeping to the time line laid down in the Plan, especially since there are so many elements and paths of development that must be coordinated.

En route automation, for example, involves two major procurements—the rehost computer, and then new software and sector suites. FAA's proposed strategy is a complicated process that involves selecting from all competitors two "finalists" for each of the two major procurements. These finalists will then be asked to demonstrate their proposed system at the Test Center in Atlantic City, after which a production contract will be awarded to one of each pair.

For just one of the many NAS Plan programs, therefore, FAA is placing itself in a position where it must manage four major contractor efforts at the same time. The work of these contractors, and possibly several subcontractors, must be coordinated and kept on schedule. Equally important, the contractors must be kept insulated from each other to preserve competition and protect proprietary information. A less complicated strategy might have better chances of success, given the management problems inherent in this approach. If FAA concludes that its proposed approach of directing four contracts at one time is to be preferred, then—as a minimum—the agency should take additional steps to increase its internal capability in the area of systems acquisition management and should plan to strengthen the role of an outside system integration contractor. FAA recognizes this need and has recently announced internal management changes to improve these capabilities.

In the face of the uncertainties about future growth, and in view of the difficulties of keeping the parts of a complex development program on schedule, it is surprising that the 1982 NAS Plan does not deal explicitly with contingencies or the effects of schedule slippage. No endeavor of this scope and complexity can reasonably be expected to adhere to a nominal schedule. There are inevitable engineering problems; delays will occur even with the best of management; unforeseen circumstances will arise. One participant in the OTA working group on computer and communication technologies characterized the schedule as a "no-problems scenario, " admirable for its conception but not realistic in view of the manifold implementation problems that might be encountered. *

*As this report was being prepared for publication, the General Accounting Office released its review of the NAS Plan (Examination of the Federal Aviation Administration's Plan for the National Airspace System—Interim Report, AFMD-82-66, Apr. 20, 1982). GAO's findings very closely parallel OTA's on several major points. They found that the NAS Plan lacks the detail and justification usually needed for budgetary approval and implementation. They also found that FAA's proposed en route computer replacement strategy poses both short-term and long-term risks, and they advise that FAA consider less risky alternatives—among them conversion of 9020As to 9020Ds. GAO points out that FAA has not yet developed a careful and detailed transition plan, which is essential to an effort of this magnitude and complexity. Finally, GAO raises questions about FAA management and adminstrative resources and advises FAA to strengthen its capability in this area as a matter of first priority.

FAA AVIATION FORECASTS

Accommodating the anticipated growth of air traffic and ATC workloads has been a primary justification for proposed system improvements. In the past, however, FAA's long-term forecasts have generally proven to be too high. This raises questions about the usefulness of FAA's traffic and workload forecasts for 10 years and beyond as a guide to long-range planning and investment decisions. For example, FAA forecasts the onset of delay problems by the late 1980's. This forecast underlies the proposed approach to en route computer replacement, a decision that sets the pace and direction for overall system modernization. That decision, if taken, may unjustifiably limit the options available for the final system design.

OTA'S review indicates that the growth projected by FAA may well ultimately occur, but there is sufficient uncertainty about near-term growth that any program for upgrading the system should emphasize a design that can be adapted to less growth (or more growth) without a fundamental change in the system. Questions about the accuracy and usefulness of FAA aviation forecasts stem from three principal concerns:

- historical accuracy of FAA forecasts;
- forecasting methodology used by FAA, including the ability of FAA forecasts to account for noneconomic influences on aviation growth;
- specific assumptions underlying the forecasts on which the 1982 NAS Plan is based.

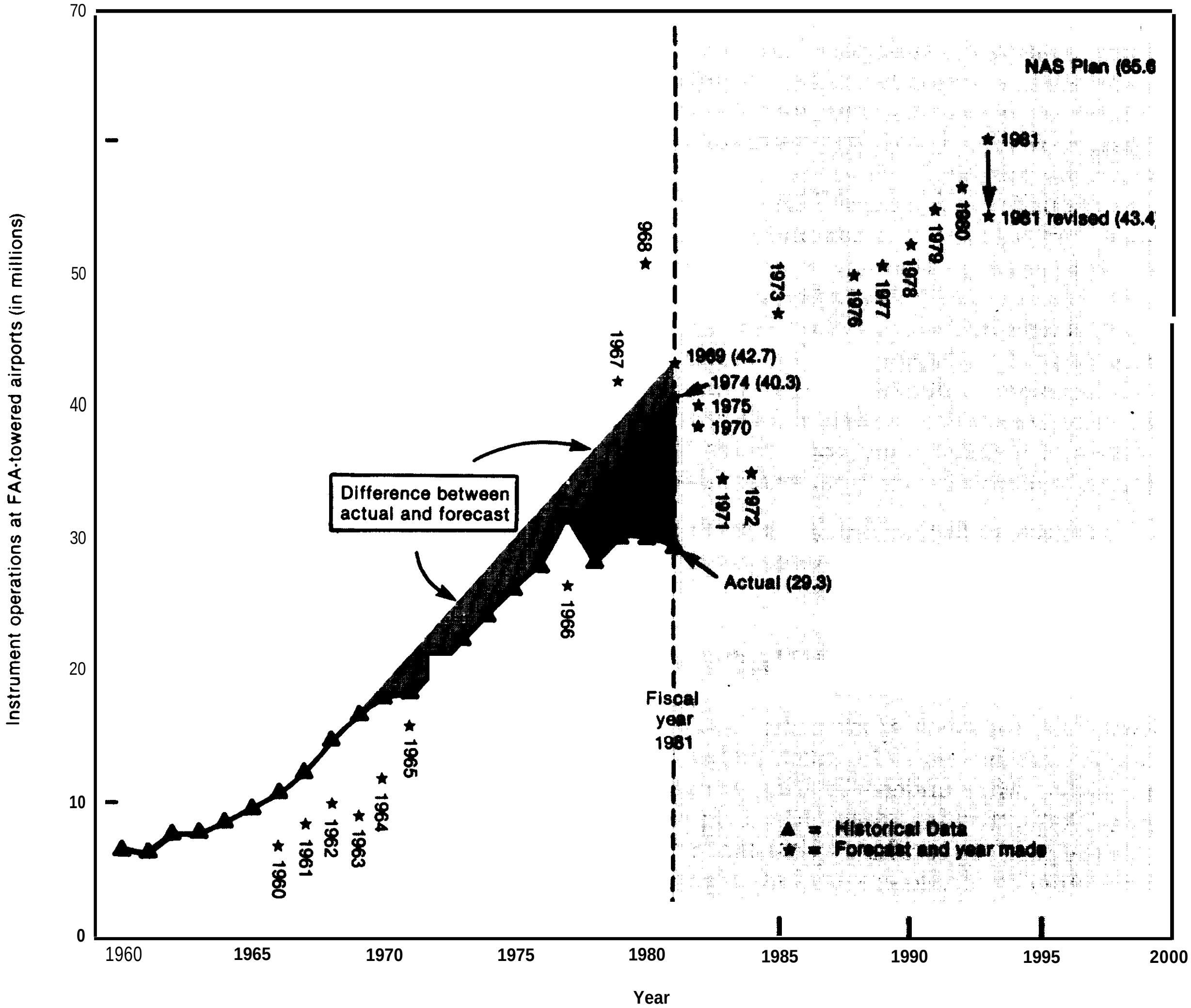
ACCURACY OF PAST FORECASTS

Recent FAA forecasts of air traffic and ATC workloads have tended to be much higher than actual results. After underestimating growth in the early 1960's, the long-range (lO-year) projections for the past 15 years have consistently been too high, often by 50 percent or more. Figures 1, 2,and 3 compare past forecasts with actual workloads at FAA towers, en route centers, and flight service stations. They show that the workloads originally projected for fiscal year 1981 (in 1970) were between 50 and 180 percent higher than what actually occurred. Alternatively, one could conclude that the forecasts were off by a decade since the levels of demand once predicted for 1981 are now expected in the 1990's or later. FAA nevertheless believes the current forecasts to be sufficiently accurate that they can serve as the basis for planning long-term system improvements.

Analysis by the Congressional Budget Office (CBO) of the accuracy of FAA forecasts shows a similar pattern (table 1). Five-year forecasts of tower operations made during 1959-65 for the years 1964-69 averaged 19 percent too low, while the 1966-73 projections for the years 1971-78 averaged almost 33 percent too high. Starting in 1974, FAA initiated a new and much improved econometric methodology for forecasting passenger enplanements and revenue passenger miles (RPMs), and the accuracy of these projections has subsequently improved.

However, ATC workloads are driven not by enplanements or RPMs but rather by operations —takeoffs and landings—and the 1974-76 projections of total tower operations for 1979-81 remained too high by an average of over 21 percent. Forecasts of total *instrument* operations at FAA towered airports—a more useful indicator of ATC workloads—have been somewhat more accurate, as have forecasts of IFR aircraft handled by en route centers. Flight Service Station workload projections have been the least accurate of the relevant forecasts.

Figure l.— FAA Tower Workload, Actual and Forecast, 1960-2000



SOURCE: Office of Technology Assessment, from FAA data,

Figure 2.—FAA En Route Workload, Actual and Forecast, 1960-2000

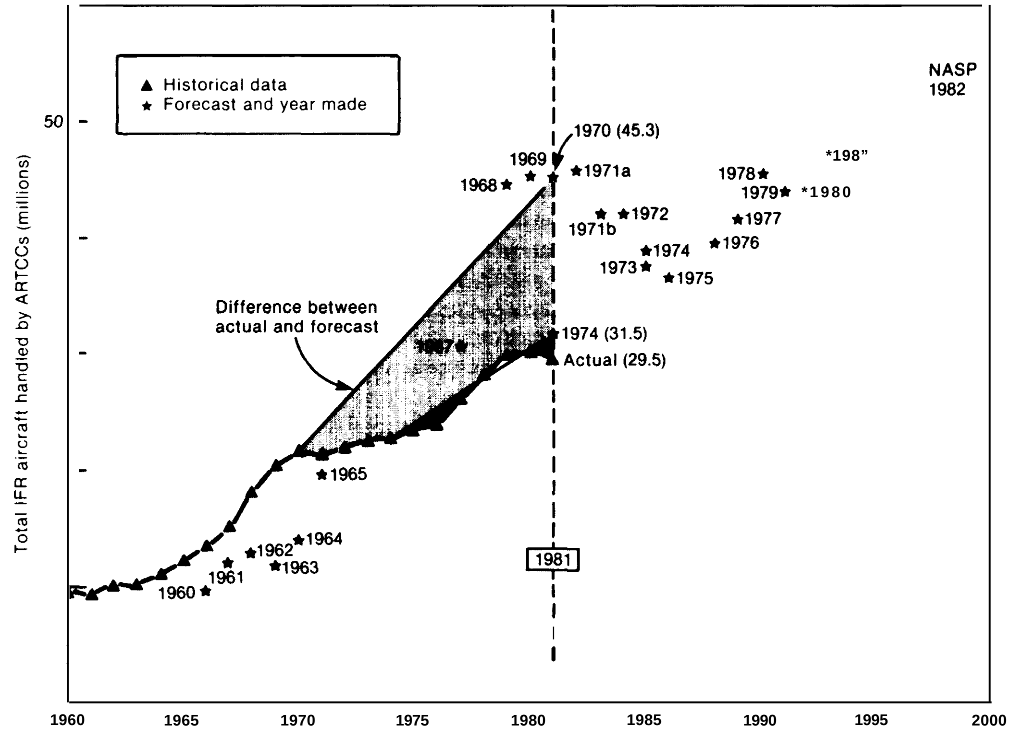


Figure 3.–FAA Flight Service Workload, Actual and Forecast, 1960-2000

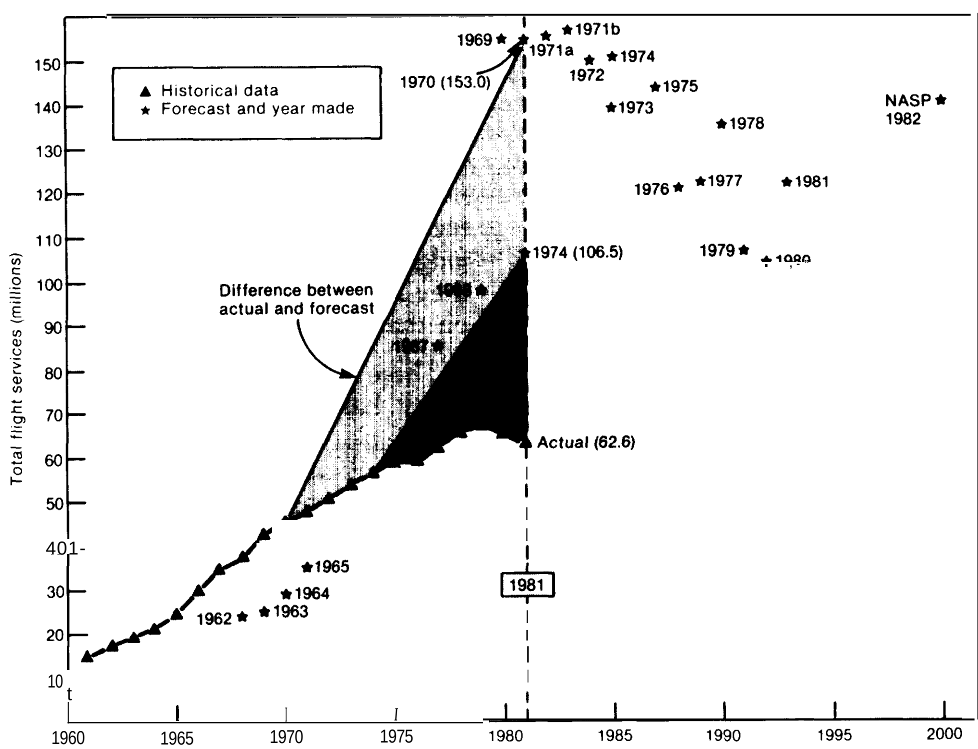


Table 1 .—FAA Forecasts Compared With Actual Data (percentage difference)

Forecast year	For the year	Total commercial air carrier enplanements	Total revenue passenger miles	Hours flown in general aviation	GA operations at FAA towers	Itinerant operations at FAA towers	Total operations at FAA towers	Instrument operations at FAA towers	IFR aircraft handled at FAA ARTCCS
1959	1964	– 1.3	– 6.5	– 0,6	4.6	6.0	9.7	– 4.8	11.7
1980	1985	- 9.5	– 9.7	– 1.2	–27.8	– 12.7	–21.6	0.3	– 12.8
1961	1966	–27.5	–26.0	– 15.3	–37.7	–20.0	–28.9	–28.0	– 14.8
1982	1987	–32.1	–31.4	–23.6	–34.7	–20.6	–27.3	–25.6	– 19.2
1963	1988	–41 .3	–41.3	N/A	–38.4	–26.9	–32.5	–41 .8	–24.5
1964	1989	–31 .4	–33.6	–23.5	–27.3	–24.0	–24.9	–31.7	–23.8
1985	1970	– 14.1	– 19.8	– 16.3	– 2.6	– 8.0	– 5.2	– 16.0	– 11.7
1966	1971	9.4	0,5	– 1,6	53,7	32.4	42.2	0.6	– 1.4
1967	1972	23.6	13.0	9.1	72.5	43.8	54.9	22.7	25.5
1988	1973	23.9	15.9	7.4	78,3	49.7	58.4	18.2	19.7
1969	1974	21.1	21.2	4.6	53.6	37.7	42.4	– 2.1	22.7
1970	1975	26.3	33.0	– 0.6	60.9	19.7	25.9	– 15.6	15.3
1971	1976	19.0	28.6	– 0.6	42.9	14.1	22.9	– 16.4	9.2
1972	1977	22.3	33.7	– 6.8	36.9		4.5	– 2.0	11.2
1973	1978	14.0	18.3	– 10.4	14.8	; : :	8.8	– 3.6	– 0.7
1974	1979	– 9.7	– 7.4	– 13.7	11.8	2.2	9.4	– 2.2	– 2.7
1975	1980	– 10.6	– 17.3	– 0.2	34.6	15.6	25.7	– 7.1	– 3.7
1976	1981	4.3	– 1.8	15.7	41.3	24.3	32.1	4.6	4.8

SOURCE: Congressional Budget Office, from FAA Aviation Forecasts, 1959 to 1976.

FORECAST METHODOLOGY

CBO's analysis of FAA forecasting models identified several methodological features that may account for at least part of the inaccuracy of FAA's forecasts. As noted earlier, the econometric models used to project enplanements and RPMs have proven to be far more accurate in recent forecasts. However, the methods for translating enplanements and RPMs into projected operations —based on assumptions about average load factor, aircraft size, and stage length—appear to be far less sophisticated. FAA's 5-year forecasts of air carrier enplanements have been off by only about 1 percent since 1974, while projected operations have been more than 20 percent too high. This discrepancy is explained in part by airlines using larger aircraft, with higher load factors, on longer routes. *

Another likely cause of error in forecasts of operations is the methodology FAA uses for projecting GA fleet size, operations, and resulting ATC workloads. In the FAA model, changes in the projected size of the GA fleet are driven primarily by changes in the gross national product (GNP) and to a lesser degree by aircraft prices and interest rates. Changes in fuel prices, however, are implicitly assumed to have no measurable effect on the growth of the GA fleet. This omission has a strong influence on the resulting forecasts of workloads imposed on the ATC system by the GA sector, because fleet size is the only causal variable used in projecting GA instrument operations at FAA towers. Likewise, forecasts of local and itinerant GA operations, as well as GA demand for flight services, are driven primarily by fleet size and only to a much smaller extent by fuel price or other variables. A number of other judgments clearly enter into these calculations, but they are not explicitly made, and their influence on the results is unclear.

These questions about GA forecasting methodology have an important bearing on overall system planning and investment, because so much of the anticipated growth in ATC demand is expected to come from the GA sector. FAA forecasts that the GA fleet will grow by 50 percent between 1980 and 1990, and that during the 1980's GA aircraft will account for 65 percent of the increased workloads at FAA towers and en route centers, and 75 percent of the increase in flight services. Yet the size of the GA fleet is assumed to be driven almost entirely by growth in GNP and personal

*This difficulty is not unique to FAA. Boeing and others cite problems in anticipating airline route structure and load factors as a source of error in their forecasts.

income, with little or no allowance for saturation in this market—a potential problem in forecasts covering 10 or 20 years. This also raises questions about the economic projections and other assumptions underlying the aviation forecasts on which the 20-year investment program of the NAS Plan is based.

GROWTH ASSUMPTIONS IN THE 1982 NAS PLAN

Economic assumptions, particularly about highly aggregate variables such as GNP and disposable personal income, are the principal drivers in FAA's forecasts, and the projections are very sensitive to changes in long-term growth rates. Past FAA forecasts included three or four alternative scenarios to allow for the uncertainties of future economic growth, with the "baseline" scenario being the most likely foreseeable outcome. These scenarios were previously based on economic indicators prepared by Wharton Econometric Forecasting Associates using their Long-Term Industry and Economic Forecasting Model. Between 1976 and 1981, the range of these scenarios became both wider and lower, indicating greater uncertainty about future trends and less optimism about the probability of continued rapid growth.

In the September 1981 forecasts, however, the baseline scenario was based on economic projections supplied by the Office of Management and Budget (OMB). These OMB projections were later withdrawn and, due to uncertainties caused by the Professional Air Traffic Controllers Organization (PATCO) strike, the resulting FAA forecasts were also discarded before publication—''sent to the shredders instead of the printers, " in the words of FAA's Director of Aviation Policy and Plans. Revised 1981 aviation forecasts based on new OMB economic projections were not released until February 1982; the NAS Plan itself is based on FAA's 1980 forecasts and Wharton's March 1980 economic projections, which do not reflect recent changes in aviation and the general economy. These economic forecasts and aviation growth projections were the subject of considerable criticism by aviation experts during OTA'S review of the 1982 NAS Plan. Several members of Working Group No. 1 observed that the administration's numbers should be considered "targets" rather than projections. Compared to Wharton's, they tend to show higher growth rates for GNP, and lower growth rates for inflation and fuel prices, resulting in a higher long-term growth rate for air traffic. Some participants questioned whether aviation could in fact continue to grow as fast as it had in the 1970's, given the current financial plight of the airlines and the recent softening of the GA market. While disagreeing with FAA's short-term projections, however, they recognized the danger of allowing long-term forecasts to be overly influenced by current economic conditions.

CONSTRAINTS ON FUTURE GROWTH

FAA's mission to foster civil aviation creates a planning process that naturally avoids the risk of imposing fundamental constraints on the growth of air traffic. It may even be better for FAA to err on the high side rather than the low side, although such predictions may become self-fulfilling prophecies to the extent that providing additional services begets additional demand. As a result, FAA's forecasts are unconstrained—they assume that past trends will continue, that there will be no limits imposed on growth, and that the proposed improvements will be made when and where needed to accommodate growth. But there are a number of factors other than the ATC system itself that could change these trends or restrict future growth. These events and influences, most of which are neither accounted for in FAA forecasts nor addressed in the 1982 NAS Plan, include the following:

- *Airports.* —The NAS Plan recognizes that congestion at major hubs and relievers is a cause of special concern, but the availability of GA airports will also be a widespread and serious constraint on growth. Although there has been a net increase in the overall number of airports in the last 15 years, over 300 GA airports have been closed or abandoned *each year* since 1965 and there has been a steady shift toward privately owned, private-use airports. The result, particularly in metropolitan areas, is a decrease in the number of public-use landing places and growing inconvenience in owning an aircraft. Both factors will influence the growth of general aviation. "One way to test the realism of doubling the fleet, " according to one aviation consultant, "is to try to figure out where they're going to put them with the present trend in runways, ramps, and tiedowns. "

- *Fuel Price.* —The greatest uncertainty facing domestic aviation in both the short and long term is the future price and availability of aviation fuels. This uncertainty can cause sudden shifts in FAA forecasts: those in the 1982 NAS Plan (based on September 1980 data) assume an average real increase in fuel prices of 3 percent per year through 1993, while the revised 1981 FAA forecasts (released in February 1982) assume real *decreases* during 1982-83 and an average real increase of only 1 percent per year during 1984-93. No long-term shortage is anticipated in either forecast. The current "oil glut" and price decreases may be transient events, however. In addition, there are indications that aviation gasoline (used by smaller piston-engine GA aircraft) may become increasingly difficult to obtain; more likely to reduce personal GA than the business, corporate or air-taxi operations that place more demand on the ATC system.
- *User Fees.* —The 1982 NAS Plan indicates that the cost of upgrading the ATC system will be borne by the users, but the 1980 traffic forecasts on which the NAS Plan is based do not reflect the administration's user fee proposals. Sudden large increases in fuel taxes could depress traffic, a situation the proposed "escalator" schedule is designed to avoid. Nevertheless, cost recovery through user fees could affect both the demand and the funding for planned system improvements.

  Many experts feel that previous user fees had a small restraining effect on GA growth in the 1970's and that the original administration proposal of a $.65/gallon tax on GA jet fuel would have had a dramatic effect on use of the system by business aircraft. The current user fee proposals will have less effect on precisely that part of GA traffic which is placing increasing demand on the system. As with fuel prices, however, the FAA model is not sufficiently sensitive to give an accurate estimate of this effect.

  Furthermore, if future traffic levels turn out to be significantly lower than projected by FAA, total revenues from airspace users may also fall short of the levels required to carry out the proposed improvements. Current FAA and OMB forecasts show steady increases in both traffic and user fee revenues, with user fees paying for 85 percent of total FAA costs by 1987 (see "Cost and Funding Issues").
- *Aircraft Technology and Ftnancing.* —Recent improvements in airline productivity have come from higher utilization and economies of scale rather than aircraft technology, and further improvements are likely to come more slowly than in the last 20 years. The development of a new generation of advanced-technology aircraft will depend on the potential market, which in turn depends on airline profitability. Some near-term increases in fleet efficiency could be achieved by retrofitting existing aircraft. Airline profits are at all-time lows, however, and capital requirements for new equipment would demand record levels of return on investment through 1990.
- *Deregulation and Industry Structure.* —Airline deregulation has destabilized the industry's price and market structure, causing over competition and low profitability that increase the risks and uncertainties of airline financing. Some analysts feel that the demise of some carriers may be a natural and desirable result of complete deregulation, and a

few predict the failure of a major carrier by mid-1982. * Restructuring of the industry through bankruptcies or mergers might remove overcapacity, and the survivors might be in a stronger financial and competitive position. Termination of sections 406 and 419 subsidies in 1985 and 1988 will also affect commuter airline profits and service to as many as 100 small communities. These service reductions could, in turn, contribute to an offsetting increase in business aviation.

- Strike Impacts. —Traffic restrictions imposed by FAA as a result of the PATCO strike will continue for at least 2 years and possibly far longer. FAA assumes that traffic will rebound rapidly when these restriction are removed, but adjustments made by users during this period may permanently alter aviation growth trends and traffic distribution. Observers have pointed out that the General Aviation Reservation system has artificially forced into the IFR system many GA operations that might otherwise have been outside the system—Visual Flight Rules (VFR)—and these users may have become accustomed to using ATC services. Others feel that airport slot allocation has helped major air carriers while hindering the expansion of commuters and new entrants. These traffic restrictions—particularly at major hubs—might have to be extended or reimposed in the future as a means of addressing-airport congestion and encouraging further redistribution of operations to relievers and second-tier hubs.

*Braniff International ceased operations on May 12, 1982, and filed for voluntary bankruptcy under ch. 11. It has 120 days to formulate a reorganization plan acceptable to its creditors.

SPECIFIC TECHNOLOGIES

The current ATC system, both in en route centers and terminal areas, is based on the technoIogy of the 1960's. Technology has made rapid strides since that time, and virtually everyone believes that the present ATC system should be upgraded or replaced. New computer hardware, software, and communications technologies can be used to build an ATC system that is safer, more reliable, and more cost effective.

The program of improvements proposed in the 1982 NAS Plan are technologically feasible and desirable for purposes of safety, capacity, and productivity. The foregoing analysis of FAA's traffic forecasts, however, raises questions about how soon additional capacity will be required, Furthermore, in some cases there are technological alternatives that might serve the ends of safety and productivity as well or better, and possibly at less cost, than those proposed by FAA. These alternatives merit reexamination; but, given the long leadtimes required for the modernization program proposed by FAA, the choices need to be studied without delay so that decisions can be reached promptly.

SYSTEM DESIGN AND TRANSITION

A key element in the 1982 NAS Plan is merger of the present 23 en route centers and 188 terminal control facilities into a total of 60 or fewer consolidated ATC facilities. There are differences in ATC requirements between en route and terminal environments, but they are not so significant that separate and distinct systems must be maintained. Consolidation would also allow FAA to use common hardware and software to support all ATC activities, rather than maintaining separate but functionally similar systems as at present. If this also allows a move toward standard, "off the shelf" equipment, FAA could be in a position to move with the technology as it develops in the future. Producers of computer and communication equipment are generally committed to providing their customers with "family" systems that can evolve to take advantage of new technologies as they become available.

FAA has chosen to move from the present ATC system to the new one in a series of incremental stages, minimizing the amount of change at each point in the transition. The FAA Administrator has stated that this approach minimizes risk by limiting the number of system components affected by a given change. Many of the participants in OTA'S general conference approved of this conservative approach, but others pointed out that there is no risk-free way to go from the current system to a new one. Though each step of the FAA incremental approach involves some risk, the overall technological risk is likely to be lower than if the change were made in a more dramatic way. Unfortunately, such incremental change introduces the possibility of an entirely different kind of risk—that the hardware choices made in the first stages might limit the options available for the final system design. The future architecture of the system, in short, may be constrained by the obsolete architecture of the system it replaces. This is of particular concern with regard to computer replacement, the first step in the plan.

Several experts have suggested that the needs of the system would be better served if FAA kept the present system running to meet short-term needs, thus making it possible to design and deploy an entirely new system to meet the long-term needs of the future. Advocates of this "clean-sheet" approach agree emphatically with other experts that the present system must be replaced, and that the first steps in this process should be undertaken as soon as possible. However, they also point out that any equipment acquired in the short term would probably have to be modified, replaced, or augmented with other computers when the new system is deployed in the 1990's. Thus, they advocate decoupling short-term remedial measures from long-term replacement by finding a cost-effective way to shore up the present system with the intent of discarding it altogether when the new system comes on line. The chief advantage of the "clean-sheet" approach is that it would allow new system hardware and software to be designed in an integrated fashion, without either being constrained by the need for compatibility with the computer system now in place.

EN ROUTE COMPUTER REPLACEMENT

FAA's plan for implementing the new en route ATC system consists of four steps: 1) "rehosting" the existing software in a new central processor that "emulates" the present IBM 9020 but has greater capacity; 2) replacing the present display units used by controllers with new "sector suites" compatible with the current software but containing sufficient processing capacity to assume some ATC functions; 3) concurrent with step 2, discarding the current software for new software capable of taking advantage of the new sector suites and (if possible) compatible with the "host" hardware; and 4) implementing a number of advanced functions designed to enhance the overall performance of the ATC system. OTA'S review indicates that, in general, this is a reasonable approach, but there are questions about the separation of hardware replacement from software redesign and about FAA's reasons for selecting this approach over others that were considered.

The current IBM 9020 computers are unique to FAA: none are in service elsewhere, and no machine now in production is capable of running the NAS software. FAA believes it has anticipated the potential problems of rehosting this software, and several vendors have indicated that they have acceptable solutions. Participants in OTA'S technical Working Group No. 2 indicated, however, that moving the existing software to a new machine, no matter how similar to the 9020, is more difficult than FAA indicates in the Plan. The task can be done, given sufficient time and money, but the schedule proposed by FAA is probably optimistic.

FAA believes that the host computer will serve as the hardware element of the ultimate system. However, they do allow for the possibility that it may have to be supplemented or replaced in the 1990's with yet another new computer to accommodate the new system software. Some experts feel that budgetary constraints might lead FAA to retain the first host computer, however, even though it proved less than ideal for the new system. Others insist that the host computer should be considered a "throwaway" and that the design of the future system should not be constrained by the requirement to incorporate the host computer selected now as an interim remedial measure.

In January 1982, FAA submitted to Congress an analysis of technological options for replacing the en route computer system.[2] One of the options examined was replacing 9020As with 9020Ds at 10 sites as a near-term measure to assure adequate capacity until a replacement system is designed and deployed. FAA's analysis showed that this option would give all 20 en route centers sufficient capacity to accommodate anticipated growth until 1996, well after the new system is scheduled to be deployed. FAA has demonstrated the feasibility of this approach in replacing a 9020A with a 9020D system at the Jacksonville center, and the option analysis report indicates that such an upgrade could be effected at other centers. FAA estimates that upgrading 10 installations from As to Ds could be completed by 1984 at a cost of $64 million; installing a new host computer at all 20 en route centers (as outlined in the NAS Plan) could be completed by 1986 at a cost of about $250 million. On several other points of comparison—such as technological risk, constraint on future system design, and impact on FAA's management resources-the FAA's January option analysis showed A-to-D upgrade to be superior to rehosting (see table 2).

Some participants in OTA'S technical working group and general conference indicated that, based on FM's own analysis, the A-to-D upgrade

'Federal Aviation Administration, op. cit.

Table 2.—Comparison of Rehosting and Upgrading 9020As to 9020Ds

	Rehosting	A-to-D upgrade
Description	Rehost present software on new computer, then replace software and add additional processors needed for advanced system.	Upgrade 9020A computers to 9020D at 10 centers, then replace hardware and software in a single step, and finally upgrade computer to advanced system,
FAA evaluation:		
Schedule	Computer replacement 1986 Software replacement 1990 Full advanced system 1992	Computer upgrade 1984 New computer and software 1989 Full advanced system 1993
Cost of first step	*$250* million	$64 million
Total cost	$1.39 billion	$1.39 billion
Risk	Rehost may constrain future system	Low
Impact on FAA resources	High	Medium
Ability to evolve	Medium	Unconstrained
Transition impact	High	Medium

SOURCE: Federal Aviation Administration, "Response to Congressional Recommendations Regarding the FAA's En Route Air Traffic Control Computer System," DOT/FAA/AA P-82-3, January 1982,

option is the one that should have been selected. It offers quick relief from capacity problems at precisely the centers that now or will have problems, with lower risks, and at a lower cost. It also preserves the opportunity to undertake the overall design of a new system unencumbered by the shortcomings of a computer capable of rehosting the existing software. This option, they added, was more conducive to both innovation and competition in the procurement of the new system. A former senior IBM executive who was intimately involved in the development of the 9020 computers, told OTA that there would be few problems in converting existing 360/65s to 9020s. ' FAA reports and FAA representatives attending the OTA conference have expressed similar opinions.

An FAA observer at the OTA conference explained that one reason for rejecting the A to D upgrade alternative was that the agency could not locate a sufficient number of IBM 360/65s to carry out upgrading at 10 centers. OTA subsequently made inquiries of dealers in used computers and was assured that there would be little difficulty in acquiring 35 IBM 360/65 systems over the next 6 months to a year. An inquiry to the General Services Administration showed a total of 103 IBM 360/65s in the Federal computer inventory as of April 6, 1982. Of these, 13 have been declared surplus and may be useable; many others are undoubtedly used in routine data-processing applications where they could easily be replaced with more modern equipment. Such an exchange would bring an immediate benefit to the Government, because the IBM 360/65 is no longer a cost-effective machine at many installations, yet good use could be made of it in the ATC application where there is now no satisfactory alternative.

FAA sources have also raised questions about the long-term maintainability of the 9020, but the agency's January 1982 report to the Senate indicated that maintainability has not been a problem and is not anticipated to become one during the remainder of the decade. IBM will not supply parts for 9020 series after 1984, but this gives FAA 2 years to determine its future maintenance needs and stockpile sufficient spare parts to last until the new system is deployed.

Statements made by FAA since the NAS Plan was released* indicate that the choice of the *rehost* approach was based on four major considerations:

*The 9020D system, which is a multiprocessor design unique to FAA, is a derivative of IBM 360 series computers. Three-quarters or more of the constituent parts of a 9020D are 360/65 components; the remainder consists of parts from other IBM system 360 computers (notably the 360/67model) plus some specially manufactured assemblies. The central processing element of the 9020D, for example, is essentially three specially modified 360/65s. To replace 9020A computers with 9020D computers at 10 centers would therefore involve acquisition and modification of 30 IBM 360/65s.

"Including remarks at the OTA conference and comments on the preliminary draft of this report.

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1. *Ability to meet capacity needs projected for the late 1980's.* —The FAA report to Congress in January 1982 asserted that A-to-D upgrade would also allow the projected demand for services to be met through the mid-1990's, or later if the demand materializes more slowly than expected.
2. *Improved reliability and maintainability.* —The reliability of the 9020 system appears to be more a problem of software than hardware, and since the present software would be retained, neither approach would alleviate this problem. Further, FAA has stated that, with or without rehosting, it plans to procure sufficient spare parts to keep the 9020s operating satisfactorily until the new computer system comes on line at the end of this decade.
3. *Ability to support productivity increases planned under the automated en route ATC system (AERA).* —The planned productivity increases to be realized from AERA will result mainly from software improvements not hardware changes; but, in any event, AERA will not be implemented until the early 1990's when the new computer system would be in place under either option.
4. *Reduced developmental risk.* —The incremental rehost approach reduces some kinds of developmental risk but—as argued above —it introduces another kind of risk, namely that hardware choices made in the first stages might limit the options available for the final system design.

In short, OTA does not find these reasons—either individually or collectively—to be persuasive arguments in favor of rehosting. OTA agrees that efforts for eventual replacement of the present system need to be pursued as vigorously and as rapidly as possible. However, FAA has not presented convincing evidence that the selected approach—rehosting—is in fact superior to other alternatives. This is not to argue that rehosting is unworkable or ill-advised. Rather, the point is that FAA has not made a persuasive case and that FAA should present a direct and detailed comparison of rehosting, A-to-D upgrading, and any other options the FAA considers workable. This justification is indispensable to an informed congressional review of the proposed computer replacement strategy. Such a head-to-head comparison of alternatives need not delay the overall schedule of the NAS Plan, and it could even advance the objectives of the Plan by providing a basis for clear understanding at the outset on where FAA is headed and how it proposes to get there.

AUTOMATION AND HUMAN FACTORS

The present ATC system is very labor-intensive and, without significant increases in controller productivity, the cost of operating the ATC system could rise precipitously as traffic grows. The number of aircraft that a controller team can handle with the present system is limited, and the conventional solution to handling a larger volume of traffic—decreasing sector size—has practical limits. FAA looks to increased automation as the principal means of achieving higher levels of controller productivity.

AERA, which is scheduled to be implemented in the early 1990's, would change the role of the controller from that of an active participant in the control process to that of a manager who oversees the operation of a highlv automated system. Many of the routine decisionmaking functions now performed by humans would be automated, with the result that fewer controllers will be required for a given level of traffic. Elements of AERA are now undergoing testing, and some features will be added to the existing en route software after it has been rehosted. Other functions—those that will have the greatest impact on the role of the controller and the character of the ATC system—will not be implemented until the early part of the next decade when the redesigned software has been installed. It is this latter group of functions that may require either enhancement or replacement of the proposed host computer in the 1990's (see above).

As envisioned by FAA, AERA is designed to increase the efficiency of airspace utilization as well as the productivity of controllers. AERA will also enable users to follow more fuel-efficient flight paths and make better use of the equipment they are now installing on their aircraft. Flight management and navigation computers, linked to AERA by a new communication link (Mode S), will eventually receive and respond to flight instructions without increasing aircrew workload. Similarly, delays in the system will be minimized by the flow control procedures, and safety will be enhanced because the system will provide for the separation of IFR from VFR traffic outside terminal areas, rather than providing separation only between IFR aircraft as is now the case.

Human factors and safety are important concerns in AERA. In a highly automated system it might be impossible to revert to manual control in the event of a system failure. Therefore, the AERA concept assumes that the functions of the future ATC system will be distributed among various elements. In the event that the main computer at an ATC facility fails, the sector suite (acquired during the second phase of system modernization) will contain enough processing power to provide at least some backup functions; other functions will be transferred in real time to neighboring centers that remain operational.

FAA has yet to refine the AERA concept completely. The distribution of functions among the various computer resources has not yet been determined, nor have the respective roles of human controllers and automated systems been defined. This task will be carried out by FAA and the contractor responsible for the design of the new system.

This point is stressed by the critics of the rehosting approach to computer replacement and those who suggest that FAA use a "clean sheet" approach to the system design. They argue that premature acquisition of host hardware for the short term could limit the options of the system design contractor in the long term. This could result in a requirement for extensive and expensive modifications of the host computers, a second wholesale computer replacement, or (since that seems unlikely) the implementation of a system that cannot take full advantage of the available technologies and design options. None of the critics suggest that replacement be deferred, and all of them recognize that at some point FAA must commit to a specific design even though there will always be a better technology available at some point in the future. Rather, their concern is that premature commitment to "rehosting" hardware could limit FAA's ability to take advantage of the best technology that is now available.

Studies of the AERA concept commissioned by FAA have generally agreed that the proposed approach is feasible. However, one study, recently completed by the Rand Corp., suggests that the AERA concept may not be sound.[3] The Rand study indicates that total commitment to automation, with the controller no longer an active part of the system, is unwarranted and could present safety problems. It suggests that the controller will not be sufficiently involved in the traffic situation to detect errors in the system and analyze them in time to take effective action. As an alternative to the AERA concept, Rand suggests a "shared control" concept in which the controller has a more active part in the control process. In the end, the level of automation proposed by Rand would be very close to that proposed under AERA, although the route to achieve that level would be different and it might not achieve the increases in productivity that would result from the implementation of the FAA plan.

FAA, on the other hand, argues that it would not be possible to achieve the incremental improvements required for the shared-control approach, and that the automated system is expected to be more reliable than a system in which human controllers are active participants. FAA maintains it would be basically unsound, beyond a point, to back up an automated system with a human one that is less reliable.

[3] Robert Wesson, et al., "Scenarios for Evolution of Air Traffic Control," The Rand Corp., R-2698-FAA, November 1981.

COMMUNICATION

Communication is the backbone of air traffic control. Instructions and information vital to the safety of flight must be communicated between ground and air and between ATC facilities on the ground. While the present requirement for air-to-air communication is minimal, this link may assume greater importance in the future.

In the proposed plan, FAA indicates that a new data link (Mode S) will be the primary channel for transmitting data from the ground to the air and between aircraft in flight. * Mode S will be necessary to support the automated ATC system that FAA proposes for the future and for the distribution of weather information and other data of interest to aircraft in flight. It may also be used to collect weather observations from appropriately instrumented aircraft as part of the real-time weather system envisioned by FM. This data link will also be used in TCAS, the collision avoidance system adopted by FAA, to coordinate the maneuvers of aircraft when a possible conflict is detected.

‘At the OTA conference, a representative of FAA outlined the differences between Mode S and the Discrete Address Beacon System (DABS) concept from which it was derived. From the point of view of the data link, Mode S and DABS are functionally equivalent. However, the ground facility requirement for Mode S will be considerably less costly because it does not involve transmitting maneuver instructions to aircraft to resolve conflicts or avoid collisions. This also means that less computer power and less complex software will be required to handle Mode S than would have been required to handle DABS. Mode S has nevertheless been the subject of controversy, primarily due to GA concern over the costs and airspace restrictions that would be imposed by eventual mandatory equipage (see “Impacts on Airspace Users”).

Use of this data link will require installation of Mode S transponders on aircraft. These transponders are also intended to improve the quality of the surveillance data available to the ATC system. FAA plans to extend the requirement for Mode S equipage to all instrument flights above 6,000 ft by the end of the century, compared to 12,500 ft for the present Mode C. However, FAA expects that most aircraft will have equipped voluntarily by that time, because of the enhanced services that will be available only to aircraft carrying Mode S transponders. Roughly three-fourths of the current civilian fleet is equipped with the present Air Traffic Control Radar Beacon System (ATCRBS) transponders, although only half this number has the more advanced Mode C altitude encoder.

Communication between ATC facilities on the ground is also vital to the operation of the system, particularly as the level of automation increases. The 1982 NAS Plan envisions a dedicated system to handle these communications requirements. It was difficult to assess FAA’s proposals because of a lack of details in the 1982 NAS Plan, but Working Group No. 2 questioned the need for a dedicated system. Despite the existing Federal investment in equipment and rights of way, several participants felt that, given the current state-of-the-art, FAA could meet its requirements by procuring needed communication services on the open market.

COLLISION AVOIDANCE

The debate over collision-avoidance systems has gone on for over 20 years. Collision-avoidance systems are designed to back up the separation assurance services provided by FAA and to resolve conflicts that may occur because of system errors. They are not designed to function as a substitute for the basic separation assurance services supplied by ground control facilities.

During the summer of 1981, FAA adopted the Traffic Alert Collision Avoidance System (TCAS) as the collision avoidance system to be implemented, and it has been labeled by the Administrator as a key element of the 1982 NAS Plan. TCAS is a totally airborne system that requires virtually no expenditures by FAA beyond those for the Mode S data link, which TCAS uses to coordinate maneuvers between aircraft. Initially, at least, installation of the required avionics will be voluntary on the part of the users.

There are two variants of TCAS. TCAS I, intended for installation in small GA aircraft at minimal cost, provides information regarding the presence of "intruder" aircraft and could be upgraded to include a display of traffic advisories on potentially conflicting TCAS II aircraft. TCAS II, designed for airliners and business aircraft, is a more comprehensive system that provides a display of relative bearing and distance and presentation of a climb or descend indicator for an avoidance maneuver. There are engineering models of both TCAS systems, although neither is presently ready for certification and deployment. The value of TCAS I has been challenged, since it indicates only the presence of another aircraft without providing data as to its relative position. The feasibility of TCAS II has also been challenged. The present working model of TCAS 11 provides only a rather coarse indication of relative bearing, and the high-resolution directional antenna required for a more accurate and useful TCAS II system remains in the early stages of development. Several participants in the OTA conference suggested that this antenna might not be available for some time.

Representatives of the military community expressed concern to OTA about the impact of TCAS on the military fleet, particularly on high-performance tactical aircraft. They point out that space in these aircraft is at a premium, particularly for the installation of avionics that do not enhance mission capabilities or low-altitude safety. They would therefore seek a Mode S design that can be integrated with a military system such as JTIDS or IFF. They also point out that the installation of the antennas required for TCAS II could adversely affect the aerodynamic performance of tactical aircraft. FAA representatives have suggested that the military may not be required by the FAA to install TCAS (see "Impacts on Airspace Users").

SATELLITE TECHNOLOGIES

Participants in OTA'S technical working group pointed out that FAA has given very little attention to the possible role of satellites in the ATC system. This technology has developed rapidly over the past few years, and satellites have considerable potential not only as a communications resource but also for use in surveillance and navigation.

FAA does envision that satellites could eventually have a role in providing ATC services to aircraft operating over land, but the agency believes they are not yet a cost-effective alternative to ground-based systems. There is considerably greater potential in the short term for using satellites to provide services to aircraft operating over large bodies of water, where only minimal services are now available.

Satellites also have the potential for improving low-altitude surveillance. There are presently no proposals to extend coverage to the ground, but the possibility of providing this level of coverage at some point in the future does exist. The area covered by a ground-based sensor is limited by terrain, and it would be very expensive to provide for full coverage of U.S. airspace using ground sensors alone. While surveillance radars would not be mounted on satellites, ATC computers could use the Mode S data link to request position reports and provide properly equipped aircraft with separation services. This would be particularly useful in resolving the problems that arise when high-speed military aircraft on operational training missions must share low-altitude airspace with small GA aircraft.

Satellites also have considerable potential as aids to navigation. The military Global Positioning Satellite system is partially deployed and, when completed, could be used to provide navigational fixes with the same level of accuracy now afforded ground-based navigation aids. While national security considerations might limit the precision of the navigation aid provided to civil aviation, FAA omitted navigation satellites from the 1982 NAS Plan on the basis of timing. The preparatory work necessary to bring civil services to an operational status could not be completed before the end of the present decade, when FAA plans to have the essential parts of the new ATC system in place. Slippages in FAA's proposed deployment schedules, however, could reopen the satellite option.

IMPACTS ON AIRSPACE USERS

FAA is attempting to modernize an ATC system that is nearing the upper limit of its productivity. New computer capacity and a higher leveI of automation should enhance the system's ability to deliver air traffic control services to those suitably equipped. In the longer term, the AERA functions will greatly ease the management of long-distance, high-altitude, point-to-point flights. Air carriers and larger business aircraft will benefit most directly from system improvements in the NAS plan. Military and some GA users, who may often fly VFR for short distances or at low altitudes will also receive benefits, but they are mixed with drawbacks as well.

The plan is written from the perspective of a ground-based manager of the airspace. As a "user" of its own system, FAA should gain a number of benefits from automating and consolidating the ATC system. Of the new functions to be added to the en route and terminal area computers, nearly all are designed to provide better information to the controller or to relieve him of routine chores. Thus, these functions will enable the FAA to do its job—provide for safe, expeditious use of the airspace—more efficiently.

If automation and consolidation work as planned, FAA will receive greatly increased productivity from controllers and maintenance personnel. FAA expects this will lead to an actual decrease in the controller workforce and a leveling of operating and maintenance costs, despite increased demand for services. It is generally agreed that modernization will lead to avoidance of the costs of maintaining the aging system into the indefinite future. However, FAA has not yet made available their basis for projecting increases in productivity. Some observers note that the introduction of NAS Stage A automation in the early 1970's, while it did slow the growth rate of the controller work' force, did not live up to FAA's expectations in this regard.

Users who are properly equipped and who operate at certain altitudes will begin receiving direct benefits from the planned AERA enhancements early in the next decade. FAA expects fuel-efficient route planning to save users $250 million per year. Most of these benefits would accrue to air carriers and business aviation because of their high fuel use. In terms of more efficient operation, these two user groups are likely to benefit most from the full range of AERA improvements.

GENERAL AVIATION

With 214,000 aircraft, the GA fleet is two orders of magnitude larger than the commercial fleet (2,541). Some 79 percent of the GA fleet are single-engine aircraft, most of which rarely fly under IFR. The automation of Flight Service Stations is expected to provide benefits to GA users—notably, improved weather information. Small aircraft operating under VFR would probably utilize few of the other new ATC services.

The plan states that after 1990, aircraft will have to be equipped with Mode S transponders to fly above 12,500 ft. After 2000, transponders would be required above 6,000 ft in order to receive ATC services.

For the majority of the GA fleet, operating under VFR, the transponders will serve only to mark their positions electronically. They will not receive the other services available to IFR aircraft. Though the 1982 NAS Plan makes the decision to equip voluntary, the GA pilot who does not have a transponder will find the volume of the airspace available to him becoming smaller. Altitude restrictions will, according to some GA representatives, force many fliers that would prefer VFR to fly IFR in order to avoid delays and unattractive routings or to gain access to more airports.

Owners of GA aircraft who wish to make full use of the ATC system may want to equip with TCAS and Microwave Landing System (MLS) avionics. The cost of this equipment will not be onerous for owners of multiengined business aircraft, who are generally eager to modernize their airborne electronics and avail themselves of the full range of ATC services. However, the single-engine operator would get a relatively small return for an avionics investment that might cost several thousand dollars.

DEPARTMENT OF DEFENSE

The Department of Defense (DOD) is both a major user and joint administrator of the national airspace. Yet, the 1982 NAS Plan appears to have been developed without prior consultation with DOD. Concern has been expressed about the effect of planned FAA actions on the interface between military and civil ATC systems. In addition, some of the improved services that FAA plans to provide may either be irrelevant to the military mission or impose more costs than benefits on the military users.

DOD controls a significant amount of the airspace. DOD's 8,000 controllers and 231 ATC facilities handle civil as well as military traffic in their sectors, and their role has increased since last summer's PATCO strike. The NAS Plan does not make clear how future upgrading and consolidation of centers and communications facilities will affect the military role or the required compatibility between military and civil ATC systems.

The military forces also have the responsibility to defend from airborne intrusion. Some FAA-owned primary radars are used for this purpose by DOD under a joint surveillance system. FAA plans to phase out these primary radars by 2000, when most of the domestic fleet is expected to be equipped with Mode S transponders. However, primary radars will still be needed for defense surveillance, and the manner of their replacement is not made clear in the proposed plan.

Military aviation accounts for about 20 percent of all ATC operations in the continental United States. (This includes ATC services provided by military facilities for civil as well as military aircraft.) Although the percentage of this traffic handled by FAA en route centers is small (16 percent) on average, it is substantial in some regions. For example, military flights account for 46 percent of en route handles at the Albuquerque center. The high concentration of military flights in certain regions makes it necessary for FAA to coordinate carefully with the military, since any planned relocation of bases or training areas could greatly affect FAA's projection of future traffic volume at selected centers.

Military use of domestic airspace is mainly for training missions, not point-to-point transportation. This means that high-performance aircraft sometimes operate at low altitudes, sharing airspace with slow-moving GA aircraft operating under VFR. See-and-avoid procedures do not work well in these circumstances, and a recent Air Force survey found that 87 percent of reported near-collisions occurred at altitudes below 7,500 ft in uncontrolled airspace. At present, Flight Service Stations (FSS) advise GA pilots of military activity only on request, and there is no indication in the plan that an improvement of this procedure is planned as part of FSS automation. Future FAA plans to put a "floor" of 6,000 ft on secondary surveillance radar mean that problems of separating military and GA traffic at low altitudes will continue into the future. Some means to provide radar coverage down to 1,000 or 2,000 ft would allow more military flights to operate under IFR and to rely on ATC for separation from VFR traffic.

FAA's plans for secondary surveillance radar depend on aircraft being equipped with Mode S transponders. The military services have reservations about this new avionics equipment because it is of doubtful value to the military. Although TCAS might have value in warning military aircraft of the proximity of other TCAS-equipped aircraft, it will be of no value in protecting against unequipped aircraft, as many small GA aircraft at low altitude are likely to be. The Mode S transponder would offer some advantage to military aircraft when they operate under IFR in the domestic airspace, but it would in no way improve their combat capability.

DOD estimates the cost to equip military aircraft with Mode S alone will exceed $1 billion. These costs, which will ultimately be borne by the general taxpayer, must be balanced against whatever benefits Mode S has for the civil system. Costs to equip military aircraft with TCAS will also be high. Further, TCAS has little military utility, and concern has been expressed that the TCAS antenna could actually interfere with the aerodynamic performance of certain tactical aircraft.

COST AND FUNDING ISSUES

The costs of implementing the 1982 NAS Plan over the next 5 years would lead to substantial increases in the FAA budget for facilities and equipment (F&E) and research, engineering, and development (RE&D). According to budget estimates supplied by FAA and OMB, the F&E costs for the period fiscal year 1983 to fiscal year 1987 would amount to about $5.2 billion (constant 1982 dollars). The RE&D costs would be $942 mil-Iion (see table 3).

Table 3.–FAA Budget Estimates, Fiscal Years f983-87

	Funding by fiscal year (in millions of dollars)[a]					
Budget category	1983	1984	1985	1986	1987	1983-87
Facilities and equipment	725	1,393	1,407	1,271	1,270	6,066
	(684)	(1,252)	(1,207)	(1,022)	(1,022)	(5,187)
Research, engineering, and development	134	286	269	204	204	1,097
	(126)	(257)	(231)	(164)	(164)	(942)
Airport aid	450	450	450	450	450	2,250
	(425)	(404)	(386)	(361)	(361)	(1,937)
Operation and maintenance	2,550	2,578	2,627	2,677	2,727	13,159
	(2,406)	(2,316)	(2,254)	(2,168)	(2,168)	(11,312)
All other	45	53	53	53	53	257
	(42)	(48)	(45)	(43)	(43)	(220)
Total	3,904	4,760	4,806	4,655	4,704	22,829
	(3,683)	(4,277)	(4,123)	(3,758)	(3,757)	(19,598)

[a]The first figures listed are current dollars; those beneath in parenthesis are 1982 constant dollars based on FAA-assumed inflation rates of 5.7 percent in fiscal year 1983, 4.7 percent in fiscal year 1984, 4.6 percent in fiscal year 1985, and 3.5 percent in fiscal years 1986 and 1987.

SOURCE: FAA and OMB budget estimates.

A comparison of these projected costs, on an annualized basis, with those of the period fiscal years 1971-80 is shown in table 4. Future F&E costs would be slightly over twice the historical level, in constant-dollar terms; and RE&D costs would be 50 percent higher. Cost estimates for the NAS Plan in the years beyond 1987 have not yet been released by FAA, but it seems likely that annual expenditures of roughly equal magnitude would be needed through the early 1990's in order to complete modernization of the ATC system, install a new communication network, and upgrade air navigation facilities.

Table 4.—Past and Future FAA Expenditures

	Average annual expenditures (millions of dollars)	
	Actual 1971-80[a]	Projected 1983-87[b]
Facilities and equipment	463	1,038
Research, engineering, and development	124	188
Airport aid (ADAP)	673	387
Operation and maintenance	2,564	2,263
All other	62	44
Total	3,886	3,920

[a]Based on FAA appropriations for fiscal years 1971 to 1980, converted to constant 1962 dollars.
[b]Based on FAA and OMB estimates.

USER FEES

Although the NAS Plan does not address matters of funding directly, subsequent statements by the administration tie implementation of the Plan very closely to funding issues. FAA Administrator Helms has indicated that the success of the Plan depends heavily upon securing a long-term funding commitment at the outset. The proposed method of assuring a stable and reliable source of funds is a system of user fees that would recover 85 percent of the FAA's future capital and operating costs from those who receive ATC services. This proposal is based on the general view of the administration that beneficiaries of Government services should pay the costs incurred in providing those services.

In essence, the system of user fees proposed by the administration would reestablish the excise taxes that were levied on airspace users under the Airport and Airway Development Act of 1970, which expired at the end of fiscal year 1980. The current proposal would reauthorize revenue deposits to the Airport and Airway Trust Fund and institute the following user fees:

- 8 percent passenger ticket tax;
- 5 percent freight waybill tax;
- $3. 00 international departure tax;
- general aviation gasoline tax of $.12/gallon for fiscal year 1982-83 and rising thereafter at $.02/year until reaching $.20/gallon in fiscal year 1987; and
- general aviation jet fuel tax of 140/gallon for fiscal year 1982-83 rising at 2@/year to 22Q/gallon by 1987.

Initial OMB estimates, published in February 1982, indicated that these tax schedules would lead, by 1987, to full recovery of the 85-percent share of FAA costs allocated to civil aviation.[4] Later figures released by FAA and OMB in April 1982 contained an increase of about $2 billion in projected FAA expenditures related to the NAS Plan for the period fiscal years 1983-87.[5] However, it was estimated that 85-percent cost recovery could still be achieved by the proposed taxes if coupled with a drawdown of about $2.2 billion from the uncommitted balance in the Airport and Airways Trust Fund (table 5).

[4]*Major Themes and Additional Budget Details, FY* **1983** (Washington, D. C.: Office of Management and Budget, Feb. 8, 1982), pp. 228-229.

[5]Estimates presented by FAA Administrator Helms to the Transportation Subcommittee of the House Committee on Appropriations, Apr. 20, 1982.

Table 5.—FAA Budget and Cost Recovery, Fiscal Years 1983.87

	Current dollars by fiscal years (in millions)					
	1983	*1984*	*1985*	*1986*	*1987*	*1983-87*
Budget authority.	3,904	4,760	4,806	4,655	4,704	22,829
User fee revenues:[b]						
Current law	1,474	1,670	1,878	2,108	2,344	9,474
Proposed increases.	1,187	1,350	1,548	1,742	1,946	7,773
Total.	2,661	3,020	3,426	3,850	4,290	17,247
Trust Fund drawdown.	657	1,026	659	107	(292)'	2,157
Cost recovery (percent):						
Current law	38	35	39	45	50	41
With proposed increases	68	63	71	83	91	75
With trust fund drawdown (return)	85	85	85	85	85	85

SOURCES: [a]**FAA and** OMB estimates presented to Transportation Subcommittee, House Committee on Appropriations, Apr. 20, 1982.
[b]OMB ,, Major Themes and Additional Budget Details, Fiscal year 1983" February 1982
[c]Return to Trust Fund.

COST ALLOCATION

A more detailed analysis of the cost recovery from proposed user fees (shown in table 6) indicates that the burden of costs recovered would not fall equally on each class of airspace user. The costs recovered from air carriers through the passenger ticket tax, international departure tax, and freight waybill tax would vary from 104 to 148 percent of the share of costs allocated to them by FAA. The proportion recovered from GA users would be between 12 and 20 percent of their allocated share. Thus, GA would receive a substantial cross-subsidy from airline passengers and shippers of air freight. Within GA, the principal beneficiaries of this cross-subsidy would be that part

Table 6.—Cost Recovery Under the Administration's Proposed User Fees (in millions of dollars)

	Fiscal year					
	1983	1984	1985	1986	1987	1983-87
Air carrier share (58 percent of FAA costs):						
Allocated share under FAA-proposed budget	2,264	2,761	2,787	2,700	2,728	13,240
Revenue under proposed user fees[a]	2,530	2,863	3,237	3,631	4,035	16,296
Cost recovery (percent)	112	104	116	134	148	123
Generail aviation share (27 percent of FAA costs):						
Allocated share under FAA-proposed budget	1,054	1,285	1,298	1,257	1,270	6,164
Revenue under proposed user fees[b]	131	157	189	219	255	951
Cost recovery (percent)	*12*	*12*	*15*	*17*	20	15
Total cost recovery from civil aviation (percent)	*68*	*63*	*71*	*83*	*91*	*76*

aMade up of 8 percent ticket tax(air carriers and Cornrnuters), 5 percent freight waybill tax, and $3 international departure 'ax

[b]Made up of taxes on gasoline and jet fuel.

SOURCES: OMB, "Major Themes and Additional Budget Details, Fiscal Year 1983," February 1982. FAA estimates presented to Transportation Subcommittee, House Committee on Appropriation, Apr. 20, 1982.

of the business and corporate aircraft fleet consisting of turboprop and turbojet aircraft. These aircraft, which now number about 7,600, or twice the air carrier fleet, operate in the ATC system much of the time and are used in a manner similar to air carriers-point-to-point flights, into and out of major airports, under IFR, and receiving full ATC services. The business and corporate aircraft segment now constitutes about 60 percent of all GA traffic that uses the IFR system and represents 30 to 35 percent of the total workload at FAA towers and en route centers. By the early 1990's, FAA projects that GA turboprops and turbojets will make up about 45 percent of the ATC facility workload. (Air carriers will make up 30 percent, other GA 15 percent, and military 10 percent.)

The administration advocates full recovery of allocated costs from each class of airspace user as a principle of taxation. However, even allowing for the imprecision of the methodology of cost allocation and revenue projection, the user fees proposed by the administration do not accomplish parity of cost recovery. A passenger ticket tax of 6.5 percent, not the proposed 8 percent, would be sufficient to produce full recovery of the commercial aviation share. For GA to pay a share roughly proportionate to the burden it places on FAA facilities, the combined gasoline and jet fuel taxes would have to be five to six times higher than the current administration proposal. Organizations of general aircraft owners and manufacturers point out that such an increase, even if phased in over several years, would have a severely depressing effect on the use and purchase of GA aircraft.

The administration's proposal is likely to be contested by airspace users on several grounds. First, there is strong disagreement by civil aviation groups about what share of FAA costs should be allocated to users and what share should be treated as a general public benefit. Their contention is that the 85-percent share allocated to users is excessive because the public benefit of the National Airspace System is much higher than 15 percent—perhaps more on the order of 20 to 30 percent if one includes the general benefits of the air transportation system. Thus, they would argue for cost recovery from civil users of roughly 70 to 75 percent of FAA costs—not the 85 percent assumed in the current administration proposal.

Second, there is also dispute about the allocation of costs between commercial and general aviation. The owners and operators of small propellor aircraft weighing under 12,500 lb contend that they make very little use of the IFR system and therefore should be charged only for the lesser services they receive under VFR.* The 1978 cost allocation study by FAA took the small aircraft owners' position into account and offered an alternative cost allocation scheme (called the "minimum services method") that reduced the overall GA share to 13 percent with the balance allocated to the general public as society's cost of maintaining a safe national airspace system.[b]

While business and corporate aircraft operators generally oppose the concept of differential taxation based on their more extensive use of the IFR system, it is precisely this small percentage of the GA fleet that is responsible for the largest projected increase in the demand for ATC services. The turbine-powered portion of the GA fleet, virtually all of which are flown for business purposes, is forecast by FAA to grow from 7,600 to 15,700 planes by 1993. The growth of business aviation activity is primarily responsible for GA projections of near-term capacity problems at en route centers.

If equitable cost recovery is to be the principle, a cost allocation formula should take into account significant differences in the burden placed on the ATC system by the various segments of the GA fleet. The administration proposal does not do so, except that the tax on jet fuel is 2a/gallon higher than the tax on aviation gasoline. In selecting the proposed scheme, the administration seems to be hewing close to the system of taxation that existed under the previous Airport and Airway Development Act, taxes which are familiar and generally acceptable to the civil aviation community. The alternative of seeking to resolve the issue of cost recovery in a more equitable, but less familiar way, would likely make the administration's proposed user fees even more controversial.

● The Aircraft Owners and Pilots Association, for instance, estimates that only 5 percent of the GA flights are under IFR and that the average flight time for GA aircraft that do fly IFR is roughly 30 minutes, compared with 1 hour 23 minutes for air carriers.

[b]*Financihg the Airport and Airway System: Cost Allocation and Recovery, FAA-AW-78-14* (Washington, D. C.: Federal Aviation Administration, November 1978).

ALTERNATIVE METHODS OF TAXATION

Other methods of levying user charges are possible: either fees based on the actual use made of the ATC system or an annual tax based on aircraft characteristics and avionics equipment.[7]

Participants in the OTA Conference on the National Airspace System Plan flatly ruled out direct user charges as unworkable. OTA does not agree. By means of the present ATCRBS transponder it is possible to identify uniquely each aircraft using the ATC system, continuously monitoring each plane from takeoff to landing. This capability would be enhanced by the future Mode S transponder. The data generated by either of these transponder systems could provide the Government with a detailed record of the services received by each aircraft. Owners could then be billed for what they used.

Toll roads provide a rough analogy. Charges on those highways are usually based on the distance traveled and the number of axles on the vehicle, a factor which approximates the burden placed on the road surface by vehicle weight. Data generated by the ATCRBS or Mode S transponders could conceivably provide the FAA with a record of the time each transponder-equipped aircraft is in the system. From that information, FAA might develop a basis for "toll charges" and collections. Computers now make it possible for persons to make a call from any of the 170 million telephones in the United States and to pay for the charges on their own phone bill a month later. Social Security mails monthly checks to over 35 million recipients, either directly or to their banks. So, before some form of direct billing is completely ruled out, FAA should determine whether the modern technology of transponders and computers could be utilized to make direct user fees a practical alternative to excise taxes.

Another possible mechanism for levying user charges is a yearly tax on aircraft by weight, number of engines, or avionics equipment. The price

These alternatives are discussed inch. 7 of the OTA report, ***Airport and Air Traffic Control System, OTA-STI-175,*** January 1982.

of admission to the future ATC System will be sophisticated avionics (Mode S, TCAS, MLS) to complement the ground-based system. Taxing that equipment could provide FAA with an alternative means of financing ATC services.

While the idea merits further inquiry, there are at least two concerns to be overcome. First, a tax on avionics equipment would not be a tax on avionics use. The charge would be the same whether an airplane flew 200 or 2,000 hours a year and whether it used the advanced equipment or not. From the user's point of view, there would be no direct link between services received and taxes paid. Still, it is not unreasonable to assume that aircraft carrying certain avionics will make use of that equipment to receive ATC services and, hence, that a tax on avionics would be an economically efficient way to recover the costs of providing services.

Another concern, voiced by several OTA conferees, is that raising the price of admission to the ATC system could have a negative effect on safety. The new avionics equipment is designed to make flying safer, and FAA hopes to induce GA owners to equip voluntarily by offering them more and better services. For example, weather is a factor in about 40 percent of all fatal aircraft accidents, and the Mode S data link is intended to bring automated and improved weather information to GA pilots who are equipped with these transponders. A tax that discourages avionics purchases could conceivably weaken the NAS Plan's principal goal: safety.

OTHER FUNDING ISSUES

There are several other issues that arise from the proposed user fees: the negative effect of fees on aviation growth, the disbursement of user revenues to cover operating and maintenance costs, and the disposition of the present uncommitted balance in the Airport and Airway Trust Fund.

The FAA's growth forecasts form an important part of FAA's justification for rapid modernization and expansion of the ATC system. Increased user fees, however, increase the price of commercial air travel and the costs to GA users. The effect of these cost increases could be to dampen the expected growth in civil aviation, perhaps by enough to alter significantly the forecast level of demand for services at FAA facilities. This, in turn, implies that ATC equipment and facilities to service this demand may not have to be as extensive as FAA expects or that they may not be needed as soon as now forecast. An analysis by FAA of the relationship between user fees and aviation growth would be a valuable aid to Congress in evaluating the proposed schedule for ATC system improvements.

The administration proposal calls for user fees to recover 85 percent of all FAA costs, including operation and maintenance (O&M) expenses, which make up about 60 percent of the FAA budget for the coming 5 years. In the past, airspace users have objected to funding O&M expenses through user fees on grounds that O&M costs include many items not directly attributable to operating the ATC system and that users should not be expected to bear these costs, which should be assigned to the general public. Figures ranging from 25 to 50 percent of O&M costs have been suggested by various user groups in the past as a reasonable upper limit of their proper share. Another objection, which pertains only to user fees collected under the previous Airport and Airway Development Act, is that use of Trust Fund revenues to cover O&M costs violates the basic purpose of that Act, which was to fund capital improvements to airports and airways. Some users, who have opposed diversion of Trust Fund monies to noncapital expenditures in the past, might oppose the current Administration proposal unless the share to be used for O&M costs were negotiated specificall y and made contingent upon not reducing expenditures for capital purposes.

A third, and related, issue is how to spend the present uncommitted balance of roughly $3 billion in the Trust Fund. The administration proposal is to draw down this balance over the next 5 years, using it to supplement user fees in order to meet 85 percent of FAA expenses in all budget categories. This is an integral part of the overall plan to put FAA funding on a base whereby users pay their full allocated share of all ATC system costs. On the other hand, aviation user groups argue that this would not be consistent with the purpose for which the Trust Fund was established.