Chapter 2

INTRODUCTION AND OVERVIEW

Photo credit: Bill Osmun, Air Transport Association

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Chapter 2

INTRODUCTION AND OVERVIEW

BACKGROUND

The National Airspace System (NAS) includes about 6,500 public-use airports serving nearly all cities and small communities in the United States. Connecting these airports is a network of air routes, defined by navigational aids, that channeI the flow of traffic. Flight along these routes, as well as operations in the terminal areas surrounding airports, is monitored and controlled by a system of ground-based surveillance equipment and communication links—the air traffic control (ATC) system.

With two exceptions (Washington National Airport and Dunes International Airport), * U.S. airports used by commercial flights are owned and operated by local, regional, or State authorities. Many general aviation (GA) aircraft also use these commercial air carrier airports, but most are served by smaller public airports and by roughly 10,000 privately owned fields. The air route system and the ATC system are operated by the Federal Aviation Administration (FAA), which has responsibility for assuring the safe and expeditious movement of aircraft in U.S. airspace and contiguous areas. FAA is also responsible for coordinating the use of airspace shared by military and civil aviation.

In all, the NAS accommodates about 180,000 operations (takeoffs and landings) per day at airports with FAA control towers, or roughly 66 million per year. Of these, 22 percent are commercial flights (scheduled air carrier, commuter, and air taxi), 74 percent are general aviation, and 4 percent are military. Most of the commercial operations are concentrated at the top 66 airports, which account for over 77 percent of commercial operations and 88 percent of passenger enplanements. Within this group, airline traffic is even more highly concentrated at a few major hubs. As shown in figure 1, the 10 largest hubs handle 33 percent of all operations and 47 percent of all passengers.[1]

*Washington National and Dunes International are owned by the Federal Government and operated by the FAA.

[1]FAA Statistical ***Handbook of Aviation, Calendar*** Year 1980 (Washington, D. C.: Federal Aviation Administration, 1981), passim.

TRENDS AND FORECASTS

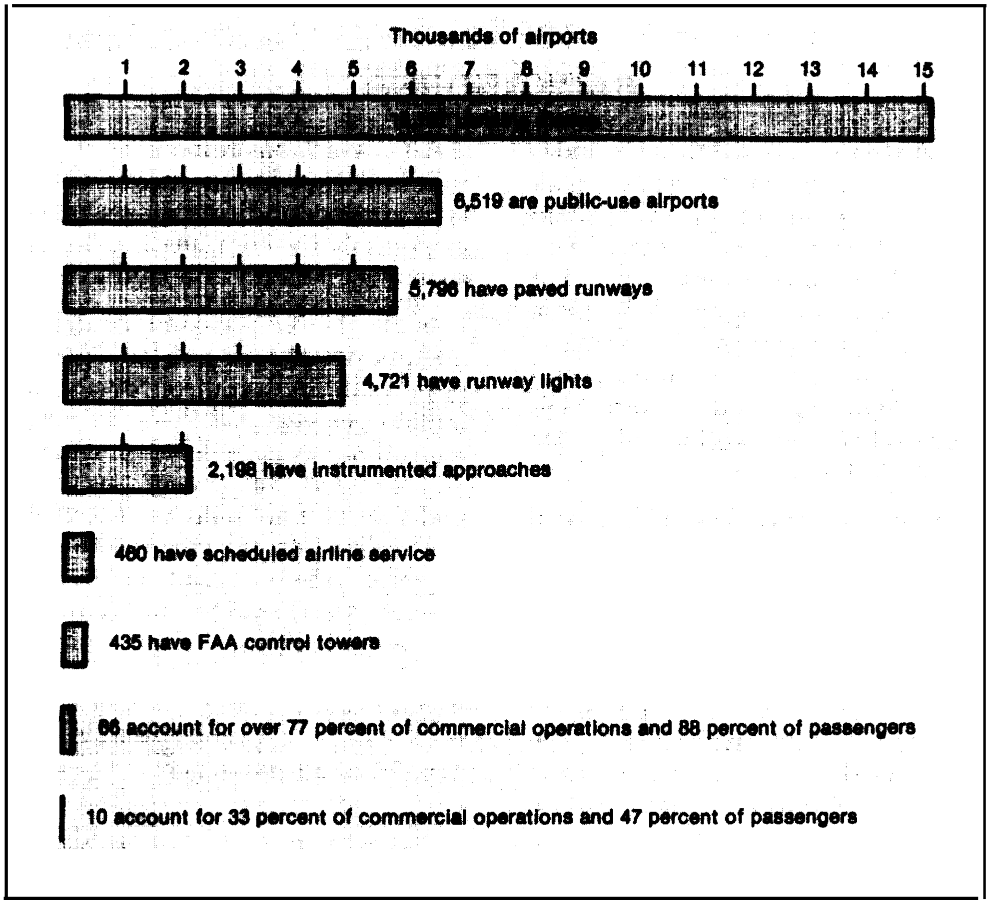
The use of NAS, as measured by aircraft operations at airports with FAA towers, has grown at an annual rate of about 4 percent in recent years, due almost entirely to the rapid growth of the GA sector.[2] FAA expects the rate of growth to slow to about 3 percent per year in the next decade, but this would still mean that the congestion now experienced at the 5 or 10 largest airports may spread to 10 or 15 additional airports by the year 2000. This growth would also lead to substantial increases in the workload of the ATC system. FAA workload forecasts indicate that there may be both capacity* and safety problems arising from the growth in demand for ATC services, problems that will not be confined to major airports or commercial operations. Projections show the demand for ATC services by GA users could increase by as much as 70 percent over the next 10 years.

The accuracy of these forecasts depends on factors that are difficult to predict reliably, For example, the growth in aviation is extremely

[2]***FAA Aviation Forecasts, Fiscal Years*** 1981-1992 (Washington, D. C.: Federal Aviation Administration, 1980), passim.

*In a general sense, capacity refers to the number of aircraft that can be ***safely*** accommodated in a given period of time. ***Airport capacity*** is defined as the maximum number of aircraft operations (takeoffs and landings) that can be accommodated in a given period of time on a given runway (or set of runways) under prevailing conditions of wind and weather and in conformance with established procedures for maintaining safe separation of aircraft. Similarly, ***airspace capacity*** is defined as the maximum number of flights that can be allowed to pass through a volume of airspace during a given period of time without violating minimum separation standards.

Figure 1.—Profile of U.S. Airports, 1980[a]



[a]Includes heliports, STOL ports, seaplane bases, and military-civil joint.use fields, excludes facilities in Puerto Rico, Virgin Islands, and Pacific Territories.

SOURCE *FAA Stat/s tical Handbook, 7980*

sensitive to the state of the national economy. The price and availability of fuel could be a serious constraint on all classes of aviation. The long-term effects of airline deregulation are uncertain but they could have an important influence on the profitability and competitive structure of the industry. Thus, while there is a consensus that air activity as a whole will continue to grow, it is not certain how much growth to expect, where it will occur, or what strategies should be adopted to accommodate it. It does seem clear, however, that growth of aviation, even at a rather slow rate, gives rise to concern about future airport capacity, terminal area congestion, and the safety and efficiency of the ATC system.

Photo credit: Bill Osmun, Air Transport Association

A **crowded terminal**

THE AIRPORT CAPACITY PROBLEM

Concentration of air traffic at a few large hubs, brought about by the economics of air transportation and by the general increase in air travel, creates congestion and delay. * The cutback in scheduled flights following the air traffic controllers' strike has caused the problem to abate temporarily, but congestion can be expected to recur when operations return to normal levels, and with it the associated problem of safely handling a growing volume of air traffic. Congestion results in delays that increase airline operating costs and, ultimately, the cost of air travel for the public. If fuel prices increase, the cost of these delays will become magnified. Commuter airlines and air taxi services are even more vulnerable to delay costs than trunk airlines, since they have a much smaller base of passengers across which to spread these costs.

*Delay occurs whenever aircraft must wait beyond the time they are scheduled to use an airport or a sector of airspace. In practical terms, delay is usually defined as occurring whenever some percentage of aircraft must wait longer than a specified period of time, e.g., 80 percent of the aircraft must wait 4 minutes or longer. Congestion occurs as demand (the desired number of operational approaches capacity. An increasing number of aircraft seeking to use an airport or an airspace sector at the same time causes queues to build up among aircraft awaiting clearance to proceed.

GA users of major hubs also feel the effects of delay in the form of restrictions on access to busy airports imposed during peak hours to deal with congestion.

Expanding airport capacity, either through construction of new airports or enlargement of existing ones, is an obvious but far from easy solution. The availability of land for airport expansion is severely limited in major metropolitan areas, and the cost of available land is often prohibitive. There is also rising community resistance to airport expansion and construction on the grounds of noise, surface congestion, and the diversion of land from other desired purposes. Even where these obstacles could be overcome, increasing capacity by building a new airport is at best a long-range solution—the leadtime from conception to beneficial use of a new airport is often a decade or more.

To deal with the problem of congestion in the near term, and in a less capital-intensive way, two management approaches may be used. One is to shift some of the demand for use of the airport from peak to off peak hours by administratively imposing quotas or by applying differen-

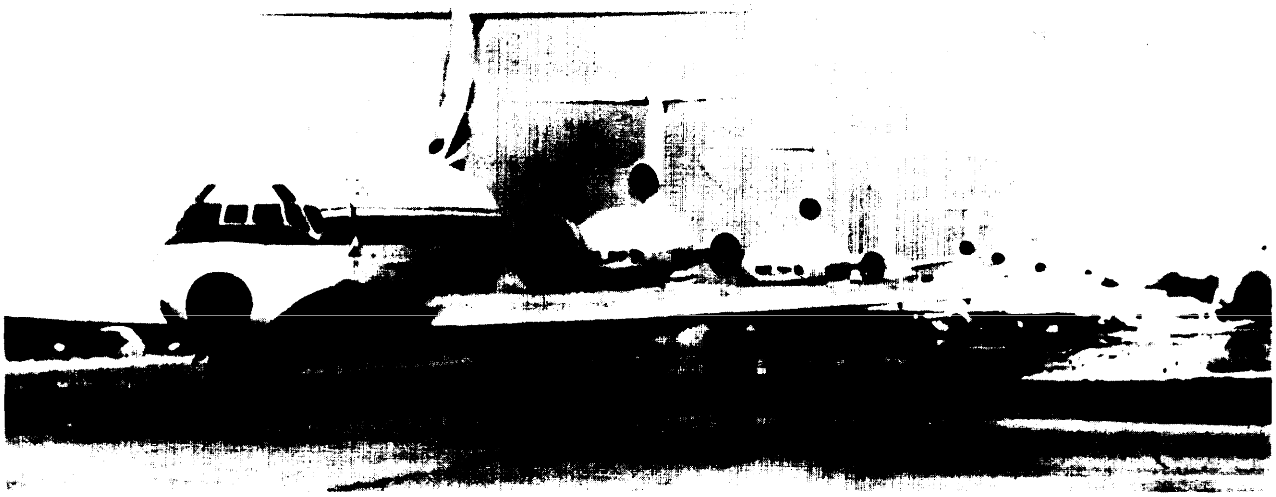


Photo credit: Neal Callahan

Congestion and delay

tial pricing for airport access according to the time of day. This solution tends to work to the advantage of major air carriers and against the commuter and air taxi operators, and even more heavily against GA users, who complain that quotas or peak-hour pricing might effectively preclude them from using major airports at all. An alternative strategy is to divert some traffic to another airport—for example, from a large metropolitan hub to GA reliever airports in the vicinity. In several cities the problem is not a general shortage of capacity but a disproportionate demand at one airport, while excess capacity exists at nearby airports that could serve as satellites or relievers. The difficulty arises in determining who is to be diverted, since few potential users of reliever airports would willingly accept diversion, especially if it imposes inconvenience or extra cost. One way to make diversion more attractive would be to improve the ground transportation links between hubs and reliever airports.

The intractability of the congestion problem and the difficulties of increasing airport capacity or making more efficient use of capacity through managerial techniques have prompted some people to look to the ATC system for an alternate solution. Through procedural changes or technological improvements, the ATC system might be able to make more efficient use of the airspace in crowded terminal areas, thereby expediting the flow of traffic to and from runways.

THE ATC PROBLEM

The task of controlling air traffic in congested terminal areas is greatly complicated when traffic consists of a mixture of large and small, piston and jet aircraft. Arriving and departing traffic, which is descending and climbing along various paths and at different speeds to and from en route altitudes, may consist of a combination of IFR and VFR traffic. * This traffic mixture is inherently difficult to manage. Efficiency dictates that aircraft be moved to and from the runway as expeditiously as possible and that gaps in traffic be kept to a minimum. Safety, on the other hand, requires a regular traffic pattern to prevent conflicts, and a minimum safe separation distance to prevent fast aircraft from overtaking slower ones. Air turbulence in the form of wake vortices,** which are more severe behind heavier aircraft, requires even greater separation between aircraft than would be needed if all were a uniform size. The overall result is that ATC procedures necessary to assure safety and to manage the workload also contribute to delays in terminal areas.

Technological improvements to the ATC system could help make fuller use of the physical capacity of the airport and reduce controller workload. Among these improvements are new surveillance, communication, navigation, and data processing equipment that could enhance the controllers' ability to separate and direct traffic. The Discrete Address Beacon System (previously know as DABS and now designated as Mode S) is a new generation of radar equipment that permits aircraft to be interrogated individually for information about identity, position, and altitude. Mode S also provides a two-way data link that could reduce dependence on the present voice radio channels and provide a much more rapid and extensive exchange of information between air and ground. Various forms of proposed airborne systems to detect and avoid potential collisions would provide a supplement to present separation assurance techniques and reduce some of the controller's burden in handling a high volume of traffic. It may also be possible to provide computer analysis of flight plans in advance that would help resolve conflicts in terminal areas, expedite traffic flow, and permit more direct and fuel-saving routing from origin to destination. Another proposed improvement is the addition of special cockpit displays that would provide a picture of

"Aircraft operating under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR).

**Eddies and turbulence, generated in the flow of air over wings and fuselage, can upset the stability of following aircraft. Wake vortices, which are invisible, cannot now be accurately detected, and their movement and duration cannot be reliably predicted.

traffic in terminal areas and thereby permit pilots to cooperate more effectively with the controller or to assume some of the controller's present responsibility for separation assurance and determining flight path in terminal areas. Finally, the Microwave Landing System (MLS) would not only improve the ability to land in conditions of severely reduced visibility, but also permit multiple or curving approach paths to the runway instead of the single-file, straighten approach required with the present Instrument Landing System (ILS). In the longer term, proposed new ATC technology might replace the present system of ground-based radar and radio navigation and surveillance capabilities.

These proposed improvements, if adopted, would require very large investments over the next two decades. These investments would be made by the Federal Government, but some of the funds could be provided by taxes on airspace users, who might also have to purchase new avionics equipment to supplement or replace what they already have. Managing the transition to a new generation of ATC would also require careful attention, both to assure continuity of service and to avoid the penalties of excessive cost or unexpected delay. It therefore seems especially important to select an evolutionary path that does not foreclose options prematurely and does allow flexibility in the choice between competing technologies.

These prospective ATC improvements raise important issues for airspace users. If the required new avionics systems become mandatory for access to terminal areas or for general use of controlled airspace, some GA, small commuter,

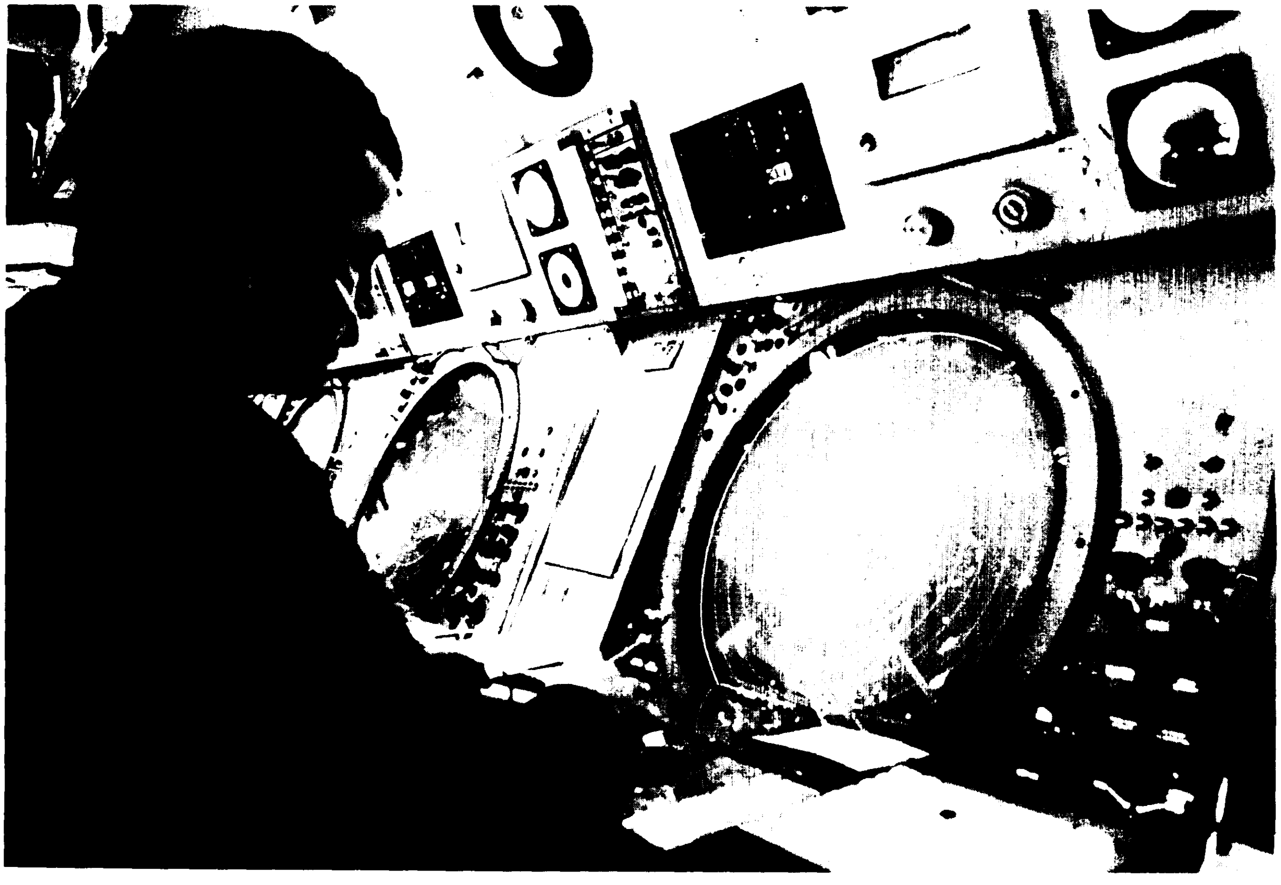


Photo credit: Federal *Aviation Administration*

Air controller and screen

and air taxi operators may find the cost prohibitive. New civil aviation requirements may not be entirely compatible with the missions or capabilities of military aircraft that share the airspace. There will probably be pressure to prolong the transition period and to retain as much of the present system as possible. Some possible improvements might ultimately have to be rejected, despite of their potential for increasing capacity or enhancing safety, because of the cost to users or infringement of the right of access to the airspace.

THE COMMITTEE REQUEST

Concerns about these problems and about te feasibility and cost of proposed solutions prompted the House Committee on Appropriations, Subcommittee on Transportation, to request that OTA undertake an assessment of airport and terminal area capacity and related ATC issues. Subsequently, the Senate Committee on Commerce, Science, and Transportation also expressed interest in these issues and endorsed the request of the House Committee on Appropriations.

Specifically, the Committee on Appropriations requested that OTA make an independent assessment in four major areas:

- scenarios of future growth in air transportation;
- alternative ways to increase airport and terminal area capacity;
- technological and economic alternatives to the ATC system modifications proposed by FAA; and
- alternatives to the present ATC process.

OTA's APPROACH

This assessment considers the growth of air transportation over the remainder of this century. Particular attention is given to large hub airports, where most of the congestion and delay is expected to occur. For the ATC system, the assessment focuses on improvements that would affect the safety and capacity of terminal airspace, but developments in other parts of the ATC system (en route and flight information services) are also considered, Effects of these changes on airspace users (commercial operators, passengers, general aviation, and the military services) are also examined. Policy options and alternative development plans are identified and analyzed.

The results of this assessment are presented in the following five chapters:

Chapter 3. Description of the functions, organization, and operation of NAS with emphasis on ATC.

Chapter 4. Analysis of possible long-range trends in air activity and the effect they might have on technical, investment, and management decisions.

Chapter 5. Examination of prospective new technologies and organizational alternatives for the ATC system.

Chapter 6. Analysis of various ways to increase airport capacity and their advantages and disadvantages.

Chapter 7. Discussion of the policy implications that arise from alternative approaches to increasing airport capacity and improving the ATC system.

ISSUES

Expanding, improving, and maintaining the national system of airways, airports, and air traffic control has been an important objective of the Federal Government from the earliest days of aviation. There have been undeniable benefits to airspace users and the general public from the greater speed and regularity of air transportation and from the remarkable record of safety that has been achieved over the years. The rationale for Federal involvement in the development and operation of NAS has traditionally rested *on* two grounds: 1) promotion and regulation of interstate and foreign commerce; and 2) enhancement of the capability for national defense. It has been argued on both grounds that the Federal Government must take an active role to coordinate the development and to manage the operation of the system. The system that has evolved under Federal sponsorship and direction is not without its flaws, however, and some observers believe that future development should be directed along lines other than those of the past. Many of their concerns are embodied in the summary of major issues which follows; these issues will be treated in greater detail in subsequent chapters of the report.

Growth

There is basic agreement among aviation experts that civil aviation in the United States will continue to grow, thereby increasing the overall demand for airport use and ATC services. There is considerably less agreement about the rate of growth, the distribution among airspace users, the demands on various types of facilities and the kinds of services that will be required. As a result, there are sharp disputes about how to accommodate this growth or to influence the form and direction it may take.

FAA's projections have led it to conclude that severe capacity restrictions will manifest themselves in terminal areas and some parts of the en route system and that perhaps as many as 20 airports may be saturated by 2000. To accommodate this expected growth, the FAA proposes the addition of new airport capacity and ATC facilities designed to handle higher traffic volumes. However, past FAA forecasts have consistently projected higher rates of growth than have actually materialized, casting doubt on the current FAA forecasts and the expected demand for ATC services through the remainder of this century. Some observers see trends already developing in a different way. They argue that recent changes such as airline deregulation, the growth of commuter service, sharp rises in fuel cost, and slower economic growth will either dampen growth or cause it to develop in a pattern significantly different from that of the past. For example, one suggestion is that in an unregulated environment, market forces will cause a redistribution of traffic as users find that delay costs outweigh the benefits of operating at congested hub airports.

GA is the sector of aviation where growth has been the most rapid and where there is most serious concern about accommodating future demand. Twenty years ago, GA accounted for only a small fraction of instrument operations; today it represents slightly over half of all instrument operations at FAA facilities, and most forecast; show GA demand for ATC services increasing at rates far higher than those of commercial air carriers. Measures to restrict GA activity at major hubs or to divert it to reliever airports or offpeak hours are certain to be controversial. GA users feel that reservations, quotas, or differential pricing schemes, would unfairly deny them access to and use of the airspace system. On the other hand, some believe that GA flights into congested terminal areas should be limited because they typically carry very few passengers and so provide less public benefit than commercial aviation per operation or per unit of airspace use.

At a more general level, the prospects of traffic growth and capacity limitations raise the issue of strategic response to accommodating future demand. In the past, the approach has been essentially to accommodate demand wherever and whenever it occurred, i.e., the aim has been to foster growth in civil aviation. Some question whether this approach is still desirable, arguing that demand and the growth of air activity should be managed and directed in ways to make the most productive use of airspace and the most efficient use of existing facilities.

Basically, there are three forms of action that *can be taken to influence growth: regulatory,* economic, *and technological. Regulatory* actions include measures imposed by the Government that would control the use of the airspace or the availability of ATC services according to user class or types of activity. Economic measures are those that would affect the cost or price of using the airspace or that would allow market competition to determine access to facilities and services that are in high demand. Technological responses include not only improved forms of ground-based and avionic equipment to increase the efficiency of airspace use, but also increases in airport capacity through construction of new or improved landing facilities. *All three approaches are likely to be used, and the issue is not which to adopt but what combination and with what relative emphasis.* Ultimately, the choice of measures will reflect a more fundamental strategic decision about how to meet increasing demand. Chapter 4 presents a further discussion of future growth, and chapters 5 and 6 examine the various responses to growth.

Technological Improvements

The many technological improvements of the ATC system being contemplated by FAA fall into four classes:

- navigation and guidance systems;
- surveillance;
- communication; and
- process improvements.

These potential improvements have three major characteristics: 1) most are technologically sophisticated and require further development and testing before they can be operationally deployed; 2) they will entail very large expenditures by the Federal Government to put them in place and—in most cases—additional costs to airspace users who will have to equip their aircraft with special avionics; and 3) many years will be required for full deployment.

There are several controversial aspects of these technologies. First, there are purely technical and engineering questions that need to be answered: will these new systems work as intended, what are their advantages and disadvantages compared to existing technology, and how can their development be managed so that options are not foreclosed prematurely? As decisions are made and implementation proceeds, it will be necessary to coordinate the program carefully in order to provide an orderly transition and to avoid the costs that could result from delay or unexpected technical setbacks.

Beyond these technical and managerial matters, there are more fundamental questions about the role of FAA in planning and carrying out technological programs of this nature. Congress, for example, has questioned FAA's proposed handling of the program for modernization of its en route computer system, as have other members of the aviation community. They are concerned that FAA is not consulting adequately with specific user groups and not taking advantage of relevant expertise available outside the aviation community. Some of them foresee a time when air traffic may have to be curtailed simply because the technology to handle increased traffic with an acceptable level of safety has not been properly planned, developed, and deployed.

On the other side, there are those who defend FAA's general strategy for ATC modernization and approve the way in which particular technological programs are being handled. They argue that deployment must proceed at a cautious pace both because of the enormous uncertainties that must be overcome and because there must be continuity of operations throughout the transition. In their view, the potential consequences of abrupt changes or premature decisions are more serious and, in the long run, more harmful to aviation than temporary curtailments that may have to be imposed while technological difficulties are being resolved.

Chapters examines some of the technological issues surrounding proposed system improvements, and chapter 7 addresses strategy and policy options for managing the transition.

Control Philosophy

Perhaps the most fundamental issue underlying the proposed improvements in the ATC system is that of control philosophy—the principles that should govern the future operation of the system. The philosophy of the present system for controlling IFR traffic is embodied in three operational characteristics: the system is primarily ground-based, highly centralized, and places great emphasis on standardized (i.e., predict-able) behavior by airspace users. In contrast, VFR traffic has little contact with the ATC system, except with flight service stations and control towers at airports, and operates much as it did in the early days of aviation, even though it shares airspace with IFR traffic in some instances.

As ATC technology evolved the locus of decisionmaking under IFR began to shift from the cockpit to the ground. Routes were determined by the placement of ground-based navigation aids; surveillance was accomplished by reports to ground centers and later by search radar; and observers in airport towers began to direct aircraft in landing and takeoff patterns. As the density of air traffic increased, ground-based ATC personnel began to take more and more control over the altitude, route, and speed to be flown. To some extent this transfer of responsibility was the inevitable consequence of the technology employed, but organizational reasons also dictated ground-based control. Decisions concerning not the movement of individual aircraft but the pattern of traffic as a whole can best be made by a single person who is in a position to observe all flights operating throughout a volume of airspace over a span of time. Coordination and direction of several aircraft required that a single individual have authority over others—a role that the pilot of a single aircraft could not be expected to assume or that other pilots would accept.

Ground basing implies concentration of control at relatively few locations, and the trend has been for centralization to increase over time. Again, the reasons are both technological and organizational: centralization is organizationally advantageous because it consolidates functionally similar activities and allows technical specialization, both of which lead to greater efficiency and reliability of operation. For example, en route traffic in continental U.S. airspace is now controlled from 20 regional centers (ARTCCs, and proposed ATC system improvements would lead to even further consolidation, with en route and terminal control eventually merging into a single type of facility. A similar trend toward centralization can be observed in FAA's plans to consolidate flight service station activities at about 60 sites, compared to the present dispersion at over *300* locations.

Perhaps the best example of the trend toward centralization is the growing importance of the Central Flow Control (CFC) facility at FAA headquarters in Washington, D. C., which acts as a nerve center for the entire airspace system. With the aid of computers, CFC reviews the national weather picture and anticipated aircraft operations for the coming day and determines the incidence and cost (extra fuel consumed) of delays that could occur because of weather and air traffic demand. This results in a daily operational master plan that smooths demand among airports and allows delays to be taken on the ground at the point of departure rather than in holding patterns at the destination. The value of this capability was demonstrated when capacity quotas were imposed as a consequence of the August 1981 air traffic controllers' strike. CFC allowed a national airspace utilization plan to be developed, with detailed instructions to airports and en route centers on how to manage traffic and minimize the adverse effects of the capacity restrictions,

A system characteristic that accompanies ground-based centralization of control authority is standardization of performance. FAA operating procedures specify the behavior of pilots and controllers in every circumstance, which increases the reliability of system operation by reducing uncertainty and by routinizing nearly every form of air-ground transaction. Safety is the prime motivating factor, but capacity and efficiency are also highly important considerations. Controller workload is reduced when the range of possibilities they have to deal with is limited, and this in turn permits a given volume of traffic to be handled with less stress or, alternately, an increase in the number of aircraft each controller can safely handle. Either way, the efficiency of the ATC system (measured in terms of hourly throughput or controller productivity) is increased, with a corresponding reduction in system operating cost.

Despite the advantages of ground-basing, centralization, and standardization, there are complaints about the control philosophy of the present system. Pilots complain that a ground-based system detracts from their control over the conduct of the flight. Centralization may also be a problem if, by concentrating control facilities or flight services, the personnel on the ground are less able to provide particularized instructions or to take action based on localized knowledge of flight conditions. Standardization, by definition, limits the flexibility of response and the freedom to pursue individual or special courses of action.

The prospective changes in ATC technology are viewed with mixed feelings by airspace users and air traffic controllers. Technology that would increase the level of automation could, on one hand, promote greater centralization and standardization of control functions and could lead to increases in safety, capacity, or efficiency, On the other, automation could serve to increase ground authority still further and to reduce the flexibility of the system in dealing with nonroutine events. Technology like collision avoidance systems or cockpit displays of traffic information could give back to the pilot critical information (and hence control responsibility) and might enhance the pilot's ability to cooperate more effectively with the ground-based controller. At the moment, these devices are thought of as backups in the event of controller or system error, but their prospective use also raises the possibility of independent pilot actions that might contravene controller instructions or disrupt the overall pattern of traffic.

Chapter S, which deals with these and other forms of advanced aviation technology for ground-based and airborne application, treats the issues that arise from prospective changes in distribution of control between the air and the ground or from further centralization of ATC functions and services.

Freedom of Airspace Use

The rising demand for ATC services and the prospect of congestion at more and more major airports are the basic stimuli for many of the technological improvements and procedural changes now being sought by the FAA. However, the very measures that might ease capacity problems or assure the safety of high-density airspace are often controversial with some categories of users because they are perceived as infringements on their freedom to use NAS. GA users feel particularly threatened, but air carriers and commuter airline operators have also voiced concern. The military services as well are wary of some new forms of ATC technology and the procedures that may accompany their use because they may interfere with military missions or be incompatible with performance requirements for combat aircraft.

As the complexity of ATC technology has increased, so has the amount of equipment that must be carried on the aircraft and the amount of controlled airspace from which VFR flight is excluded unless the aircraft is equipped with a transponder to allow identification and tracking by the ATC system. Restrictions on airport use, especially at large and medium hubs, have also grown more confining for VFR flights, and the airspace around many of the busiest airports is now designated as a "terminal control area" in which all aircraft are subject to air traffic control and may operate only under rules and equipment requirements specified by FAA. GA, the principal user of the VFR system, finds itself pressured in several ways. Uncontrolled airspace is shrinking and may disappear altogether; it is becoming increasingly difficult to use metropolitan airports because of equipment requirements; and the cost of equipping the aircraft with IFR avionics and acquiring an instrument rating are often out of economic reach for the personal GA pilot. Prospective technological improvements—such as the Traffic Alert and Collision Avoidance System (TCAS), data link, or MLS—are viewed by many GA users as further restrictions on their access to airports and airspace. Many of them feel that, while this new technology may be desirable or even necessary for air carriers and larger business aircraft, it should not be required of all GA users or made a prerequisite for IFR services or access to commercial airports.

Commuter airline operators share some of these GA concerns. Virtually all commuter and air taxi operators are equipped for IFR operation and find their needs well served by the present

ATC technology. They see little further advantage in new technology and are concerned about the expense of having two sets of equipment serving the same purpose—advanced avionics needed for a high-density terminal at one end of the flight and present-day equipment that may be useful for many years to come at small community airports. They are also concerned that the more advanced avionics might eventually lead to more restrictive rules of operation or access to terminal areas. Thus, many commuter and air taxi operators would favor a dual-mode system that allowed them to retain their present IFR avionics even though more advanced forms were in use by other types of aircraft operators.

Military aviation operates under the civil ATC system in all shared airspace and under military control in areas restricted to military use. In flying through civil airspace to and from training areas, military aircraft must often follow circuitous routes or observe altitude and speed restrictions that lengthen transit time. The military services would prefer an arrangement that allows more direct access to training areas and avoids operation in mixed airspace. Air carriers have a different view: the most direct routes for trunk airlines are often blocked by restricted military areas, and the air carriers argue for procedures that would allow them to traverse these areas in the interest of shortening flight time and saving fuel.

Another issue has to do with new technology that might be adopted for civil aviation, which in most cases would be extra equipment for military aircraft. For combat aircraft, particularly fighters, the space for avionics and antennas is often at a premium. While careful coordination of military and civil requirements can eliminate some of these problems, certain basic incompatibilities are likely to remain and to produce continuing controversy.

The issues of freedom of airspace access and use are discussed further in chapters in connection with specific forms of new aviation technology.

Automation and Controller Functions

Despite the vast complex of ground-based equipment and facilities for surveillance, communication, and data processing, ATC remains a highly labor-intensive activity. FAA is keenly aware of this and has sought for some time to find ways to automate selected ATC functions. However, most of the automation that has been instituted so far has been to assist air traffic controllers rather than replace them. Decisionmaking and communication—two major elements of controller workload—have not been automated to any appreciable degree, and the ratio of controller work force to aircraft handled has remained relatively constant. In addition, the present method of backup to automated control functions involves reversion to manual procedures used in the previous generation of ATC equipment; this method of assuring service in the event of outages has tended to perpetuate the team size and staffing patterns of the previous generation.

Plans for an advanced generation of ATC call for automation of several manual controller functions: conflict prediction and resolution, terminal area metering and spacing, flight plan approval and issue of clearances, and communicating routine control instructions to individual aircraft. Such forms of automation could lead to substantial increases in controller productivity and might eventually provide the basis for a more extensively automated system in which most routine control functions are carried out by computers, with the human controller acting in the role of manager and overseer of machine operation.

This path of evolution raises three important groups of issues. First, there are questions about the feasibility and advisability of replacing the human controller to such an extent. ATC now relies heavily on judgment and awareness of the dynamics and subtleties of the air traffic situation. Some observers doubt that all of these characteristics could be dependably incorporated into computer software in the foreseeable future. The proponents of automation argue that much of the routine, repetitive, or predictive work of ATC is ideally suited to computers, and that an incremental approach to automation will help solve many of the problems since each new step can build on successful previous advances.

A second major set of issues is the reliability of automated systems and the backup methods to be used when the inevitable equipment failures occur. Experience with the present automated ATC equipment indicates that computer failure rates are a cause for concern, and the loss of computer-supplied data may mean that ground personnel lose effective control of traffic until manual backup procedures are instituted—a process that may take several minutes to complete. Computer experts maintain that equipment and software reliability can be greatly improved and that automated systems can be designed to be more failure tolerant. These experts also contend that present experience with manual procedures as backups to outages of automated equipment indicates a fundamental flaw in design philosophy because the proper backup to an automated system is not manual operation, but another automated system. Critics of automation question the acceptability of a system in which the human controller has no effective means of intervening in degraded states of operation.

A third issue is whether some of the responsibility that now resides with the ground-based system ought not to be transferred to, or at least shared with, the cockpit. A pilot in an aircraft equipped with an airborne collision avoidance system and a display of the immediately surrounding air traffic might be in a superior position to select the appropriate maneuver in case of conflict; in effect, such an airborne system would create a mode of IFR operation similar to the present VFR system. The chief disadvantage of this concept is that it could lead pilots to make a series of short-term tactical responses that might not be consistent with the overall scheme of managing traffic in congested airspace. In this case, the ground system would still have to act in the capacity of referee, and some contend that it would be better to keep all control of individual flight paths under one authority.

Chapter 5 contains a further examination of the issue of automation in connection with the discussion of the proposed en route computer replacement program and the mechanization of the Mode S data link and TCAS systems.

Funding and Cost Allocation

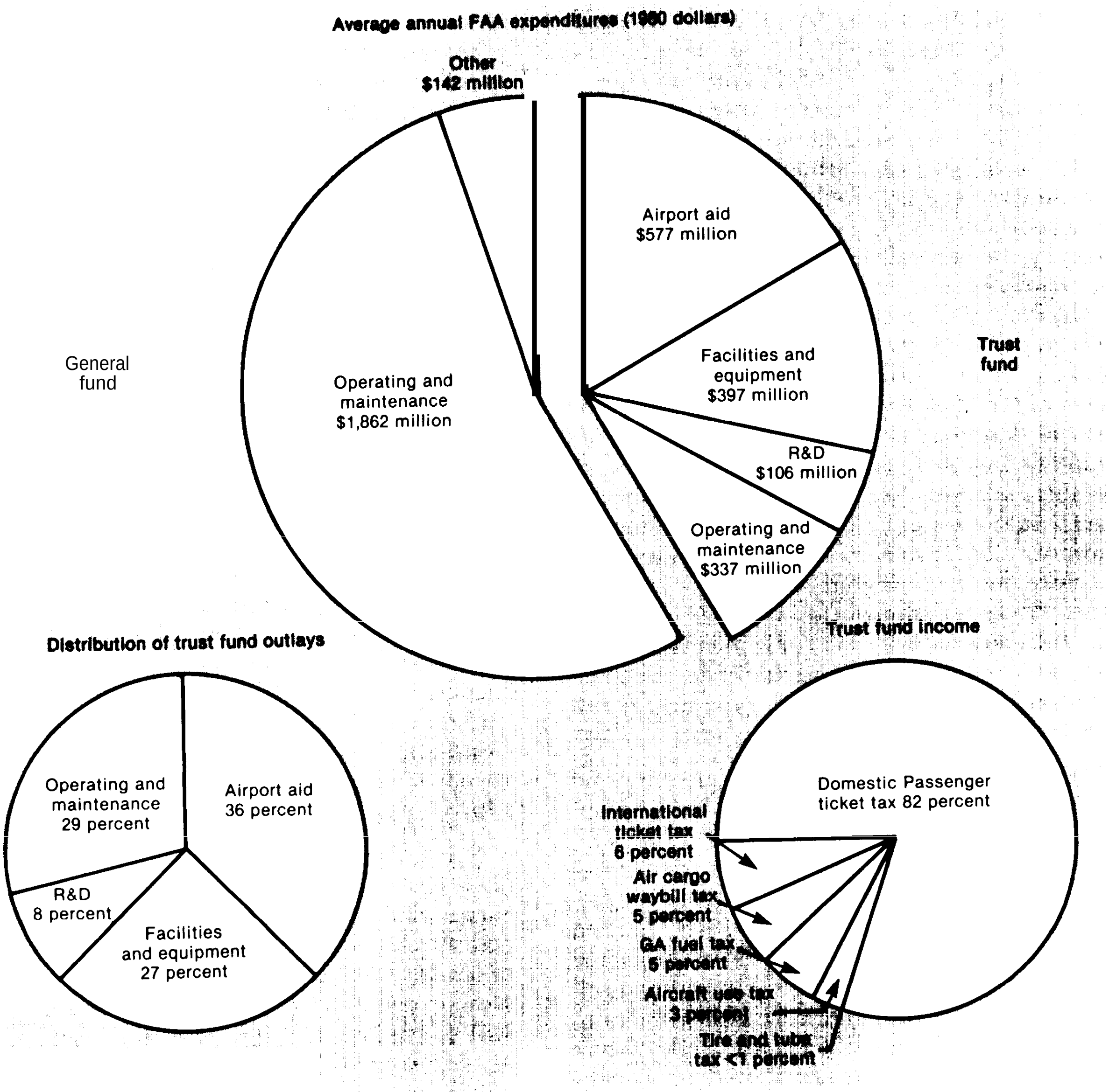
The expenditures that are likely to be required for ATC system improvements over the coming years could be considerably higher than those of past years. For the period 1971 to 1980, the amounts budgeted for facilities and equipment (F&E) and associated research, engineering, and development (RE&D) have averaged $397 million and $106 million respectively (in constant 1980 dollars).[3] Future improvements of the en route and terminal area ATC system and related programs for flight service station, navigation, and communication facility modernization may call for spending at twice this annual level or more. At the same time, operating and maintenance (O&M) costs are expected to rise, at least until modern labor-saving equipment is installed and productivity gains begin to be realized.

Since creation of the Airport and Airways Trust Fund in *1970,* FAA has had two sources of funding. F&E, RE&D, and airport grants-in-aid have been covered wholly by appropriations from the trust fund. In addition, the trust fund has covered about 15 percent of O&M expenses, although this proportion has varied considerably from year to year. The balance of O&M costs, about $1.9 billion per year (1980 dollars), and all other FAA budget items have been from general fund appropriations. Overall, trust fund outlays have met about *40* percent of annual FAA expenses. The major source of revenue for the trust fund has been a tax levied on domestic and international airline passengers (see fig. 2).

In October 1980, the Airport and Airways Development Act expired, and Congress declined to pass reauthorizing legislation. At that time the trust fund had an uncommitted balance of

[3] 0TA calculations based on FAA budget data, 1971-80.

Figure 2.— FAA Budget and Funding Sources, 1971-80



SOURCE: Off Ice of Technology Assessment, based on FAA budget data, 1971-80.

$2.9 billion, the equivalent of about 2 years' expenditure at the then prevailing rate. Since that time some of the user taxes contributing to the trust fund have still been collected (but at reduced rates of taxation), and these revenues have been deposited partly in the General Fund and partly in the Highway Trust Fund. If these revenues are included and if authorizations from the trust fund during fiscal year 1981 are deducted, the uncommitted trust fund balance stood at roughly $3 billion at the beginning of fiscal year 1982.

In considering sources of funding for future airport and ATC system improvements, Congress will encounter three broad and long-standing areas of controversy. In the absence of a trust fund or some other form of user charges to support capital improvement programs, these parts of the FAA budget would have to be funded from general revenues, which is certain to raise the issue of whether civil aviation and the airport and ATC system should be subsidized by the general public. The argument that the recipients of a service should pay the costs for the Federal Government to provide that service (a position strongly supported by the present administration), holds that capital improvements of facilities and equipment and the O&M costs of running the airport and ATC system should be borne by airspace users through various specific taxes. On the other hand, it can be argued that civil aviation, like other modes of transportation, provides a general benefit and therefore deserves support with public moneys. Other modes of transportation receive subsidy from the Government, and some members of the aviation community contend that there is no justification for singling out civil aviation for full recovery of capital and operating costs.

The resolution of this issue that has prevailed for the past 10 years has been a combination of special users taxes and General Fund financing, with the former going for capital expenditures and a small share of operating costs and the latter for the balance of FAA costs. A perpetuation of this scheme, through reestablishment of the Airport and Airways Trust Fund, could embroil Congress in another issue—what is the "fair" amount to be paid by various user classes. Most people concede that each user should pay roughly in proportion to the cost that they impose on the system, but there is violent disagreement within the aviation community as to what these costs are and how they are to be reckoned. Cost allocation studies conducted by the Department of Transportation and the FAA have generally concluded that, under the tax structure that existed before October 1980, commercial aviation paid nearly all (88 percent) of the cost of services provided to them. On the other hand, general aviation taxes returned at almost one quarter of allocated costs.[4] GA representatives have disagreed strongly with these findings, arguing that there is a substantial public benefit of aviation that has been undervalued in these cost allocation studies and that GA is charged for facilities and services that are neither required nor used by a major part of GA operators. Congress has shown little inclination to alter the user charge structure, and most of the proposed legislation to reestablish the trust fund would have little effect on the distribution of user charges that existed previously.

The third area of controversy concerns how the collected levies should be applied to costs. By congressional action, the use of trust fund moneys is restricted largely to capital expenditures and research and development activities, with some contribution toward operating expenditures. There are two major points at issue: 1) how should expenditures for capital improvements be allocated between airports and ATC facilities and equipment (and among airports and ATC facilities used by various types of aviation); and 2) should the allocation be broadened to cover a substantial part (or perhaps all) of O&M costs.

Resolution of these issues will become especially important when FAA presents its long-range plan for ATC system improvement. Increased expenditures for facilities and equipment and associated R&D will be called for, and operating expenses will probably remain high. FAA will be seeking a long-term commitment and an assured source of funding, but it will face strong opposition from segments of the aviation community if paying for FAA's programs and operating costs entails an increase in user taxes or a reallocation of the share to be borne by various classes of airspace users.

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[4] J. M. Rodgers, ***Financing the Airport and Air-way System; Cost Allocation and Recovery, FAA-AVP-78-14*** (Washington, D. C.: Federal Aviation Administration, November 1978).