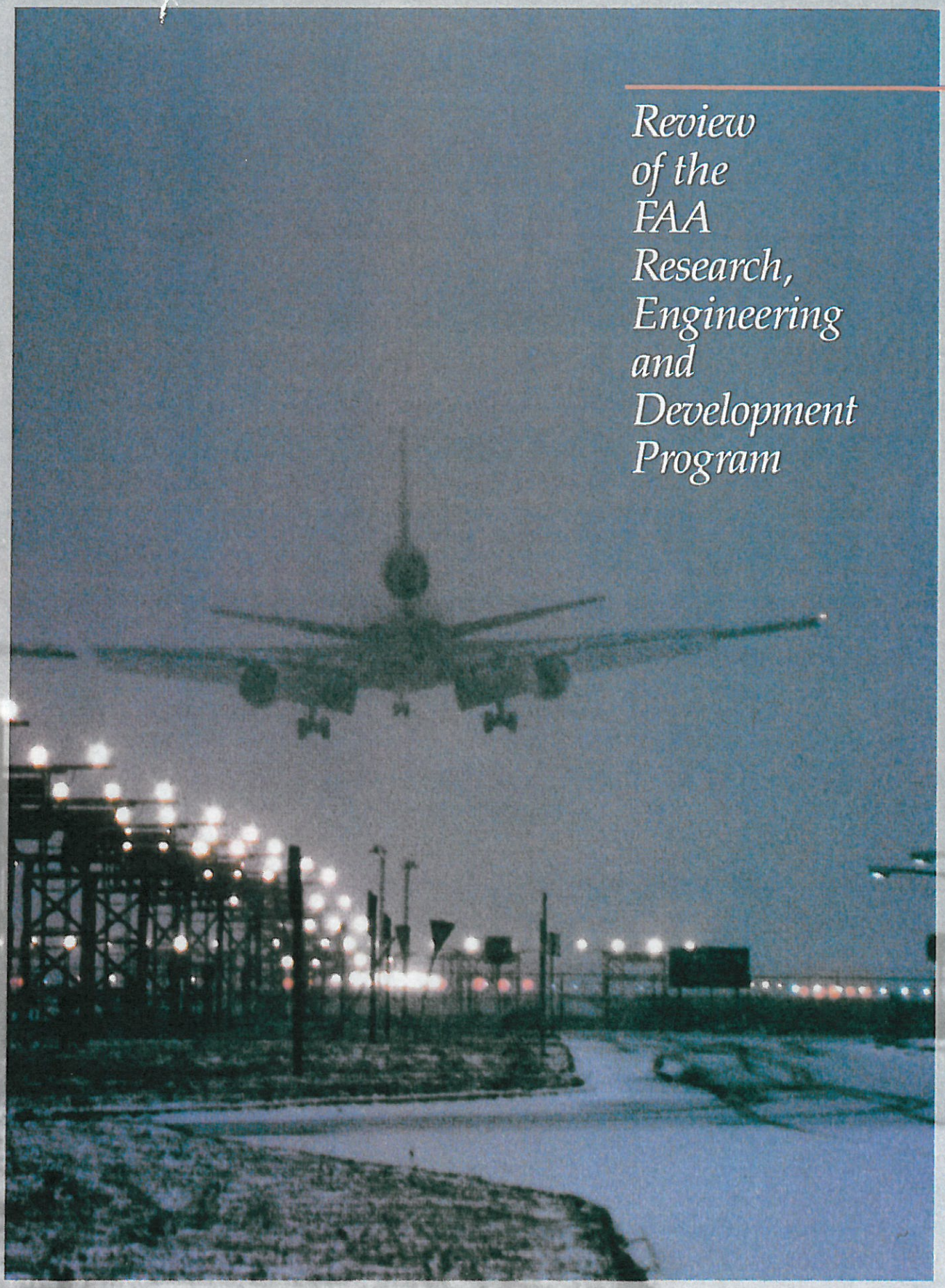
Review of the FAA Research, Engineering and Development Program



Review of the FAA Research, Engineering and Development Program

R&D Plan Review Panel
of the FAA Research,
Engineering and
Development
Advisory Committee

November 1991
Washington, DC

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R&D PLAN REVIEW PANEL
OF THE
FAA RESEARCH, ENGINEERING AND DEVELOPMENT
ADVISORY COMMITTEE

November 25, 1991

To: The Administrator of the FAA

Attached herewith is the final report of the Research and Development Plan Review Panel of the Federal Aviation Administration Research, Engineering and Development Advisory Committee. The Panel, in accordance with your request, has reviewed the FAA's technology prospectus as contained in *The Federal Aviation Administration Plan for Research, Engineering and Development* and examined the process management and funding needs.

It is the conclusion of the Panel that the FAA's Plan provides an excellent foundation for continuing to upgrade the nation's air transportation system well into the next century. However, given the nature of the challenges faced in terms of increased traffic, security concerns, and rising standards of safety — to name but a few — it is certain that the historical level of research and development funding will prove inadequate for the tasks prescribed. In our judgment, investments in the research and development base and a skilled team of technologists and managers comprise the underpinning of the future air transportation system. Any shortcomings in this effort will eventually evidence themselves either as denied opportunities or, should major system enhancements be undertaken without adequately proven technology, as potentially serious operational problems.

It is the unanimous opinion of the Panel that although research and development is, in a relative sense, not a major consumer of funds (today representing only 2.5 percent of the FAA budget), it is critical to the future of the nation's air transportation capability; is generally supported at a lower level than in other technologically-oriented organizations; and will require substantially increased funding if objectives in such areas as capacity, safety and security are to be achieved.

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Executive Summary

An efficient air transportation system is critically important to the United States. Over a million people per day utilize America's airspace in the conduct of business and leisure pursuits. In addition, the nation is increasingly dependent upon air transportation for the shipment of cargo ranging from overnight mail to perishable commodities. A significant portion of the nation's Gross National Product is tied to the existence of a modern air transportation system. U.S. commercial airframe manufacturers, airlines and air traffic management equipment manufacturers are major domestic employers as well as significant factors in America's global competitiveness and trade balance.

In 1991, the FAA categorized 21 major airports as "congested" (as compared with 16 three years earlier). Each of these airports represented an annual accumulation of departure delays exceeding 20,000 aircraft-hours.

Growth in air travel and thus growth in a significant portion of the Gross National Product are dependent upon a safe, efficient and effective system of air traffic management and air traffic control. Government forecasts predict increases in demand for air travel exceeding 50 percent between 1990 and the year 2000, yet plans currently underway to modernize and enhance the nation's air traffic management and control system in this general time frame are expected to increase capacity on the order of half that amount.

Simply stated, the present system is not able to satisfy current demands in inclement weather or projected future demand without incurring extensive delays — delays which in themselves are costly and have a negative impact on the nation's economy and traveler convenience.

The Federal Aviation Administration (FAA) has the principal responsibility for providing the infrastructure which underpins air operations within the United States. This responsibility extends from air traffic control to system security and from safety to international coordination. These responsibilities must be met 24 hours a day, 365 days a year, with a requirement for excellence that is unmatched in virtually any other undertaking. Nothing short of perfection is tolerable — and certainly nothing short of perfection can be the goal.

In the face of these stringent demands, perhaps no factor poses more severe potential limits on future air transportation than that of system capacity. If the air traffic system is to satisfy the needs of the American airspace user in the decades ahead, the task of resolving these existing and impending capacity limitations must be treated as a matter of utmost urgency.

A substantial, perhaps even preponderant, part of the solution to the air traffic saturation problem resides in the application of new technology. Such technology includes that associated with aircraft design, position location, telecommunications, collision avoidance, computerized traffic management, automation and weather prediction — to name but a few. Additionally, technology plays an important role in meeting many of the other challenges confronting the FAA including, but not limited to, the task of enhancing fire safety and improving airport design.

Although a considerable body of technology developed elsewhere, particularly by the military, the National Aeronautics and Space Administration, and the telecommunications and computer industries, has significant bearing upon FAA roles and missions, it is not possible for the FAA simply to be a consumer of technology developed elsewhere. Many of the requirements of air transportation modernization are unique, either in terms of application or in the basic technologies themselves. Activity to detect explosives, predict highly localized weather phenomena and enhance aircraft crashworthiness are but a few such examples.

Over the years, the FAA's process for converting new technology into field usage has too often lagged that of commercial practice. This is attributable in part to the conservatism necessarily imposed by the stringent safety demands affecting all FAA operations. On the other hand, some portion of these delays in exploiting promising new technologies is a consequence of relatively burdensome procurement procedures, organizational structures and personnel management practices which have been in place for many years.

To assure the full utilization of technology which is potentially available to meet the critical and challenging problems faced by America's air transportation system will require that the FAA has available an adequate share of the nation's most talented scientists, engineers and technical managers. It also will require a willingness to accept risk in research and development — just as risk must be strictly proscribed from the operational arena. In short, increasingly streamlined methods must be

found to transfer promising technologies into actual implementation, in part by carefully limiting barriers between operators and developers.

The recently announced reorganization of the FAA includes a number of positive steps in the above regards, organizationally integrating more closely air traffic and facilities functions, tying together certain operating entities with those responsible for research and development, and obtaining a better balance among those responsible for contracts, engineering, and program management.

The Research and Development Plan Review Panel of the FAA Research, Engineering and Development Advisory Committee was asked to assess the FAA's plans for generating new technology in support of its operations and to comment upon the soundness of the management process being utilized to introduce the technology thereby derived into the field. This review, which included a number of field visits, has resulted in a series of fifteen specific recommendations which are offered herein, along with a number of more general observations.

Preeminent is the conclusion that the FAA Research, Engineering and Development Plan, as now defined, offers a sound approach for resolving many of the problems confronting the nation's air transportation system; but that Plan is at present insufficiently funded to achieve the goals that have been established. It is the Panel's view that for many years the technology budget for enhancing the nation's air transportation system infrastructure has been modest as compared with investments being made by other technologically dependent organizations. The Panel believes that the nation's expenditures for advanced technology in support of the air transportation system must now move to a new plateau. Even recognizing the severity of the budgetary constraints affecting all categories of federal expenditures, such an increased emphasis is not overly burdensome given the rather modest level of expenditures traditionally devoted to this activity: about $200 million per year.

Once the necessary funds have been provided, additional management steps will be required. First, the techniques of system engineering should be applied to allocate requirements, establish measurable output parameters, conduct trade-offs, and identify solutions. This process can be enhanced through further application of modern simulation techniques, including incorporation of hardware and humans into the simulation loop. This effort can in turn be buttressed by increased emphasis on prototyping, particularly where new systems offering considerable promise but substantial risk may be involved.

The process for exploiting technology can be expected to succeed only if the FAA has a significant number of highly qualified technical implementors and managers. The Panel is not sanguine about the ability of the government to obtain and retain such individuals in adequate numbers given the personnel policies now in existence. Although these policies have been substantially improved during the past year, they are still not competitive with those prevelant in most other segments of the economy.

It is important that the FAA make maximum utilization of the capabilities of other organizations having particular competencies in air transportation matters, including government laboratories, industry, federally-funded research and development centers, and academia. Nonetheless, the FAA must maintain sufficient in-house expertise to define requirements and oversee the performance of outside organizations in meeting those requirements. This is a responsibility which the FAA cannot delegate if it is to be held accountable for the overall performance of the nation's air transportation system.

Although the above findings are considered by the Panel to be the most important among those offered herein, recommendations concerning a number of other matters are also proffered. These include the need to closely couple user requirements with developmental activities, yet assure that the requirements process not be so rigid as to preclude pursuit of innovative new technologies which may challenge the *status quo*. It is proposed that an increased amount of discretionary funding be provided to organizations which support the FAA in the technology arena in order to eliminate the hazards associated with seeking to centrally manage innovation.

Additionally, improvements are in order in the government-wide acquisition management system under which the FAA is required to function. Further, there are a number of opportunities for increased intra-governmental cooperation on technologies of importance to the FAA, and means of streamlining the technology insertion process are in order. Increased effort in basic and applied research will be required if significant further

improvements are to be expected in ensuring the physical security of the air transportation system. Finally, the use of spaceborne platforms offers significant opportunity for global enhancement of air operations; as does the conduct of expanded research in human factors.

Overall, the FAA's Research, Engineering and Development Plan comprises a sound beginning and, adequately funded and pursued in a timely manner, should alleviate or eliminate many of the problems which otherwise can be expected to increasingly constrict the nation's airways.

Research, Engineering, Development and the FAA

Introduction It is the function of the FAA to provide the infrastructure necessary to support readily available, punctual and safe air transportation in a secure environment. The nation's air transportation system must ensure that sufficient volumes of traffic can be supported; that flights are *accessible* when desired; that *delays* are minimal; that air operations are accomplished in a *safe* manner; and that users are *secure* from unwanted external interferences such as terrorism. Additionally, the FAA is, of course, expected to carry out these objectives in an efficient, cost-effective manner.

Although rather straightforward to state, accomplishment of the above goals represents one of the most technologically demanding tasks faced by any organization in the world today. Further, the standard of excellence is perfection. Large numbers of citizens each day place their lives in the hands of the FAA — a degree of trust so consequential that extraordinary demands are placed upon the people, equipment and procedures of the FAA and its associate organizations.

Each day, well over a million revenue passengers use the skies over the United States as an avenue of transportation. Airlines now carry nearly 39 percent of all domestic intercity passengers traveling by "for-hire" modes and account for about 25 percent of the small-shipment freight market. Even when use of the automobile is considered, air carriers were responsible for nearly 17 percent of all domestic intercity passenger miles during 1989, the most recent year for which data are available.

In 1990, U.S. air carriers scheduled some 7.3 million departures and flew 4.4 billion miles. Aircraft of all types flying in the United States logged over 47 million hours.

The magnitude of the 24-hour-a-day task faced by the FAA in carrying out its mission is suggested by the fact that the nation's Air Route Traffic Control Centers handled approximately 39 million aircraft during fiscal year 1990. In addition, during this same time period, FAA towers logged some 64 million operations and on some 43 million occasions the FAA's Flight Service Stations provided support activities. This overall effort was related to some 465 million passenger enplanements leading to 460 billion revenue passenger miles of operation by the certified route air carriers. In addition, some 220,000 general aviation aircraft were assisted as they flew nearly 35 million hours during 1990 alone.

In order to provide these services, 21 Air Route Traffic Control Centers were maintained by the FAA, together with 458 Air Traffic Control Towers and 179 Flight Service Stations. The activities of the FAA include the maintenance of 200 terminal air surveillance radars and 114 en route surveillance radars — all tied together through 1,739 remote communications outlets.

In order to carry out its crucial role, the FAA is dependent upon the application of technology — including, from time to time, the introduction of what could be characterized as leading-edge technology. Examples include the adoption of advanced computer systems such as those currently being installed throughout the air traffic system, or the introduction of Terminal Doppler Weather Radars which were specifically developed by the FAA to detect a particularly hazardous weather phenomenon known as microbursts. In many instances, the FAA's technological needs are not satisfied by standard, off-the-shelf commercial products. Although there is clear commonality with certain requirements of the Department of Defense and the National Weather Service, as well as certain commercial users, there are nonetheless many unique aspects of the FAA's needs which require that it maintain its own dynamic research and development capability.

The FAA's challenge in introducing new technology is significantly complicated by the fact that day-to-day operations must continue with minimal disruption as new items of equipment or new procedures are introduced. This demands that new technological developments be compatible, or at a minimum non-disruptive, with the prior generation of equipment and procedures.

Technology which underpins the FAA's activities is generated in accordance with a document referred to as *The Federal Aviation Administration Plan for Research, Engineering and Development*. In the Spring of 1991, the FAA Administrator requested that the Research, Engineering and Development Advisory Committee, which provides independent views to the Administrator on selected technological matters, establish a panel to review this

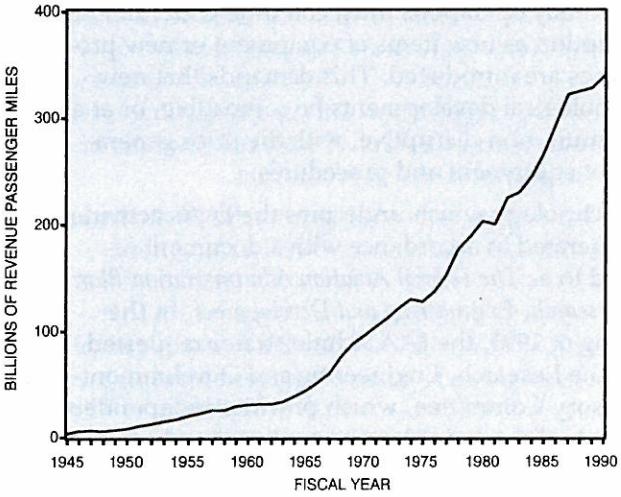
draft Plan. The review was conducted at two levels: the first, a general overview of key issues, as reported in this document; the second, a more detailed assessment of individual tasks within the Plan. The findings of this latter examination are separately reported in communications between the Panel and cognizant FAA management personnel.

Challenges

In consonance with its responsibilities as examined herein, the FAA's principal challenges can be addressed in four groups: the provision of an infrastructure which will support air travel when and where desired by the customer; the assurance that such air travel is conducted punctually (that is, without delays); that such travel is conducted safely (i.e., free of natural or inherent hazards); and that it is conducted securely (i.e., free of overt hazards). Each of these factors is profoundly affected by the quality of the technology which is available to the FAA.

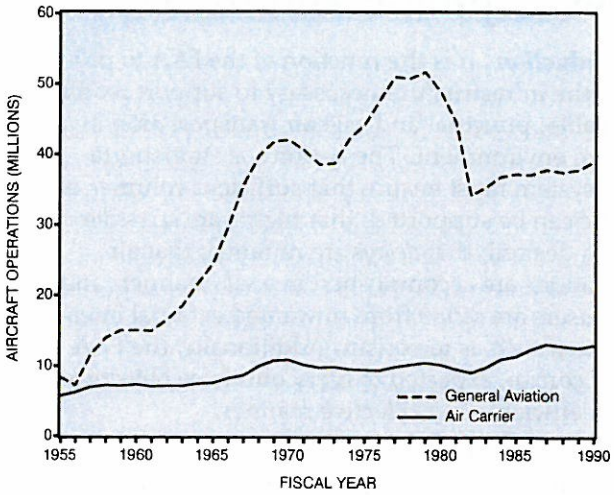
Accessibility The magnitude of the demand for readily accessible air service is suggested by the rapid increase in passenger miles flown each year. Figure 1 illustrates this trend since the end of World War II. Most projections suggest significant continued growth into the foreseeable future, with only modest periodic interruptions due to temporal economic conditions. The number of aircraft operations implicit in such airspace usage is shown in Figure 2, both for scheduled commercial traffic and for general aviation traffic. Such an aggressive level of flight activity not only places severe demands upon the airspace management segment of the nation's air transportation system, but also imposes corresponding demands upon airports. These latter demands include the assurance of adequate numbers of runways and gates, and sufficient handling capacity for passengers, baggage and other logistical items. Many seemingly mundane activities take on substantial importance in this environment — for example, the matter of providing security while each day handling several million items of passenger baggage in a timely and efficient manner.

Figure 1. Revenue Passenger Miles U.S. Commercial Air Carriers (Domestic)



Source: Civil Aeronautics Board Handbook of Airline Statistics; FAA Aviation Forecasts.

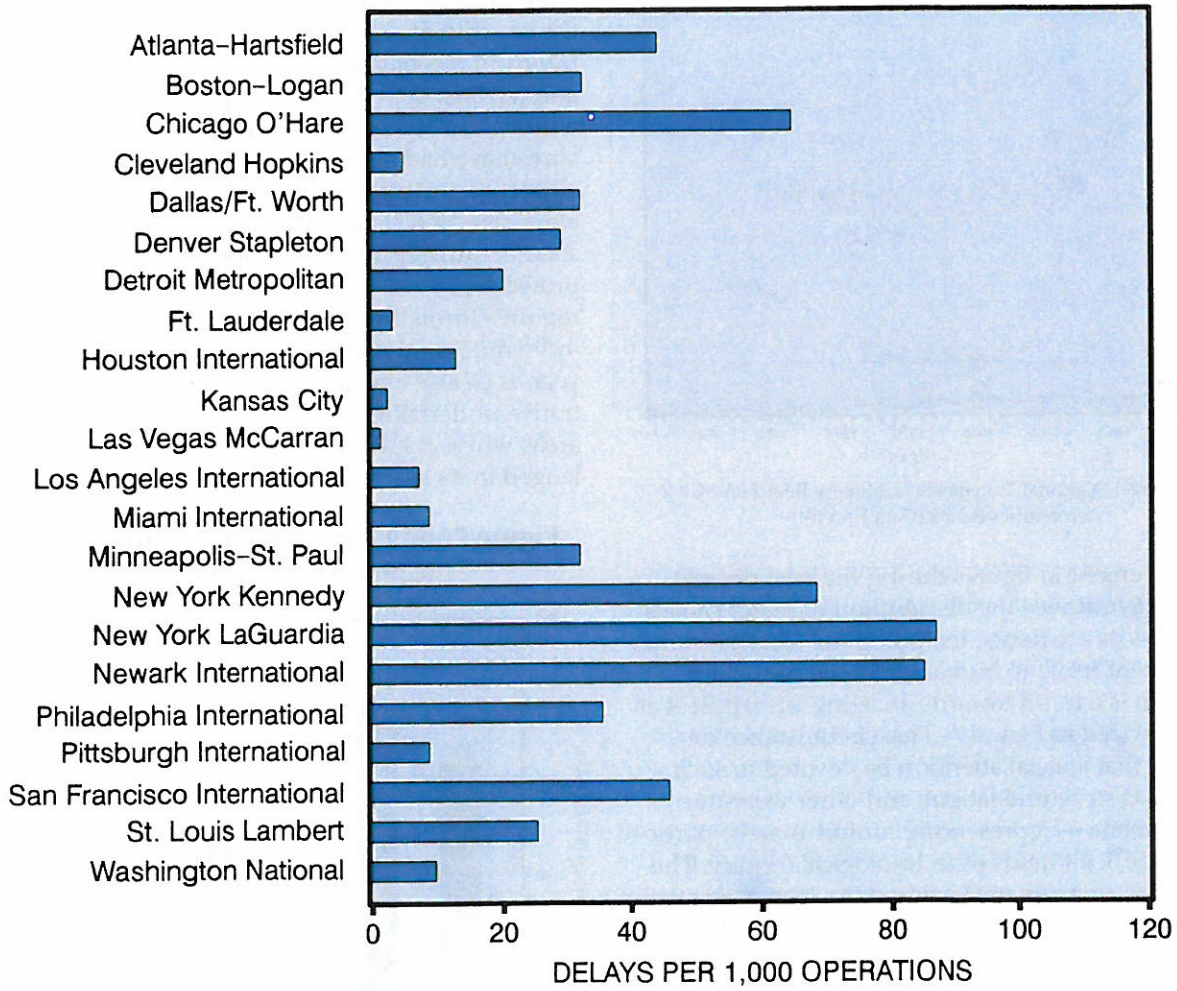
Figure 2. Aircraft Operations at Airports with FAA Traffic Control Service



Source: FAA Aviation Forecasts.

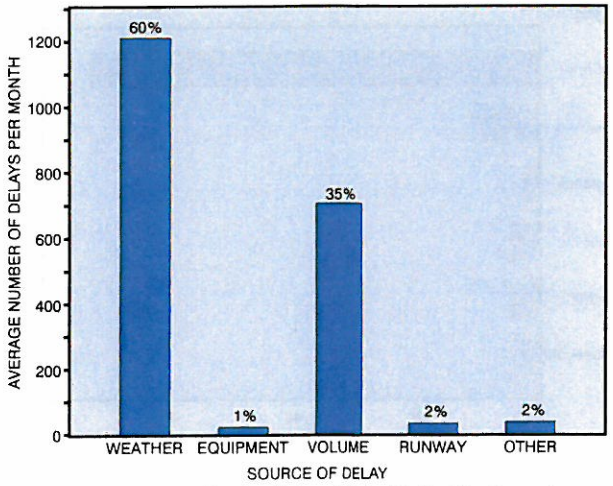
Punctuality Of growing concern, as the volume of air traffic increases to levels nearing the overall capacity of the current system, is the matter of aircraft delays. Figure 3 summarizes the status of delays at various terminals. As use of the airways approaches the available system traffic capacity, operations become more "brittle" and vulnerable to disruption due to the effects of adverse weather and equipment malfunctions. That is, the system retains little resilience to accommodate the unexpected or uncontrollable. When such disruptions do occur, they can potentially impact substantial numbers of people. In the year 1990, delays at the nation's ten busiest airports alone resulted in 50 million hours of passenger delay — attributable to causes summarized in Figure 4.

Figure 3. Air Transportation Delays (1990)



Source: OPSNET Report, December 1990.

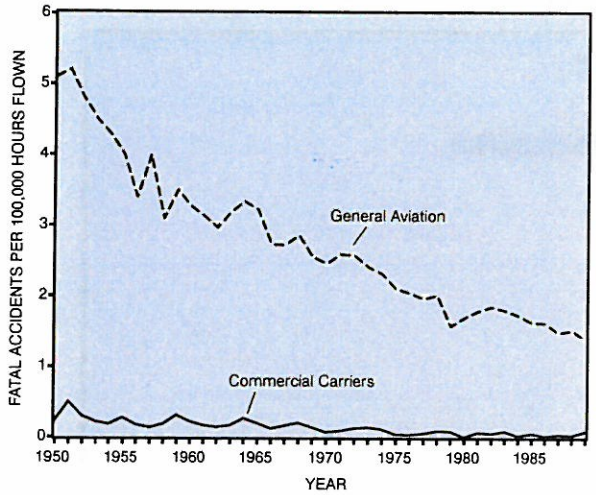
Figure 4. Causes of Delays at Top Five Airports with Most Enplanements



Source: Data Derived From FAA Air Traffic Operations Management System (ATOMS).

Safety The safety of the nation's airways is generally considered to be extraordinarily good, particularly given the complexity of the human and technological interactions involved in their operation and the level of demand placed upon the system. This conclusion is drawn in part based upon comparisons with other modes of transportation. However, as previously noted, nothing short of perfection is acceptable. Figure 5 displays the air transportation safety record as measured in fatal accidents per 100,000 hours flown for both certified route air carriers and for general aviation. In 1990, U.S. air carriers were involved in 0.08 fatal accidents per 100,000 *departures*. United States general aviation averaged 1.4 fatal accidents per 100,000 *aircraft hours* during the same year. It is noteworthy that there has been no significant

Figure 5. Aviation Safety

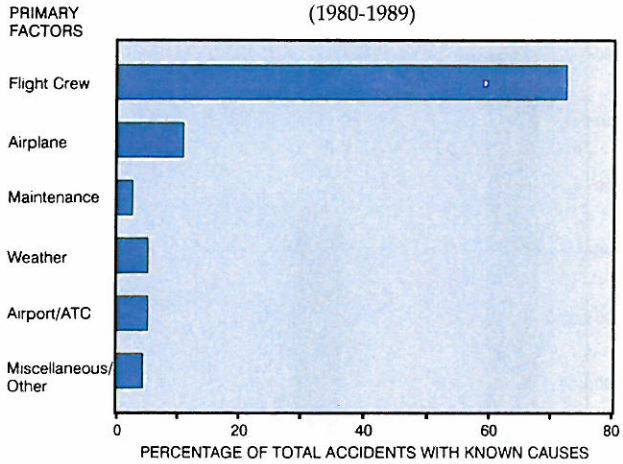


Source: National Transportation Safety Board and Civil Aeronautics Board (Data Faired).

improvement in figures during the past decade. Figure 6 indicates the distribution of major causes of hull-loss accidents, including the fact that some 70 percent relate to human error. Of particular concern is a trend towards an aging aircraft fleet as summarized in Figure 7. This circumstance demands that special attention be devoted to such effects as structural fatigue and other wear-out phenomena — representing, unfortunately, particularly difficult fields of technological inquiry. The matter of aging aircraft will require increased attention by the FAA, aircraft manufacturers and aircraft operators alike in the years ahead.

Figure 6. Primary Cause Factors — Hull Loss Accidents

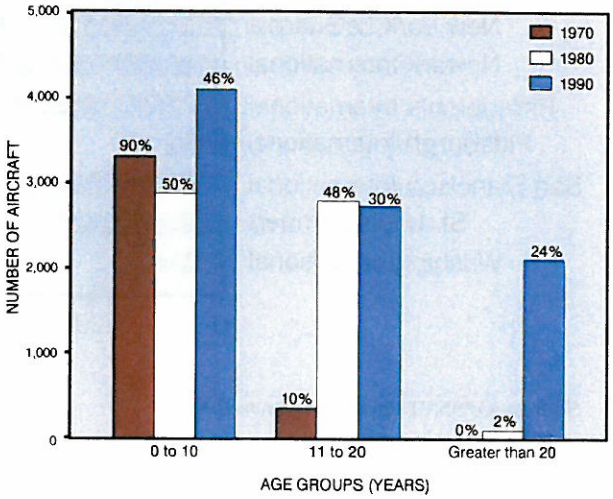
Worldwide Commercial Jet Fleet (1980-1989)



Source: FAA.

Security The increasing political turbulence in many parts of the world during the past two decades has evidenced itself in growing challenges to the security of air travel. Figure 8 summarizes the trends in recent years of fatalities due to criminal and terrorist activities affecting aircraft operations, although in recent years increased security measures have had a positive impact. During 1990, airport security screening in the United States alone detected some 3,000 hand guns and a substantial number of other weapons. The task of providing security, for a system which necessarily requires throughput of hundreds of millions of individuals and literally billions of packages each year, is clearly a major technological and administrative undertaking — and represents one of the areas where the FAA will be most heavily challenged in its search for technological solutions.

Figure 7. Jet Fleet Unit Distribution by Age (Commercial Aircraft)*

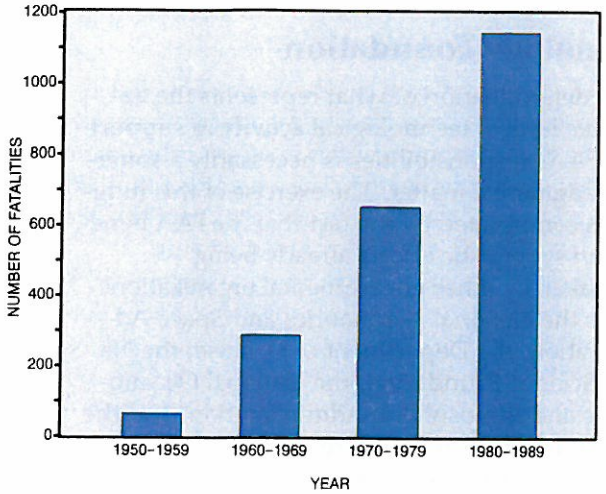


Source: Boeing Commercial Airplane Group.
*Total World Excluding USSR.

Environment Among those factors associated with aircraft operations that affect the natural environment are fuel usage and engine noise. Both of these parameters are influenced by operating procedures as well as by inherent design features. For example, airport design, climb-out profiles and traffic management efficiency all influence noise considerations. Routing efficiency can have a significant impact on fuel usage. Considerable progress is being made in reducing the number of people subjected to aircraft noise of a given level by means of improved designs and better procedures, as indicated in Figure 9. On the other hand,

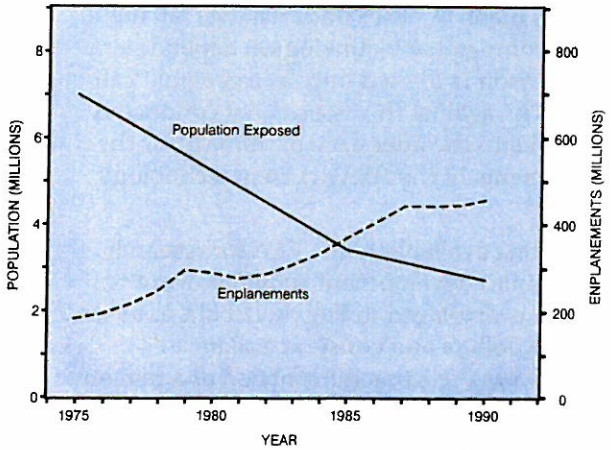
increases in air traffic volume continue to outpace gains being made in engine and airframe efficiency insofar as fuel consumption is concerned, as indicated in Figure 10. Further technological advancements offer considerable promise of easing each of these problems.

Figure 8. Worldwide Fatalities Due to Explosives Aboard Air Carriers



Source: Aircraft Hijackings and Other Criminal Acts Against Civil Aviation Statistical and Narrative Reports, May, 1986 and Semiannual Report to Congress on the Effectiveness of the Civil Aviation Security Program, February 1991.

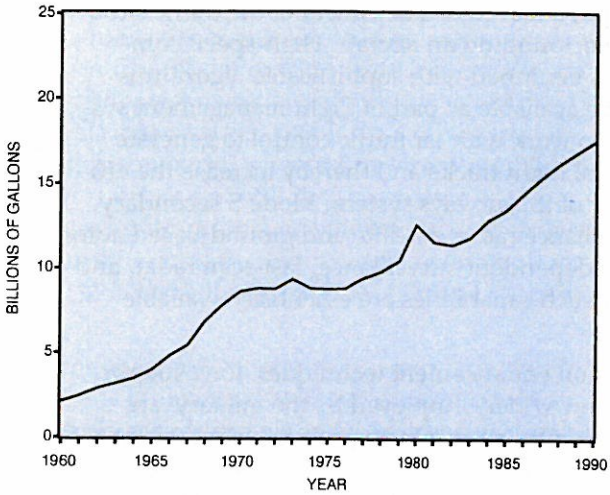
Figure 9. Population Exposed to DNL* 65dB or Higher at U.S. Civil Airports vs. Revenue Passenger Enplanements



Source: Preamble of Federal Regulation Issued on September 25, 1991.

*DNL = Day-Night Average Sound Level, the Accumulation of Aircraft Noise Exposure in a 24-Hour Period.

Figure 10. U.S. Civil Aircraft Fuel Consumption (Jet Fuel and Aviation Gas)



Source: FAA Aviation Forecasts.

Technology Opportunities

Commensurate with the enormity of challenges facing the FAA as this millennium draws to a close, a revolution is taking place in technology which places many solutions within grasp.

Computers which previously would have filled large rooms can now be placed on a desk and can be purchased for a fraction of the cost of their predecessors, with the cost of storing a bit of information dropping by a factor of 100 every ten years. The possibility of storing an entire encyclopedia on a single semiconductor chip may soon become a reality. The revolution in computers has been accompanied by a revolution in telecommunications. Satellites used for navigation will create major opportunities for aviation across the globe and, in particular, over the oceans and in less developed parts of the world — including enabling high quality approach guidance to landing points without ground aids.

Digital communications (data links), a technology which has been waiting to be used in aviation for a number of years, will enable modern air traffic control computers to be used to full advantage. This will in turn permit greater automation and provide increased safety by greatly reducing problems associated with misunderstood

communications. It will also enable connection of the increasingly formidable capabilities of aircraft on-board systems with the ground air traffic control automation system.

The technology of airborne collision avoidance systems, in itself a major safety enhancement, will become increasingly available to create, in the cockpit, a real-time assessment of the traffic situation surrounding an aircraft. High-speed computers equipped with sophisticated algorithms will be available as part of flight management systems to work with air traffic control to generate optimal flight tracks and thereby increase the efficiency of the airways system. Mode S secondary surveillance radar, satellite and ground-based automatic dependent surveillance, fast-scan radar, and other such capabilities are essentially available today.

Vision enhancement techniques, long sought and now widely employed by the military, are likely to play an increasing role in airline cockpits, affording flight crews the opportunity to "see" in the night and, eventually, in weather-related low visibility conditions. Additional modern techniques involving the use of ground, airborne and satellite-borne sensors will enable greatly improved weather prediction — including windshear detection, winds aloft, and severe storm conditions. Similarly, knowledge concerning wake vortices is becoming available and will help ameliorate the consequences of this phenomenon, now a cause of major erosions of airport capacity.

Advances in materials sciences, especially in structural composites, ceramics, fire resistant polymers and high-strength concrete, are making it possible to "engineer" materials to function under extreme conditions.

By its very nature, research and development will include both successes and failures. If there is an overwhelming preponderance of successes, then technologists have probably not stretched sufficiently into the unknown or unproven. If there is a preponderance of failures, technologists have stretched too far or, alternatively, may have an inadequate technology foundation or may apply inappropriate management practices. Over the years there has been a number of noteworthy successes in FAA-sponsored technological activities. For example, the FAA invested some 20 years to develop a method of preventing mid-air collisions. Today, the Traffic Alert and Collision Avoidance System (TCAS) is in production and will be fully installed in virtually all airliners by the end of 1993.

A further example of past successes is the introduction of data link predeparture clearance information at some 30 airports. This has significantly reduced controller and aircrew workload while reducing the potential for miscommunications and relieving frequency congestion.

Technology Foundation

The determination of what represents the appropriate level of technological activity in support of the FAA's responsibilities is necessarily a somewhat judgmental matter. The exercise of this judgment is complicated by the fact that the FAA benefits from synergistic efforts already being undertaken by other governmental organizations such as the National Aeronautics and Space Administration, the Department of Defense, the National Science Foundation, the National Oceanographic and Atmospheric Administration, and the National Institute of Standards and Technology — as well as by many organizations in the commercial sector and academia.

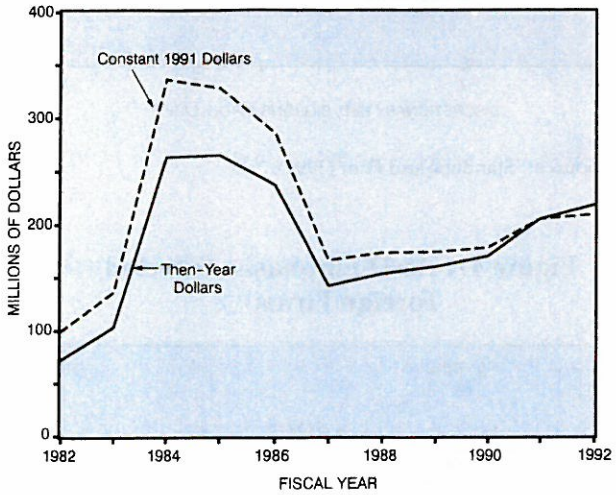
It should be cautioned that the very definition of research, engineering and development is not generally agreed upon and there is a lack of consistency in this regard throughout both the public and private sectors. In some instances, the FAA has traditionally categorized as "Facilities and Equipment" activities which others might consider to be development. Nonetheless, it is instructive to examine certain broad comparisons of the *overall* level of technology investment in support of the air transportation system, with corresponding investments made in other undertakings having somewhat comparable technological dependency. This comparison is offered only as a general "calibration check" against the assessment conducted by the Panel into the adequacy of funding for the various elements of the FAA's current technology Plan.

The funding available to the FAA for research, engineering and development activities over the past decade is displayed in Figure 11 both in terms of then-year dollars and constant dollars. Figure 12 shows the same information as a percentage of total FAA appropriations. It is seen that research, engineering and development funding has declined in recent years from about 6 percent of the total FAA budget to about 2.5 percent, although a considerable part of the increase in spending in the early 1980's was to engineer the National Airspace System Plan. Although

addressing a problem of major national consequence, this spending level represents but two one-thousandths of a percent of the Gross National Product.

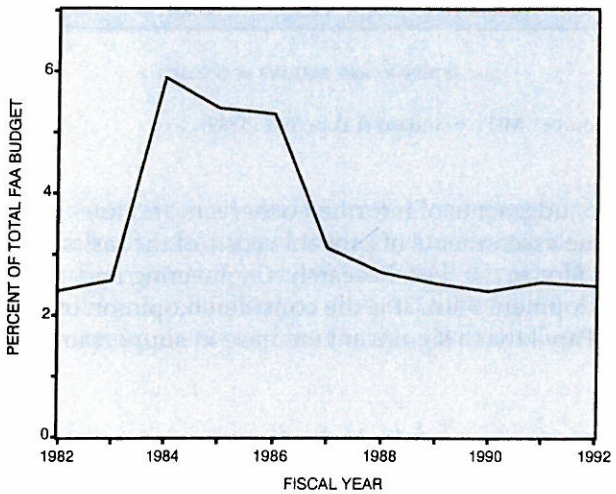
Figure 13 summarizes the research, engineering and development investments being made by several United States government organizations. Figure 14 presents this same information as a percent of the total budget of each respective organization. As noted, in FY 1991, the FAA devoted about 2.5 percent of its resources to what has traditionally been defined as "research and development," and roughly the same percent is planned for the current fiscal year.

Figure 11. FAA Research, Engineering and Development Expenditures



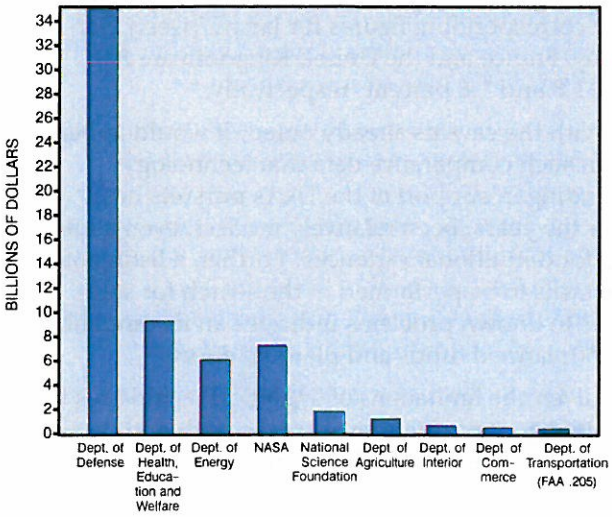
Source: FAA.

Figure 12. FAA Research, Engineering and Development Expenditures



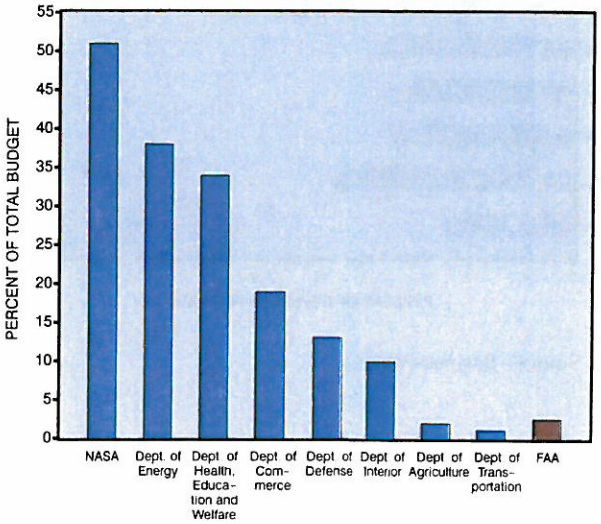
Source: FAA.

Figure 13. FY 1991 Research and Development Budget Authority



Source: The Federal Budget of the United States.

Figure 14. FY 1991 Research and Development Budget Authority as Percent of Total Budget



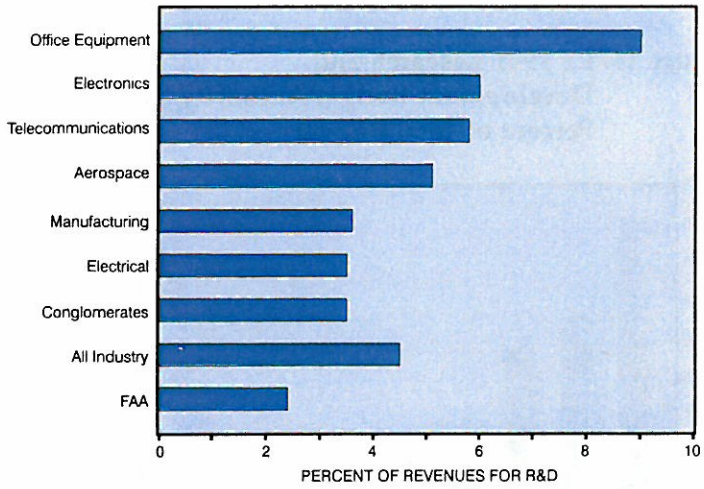
Source: The Federal Budget of the United States.

Figure 15 compares spending for *discretionary* research and development (that is, research and development activity that is not contracted on behalf of some other party) for several U.S. industries which, like the FAA, are relatively dependent upon technology for their continued viability. Figures 16 and 17 present similar information for several selected corporations in the United States and in other parts of the world, respectively. Overall, the United States devotes about 1.9 percent of its Gross National Product to what is generally defined as non-defense research and development. The corresponding figures for Japan, (west) Germany, France and the United Kingdom are 3.0, 2.8, 1.8 and 1.6 percent, respectively.

With the caveats already noted, it would appear from such comparative data that technology spending in support of the FAA's pursuits has, over the years, been relatively modest, even allowing for definitional variances. Further, a listing of the tasks to be performed in the search for solutions to known problems indicates an incompatibility of planned funds and planned efforts.

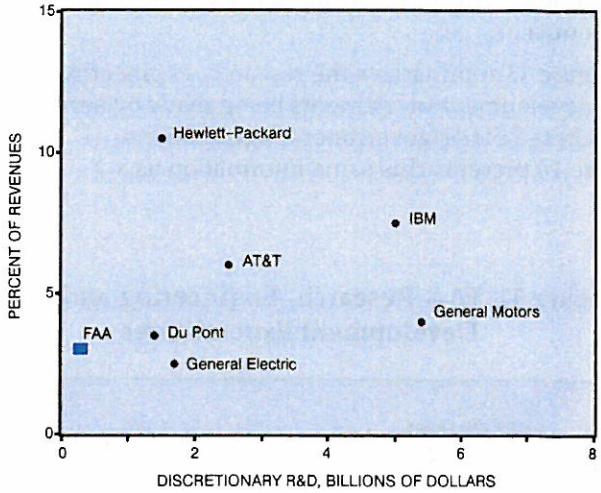
Given the limitations of analytical techniques in assessing appropriate levels of research and development, it is to a large degree necessary to rely upon judgments of informed observers and line-by-line assessments of probable costs of the tasks called for in the FAA Research, Engineering and Development Plan. It is the considered opinion of this Panel that a significant increase in support for

Figure 15. R&D Emphasis: Selected U.S. Industries



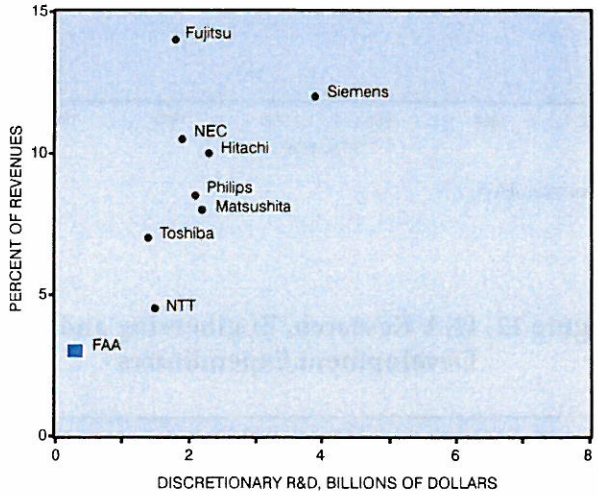
Source: Business Week.

Figure 16. R&D Emphasis: Selected U.S. Firms



Source: Standard and Poor (1990).

Figure 17. R&D Emphasis: Selected Foreign Firms



Source: MITI, Standard & Poor, BW (1989).

technological activities will be required if the major challenges which lie ahead in the areas of system capacity, avoidance of delays, safety, security and environmental impact of the nation's air transportation system are to be resolved in the years ahead. Taken together, these factors can have profound impacts on America's global economic competitiveness and quality of life.

The increase in technology expenditures programmed for FY 1992 is viewed as a healthy indicator of the recognition of this problem by the Executive and Legislative Branches alike.

The Air Traffic Management Vision

Conceptual Foundation The National Airspace System (NAS) and the air traffic management system are evolving in response to increasingly challenging demands for airspace. The National Airspace System, encompassing the common network of airspace, airports, navigation aids and air traffic control equipment across the United States, and the air traffic management system, encompassing the processes used to ensure safe, efficient and expeditious aircraft movement during all phases of operations, are used by the FAA to operate the nation's airspace.

Recognition of changing operating environments and opportunities to use new technologies beneficially led the International Civil Aviation Organization (ICAO) and the FAA to develop new concepts for the future aviation system support infrastructure. These concepts are based on the employment of advancing technology, but also incorporate many human factors and human-technology interactions.

The International Civil Aviation Organization established the Future Air Navigation Systems (FANS) Committee in 1983 to investigate ways to build on state-of-the-art systems and technologies to improve the worldwide management of air traffic. The committee focused largely on the need for improved communications, navigation and surveillance technologies to accommodate the projected growth and diversity of civil aviation into the next century. In particular, the committee emphasized satellite-based navigation, communications, and automatic dependent surveillance.

In February 1990, the Administrator of the FAA articulated *A Vision of the Future: The ATC System Beyond the NAS Plan*. Like the Future Air Navigation Systems Committee, the Administrator relied heavily on technological advances in communications, navigation and surveillance to attain long-range objectives. The Administrator's vision of the future included the increased use of aircraft-based systems to address both separation assurance and capacity management issues. This use of aircraft-based systems is an important addition to the Future Air Navigation Systems Committee's ideas. The Administrator also incorporated some elements of system automation (e.g., Automated En Route Air Traffic Control) into his vision of how capacity management would be achieved in the future.

More recently, in April 1991, the FAA published the *Concepts and Description of the Future Air Traffic Management System for the United States*. The *Concepts* paper builds on the work of the Future Air Navigation Systems Committee and the Administrator's vision statement. Among the important features of the *Concepts* paper is an emphasis on the evolutionary nature of the development of the future air traffic management system and the National Airspace System, building on existing technologies to better serve a broad user spectrum. The *Concepts* paper recognized that the vision is not fixed, but will evolve as the air traffic management operating environment (both physical and organizational) changes.

The *Concepts* paper expressed, for the first time, specific goals for the future system, incorporating many elements of human-technology interaction. Specifically, the *Concepts* paper notes the need for automation of the air traffic management system, and looks at a future in which models and knowledge bases would be used in real time to evaluate demand and to minimize delay in traffic flows. Finally, as was the case with both the Future Air Navigation Systems Committee's work and the Administrator's vision, the *Concepts* paper emphasizes the need to look to satellite-based communications, navigation and surveillance technology to replace today's ground-based systems.

In aggregate, these visions of future technology and a revised air traffic management system hold the promise for a much more efficient operation, with greatly expanded capabilities in such areas as capacity management and separation assurance. This promise is based both on improved hardware and, perhaps more critically, on improvements in the software that provides the human-technology interface. Ultimately, such a system will better meet the needs of the flying public and the FAA.

Expanded Research and Development Program In order to accomplish these changes to the air traffic management system, the FAA must revise and considerably expand its research and development program. But there are additional demands on the FAA's research and development budget beyond the demands of the air traffic management system. Increased public emphasis on safety and security implies that additional resources will be needed to investigate issues

related to aging aircraft, fire safety and airport security. Moreover, public concern over environmental and energy conservation questions will require increased FAA attention regarding its research activities.

The expansion of the FAA's role in capacity management and separation assurance will require the FAA to devote substantial resources to at least two additional major areas. The first is development of technologies that will enhance the National Airspace System performance (including reliability, maintainability, availability, etc.), specifically communications, navigation and surveillance technologies. The second is development of automation and human factors technologies that will enhance the functionality of the air traffic management system.

Overall, in order to meet the expectations of the stated vision, the FAA will need to ensure that adequate resources are programmed to meet the safety, security and capacity management needs of the air traffic management system and National Airspace System.

The Research, Engineering and Development Plan

System Engineering For some time the FAA's Research, Engineering and Development and Capital Investment Plans have been criticized for what is most often characterized as a "bottom-up" approach to project selection. That is, projects are selected on their individual merit rather than on the role they play in combination with other projects to provide desired operational capability. Recently, however, the FAA has established a cooperative framework for system engineering that is aimed at solving problems in a top-down, systematic way. Each problem within this new framework is to be addressed from four views or levels. The System view (Level 1), the User or Domain view (Level 2), the Functional or Technology view (Level 3), and the Project view (Level 4).

Level 1 addresses problems from a System perspective. It evaluates user needs, identifies future target capabilities, and establishes a top-level evolutionary architecture based on a sound analytic and experimental basis. It is the goal of Level 1 to analytically assess future needs of the National Airspace System, identify new required capabilities to meet those needs, and develop plans to implement the capabilities in a timely manner. For example, the FAA identified the need for more efficient system operation from a traffic flow perspective and discovered many conflicting and unintegrated proposals on how to improve the system. At Level 1, the overall task is analyzed from a top-down system view. Alternative scenarios are developed and evaluated, and specific functions are allocated to different types of facilities, operators, or automation based on a single integrated traffic flow management strategy. The division of responsibility between the participants in the traffic flow management area, for example, is determined at this highest level of system analysis.

Level 2 addresses problems from a User/Domain view. It ensures that the capabilities delivered to the field are useful to the users, and that the operational standards and procedures are effectively integrated to meet the user/operator needs. For example, the FAA has identified a growing physical space problem in many of the air traffic control towers as more equipment is added to the towers. It is the responsibility of Level 2 effort to examine the problem and evaluate a number of alternatives from a user perspective. Once alternatives have been identified, it is also a Level 2 responsibility to work with users and engineers to develop the operational concept and the associated procedures and standards needed to work in the new environment. The results are communicated to the functional engineers (Level 3) for design and specification.

Level 3 addresses problems from a Functional or Technology perspective. It provides the engineering required to make systems and equipment work together. For example, it is the goal of Level 3 to develop the subsystem architectures and to define the individual projects that are needed to make the transition to the use of global navigation satellite systems for navigation and landing within the National Airspace System.

Level 4 addresses problems from a Project view. It supports (through matrix management) the ongoing projects in making engineering decisions in a systems context. For example, it would be the responsibility of Level 4 to conduct the necessary modeling and network topology analyses to ensure the cost-effective implementation of the Routing and Circuit Restoral Project.

Operational Requirements Development Process The system engineering process described above serves not only as an essential capability for managing the FAA research and development and capital investment programs, but will also provide the aviation community with an integrated vision of what is to be accomplished and how it will be managed. The FAA has taken a very positive step in establishing this system engineering process, organizing to manage it, and creating team-building sessions to encourage "buy-in" from those who must cooperate to achieve National Airspace System and air traffic management goals.

Until now, however, this participatory management has been accomplished only within the Office of the Executive Director for System Development. Level 1 of the system engineering process, as described above, depends heavily on an informed and cooperative interaction with the Office of the Executive Director for Operations — the operator of the air traffic control system. In the past, the establishment of a commonly agreed upon set of requirements among personnel in the Operations and the System Development organizations has been difficult to achieve. Nonetheless, no vision or concept can be effectively

implemented unless the two organizations work closely with each other and operational personnel are integrated into the Level 1 process.

The FAA is moving on two fronts to meet this challenge. First, the Administrator has recently transferred the Executive Director for System Development to the job of Executive Director for Operations. In so doing, the Administrator specifically cited the organizational and team-building successes in the System Development organization. An extension of this approach to achieve more efficient and enthusiastic participation in the system engineering (especially requirements) process is needed.

Secondly, the FAA is considering the establishment of a national simulation capability which will integrate the output of many of the existing air traffic control simulation, prototype, and test bed facilities. This capability will provide the FAA with a modern mechanism to evaluate alternative operational and technological ideas in a simulated operational environment and, thereby, to validate operational or technical requirements prior to incorporating them into either the Capital Investment Plan or the Research, Engineering and Development Plan.

Research, Engineering and Development Plan Categories The fundamental integrating theme among all the projects contained in the FAA's Research, Engineering and Development Plan is the common goal of improving the safety and security of the National Airspace System, and improving the capability of the air traffic management system and the National Airspace System to accept and efficiently process increasing workloads. In the sections that follow, assessments are provided of individual components within the FAA research and development program.

The technologies that are discussed in the following material, including capacity and air traffic control automation, communications navigation and surveillance, weather and airport technology, will only be effective if they are able to function in concert in support of validated FAA requirements. As an example, airport systems need to be linked to automation systems so that there is an efficient transfer from terminal airspace to the en route system, and *vice versa*. Similarly, it is important that the FAA conduct a coordinated research and development program that is cognizant of the operating environment of its customers — aircraft owners and operators *and their customers*, passengers, cargo shippers and civilian pilots. Advances in the FAA's ability to understand weather conditions affecting flight, and the potential impact that those conditions may have on system capacity, are obviously important to the efficient operation of the air traffic management system.

The FAA has recently established a potentially powerful system engineering process. This process should be used to drive the execution of both the Capital Investment Plan and the Research, Engineering and Development Plan.

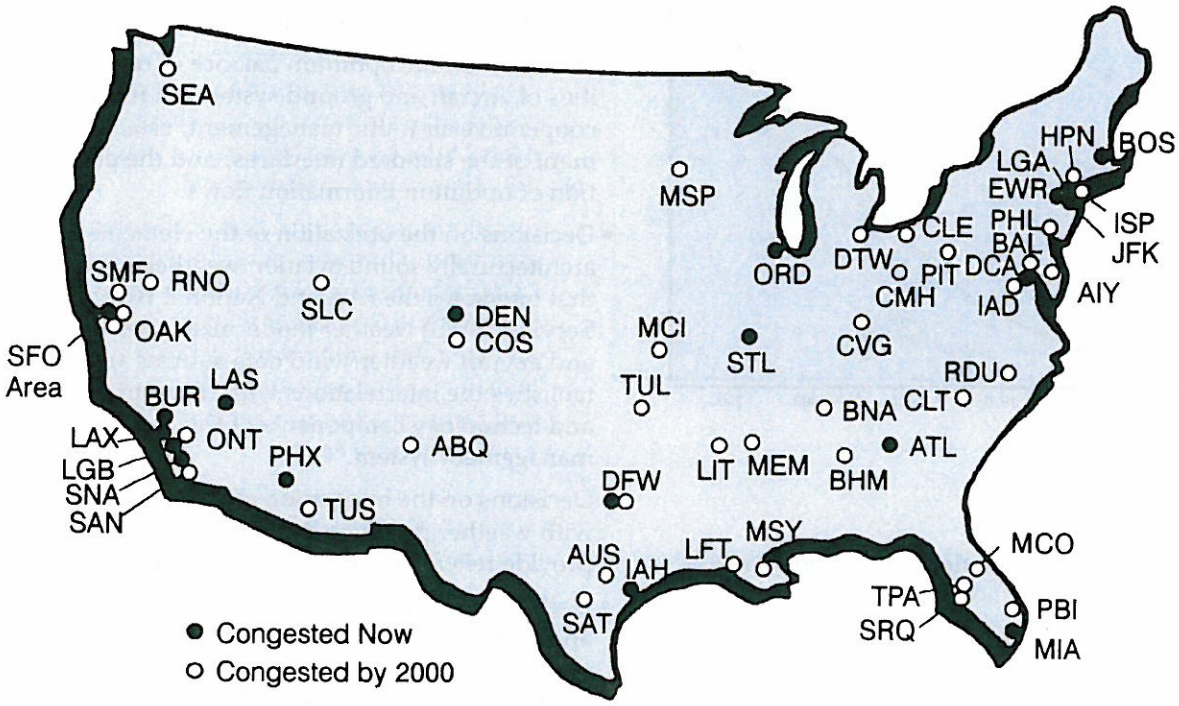
Capacity/Air Traffic Control Automation

The Panel is keenly aware of the delays and congestion plaguing the aviation system and the growing number of airports at which annual delays are high. The FAA has indicated that it expects the number of airports with more than 20,000 hours of annual aircraft delay to grow from 21 in 1991 to 41 by 1998. As suggested by these figures, there is a high degree of traffic concentration. The FAA's 1990-91 Aviation System Capacity Plan notes that 100 airports enplaned more than 90 percent of the 459 million passengers who traveled in 1988. Aircraft operations at these facilities are expected to grow from 25 million operations to 34 million in the next ten years. This includes the ten busiest airports which together handle about one-third of all passenger enplanements. By the year 2000, forecasts indicate up to 58 congested airports and an increase in enplanements by 75 percent, as shown in Figures 18 and 19, respectively.

Since airline deregulation was introduced in 1978, the number of passengers using the U.S. commercial aviation system has increased by 87 percent. Without capacity improvements or substantive changes in the time or location of travel, 76 percent of all airline passenger traffic, equaling 600 million travelers, could experience significant, capacity-related delays by the end of this decade.

Currently there are approximately 1600 airline gates in the United States and about four aircraft per gate (approximately 4200 U.S. jet and turboprops and a portion of the over 7800 foreign flag aircraft). A significant number of airplanes, mostly under 150-passenger capacity, is projected to be added to the system by the year 2005.

Figure 18. Growing Airport Congestion



Source: FAA & NPIAS Reports.

It is further estimated that 590,000 hours of delays at the top ten airports alone (as actually occurred in 1990), cost the public a staggering 50 million hours of lost time. This represents over 25,000 person years of productive work time lost. These delays affected the schedules of an estimated 190 million people.

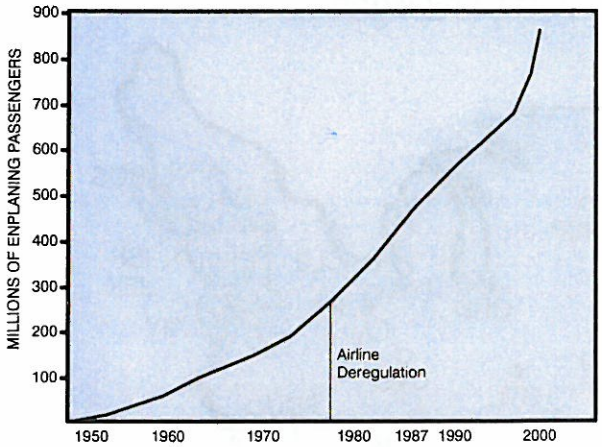
The dramatic growth in demand will place tremendous strain on the existing airspace and airport system, and require renewed focus on the requirement to expand system capacity and the research and development to help create it. Work to increase effective capacity is justifiable merely in light of the score of airports already burdened with serious delays and delay costs. The inevitably lengthy development and implementation tasks to provide new airport and airspace capacity warrant vigorous effort now to ameliorate the already very serious capacity shortfall.

Beyond the turn of the century, the capacity picture is much more difficult to predict; but a guide may be a 1988 study by the Transportation Research Board of the National Research Council. It concluded that "Demographic trend data indicate two to three times the 1986 traffic by 2050. Combined with the econometric assumptions of the FAA and Port Authority of New York and New Jersey forecast model ... a range of two to six times the 1986 traffic might be expected by 2050." Even at a probably conservative doubling of traffic, the nation is challenged to adequately expand the capacity of the airways system.

Sources of Additional Capacity In considering the issue of system capacity, the airspace system and airports both are major considerations. For practical purposes they must be considered as an integrated entity.

Airspace is a limited commodity which cannot be expanded. Additional capacity is gained by more efficient use of the available airspace. A vision of the support infrastructure for the future aviation system has been defined and has the broad understanding of the world's aviation community. A series of efforts is underway within the

Figure 19. Growth in U.S. Passenger Enplanements



Source: FAA.

FAA to bring these activities to operational reality in a reasonable time.

The Importance of System Engineering As the aviation system grows more complex, technologies grow more capable, aircraft systems become more sophisticated and have the ability to be partners in, and not just served by, the air traffic management system, the need for system engineering and system integration becomes an absolute necessity.

The effort required — research and development and, later, implementation — for a number of evolutionary improvements is clear. But for certain areas, the FAA system engineering process must generate system decisions and establish the future system architecture, which can then allow breaking major tasks into manageable development and implementation projects. This requires early and intensive analysis, support studies, simulation and, above all, a system vision and the willingness to make difficult decisions — often with less-than-perfect data.

Among the issues which fall into this category are the following:

- Decisions on the direction of air traffic control automation services, including the integration of the several FAA automation efforts (e.g., flow management automation, en route and terminal area automation, airport surface traffic automation, oceanic automation) and establishment of standard interfaces between them.
- Decisions on the appropriate balance between the separation assurance task of air traffic control at the scene and the overlying task of providing the least intrusive flow management when capacity limitations become evident.
- Decisions on the optimum balance of responsibilities of aircraft and ground systems in future cooperative air traffic management; establishment of the standard interfaces; and the definition of optimum information flows.
- Decisions on the utilization of the elements of an architecturally sound aviation weather system that integrates the FAA and National Weather Service (NWS) weather modernization programs and aircraft weather/wind data sources and establishes the interrelations with the automation and technology components of the air traffic management system.
- Decisions on the integration of wake vortex data with weather products and automation aids to provide relief from the effects of wake vortices.
- Decisions on the most efficient information flow and communications interfaces for the aviation system, including decisions on the evolution of digital communications (and its relationship to residual voice communication needs) to rationalize the roles and utility of different data link systems (the airline data link and its evolution, Mode S data link, satellite data link systems and their International Civil Aviation Organization architecture).
- Decisions on the ingredients for an Airport Surface Traffic Management System, assigning appropriate functions to the several system elements — surveillance, visual aids, signage, automated surface traffic management, etc.
- Decisions on the future air traffic control surveillance system(s) (assuming that en route primary radar for traffic separation will no longer be utilized) to establish the appropriate future roles of secondary radar and navigation-derived automatic dependent surveillance and to establish the requirement for accuracy.

In some cases the issues primarily require management decisions based on experience and judgment. In other cases, research and development will be required to support decisions. For some of the issues, simulation in the most realistic environment possible will be necessary.

Airport capacity, although related to airspace capacity, is not a naturally limited commodity. Nonetheless, there are not many sources for additional airport capacity. The 1988 Transportation Research Board study concluded the following:

- The present airport system should be optimized through:
  - Physical airfield and terminal improvements and expansion;
  - Ground access enhancement;
  - Procedural/operational changes and flow management;
  - Use of new capacity technology.

[The Transportation Research Board Panel estimated that such optimization of the present airport network by technological and managerial measures, "even if fully successful, might enable the present airport network to handle a level of traffic no more than 50 percent greater than that of today."]

- Adding new airports near cities with the most serious congestion.
- Adding new types of airports — e.g., the "Remote Transfer" Airport.
- Incorporating new vehicle technology:
  - New Aircraft — large aircraft and vertical/short take off and landing aircraft;
  - Surface transportation technology.

In a recent study of the three major New York airports' 1988 traffic, it was found that 56 percent of the departures carry 82 percent of the passengers greater than 300 miles. This implies that 44 percent of the slots carry only 18 percent of the passengers to a distance of less than 300 miles. It becomes evident that converting these 44 percent of the slots to larger, long-range aircraft would greatly increase airport capacity that is currently runway restricted at these sites. This, of course, would require providing reasonable alternatives for short-haul travel, including tiltrotor rotary wing, Short Take-Off and Landing (STOL) aircraft, high-speed rail, etc.

Smaller airports are likely to be major contributors in the provision of new capacity beyond that available from expansion of existing major airports. In its 1989 Airport Capacity Enhancement Plan, the FAA identified, for each of 38 airports then estimated to be congested by 1997, available airports within approximately 50 miles of the delay-encumbered airport. An air traffic control system that facilitates the use of these reliever airports is essential.

The wake vortex problem, a major deterrent to the safe achievement of additional airport capacity, is representative of a problem in the past conduct of FAA research and development. The effort has often suffered from limited management attention, erratic funding and lack of focus. The wake vortex effort, like most FAA activities, is interdependent with other projects and must be carefully integrated on a systems basis. The recent FAA initiative to establish a small executive-level, highly competitive system analysis and decision-making group addressing this subject is important and must be nurtured. It is clear that new types of aircraft, especially vertical takeoff and short takeoff and landing aircraft, offer the significant capacity benefit of requiring only limited space at major airports and permitting construction of new airfields where little space is available. Their operating characteristics may give them very attractive noise "footprints," especially if these aircraft can be built to operate quietly in relative terms.

At the growing number of airports where noise is a significant factor in limiting capacity, other technologies also offer promise. Wise use of curved, segmented and short final approach paths and flexible departure paths can provide significant benefits. Flexible noise abatement procedures help, and the FAA's work to exploit better navigation capabilities (e.g., flight management/area navigation systems, the Microwave Landing System (MLS), and the Global Navigation Satellite System [GNSS]) needs to proceed rapidly.

Industry Capacity Recommendations The FAA's Aviation System Capacity Advisory Committee (in a 1991 report entitled *Airport/Airway System Capacity Technology and Procedure Needs)* made a series of recommendations to the FAA on ways to achieve additional airport and airway system capacity through the development and application of technology and procedures. These efforts represent promising directions.

Among the 24 specific initiatives recommended by the Aviation System Capacity Advisory Committee are projects to reduce required spacing for independent precision approaches to parallel runways; to reduce minimums for operations to converging runways; and to establish procedures for Instrument Flight Rules (IFR) operations to closely-spaced parallel, triple, and quadruple runways.

Exploitation of the Global Navigation Satellite System and development of procedures for its use are essential in this regard.

Effort is also needed to create additional computer capacity/memory for terminal operation. The development of ground hardware, software and procedures to make full use of digital communications is correspondingly essential.

Systematic and scientific analysis is needed of en route and terminal capacity along with early completion and transition to initial sector suites in order to serve the growing traffic.

Requirements and procedures for use of cockpit traffic displays are needed to provide better information to pilots on traffic situation and to permit pilot participation to approach Visual Flight Rules (VFR) capacity in Instrument Flight Rules conditions.

The development/refinement of airspace and terminal area traffic flow analytical models should be completed and applied to help achieve efficient flow management and hasten the evolution to increasingly cooperative air traffic control.

Development of procedures should be pursued for application of Microwave Landing System or equivalent systems to achieve precision arrival and departure paths.

Optimum civil/military airspace use is an important ingredient of system capacity. Additional efforts are necessary to release special-use airspace to the civil system wherever appropriate. Rapid completion of the Military Airspace Management System is also needed.

Finally, improvements to increase capacity and efficiency of oceanic operations need to be completed.

The FAA is actively working on a number of these thrusts. There remains much to exploit in the technologies relating to capacity.

The Research, Engineering and Development Plan In the areas of airspace system capacity and air traffic control automation, the FAA's Plan begins with a broad and valuable overview. The Plan identifies a number of significant projects; however, there appears to be inadequate coherence among them and lack of a clearly defined common direction. Many projects exist which must necessarily be treated in consonance with one another — data link and weather projects being examples. It is important that each of the projects undertaken be structured in a manner where it can be traced to the overall system goals that have been defined in the Administrator's *A Vision of the Future : The ATC System Beyond the NAS Plan* and the broadly supported *Concepts and Description of the Future Air Traffic Management System for the United States.*

Communications, Navigation and Surveillance

Communications, navigation and surveillance technologies will continue to become of greater importance in the evolution of the future air traffic control system. In earlier years the FAA appears not to have adequately embraced the potential offered through satellite technologies. It is clear in almost all future air traffic control visions that satellites should play an increasingly important role — both domestically and internationally.

In many or most instances it will not be appropriate for the FAA to compete with the private sector or the Department of Defense in developing basic satellite technologies. However, the FAA must begin to seriously focus on the application of these technologies to all aspects of air traffic operations. Satellite technologies will be heavily relied upon to support basic safety services for air traffic control. The FAA must take an active and aggressive role in setting standards and minimum requirements that satellite system providers as well as avionics suppliers must meet. It must also accelerate its efforts to investigate the myriad of applications of these systems, ranging from oceanic communication and automated dependent and domestic navigation and surveillance to airport surface operations.

The Communications, Navigation and Surveillance section of the FAA Research, Engineering and Development Plan addresses top-level issues. The next phase of plan development should provide greater detail in each area so as to identify the research and development required to implement the systems and subsystems addressed. Furthermore, there remain several general concerns that need resolution:

- Schedules in some cases seem unduly prolonged, with studies scheduled for the mid to late 1990's. Earlier efforts could be used to identify the key technical issues so the appropriate

front-end research and development could be carried out in a more timely manner.

- There is too little emphasis on fixing today's problems.
- There is insufficient emphasis on coupling with the Department of Defense and other government agency research and development efforts as well as industry research and development efforts.
- Detailed schedules and planning data are not complete. An example "roadmap" would be an excellent tool.

FAA planning appropriately avoids development of specific satellite technologies. It focuses on the application of already available and soon to become available technologies to air traffic control needs. The global nature of satellite technologies makes this a very appropriate subject for worldwide application.

The FAA Research, Engineering and Development Plan properly concentrates on a new look at the airspace surveillance technologies required for the terminal area of the future. Automatic Dependent Surveillance (ADS) is one such potential application, as is the application of integrated radar technologies (such as phased array, multifunctional radars) for the terminal area. The plan de-emphasizes en route radar surveillance and concentrates on Mode S beacon applications as the primary system.

This approach to terminal needs may allow a multi-functional radar application at a competitive cost rather than the continued proliferation of individual stand-alone radar systems.

The following specific comments are offered:

- Recognition is needed of the potential requirement for a next generation Mode S sensor with flexible data link tasking and flexible scan management.
- The program description of a next-generation terminal primary radar would be strengthened by recognition of early research and engineering efforts that can be initiated beyond current sensor technology.
- Specific activities to address problems in future digital voice and data systems, such as error correction, privacy, security and fault-tolerant hardware and software, should be identified.
- Greater specificity in future program technical requirements would provide a basis for industry to identify appropriate internal programs and provide a basis for coupling into the Department of Defense technology base.

The Global Navigation Satellite System will almost certainly ultimately replace ground-based transmitters as the U.S. standard for en route navigation. The Research, Engineering and Development Plan reflects this view. It also begins to seriously address the questions of system integrity which must be solved to take this significant leap to the future navigation system.

On the other hand, the current FAA Research, Engineering and Development Plan does not appear to adequately address the issue of total system evolution. It is not possible to achieve a satellite navigation capability as the primary system by continuing to incrementally evolve the ground-based system. The technologies involved are fundamentally different and a deliberate transition strategy needs to be defined. While the transition can be and is addressed in other plans, such as the Federal Radionavigation Plan, its consequences must be reflected in the Research, Engineering and Development Plan.

Weather

With the advent of new automated systems, weather-related technologies must be developed if the highest safety and capacity levels are to be realized. The FAA Research, Engineering and Development Plan calls for the development and integration of automated weather display and communications capabilities appropriate for specified users. Until these technologies are better understood, a broad spectrum of scientific and engineering development efforts will need to be supported. During this period of development, the Plan envisions the evolution of a weather system based on the characteristics of the products selected and the means chosen for accurate and timely distribution.

Once again, care must be taken not to allow the independent development of these technologies without a comprehensive system-level understanding of how they can be integrated into the automation and information systems which support the air traffic control operations.

The Plan defines a new generation of weather products as well as a process to deliver them to end-state users. By becoming attached to new Capital Investment Plan weather elements, the

current weather projects of the National Airspace System are organized in a way that has an excellent chance of providing these capabilities near the turn of the century.

A critical and recognized need of this weather research, engineering and development effort is its interface with the extensive modernization efforts that the National Weather Service and the FAA have recently undertaken producing the Next Generation Weather Radar (NEXRAD), Automated Weather Observing System (AWOS), a modern Automated Weather Information Processing System (AWIPS), Terminal Doppler Weather Radar (TDWR), Airport Surveillance Radar (ASR-9) weather channel, and several other systems. The FAA research and development weather program leverages these developments which are already well underway, and further leverages the ongoing U.S. atmospheric science research effort sponsored by the National Science Foundation, National Oceanic and Atmospheric Administration, and National Aeronautics and Space Administration.

There remain two major concerns: the need for horizontal integration of the weather program and the development of operational concepts for the new weather products. The first relates to the fact that the systems integration of advanced technology weather data will require a considerable effort in "horizontal" design, engineering, and total system integration. Many advanced automation systems of the FAA essentially have failed to include modern weather products that are emerging from the Capital Investment Plan and research and development efforts. The existing highly data-rich systems seen in standard weather briefing packages have been accommodated without serious thought given toward processing these data to end-state, user-friendly products. An immense amount of work will be necessary in order to interface advanced aviation weather products into such systems as data link, etc. A related problem is that the engineering infrastructure addresses only the National Airspace System baselined weather projects. Now that there is a set of new concepts, the FAA's system engineering element has a large task ahead to engineer and integrate these new systems effectively.

The second concern relates to the application of these new weather products into the operational environment. Even with the older, data-rich information-poor system baselined in the National Airspace System, there was little focus on an operational concept. New generation, information-precise, end-state friendly products featuring color graphics, both in air traffic control facilities and in the cockpit, will require new operating concepts. The FAA, exploiting its rapid-prototyping efforts in weather, needs to entrain the operational arms of the agency, along with the external user community, to develop and evolve concepts for advanced aviation weather activities during development and not await fielding before user acceptance or needs are systematically considered.

The technology work being sponsored at the National Center for Atmospheric Research, Massachusetts Institute of Technology Lincoln Laboratory, The MITRE Corporation, and other organizations under the auspices of the FAA appears appropriate. Efforts in the private sector are maturing rapidly and "technology refresh" through application of these initiatives can be generally achieved in the private sector at a much faster rate than the government appears capable of assimilating.

Airport Technology

Airport capacity is affected by much more than operational separation standards and air traffic control factors.

In the light of heavy federal investment in the Airport Improvement Program (AIP), with perhaps $1 billion expended annually on airport pavement alone, a meaningful effort on product improvement research and development seems fully justifiable, especially if it is specific and directed at meaningful, measurable results.

The most important requirement is for a well-structured and adequately funded effort to develop, test, and validate pavement performance requirements and a unified pavement design methodology. It has become increasingly clear that the time-honored criteria for the design of airport pavements are probably not valid for the conditions of the 1990's and beyond. Creating new criteria will be difficult and expensive, but is essential and must be undertaken in a timely fashion. It is all but certain that new, larger and heavier aircraft will be operational in the relatively near-term. Moreover, new paving materials and systems, including high-strength concretes, may make possible totally new and more efficient designs.

The Aviation System Capacity Task Force has endorsed a series of efforts which deserve priority

attention. These include a universal non-destructive testing methodology; runway friction measurement criteria and relation to aircraft stopping distance; runway rubber removal and friction retention methods; continued directed research and development and validation testing for improved joint and fixture sealants; and development of standards and criteria for runway/taxiway surface roughness. Research into more effective pavement construction quality control methods could also pay high dividends.

A number of these topics are covered in a general manner in the FAA's current Research, Engineering and Development Plan, but need to be augmented with specific project descriptions. It also appears appropriate for the FAA to identify and focus on a limited number of priority projects. Because funding and personnel resources are limited, the FAA should consider restricting its efforts to the most promising items. For example, while effort to increase worldwide standardization of airport airside signage, marking and lighting is important, it should be responsive to the needs of FAA's more encompassing runway incursion and airport surface traffic management system work, and not dealt with separately. Similarly, the topics "lighting and marking requirements..." and "future requirements for airport surface traffic automation" are being addressed by others, and need to be reviewed to avoid duplicate efforts.

The Plan addresses several aspects of Rescue and Firefighting. A framework for developing requirements for rescue and firefighting and for the evaluation of technologies and practices designed to meet them was not easily discernible. This issue is important for aircraft and equipment that will come on line in the 1995-2000 time frame. Rescue and firefighting issues appear in several parts of the Plan and need to be tied together.

The issues of ground access to major airports and terminal design are not predominantly technical issues, but require cooperative problem-solving by a variety of local, regional and federal agencies including several Department of Transportation modal administrations and the Environmental Protection Agency. Further, FAA work in this area should be driven by the organizations responsible for solutions. Several issues such as terminal design simulation, passenger baggage clearance, and aircraft/gate/apron compatibility, are far advanced in the industry, and may well be better addressed by the industry which bears the primary burden of implementation.

Human Factors and Aviation Medicine

Human Factors Human error has been identified as a causal factor in over 70 percent of air carrier accidents.

The predominance of human error in aircraft accidents points to the significant need for additional research in this area, as well as focus on human performance considerations early in the design cycle of new systems. Over the last several years, interest in human factors has grown considerably for at least two reasons. One reason relates to the dramatic rise in traffic predicted for the next decade. The other relates to the introduction of automation in the cockpit and on the ground and concern regarding "automation-induced" incidents.

This situation has been brought to the public's attention by a number of well-publicized and preventable aircraft accidents in recent years. Ironically, some of these accidents occurred in "new technology" aircraft that were automated as a means of reducing operator workload and human error. These events, as well as those in non-aviation environments, have underscored the consequences of inadequate human factors planning in the design and operation of complex systems.

The heightened public concern about human factors problems in aviation prompted an in-depth investigation by the United States Congress Office of Technology Assessment (OTA) which concluded, in *Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment*, that support for human factors research was not adequate considering the magnitude of the problem. This sentiment was also reflected in recently enacted legislation, the Aviation Safety Research Act of 1988 (Public Law 100-591), which directed the FAA to substantially augment its human factors research program and to coordinate its efforts with those of the National Aeronautics and Space Administration.

Many productive research programs dealing with human performance in aviation have been underway in the FAA, the National Aeronautics and Space Administration, the Department of Defense, academia, and industry for years. However, these efforts generally were not organized into an overall plan that addressed the comprehensive nature of human factors issues in

the operation and maintenance of all types of aircraft, in air traffic control systems operation and maintenance, and in the interface between air and ground operators and controllers.

Two examples should illustrate the growing need for human factors research and application brought about by increased automation.

The first example, quoting from the report "Controller Perspectives of Automated En Route Air Traffic Control (AERA 2)," notes that "The introduction of AERA 2 will have a great effect on the controller work force and will raise several complex human resources issues. Reliance by the controller on the AERA's problem detection and resolution capabilities will shift the controller focus of attention to strategic planning tasks, with less focus on tactical monitoring, problem analysis, and consideration. These changes will create a need for new controller procedures, training, performance, evaluation criteria, and a review of controller selection criteria." Significant human factors considerations must be incorporated into this activity in order to ensure its success.

A second example of human factors research relates to data link, which has been addressed for many years yet receives little attention in the current Research, Engineering and Development Plan. The subject is important enough for at least two industry bodies, the G-10 committee of the Society of Automotive Engineers and the Human Factors Task Force of the Air Transport Association, to prepare prioritized lists of needed research on the subject. Commercial aviation is thus confronted with the prospect of data link being implemented while some very fundamental and researchable human factors questions remain unanswered.

In response to these system demands, the *National Plan for Aviation Human Factors* was developed. The plan is the first step toward a coordinated program and is the result of a major effort by the FAA in partnership with the National Aeronautics and Space Administration, with significant assistance from the Department of Defense, the Department of Transportation Research and Special Projects Administration's Volpe National Transportation Systems Center, and the Department of Energy. This plan is also a key element of the recently released U.S. Department of Transportation National Transportation Policy. It forms the foundation for the human factors portion of the FAA Research, Engineering and Development Plan.

It appears evident that the facilities, people, and budget are not currently available within the FAA to meet even the major demands imposed on the FAA in the human factors plan. The FAA in-house human factors technical capability exists primarily at the FAA Technical Center in Atlantic City, New Jersey. The focus there is more in a testing role than in a true research and development function.

Activities underway at the National Aeronautics and Space Administration Ames Research Center can be cited as an illustration of what can be accomplished. Human factor programs are emphasized at Ames where excellent research has been performed for a number of years. The U.S. Army has over 100 technical people assigned and working at Ames in pursuit of vertical flight specific programs (rotorcraft, tiltrotor, etc.). The activity is so highly integrated that it is difficult to discern which employees are National Aeronautics and Space Administration civil servants and which are Army personnel.

In contrast, the FAA has a total of four people assigned to Ames, mostly in a management capacity. It has a total program funded at that facility for human factors of less than $5 million.

Given these considerations, it seems appropriate that the FAA establish a human factors program which addresses requirements imposed by the *National Plan for Aviation Human Factors* and is coordinated with the rest of the relevant technical community. This will require that the FAA establish a highly qualified, in-house, human factors capability specifically connected to the system development effort which avails itself of that national expertise which already exists.

In addition to considering collocating such an activity at the National Aeronautics and Space Administration Ames Research Center, it would appear beneficial to establish a capability in human factors at the FAA Technical Center to integrate human factors research carried on by the National Aeronautics and Space Administration Ames and Langley Research Centers into operational systems. A human factors management office at the FAA headquarters is also needed to guide and oversee critical system engineering considerations and coordinate human factors efforts.

Aviation Medicine The FAA Research, Engineering and Development Plan's section on Aviation Medicine is a useful and comprehensive

statement of requirements, present programs, and future efforts. Nonetheless, the Plan warrants strengthening in several regards. First, a major component of the program should contribute directly to accident investigation, with new and better toxicological testing and with assessments of the significance of aviator pre-flight and in-flight stresses and behavior.

Another major component of the program should contribute directly to airworthiness certification of new materials, designs, and safety procedures. Additionally, a major component of the program needs to contribute directly to formal revisions of medical certification rules and to the day-to-day application of existing rules, an activity which potentially affects thousands of aviators annually.

The FAA human factors plan currently addresses only a minuscule part of another topic of truly gigantic proportions: assessments of the impact on aviators of over-the-counter and ethically prescribed drugs. Much more must be done on this topic in a systematic way, an effort that will take far more resources than are presently available. It should further be closely integrated to other related government efforts.

Aeromedical research contributes directly to many other research and development programs; for example, fire safety and emergency evacuation. It is an oversimplification to say that all aeromedical tasks are derived from Federal Air System Requirements. Research tasks are also derived from requirements of air safety, security, flight standards, and air traffic, as but a few examples.

Finally, it is noted that many other transportation systems have similar concerns (i.e., metro transit systems, trucking firms, railroads, etc.). The FAA cannot be expected to carry the entire burden of this effort by itself.

Security

The Aviation Security Improvement Act of 1990 directed the FAA to accelerate its system security program to fit within a 36-month period, address current and future threats, and expand emphasis on aircraft hardening and human factors. In the U.S. alone, the immediate impact of the Pan Am 103 event was to double airline security costs from $500 million to almost $1 billion per year.

The FAA Research, Engineering and Development Plan provides a sound basis for further enhancements in most elements of security associated with air travel, but does not sufficiently address the security of data and data processing/transmission.

Security is an area wherein considerable progress has been made throughout the world, although enormous challenges remain. By the very nature of the subject, the FAA Research, Engineering and Development Plan is precluded from providing particularly definitive information relating to planned research and development activities. Detailed discussion in the Plan, or in this review, would be counterproductive. It is noted, however, that the general approach to this problem has been more of a "bottom-up" character than a structured flowdown of requirements based on systems objectives. It is essential to study the philosophical underpinnings of the approach to security and to apply techniques flexibly to keep terrorists off guard. The Plan could be strengthened by a more detailed assessment of future threats, closely coordinated with other appropriate government agencies. The FAA should establish a program specifically directed to "terrorism of tomorrow," and weave it into the threat analysis.

The immediate response to inhibit the probability of increased terrorist activity has focused on the aircraft itself, both from operations as well as the screen of access to the aircraft, passengers, maintenance, baggage and cargo. These efforts have included programs such as explosive detection, weapons detection, airport physical security, security systems integration, aircraft hardening and aviation security human factors. Detection technology has received most of the emphasis, and several different approaches are being pursued. However, this work is very much in the area of "advanced technology," and it can be expected that some pursuits will not work or will not be capable of economical introduction into the air transportation system. Much of this advanced effort is on the edge of known technology, and finding ways to apply it to a potential operational system will take some years.

Advanced air defense weaponry is beginning and will continue to proliferate around the world. Many of these weapons, such as the hand-held Redeye, Stinger, SA-7 and Blow Pipe air defense missile systems, can be employed by a single person against most low altitude aircraft. Access to such weapons will become more difficult to control as they are increasingly proliferated and used in

combat. Preparation must be made for equipping civil aircraft with defensive systems which are currently employed on military aircraft to detect and defeat these sophisticated weapons.

Consideration must be given to the security of the air traffic control systems of the future. The Plan does not disclose any effort to insure the security of the data, the processing or transmission of air traffic control information. The effect of computer "hackers" has already been observed in certain military and commercial computer systems. Since air travel is "live," and in "real time," an unexpected "virus" could be extremely dangerous — literally in a matter of seconds. Terrorists of the future must be given credit for being capable of penetrating these new air traffic control systems and holding an entire area or en route portion hostage. This situation can become much more dangerous than the very complex threat currently posed by one or a few individuals with a single aircraft as a target. The FAA should of course coordinate closely with the Department of Defense on the systems they have developed to protect against these threats.

The FAA Research, Engineering and Development Plan calls for construction to be completed in 1992 of an explosives detection laboratory. It is noted that the Research, Engineering and Development Advisory Committee has questioned the need for this in the past on the grounds that other similar facilities already exist within the government.

Finally, animal olfaction techniques for explosives detection appear to offer continuing promise, but do not seem to be given commensurate attention within the FAA's research planning. The Department of Defense has a number of activities underway in this area which can also be of value to the FAA's mission.

Safety

Safety considerations are obviously a top priority and appear to be well integrated into all appropriate developmental activities of the agency. In the past, the FAA safety program has produced many improvements by responding to hazards identified as a result of incidents, accident investigations, and public concerns. The current Research, Engineering and Development Plan identifies a number of crucial safety objectives relating to planned as well as existing aircraft, operational practices and facilities. The central concern is the capability of the agency to mount sufficiently proactive safety research, engineering and development efforts to stay abreast of changes in risk factors caused by capacity increases and the introduction of otherwise beneficial new technologies.

Most of the planned safety objectives address areas in which the FAA has prime responsibility: aircraft systems fire safety, aircraft catastrophic failure prevention research, and aircraft operator information systems. In other important areas the FAA works closely with other agencies to develop national programs in aviation safety. A number of the planned activities respond to Congressional guidance as specified in the Omnibus Budget Reconciliation Act of 1990, the Aircraft Catastrophic Failure Prevention Act of 1990, and the Aviation Safety Research Act of 1988.

The fact that aviation fatality rates are what is generally considered to be low, especially when compared to other forms of transportation, is a tribute to the effectiveness of past programs of the FAA, associated laboratories and of the industry it regulates. However, new aircraft (such as the High Speed Civil Transport and tiltrotor), new materials (such as advanced polymers and designer composites), new systems technologies (such as automation), higher traffic flows, and concentrations; all require increased attention to aircraft safety, to the cost-effectiveness of related measures and procedures as well as a substantial commitment to fundamental, long-term research, particularly in the area of aircraft fire safety.

In conjunction with other national agencies, the FAA has active research programs addressing:

- Icing and icing protection systems;
- Lighting and High Intensity Radiated Fields (HIRF) effects on carbon fiber composites in airframes;
- Radio Frequency (RF) microelectronics susceptibility and damage/upset levels;
- Digital systems validations for airworthiness criteria in fly-by-wire/light flight control concepts;
- Windshear detection and avoidance systems.

The FAA is a crucial participant with the National Aeronautics and Space Administration and the Department of Defense in developing and implementing the National Rotorcraft Master Plan,

including safety considerations in the certification and operations of new concepts, such as the use of the tiltrotor in civil applications.

A significant concern in the safety area stems from the fact that the U.S. commercial air transport fleet is aging. Fatigue and corrosion induced structural failures are of particular importance in this regard and require the heightened attention of the FAA, aircraft manufacturers and operators alike. The FAA and the National Aeronautics and Space Administration have established a cooperative research and development effort to provide a technological basis for ensuring the continued safe operation of the U.S. commercial airplane fleet. The agencies have signed a Memorandum of Agreement which coordinates technical projects, defines tasks to meet overall goals, and provides a mechanism for cooperative participation in a comprehensive national aging aircraft research program.

The Aircraft Systems Fire Safety and Crashworthiness programs are sound extensions of high quality test and evaluation work performed in the past at the FAA Technical Center, using its full scale facilities to develop improved flammability requirements for interiors and requirements for seats, extinguishers, etc. This needs to be complemented by a proactive, longer-term research strategy that establishes the basis for future requirements and technologies consistent with future needs.

Two other programs provide examples whereby the FAA has primary responsibility but utilizes cooperative activities with other agencies to bring the greatest leverage to bear on a specific problem area.

The first of these is Propulsion-Enhancement Flight Control Research being conducted at the National Aeronautics and Space Administration Ames Research Center. Through the selective modulation of engine power, an aircraft can in some circumstances be controlled to a safe landing in the event of loss of normal aerodynamic controls. An example was the event involving a DC-10 in Sioux City, Iowa, wherein all flight controls were lost due to a turbine engine failure which in turn crippled the hydraulic system. The pilot in this instance was successful in reaching an airport, utilizing engine power as the sole control mechanism.

The second example is the Aviation Safety Reporting System (ASRS) maintained by the National Aeronautics and Space Administration Ames Research Center. This system receives, processes, and analyzes voluntarily submitted aviation safety reports from pilots, controllers, and others; distributes the information to further the cause of safety; takes action to remedy reported hazards; and conducts research on pressing safety problems.

On the horizon lies the major transition to system automation and the change from controller/operator management of each aircraft in a "tactical" environment, to a more strategic environment utilizing space-based sensors, related technology and automation.

The challenge of the future for civil aviation safety will be to improve the relatively stable 20-year record of annual passenger fatalities. This will require balancing investments in automation hardware with progress in human-centered designs, procedures and software. It would also require that safety be engineered into all aspects of the greatly advanced technologies of the future air transportation system.

Restraint systems and energy-absorbing seats developed for Federal Aviation Regulation Part 25 and Part 23 aircraft are accepted by the airframe and safety communities as significant advancements that hold the promise of reducing fatalities and debilitating injuries in survivable accidents. The FAA is encouraged to extend this work promptly to commuter aircraft with less than 20 seats. Such aircraft are important elements within our nation's transportation system and are subject to design reviews as production of Special Federal Aviation Regulation 41 aircraft ceases.

Even though it is generally accepted that 70 percent of aviation accidents are due to human error, equipment design can be improved to minimize human error. This philosophy should be widely implemented.

Environment

Civil aviation continues to expand to meet demand. This expansion means more flights carrying more passengers and, probably in the future, to more places; i.e., airports, heliports, vertiports, etc. This has the potential to affect the world's environment in a significant manner. Relating to this is the fact that the quality of the natural environment is a growing concern of the world's population today. Current and expanding aviation activities affect the environment by noise, emissions

and energy consumption. Perhaps the most serious current environmental concern and limitation on aviation is noise.

The United States Congress has recently passed several pieces of legislation addressing this subject. They include the Aviation Noise and Capacity Act of 1990 and the Clean Air Amendment of 1990. It is currently estimated that 2.7 million individuals live within areas that are considered to be exposed to "significant" airplane noise — that is, a day-night weighted average sound level of 65 decibels or more. More than 400 airports have adopted procedures to reduce aircraft noise or mitigate its effects. These procedures have reduced potential airport capacity by as much as 30 percent. Additionally, there is an effort to ensure the early phase-out of older, noisier aircraft. There will undoubtedly be a demand for even more stringent limitations on aircraft noise in the future.

Increases in available capacity achieved by technological or procedural improvements could in turn create greater concentrations of noise and thus compound the environmental challenges. A number of initiatives need to be pursued which can help ameliorate this problem. Prominent among these is intensified research and development to achieve quieter aircraft for the future. While this research should be accomplished largely by agencies other than the FAA, the establishment of needed results and the support and monitoring of this work are important FAA tasks.

The research and development program on the tiltrotor vehicle which is being conducted by the Department of Defense with the support of the National Aeronautics and Space Administration (in part addressing certification standards) needs to be addressed in the FAA's analyses of noise profiles. The feasibility of vertiports in or near residential areas will in part be determined by the ability to deal with the attendant noise considerations. The use of the Microwave Landing System, satellite navigation for precision departure routes, steeper glide path on approach and other new developments can also help mitigate the problem.

In the near term, noise reduction and control activities include updating and improving the Integrated Noise Model, Helicopter Noise Model, the Area Equivalent Method, and the Nationwide Airport Noise Impact Model. Cooperation with the National Aeronautics and Space Administration in noise research aimed at developing a better understanding of community response, investigation into source noise reduction, engine design parameters, advanced acoustic absorption materials, active noise control devices and methods to reduce airframe generated noise, need to be continued aggressively.

Some major conclusions can be drawn from research already underway:

- Acoustically treated high bypass engine technology as implemented in the industry, represents the best level of technology possible for at least the next decade. With Stage 2 noise reduction airplane phase-out, airport noise levels will diminish until the transition to an all-Stage 3 fleet is completed, at which time air transportation system growth can be expected to cause the cumulative fleet noise levels to increase again.
- Adoption of more restrictive noise rules by some local governments or airports must be anticipated on both a domestic and international basis as a requirement for airport expansion. It is unrealistic to expect unrestricted fleet growth with Stage 3 technology alone. Significant economic impact is likely.
- Currently planned and funded research programs in the United States, involving the National Aeronautics and Space Administration and the aviation industry, must be strengthened and accelerated if the nation is to maintain a vigorously growing aircraft industry.

As advanced technologies continue in programs such as the High Speed Civil Transport, research is needed relating to their emissions in the upper atmosphere. Jet engine designs must be pursued that reduce emissions, specifically nitrogen oxide due to its effect on the ozone layer.

In summary, environmental considerations will dictate to a considerable extent how civil aircraft will operate in the future, the degree to which the United States can maintain its share of the international market, the location of future facilities and the design of future aircraft and airports.

Management of the Research, Engineering and Development Plan

The vision of the National Airspace System discussed herein establishes the FAA's long-range goal. As such, the vision implies that a substantially expanded research program is required to meet both expanding safety, security, energy and environmental requirements and the need to create the future National Airspace System and air traffic management system that are fundamentally different from today's system. But the vision in itself does not, and should not, provide details on the specifics of the research to be conducted.

As discussed in a previous section of this report, Level 1 of the system engineering process proceeds from established needs and the vision of the future to develop first a set of operational concepts and associated requirements and then a functional architecture. These, in turn, serve as directives for the design of new research, engineering and development programs and for the evaluation of existing programs. This process requires that the entire research, engineering and development program be managed as a single, comprehensive entity. Such a management process would build a research program that has a consistent, well-defined and potentially achievable set of goals and a procedure for demonstrating how individual components of the program support attaining those goals. In the material that follows, a process is suggested for managing a research, engineering and development program to meet the prescribed Level 1 operational requirements and functional architecture.

In the opinion of the Panel, it is necessary that the FAA not only establish a comprehensive approach to defining and evaluating research and development programs, but also find new ways to introduce the products of research into the field by streamlining the existing sequential development process.

Managing the Plan as a Comprehensive and Integrated Program

The FAA has recently embarked on an effort to establish research, engineering and development program goals and to rank individual projects on the basis of how well, taken together, they satisfy these goals. This evaluation process should play a central role in the definition of all research and development projects. The procedures for evaluating research and development activities should not be an opportunity for, in the vernacular, "paralysis by analysis." Rather, they would provide the FAA research and development management with a mechanism to make decisions quickly and effectively concerning investment in its future research and development program. Figure 20 illustrates one possible structure of the output from such a process, which should help materially in making next year's update of the Research, Engineering and Development Plan an increasingly comprehensive and comprehensible document. In this figure, FAA goals (represented by analytic measures, or metrics) are compared to the estimated contributions of individual research projects.

Using a structure such as the one illustrated would allow the FAA to determine readily if a given project is likely to help the agency meet its established goals. Similarly, use of such a matrix could allow the FAA to evaluate how projects might interact to provide synergies that would allow established goals to be met more rapidly. For example, bringing both data link and the en route automated air traffic control projects on line will enhance the performance of the air traffic management system much more than the sum of the individual projects.

This approach is complementary to current FAA practices, including cost-benefit analysis. The FAA has traditionally applied cost-benefit to capital investment projects, and has recently applied the technique to its research, engineering and development program. But this process will require information that can be gathered using the type of top-down analysis suggested by the methodology of Figure 20. In effect, the information used in this structure would be an input to individual and programmatic cost-benefit analyses. A combination of these types of analyses can help the FAA better select projects from among competing alternatives.

In addition to providing a mechanism for evaluating research projects and selecting those projects to initiate, continue or eliminate, a well-managed research and development program should provide a mechanism to balance risks. Program formulation should consider projects that are relatively risky (the effort may fail to produce useful results insofar as meeting FAA goals and objectives

Figure 20. Relationships of Projects to Metrics

Illustrative Example Using Analyses from the Oceanic (North Pacific) Operating Domain

System Goals as Characterized by: METRICS	PROJECTS: RE&D Planning Baseline	Appl of Auto Dep Surv (ADS)	Oceanic ATC Automation	Terminal ATC Automation (TATCA)	Airport Surface Traffic Automation	Airport Capacity Improvements	Wake Vortex A/A System	Cockpit Display of Traffic Info (CDI)	Adv AERA Concepts	UNITS
Capacity: Airspace	240	P	+ 624	S	NA	P	P	P	P	Flights Per Hour
Capacity: Intersection	4	P	+ 8	S	NA	P	NA	P	P	Flights Per Hour
Capacity: Airfield		NA	S	S	S	P	P	S	S	
Efficiency: Airborne Delays	26	P	- 21	S	NA	P	S	P	P	Minutes Per Flight
Efficiency: Departure Delays		S	S	P	S	P	P	NA	S	
Flexibility: Route Deviations	88	P	-77	S	S	P	S	S	P	nmi Per Flight
Flexibility: Altitude Deviations	53	P	-1	S	S	P	NA	S	S	% of Flight Segments
Flexibility: Excess Fuel Usage	3610	P	-2520	S	S	S	S	S	S	Gallons Per Flight
Safety: Airframe		NA	NA	NA	NA	NA	NA	NA	NA	
Safety: Airborne		P	NA	NA	NA	S	S	P	S	
Safety: Ground		NA	NA	NA	P	S	S	NA	NA	
Leadership:		P	NA	P	S	S	S	P	P	

P = Primary Impact
S = Secondary Impact
NA = Not Applicable

is concerned, but, if successful, would have tremendous positive results) with projects whose contribution may not be truly decisive but are highly likely to be attainable as well as useful. In this regard, it is critical that the proposed research and development program not be evaluated by the performance of individual projects but by the performance of the program as a whole. An understanding is necessary that some research projects will fail, while most others will be successful.

Bringing Projects On-Line Efficiently and Effectively

Historically, research and development projects at the FAA have been intended as precursors to future capital improvement programs. These projects frequently took decades to bring on-line, following complete and sequential testing at each stage in the project. There was a focus on component technologies such as radar, communications equipment, computers, and other hardware. Most of the elements of today's Capital Investment Plan were originally conceived as research projects.

Today's research, engineering and development projects cannot and need not be managed by unquestioningly following the dictates of classical acquisition procedures. The rapidity of creation of new technology along with the requirements for increased airport and airspace capacity, increased fire safety, increased knowledge of aircraft structures, increased airport security, etc. all militate against projects with long life cycles. The nature of system enhancements and the advent of new technology now make it possible to manage FAA research and development as a process of innovation, which stresses prudent overlap in concept formulation, development and implementation, rather than a purely sequential process that begins with invention and postpones subsequent programmatic decisions until total demonstration of each facet of the concept and technology. To manage its research and development as an innovation program, the FAA must rely on the following practices:

- Applying rapid prototyping and innovative acquisition strategies. For example, the FAA was able to introduce new, automated approach control technologies for converging runways by using rapid prototyping to establish functionality and validate user requirements.
- Ensuring that the automation environment is designed to match human functional capabilities through early and continued involvement of controllers, users, and human factors experts. Early automated en route air traffic control applications are examples of this process.
- Leveraging commercial, "off-the-shelf" products to advance FAA research work using proven technology, including work accomplished by the Department of Defense and the National Aeronautics and Space Administration.
- Leveraging the massive investment in the Capital Investment Plan and ongoing capital improvement programs by incrementally adding functional capability to the existing FAA infrastructure.

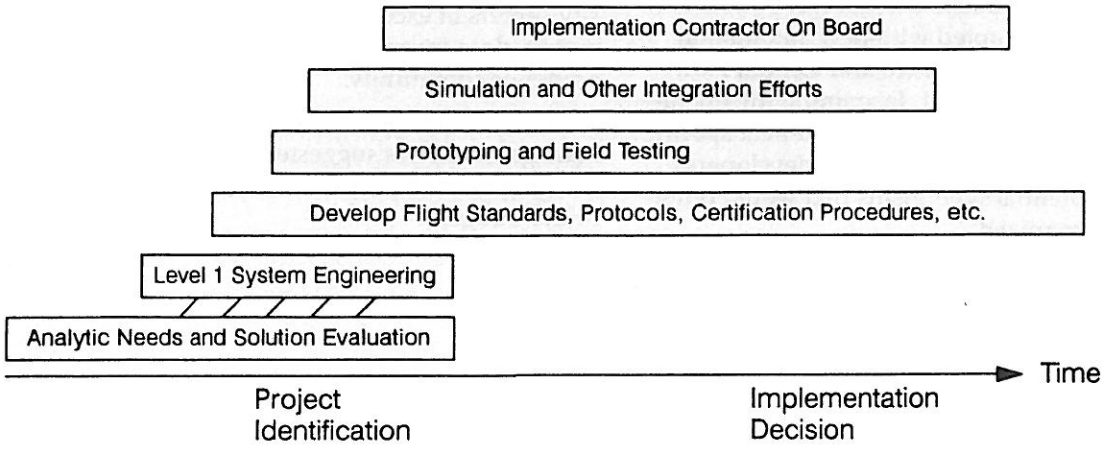
By managing its research and development program in this manner, the FAA can bring original ideas incorporating new technologies on-line as they are developed. Specific new technologies can be integrated with existing systems and thereby provide immediate benefit.

An important part of developing new technologies is concurrently developing certification standards, protocols, operating procedures and the like. These processes are critical in bringing new technologies on-line.

In addition to completing the efforts described above, the FAA should involve contractors early in the life cycle of a project in cooperation with FAA research organizations. Under this system, the FAA could make experimental data available to the selected contractor. Further, contractor ideas and algorithmic concepts could be incorporated into upgraded experimental efforts at an early stage. In the example of rapid prototyping mentioned above, the implementation contractor was afforded access to initial experimental data and was thereby able to quickly implement the system in the field. The interaction between the contractor and the results of the prototyping effort created an effective feedback between development and production engineers. In general terms, such a process improves the probability for success and early introduction to the field for any given project.

Figure 21 illustrates how various components of the FAA research planning and implementation process could be designed to occur with a prudent degree of overlap rather than purely sequentially, as is now most often the case. By employing such a process, reinforced by senior management

Figure 21. Some Elements of Research and Development Planning and Implementation



attention to the overall programmatic needs of the entire research program, it should be possible to identify projects that are most likely to be of use.

The Panel believes that using various existing simulation techniques, augmented as necessary to produce a complete set of simulations, to evaluate prototypes and to validate requirements would be a major step forward in determining how a project might fit into the overall air traffic management structure. This integrated suite of simulations will allow the FAA to conduct analytic (e.g., computer model and technology mock-up) as well as "man-in-the-loop" evaluations. These evaluations can provide a concrete indication of the potential for a specific project, along with a realistic indication of how the technology might be implemented in the field.

Another important capability of simulations is to test human factors to determine whether specific changes to system components (e.g., controller work station configurations) will provide a benefit or will reduce the ability of controllers to maintain a given level of effectiveness.

These simulations can underpin the rapid prototyping of technologies prior to investing substantial funds in their development, and will allow the FAA to determine efficiently if work should proceed or be stopped early in a project's life. The benefits of an appropriately developed national simulation capability should not be underestimated in this regard.

One major benefit of a national simulation capability would be to assist the FAA in evaluating how various technologies will be integrated across the entire aviation structure. For example, a national simulation capability can help evaluate how Automated En Route Air Traffic Control will perform at the regional level, coupled with new automation techniques in terminal airspace and Central Flow Control at the national level. Examining the operation of the air traffic management system at specific geographic regions may help system developers make use of potential synergisms that would otherwise not be recognized.

Providing Technical Personnel

A final and critical component of managing the FAA research and development program resides in ensuring that the managers of this effort are sufficiently trained and sophisticated to lead these programs from early definition through final implementation. This will require management styles and practices that are, as suggested above, often different from those normally employed in government research and development activities and will require experience in directing a variety of tasks at different stages of development simultaneously.

In order to accomplish this, the FAA needs to take several actions. It must continue to strive, within existing regulations, to hire additional highly qualified scientific and engineering personnel. These persons need to have early career exposure to a variety of FAA assignments, both within the research and development community and in the operational services. Such exposure, perhaps on a three-year rotational basis, would help ensure that managers of the research program understand the operational constraints facing the airspace system. Overall, managers need wide experience in the research and development field. Senior managers of the FAA research and development program will require sufficient job tenure to provide organizational continuity to a project.

Unfortunately, in some past instances FAA managers may not have received adequate training to implement a truly innovative acquisition program of the type contemplated herein. In fact, the highly ritualized government acquisition regulations discourage such practice. Training is therefore of the utmost importance. In particular, the Panel suggests that the FAA support university programs that are capable of educating students for positions within the FAA, and encourage the development of centers of excellence within several universities to encourage study of disciplines useful to the FAA. Fellowships and sabbaticals at such university centers of excellence should be funded to promote a close interaction between the FAA and the academic community.

Finally, rewards are needed for excelling in the management style suggested above — including bringing needed projects on-line, on time and under budget.

Recommendations

The recommendations of the Research and Development Plan Review Panel are separated into two categories. The first comprises those major findings requiring the attention of senior FAA management and potentially having fairly broad impact. These are summarized in the text which follows. The second category consists of a substantial number of more detailed comments having to do with specific aspects of the FAA's Research, Engineering and Development Plan or the projects which comprise that Plan. This latter set of comments is being provided to the FAA in separate communications between the Panel members and cognizant FAA personnel.

A total of fifteen principal recommendations are offered for consideration.

System Capacity Delays and congestion are increasingly plaguing the aviation system at a growing number of airports, particularly in adverse weather. The FAA expects the number of airports with more than 20,000 hours of annual delay to increase from 21 in 1991 to 41 by 1998. It is noted that there is a high degree of traffic concentration within the nation's air terminal system. One hundred airports together enplaned more than 90 percent of the 459 million passengers who traveled by air in 1988 and these airports are expected to incur an increase in passenger volume of 56 percent by 1998. Correspondingly, aircraft operations at these airports are expected to grow from 25 million to 34 million over the next ten years. In considering the issue of system capacity, the airspace system (en route and terminal areas) and airports must be considered as an integrated entity.

Recommendation 1: **The Panel recommends that the safe achievement of additional airspace and airport system capacity be assigned as the highest priority within the FAA research, engineering and development activity.**

Financial Resources Many of the challenges facing the nation's air traffic system can be expected to have considerable technological content in their solutions. Problems having this characteristic include those affecting system capacity, safety, security, reliability, and cost. The FAA has taken steps to create a plan which will assure that the needed technologies are indeed available and it is the judgment of the Panel that the Plan is both fundamentally sound and worthy of strong support. On the other hand, it would appear that the financial underpinning of the proposed effort is insufficient to accomplish the goals which have been identified. Comparisons with other organizations which are similarly dependent upon technology suggest that the FAA for many years has been underinvesting in its technology base. The steps initiated in fiscal year 1992 to rectify this situation are encouraging; however, considerable additional effort will be required to assure the long-term viability of the Plan.

Recommendation 2: **The Panel recommends that, in view of the conviction that historical funding levels are not adequate to execute the proposed research and development program, additional financial resources, be programmed based upon a re-examination of likely costs of each individual project.**

Technical Capability The most carefully constructed research and development plan, backed by abundant financial resources will not succeed if it is not conducted and managed by an adequate number of highly qualified and motivated individuals. Over the years, the cadre of highly capable personnel in the United States whose careers have been dedicated to air traffic management has shrunk considerably. It will be necessary that the FAA continue to obtain and retain a share of the nation's most talented technologists and managers in the years ahead. The committee is not sanguine about the ability of the FAA to accomplish this objective given limitations on federal salaries, incentives, the public sector decision-making environment, and the degree of prestige afforded public servants in general.

Although the Panel urges that the FAA draw upon the private sector to the greatest extent possible for the actual development and provision of new systems, the Panel also believes that the FAA must maintain a strong *internal* technological capability in order to manage this effort. If FAA personnel are in fact to direct major engineering projects, these individuals must be, or at least once have been, *practicing*, hands-on engineers themselves. The government should take a leadership role in encouraging academia to offer courses related to

FAA missions and promising young employees should be rotated through a variety of positions (operational as well as developmental) during the early phases of their careers.

Recommendation 3: **The Panel recommends that the FAA take steps to enhance competitiveness in acquiring and retaining highly qualified technical personnel, including fully utilizing recently approved government-wide personnel legislation; and that it establish centers of excellence at selected universities to address FAA-related issues and train a cadre of future leaders.**

Requirements It is critical that the FAA's research, engineering and development activities respond to identified needs of the operating services, and in fact to the needs of all who must make the FAA systems function, such as the air traffic controllers and pilots; but it also must respond to those who are the ultimate *users* of the nation's airways, including airline passengers, cargo shippers, and private pilots. The operators, however, of necessity, tend to concentrate their attention on "today's" problems — and thus should not be permitted to exert unilateral control or veto-power over the long-term research and development process. A significant part of the effort in this endeavor should address innovative new concepts and the exploration of unique ideas which in many cases will challenge the *status quo*. It is necessary to both solicit the "real-world" perspective of operators and the technological innovativeness of researchers, if a truly effective research and development program is to be maintained.

Recommendation 4: **The Panel recommends that the process for establishing requirements and justifications for the technology program draw heavily upon the FAA's operating organizations and users' stated needs, but that the research and development organization also be encouraged to pursue promising technology possibilities and innovations even though they may not yet have the support of users or operating services.**

System Engineering During the past year the FAA has taken a number of steps to revamp and strengthen its system engineering process. This process includes the definition of specific goals, which are coupled to system needs and the allocation of requirements to the task plans which lead in turn to the achievement of these goals. It is particularly important that clear measures of success be established so that progress can be monitored throughout the lifetime of a technology initiative. If this is done properly, a coherent, coordinated plan can be derived with specific objectives for each undertaking. The overall effort to increase the degree of automation in the air traffic system is an example of an activity warranting particular attention in this regard.

Recommendation 5: **The Panel recommends that the FAA's system engineering methodology be used and strengthened to translate user needs and technological opportunities into goals and to flowdown requirements, establish programs, assess results, provide integration across program areas, and serve as the basis for the allocation of technology funds.**

Simulation The introduction of truly innovative technological concepts often leaves managers with little basis in past experience for assessing their potential worth. Similarly, it is often difficult to successfully integrate new technologies which represent a quantum change into existing systems. In this regard, one of the more promising developments in recent years has been the evolution of powerful simulation tools. These tools include purely analytical (computer-based) models, as well as hybrid models involving emulation of hardware and software, and the inclusion of actual hardware components themselves as well as humans in the loop. The FAA has a number of element simulations, and major advances are now possible in large-scale simulation.

Recommendation 6: **The Panel recommends that the national simulation capability be funded on an expedited basis and used to streamline the transition of new technologies and concepts into the nation's air traffic system.**

Prototyping Once the merit of a new component, system or procedure has been verified in simulations, the next step in many cases is to build a prototype. There is particular need for a rapid prototyping procedure which permits early assessment of the utility and practicability of proposed hardware, software, procedures and operational

concepts. Properly structured, prototyping can greatly reduce risk while actually expediting the transition of new technology into the field.

Recommendation 7: **The Panel recommends that the FAA's current activities for prototyping of critical new technologies be strengthened through the provision of greater budgetary support, broader integration and increased management attention so as to expedite the fielding of new ideas.**

Procurement Practices The procurement process provides the means by which new technologies and system concepts are taken from the laboratory to the field. The FAA operates its procurement process under the overall umbrella of government-wide acquisition laws and regulations. In many instances, these laws and regulations are quite broad and unfortunately do not adequately recognize the unique character of research and development activities. This is particularly true in the case of innovative new technologies which may offer the potential of major breakthroughs — but at the same time have inherently high risk of failure. It is critical that such projects be aggressively pursued, and that the penalties for failure in technology development activities (as opposed to major system developments) not be inordinately severe — since the converse would inevitably have the effect of discouraging the very innovation that was being sought in the first place.

Recommendation 8: **The Panel recommends that the project manager exercise principal authority in the execution of technology programs, with the support of a qualified contracting officer, and that contracts for technology development recognize the uncertainty inherent in such activity and utilize contract instruments which appropriately balance risks between the government and its suppliers.**

Discretionary Research and Development Innovation is not the unique province of any particular organization or even any particular kind of organization. It is therefore important to provide modest amounts of resources and management latitude to a number of the entities involved in the research and development process such that they can pursue, *at their own discretion*, promising avenues of technical inquiry. In the case of industry this can be accomplished through a strengthened Independent Research and Development program, as currently permitted under the Federal Acquisition Regulations (FAR's). In the case of academia, federally funded research and development centers, and government laboratories themselves, this can be enabled through the provision of a limited amount of unencumbered funds to each organization's technical leadership. The management of each organization must then, in turn, be accountable over the long term for results from this investment.

Recommendation 9: **The Panel recommends that the latitude to determine which early technological pursuits are worthy of funding not be narrowly reposited in a few senior management individuals but rather be widely diffused throughout industry, academia, government and not-for-profit organizations through the provision of modest sums of discretionary funding to be used to encourage innovation.**

Intra-governmental Coordination Many of the technologies critical to the FAA are also important to other governmental organizations such as the National Aeronautics and Space Administration, the Department of Defense, the National Institute of Standards and Technology, the National Oceanic and Atmospheric Administration and the National Science Foundation. In addition, industry and academia conduct significant programs in such areas as noise reduction, fuel efficiency, aircraft safety, etc. The FAA at present engages in a number of joint programs with organizations such as the above, and by so doing has been able to stretch the funding which has been available for technology enhancement.

Recommendation 10: **The Panel recommends that the FAA plan the augmented program recommended herein with the maximum appropriate intra-governmental, academic and industrial cooperation to maximize and leverage the synergistic benefits of each of their capabilities.**

Technology Insertion The area in which the nation's air transportation technology management process can achieve the greatest enhancement is in streamlining the process of safely introducing new technology into the field. In some cases, new

technology can be more readily incorporated at the component level as opposed to the total system level. This suggests the possibility of introducing new technology into the field without waiting for an altogether new generation of systems; a practice which has in fact been successfully pursued by the FAA on a number of occasions in the past. In other instances there have been major system upgrades, such as those outlined in the National Airspace System Plan. In either event, a management process which enables more timely benefit from the application of new technologies appears very much in order.

Recommendation 11: **The Panel recommends that a process be created which accelerates the introduction into the field of system improvements funded in the Research, Engineering and Development Plan and that all projects be supported by an implementation plan (contingent upon the success of the development effort).**

Security The answer to the security issues affecting the world's air transportation system resides only in part in technology; nonetheless, much of the burden does in fact fall upon technical innovation. This is an area requiring increased attention to truly basic research, more so in fact than most other air transportation issues. Considerable emphasis has been focused to date on the prevention of threats aboard aircraft. Additional security attention in the future will need to be focused on threats to airborne aircraft from the ground as more advanced weaponry becomes diffused around the world. A different type of security concern resides in the potential vulnerability of data systems to "hackers." This newer category of threat will require increasing attention in the years ahead. In all such areas technology and operating practices must be tailored to produce uncertainty and degraded confidence on the part of would-be terrorists.

Recommendation 12: **The Panel recommends that an expanded portion of the funding now being devoted to security be allocated to basic research in that area, and that efforts addressing the security of data systems be considerably enhanced.**

Spaceborne Assets The existing worldwide air traffic management system has been relatively slow to benefit from developments in the space program, both military and civil. This is in part due to the major investment already in place for ground-based sensors and communications in the nation's air traffic control system, and in part due to the need to assure that the introduction of new approaches is non-disruptive with respect to the operation of existing systems. On the other hand, major strides have been achieved in recent years in the use of satellites for such functions as aircraft surveillance, communications and weather monitoring. Furthermore, much of the research and development cost of new space capabilities has already been underwritten as part of the ongoing space program — both commercial and governmental. This affords the opportunity for the FAA to benefit from this major investment in technology without itself having to allocate large amounts of funds for the creation of that technology. The impact on general aviation could be particularly beneficial.

Recommendation 13: **The Panel recommends that increased effort be devoted to the early application of spaceborne elements in support of the air traffic control system and to the solution of remaining integrity issues and procedure development pertaining thereto.**

Human Factors A considerable portion of aircraft accidents and security escapements occurring in the past decade has been attributable to shortcomings in the area of human factors. The field of human factors, therefore, comprises a particularly important area for FAA research and development attention. Significant benefits can be derived in this regard from close cooperation among government agencies, industry and academic institutions on the projects identified in the National Plan for Aviation Human Factors.

Recommendation 14: **The Panel recommends that the FAA ensure that activities are closely coordinated in the critical human factors area and that projects described in the National Plan for Aviation Human Factors as having FAA prime responsibility be included in the FAA Research, Engineering and Development Plan and appropriately budgeted.**

Technology Plan Structure The work identified in the FAA Research, Engineering and Development Plan as "Innovative Cooperative Research" is extremely important, and as such is strongly endorsed by the Panel. The Panel does, however, believe that it is inappropriate to isolate work of this type into a separate and distinct section of the Research, Engineering and Development Plan. The current Plan in fact segregates such activity as if it were a separately managed activity and treats it in a separate chapter with separate goals. It would seem that work of this type is of the utmost importance and should be infused throughout each element of the Plan — relating to areas spanning from weather to safety; from security to aviation medicine.

Recommendation 15: **The Panel recommends that the section on innovative and cooperative research be deleted as a separate topical section in the FAA Research, Engineering and Development Plan and be emphasized throughout the entire body of the Plan.**

Appendices

I. Statement of Work

II. Panel Membership

III. List of Field Visits

IV. Principal References

Appendix I
Statement of Work

The objective of the FAA Research, Engineering, and Development Advisory Committee is to provide advice and recommendations to the FAA Administrator regarding the needs, objectives, plans, approaches, content, and accomplishments with respect to the aviation research program.

The agency developed its Research, Engineering and Development Plan covering Budget Year 1993 and beyond, and tasked the Committee to take a high-level look at its content to ensure that it:

- responds to the needs of the system and its users,
- capitalizes on emerging technological advances, and
- reflects a solid foundation for the air transportation system of tomorrow.

To accomplish this review, the Committee established the Research and Development Plan Review Panel, under its Research and Development Technical Subcommittee, enlisting Committee members, as well as various technical experts as consultants.

On behalf of the Committee, this Panel of experts will review the Plan, advise the FAA of any gaps, provide a sense of priority setting across activities, and perhaps point to outside research organizations which the agency can better utilize in research, engineering and development partnerships.

Appendix II
Panel Membership

Chairman:

Norman R. Augustine Mr. Augustine is Chairman and Chief Executive Officer of the Martin Marietta Corporation and a member of the FAA Research, Engineering and Development Advisory Committee. He holds a BSE and MSE in Aeronautical Engineering from Princeton University, where he wrote his thesis on vertical take-off aircraft, and holds three honorary doctorate degrees. He is a former chairman of the Aeronautics Panel of the Air Force Scientific Advisory Board, the NASA Space Systems and Technology Advisory Committee, and the Defense Science Board. He has served as Under Secretary of the Army, Assistant Secretary of the Army for Research and Development, and Assistant Director of Defense Research and Engineering. He is a member of the National Academy of Engineering, a Fellow of the Institute of Electrical and Electronic Engineers, and an Honorary Fellow of the American Institute of Aeronautics and Astronautics.

R,E&D Advisory Committee Members:

Robert R. Everett Mr. Everett, a pioneer in the development of digital computers, received his BS degree from Duke University and his MS from the Massachusetts Institute of Technology (1943), both in Electrical Engineering. In 1945, he became associated with Jay W. Forrester in the development of electronic digital computers. Mr. Everett joined the newly organized MITRE Corporation in 1958, and rose to President and Chief Executive Officer. He serves as a member of numerous boards and is Chairman of the FAA's Research, Engineering and Development Advisory Committee. He has received numerous awards and honors, including the 1990 Air Traffic Control Association's George W. Kriske Memorial Award, for his contributions to air traffic control.

J. Lynn Helms Mr. Helms entered the Navy cadet program while in college during World War II, and was commissioned a Second Lieutenant in the U.S. Marine Corps in 1945. After retirement he held positions in industry of General Manager, Vice President, Group Vice President and President. He was Chairman and CEO of Piper Aircraft Corporation prior to retirement in 1980. He was nominated by President Reagan for Administrator, Federal Aviation Administration, and filled that role until 1984. Mr. Helms now works as an International Consultant in the fields of strategic planning, acquisition and divestiture, high technology program evaluation and international finance.

Jonathan Howe Mr. Howe is President of the National Business Aircraft Association (NBAA) and has served on the Board since 1986. Mr. Howe came to the NBAA from the FAA where he held several positions including Deputy Chief Counsel and Director of the FAA's Southern Region. He has been an active pilot for more than 30 years and serves as Chairman of the FAA's Aviation Rulemaking Advisory Committee. Among his numerous honors and awards is a Presidential Meritorious Award from President Carter. Mr. Howe served on Recertification Teams for both 1974 and 1979 DC10 accidents. He is a member of several local, state and federal bar associations, and is a recognized teacher, lecturer and published author in aviation law. He attended Denstone College in England; graduated from Yale University with a BA degree, cum laude, in 1960 and from Yale Law School in 1963.

John McCarthy Dr. McCarthy is the Director of the Research Applications Program at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, where he directs research associated with aviation weather hazards. Dr. McCarthy participates on the FAA Research, Engineering and Development Advisory Committee and the National Airspace System Design Review Team. He is past chairman of various committees of the American Meteorological Society, the American Institute of Aeronautics and Astronautics, the FAA, and the National Weather Service. He is a former Professor of Meteorology, University of Oklahoma. He holds a BA in Physics from Grinnell, MS in Meteorology from the University of Oklahoma, and a PhD in Geophysical Sciences from the University of Chicago.

John L. McLucas Dr. McLucas is Chairman of the Board of External Tanks Corporation, Avion Systems, Inc. He is a member of the Boards of Directors of DARTRAIL and Orbital Sciences Corp. and serves on Boeing's Technical Advisory Council. He is also chairman of International Space University, International Space Year Associates, and a member of various boards and committees of the Corporation for Atmospheric Research,

U.S. Space Foundation, FAA, and the National Academy of Engineering and the Academy Committee on Science and Engineering Public Policy. He has served as Administrator of the FAA; Secretary and Under Secretary of the U.S. Air Force; and Assistant Secretary General of NATO for Science. Dr. McLucas is the author of *Space Commerce*, published in 1991 by Harvard University.

John E. O'Brien Mr. O'Brien is the Director of the Air Line Pilots Association's (ALPA) Engineering and Air Safety Department. His career with ALPA began in 1972. In 1975, he was promoted to Deputy Director Operations, and in 1978 he became Manager of Engineering and Operations. He was promoted to his present position in 1982. Prior to coming to ALPA, he spent seven years with Pan American Airlines, two years with the airline division and five years with the aerospace services division. In addition to flying for Pan American, he was a project engineer on a study of margins for space shuttle design operations and safety. He received an MBA from Stetson University and a BSAS from Embry-Riddle Aeronautical University.

John W. Olcott Mr. Olcott is Vice President and Group Publisher with the McGraw-Hill Aviation Week Group, responsible for Business and Commercial Aviation, AC Flyer and the McGraw-Hill Aviation Week Groups' Show Dailies. He has fixed wing experience, is qualified on helicopters and auto gyros, and has been licensed as a flight instructor since 1956. He received his BS and MS degrees in Aeronautical Engineering from Princeton University and an MBA from Rutgers. In the early 1970's he was the principal investigator for a number of NASA-sponsored research programs. He has served as a Flight Research Specialist for Princeton University and was assigned to the Indian Institute of Technology in Kanpur, India. He is a member of numerous boards and committees, including the FAA's Research, Engineering and Development Advisory Committee, and served as chairman of the General Aviation Safety Panel.

Siegbert B. Poritzky Mr. Poritzky is responsible for aviation technical matters of the Airports Association Council International-North America (AACI). He joined the organization (then called AOCI) after 11 years with the Federal Aviation Administration. Prior to his service with the FAA, he worked for the Air Transport Association of America, Aeronautical Radio, Inc., the Civil Aeronautics Administration, the McDonnell Aircraft Corporation, and Trans World Airlines. He served as the U.S. member of the International Civil Aviation Organization's Special Committee on Future Air Navigation Systems. He is a member of the FAA Research, Engineering & Development Advisory Committee, Chairman of the Capacity Technology and Procedures Development Working Group, and a member of the Board of RTCA.

Robert R. Rankine, Jr. Major General Rankine is the Deputy Chief of Staff for Technology at Headquarters Air Force Systems Command, Andrews Air Force Base, Maryland. He is responsible for managing the science and technology programs conducted by Air Force Laboratories throughout the United States. Previously he served as Vice Commander of Space Systems Division in Los Angeles, where he was responsible for acquiring satellites and space launch vehicles. General Rankine also held various positions at the Pentagon where he was directly involved with planning for the Strategic Defense Initiative, the National Aero-Space Plane, and the expanded use of unmanned rocket boosters for space launch. General Rankine holds BS, MS and doctorate degrees in Engineering. He received his commission in the United States Air Force in 1958.

Robert Rosen Dr. Rosen is the NASA Deputy Associate Administrator for Aeronautics, Exploration and Technology. As such, he shares, with the Associate Administrator, the planning, direction, execution and evaluation responsibility for NASA's aeronautics and space technology programs, NASA's portion of the National Aero-Space Plane Program, the President's Space Exploration Initiative and the institutional management of Ames, Langley and Lewis Research Centers and the Ames-Dryden Flight Research Facility. Dr. Rosen has held positions in industry at Rocketdyne and McDonnell Douglas, and holds BS, MS, ME and PhD degrees. He has published over 25 technical papers in fluid dynamics and aerodynamics and has received numerous achievement awards, including NASA's Outstanding Leadership Medal.

Technical Consultants:

Albert P. Albrecht For the past 49 years, Mr. Albrecht has been active in the aerospace community on both sides of the government-industry interface. Most of this effort has been related to technology and Air Traffic Control.

As the FAA Associate Administrator for Engineering and Development and later for Development and Logistics, Mr. Albrecht has been a major participant in the Air Traffic Control development and acquisition programs. In industry, Mr. Albrecht pioneered the use of radar for Air Traffic Control, developed automation and navigation concepts, and led the development of military Ground Controlled Approach applications. Mr. Albrecht's consulting activities are focused on system engineering, integration, strategic planning, and emerging technology applications related to air traffic control.

Antonio A. Cantu Dr. Cantu received a BS degree in Chemistry and a PhD. in Chemical Physics from the University of Texas at Austin. After post-doctoral work at the University of Alberta, Edmonton, he began his career in the application of science and technology to law enforcement in 1972. He has been with the Bureau of Alcohol, Tobacco, and Firearms, the Federal Bureau of Investigation, and for the past five years with the U.S. Secret Service. His duties include threat assessments, explosive detection, hazardous material countermeasures, and forensic science. Dr. Cantu is involved in several interagency committees concerned with science and technology and terrorism.

John J. Fearnsides Dr. Fearnsides directs MITRE's aviation and air traffic control research and development for the Federal Aviation Administration (FAA) and foreign governments. He also directs all of MITRE's weather-related research and development for the FAA, the National Weather Service, and the National Oceanographic and Atmospheric Administration. Prior to joining MITRE, Dr. Fearnsides served at the U.S. Department of Transportation holding positions of Deputy Under Secretary, Chief Scientist, Acting Assistant Secretary for Policy, and Acting Administrator of the Research and Special Programs Administration. Dr. Fearnsides has PhD, MS and BS degrees in Electrical Engineering. He has served on several National Academy of Sciences panels on transportation, and as Adjunct Professor, Engineering and Public Policy, at Carnegie-Mellon University.

J. Roger Fleming Mr. Fleming joined the Air Transport Association (ATA) in January 1966, served in several different capacities in the ATA Operations, Engineering and Air Traffic Management Divisions, and in July 1988 was appointed Senior Vice President - Technical Development and Planning. Mr. Fleming serves as industry spokesman and directs ATA programs supporting U.S. scheduled air carrier objectives in matters related to aviation safety and system development. He has been responsible for airline industry assessments of and support for FAA's Research, Engineering and Development programs and related projects. He is also involved with FAA and airlines in planning the transition to space-based communications, navigation and surveillance functions.

C. A. Fowler Mr. Fowler's career at MIT Radiation Lab, AIL, Department of Defense, Raytheon and MITRE includes participating in the development of the Ground Controlled Approach radar landing system; project engineer for the first radar air traffic control system and the first radar for civilian air traffic control; and contributing to the development and production of other radars and electronic systems. He is a Fellow of the Institute of Electrical and Electronic Engineers, the American Institute of Aeronautics and Astronautics, and the American Association for the Advancement of Science; a member of the National Academy of Engineering and the Association of Old Crows; a member and past Chairman of the Defense Science Board and the Defense Intelligence Agency Advisory Board; and a former member of the Air Force Scientific Advisory Board. He has published widely in his fields of expertise.

Jack E. Snell Dr. Snell, Deputy Director of the Building and Fire Research Laboratory, heads the fire research program at the National Institute of Standards and Technology (NIST). He has a BSE in Aeronautical Engineering from Princeton University, a MSE degree in Operations Research and a PhD in Transportation System Engineering from Northwestern University. He has airline and Air Force aircraft maintenance engineering experience. He is U.S. Chair of the U.S.-Japan Panel on Fire Research and Safety, serves on the Board of Directors of the National Fire Protection Association, chairs its Toxicity Advisory Committee, is a member of the Society of Fire Protection Engineers, American Society of Testing Materials Committee E5, and a Fellow of the American Society of Mechanical Engineers.

John F. Zugschwert Mr. Zugschwert is a thirty-year veteran of military service. He served 11 years at the Pentagon, where he was involved

in aviation research and development. He is a member of Army and Defense Science Board activities specifically addressing aviation programs. He is a pilot with over 3,000 hours of fixed and rotary wing flying time, and multi-engine, instrument, weapons systems qualifications and night vision technology experience. Mr. Zugschwert has experience flying the XV-15 tilt rotor, Apache, and AHIP advanced combat helicopters, and the NOTAR helicopter. He is engaged in establishing the Vertical Flight Program Office at the FAA and the NASA vertical flight program, and is presently Vice President, Washington Operations, for Bell Helicopter Textron, Inc.

Panel Support:

Laura J. Cooper - Administrative
Louise M. Guida, Maj. (USAF) - Technical
Jack Haneklau - Technical
Lorraine Iritano - Administrative
Jan Peters - Special Assistant to FAA Liaison
Martin T. Pozesky - FAA Liaison
Steve Zaidman - FAA Designated Official

Appendix III
List of Field Visits

- FAA Technical Center
  Atlantic City, NJ
  August 6, 1991

- NASA Ames Research Center
  Moffett Field, CA
  August 14/15, 1991

- The MITRE Corporation
  McLean, VA
  August 23, 1991

- MIT Lincoln Laboratory
  Lexington, MA
  August 28/29, 1991

- NASA Langley Research Center
  Hampton, VA
  September 4, 1991

- Wright Laboratory
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  September 12, 1991

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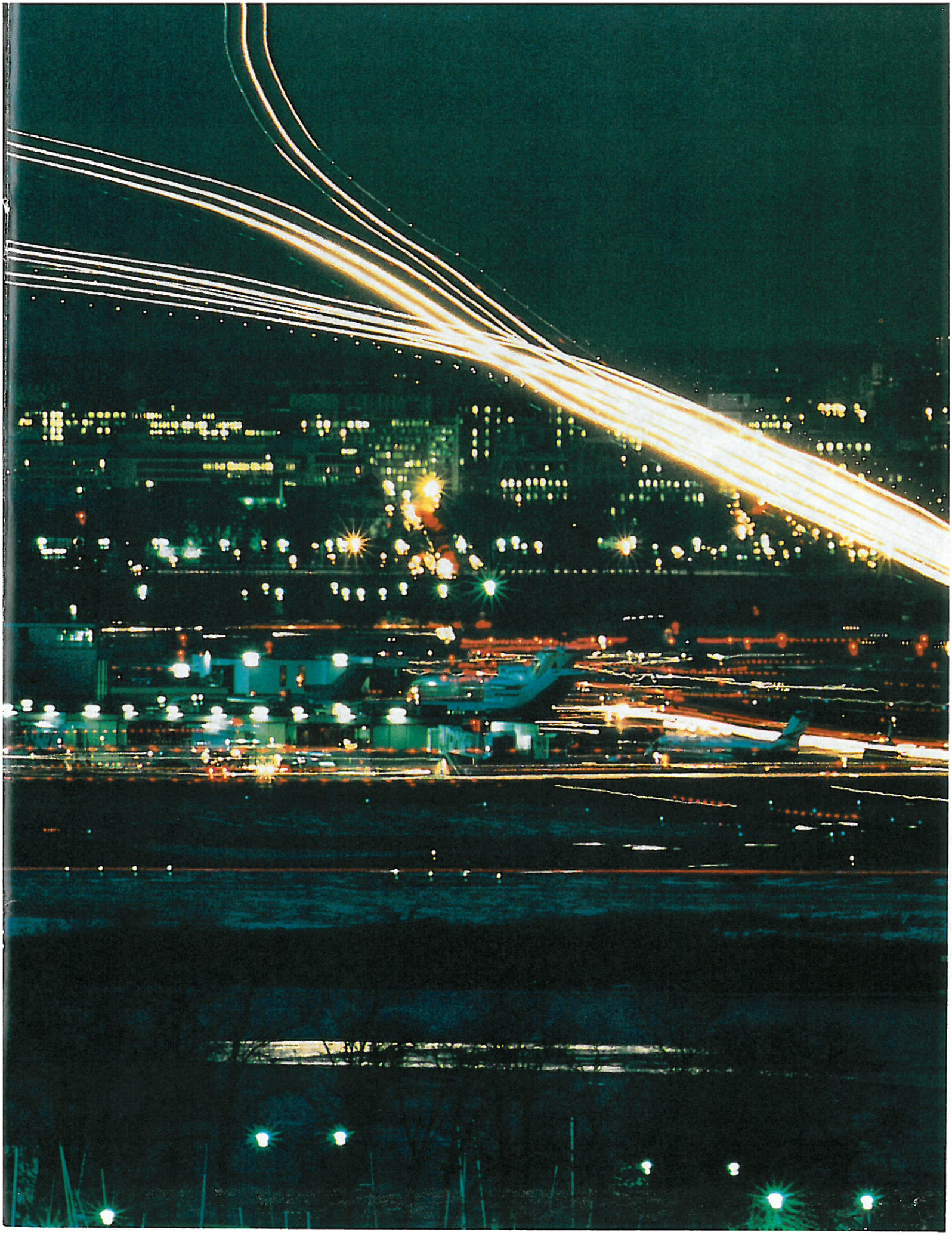
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