Federal Aviation Administration

R&D Strategy

September 2002

Preface

Largely because of its research and development (R&D), the Federal Aviation Administration (FAA) has developed a national aviation system that universally is recognized as the safest and most technologically advanced in the world. The agency's research organizations have provided a solid foundation for these advances in aviation--an evolutionary process that has taken us from the first rotating light beacons to the threshold of satellite-based communications, navigation, and surveillance systems. This strong commitment to R&D will be even more vital in the years ahead as the FAA continues to develop new aviation technologies and systems in support of a safe, secure, modern, and environmentally-friendly global aviation system.

As the nation's premier research organization for aviation technology, the FAA's R&D program has made significant contributions to assure the safety, efficiency, and cost effectiveness of the national aviation system. Today that system is under heavy pressure to keep pace with rising traffic demand, needs for essential safety improvements, airspace user requirements for more flexible and efficient air traffic management operations, and demands for further mitigation of the environmental impacts of aircraft operations. As air travel increases in the years ahead, the FAA is taking the lead in developing a global aviation system for the 21st century and beyond.

To meet these challenges, the FAA has developed the R&D Strategy to guide its R&D program over the next 5 years. This strategy provides a roadmap to the future, to ensure that the agency's R&D resources remain customer-focused and targeted on the highest priority activities. The FAA is leading the world in the development of an entire portfolio of advanced aviation technologies. This strategy will assure that the agency's investments in fundamental technological innovation will continue to have far-reaching implications for the aviation industry.

Dr. Herman A. Rediess, Ph.D.
Director, Office of Aviation Research

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1. Introduction

Overview

The FAA R&D Strategy will guide the FAA's R&D program over the next 5 years, with appropriate biennial revisions. Given the lengthy period of time typically required to move from completion of research to operational application or deployment of results, a 5-year strategy requires at least a 10-15 year perspective on future evolution and needs of the aerospace system.

The strategy addresses only research to be performed by FAA, singly or in collaboration with others, to meet its specific mission elements, goals, and responsibilities. A broader description of Federal civil aviation goals and research being conducted or planned by FAA, the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD), is found in the National Science and Technology Council's *National Research and Development Plan for Aviation Safety, Security, Efficiency and Environmental Compatibility* (November 1999).

This document addresses R&D objectives and strategies in a manner independent of the organizational structure and management processes involved in the planning and implementation of specific programs and projects. Project-level information on the current program is found in the FAA *National Aviation Research Plan*, which includes programmatic, budget, and schedule information.

R&D as a Strategic Element in Fulfilling the FAA Mission

The purpose of the FAA R&D program is to support FAA's strategic goals and mission, which embody the overarching Department of Transportation (DOT) strategic goals. In so doing, the R&D program collaborates with and supports the entire aviation community in achieving beneficial outcomes for all system users.

DOT Goals

The DOT has defined five strategic goals in its Strategic Plan: Safety, Mobility, Economic Growth, Human and Natural Environment, and National Security. [1]

Safety: *Promote public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage.*

Mobility: *Shape America's future by ensuring a transportation system that is accessible, integrated and efficient, and offers flexibility of choices.*

Economic Growth: *Advance our economic growth and competitiveness domestically and internationally through efficient and flexible transportation.*

[1] *Strategic Plan 2000-2005,* U.S. DOT, 2000.

Human and Natural Environment: *Protect and enhance communities and the natural environment affected by transportation.*

National Security: *Advance the nation's vital security interests in support of national strategies such as National Security Strategy and National Drug Control Strategy by ensuring that the transportation system is secure and available for defense mobility and that our borders are safe from illegal intrusion.*

FAA Goals

The FAA Strategic Plan outlines goals consistent with the DOT goals.[2]

Safety: *By 2007, reduce U.S. aviation fatal accident rates by 80 percent from 1996 levels.*

In addition to the reduction in the air carrier accident rate, this goal also has the parallel objective of limiting the number of general aviation fatal accidents to 350 per year by 2007. Increased survivability in air carrier flights is also explicitly identified as an objective. Accident prevention and the analysis and sharing of safety information are key elements of the FAA strategy for this goal, which is a key constituent of the DOT Safety goal.

System Efficiency: *Provide an aerospace transportation system that meets the needs of users and is efficient in the application of FAA and aerospace resources.*

The key objectives associated with the System Efficiency goal are (1) to enable users of national airspace system (NAS) services to continue to meet their business or personal objectives in the face of increasing system demand and to increase the availability of NAS services and facilities to users; (2) to reduce their costs associated with use of those services, and (3) to reduce costs borne by the federal government in providing the services. Key agency strategies include implementation of Free Flight capabilities, modernization of the NAS, and integration of airport and commercial space requirements into NAS planning and architecture. The System Efficiency goal is supportive of the DOT Mobility, Economic Growth, and Human and Natural Environment strategic goals.

In addition, the FAA has established another goal considered critical to accomplishing its mission.

Environment: *Prevent, minimize and mitigate environmental impacts, which may represent the single greatest challenge to the continued growth and prosperity of civil aerospace.*

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[2] In legislation signed on November 19, 2001, the President created a new Transportation Security Administration (TSA) within the Department of Transportation. The FAA's responsibilities for aviation security were transferred to TSA, but the FAA is cooperating closely with TSA and will continue to be highly sensitive to security implications associated with evolving aviation technology and operational concepts.

Increased understanding of aerospace system environmental impacts, and identification of means to reduce them to acceptable levels are activities central in meeting this goal. Additionally, this area includes the objective of quantifying and mitigating the environmental impact of FAA activities.

FAA Mission

The FAA mission is to maintain and enhance a safe, secure, and efficient global aerospace system.[3] This mission is derived from FAA's legislative charter and fully supports the DOT and FAA Strategic Plans. Its key elements are to:

- Regulate civil aviation and commercial space transportation to promote safety.
- Enable the safe and efficient use of the aerospace system by civil and military aircraft.
- Promote and facilitate commercial space transportation.
- Provide leadership in planning and developing a safe and efficient national system of airports.

In performing this mission, the FAA (1) establishes safety standards; (2) issues certificates for aircraft and components, airmen, and air operators; (3) licenses commercial space launches and launch and re-entry sites; (4) monitors safety; (5) provides approximately 600,000 air traffic services daily, and operates, maintains, and modernizes approximately 25,000 subsystems in support of air traffic management; (6) oversees the federal role in the national airport system; and (7) sponsors related research and education to make the aviation and commercial space transportation systems safer, more modern, and efficient.

The Role of R&D

A solid scientific and technical foundation is required to meet agency goals. Both short- and long-term R&D are necessary to enable ongoing technical and operational innovation and to support informed decision-making in all areas of FAA responsibility. Continued investment in a strong and multi-faceted R&D program is a critical component in meeting the current and future FAA mission in an efficient, timely fashion.

The FAA R&D program is necessarily directed toward specific needs of FAA's various organizations, such as Regulation and Certification, Airports, and Air Traffic Services. It is largely through the activities of these organizations, and the impact of those R&D activities on the aerospace enterprise, that the FAA goals are achieved. While predominantly near-term in nature, a substantial portion of this research includes longer-term components. A comprehensive process is in place for developing a research portfolio in which R&D resources are requested and allocated in accordance with the needs and priorities of each FAA organization.

Activities supported by the research program include:

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[3] *FAA Strategic Plan,* FAA, 2001.

- Licensing, Regulation, Certification, and Standards Development:

Aircraft
Air Operators
Aviation Agencies
Manufacturers
Aircrew and other aviation personnel
Airports
Commercial Space Transportation
Security
Environment

- Modernization, operation, and maintenance of the NAS.
- Aerospace policy formulation, planning, and analysis.
- Effective response to incidents, special situations, and emerging issues.
- Guidance, coordination, and collaboration across the global aerospace transportation community.
- Identification, exploration, and assessment of emerging technological and operational concepts.

Given the complexity and dynamic nature of the long-term challenges faced in aerospace activities, and the importance of technology (broadly defined) in coping with them, it is particularly important that the pressure of immediate concerns not obscure the need to provide a solid foundation for meeting future needs. The magnitude and complexity of these challenges will require a strong and well-conceived R&D program, based on a very long-term perspective, to develop and validate effective solutions and innovations, whether they involve technology advances, innovative concepts, new operational procedures, or regulations. In addition, it will be critical to establish innovative ways to deploy new technologies into the operational environment to demonstrate applications for effectiveness and position the infrastructure for early deployment.

Thus, it is imperative that the overall program combine required near-term applied R&D with a vigorous and ongoing long-term research program that can define and characterize emerging issues and potential problems, and identify and pursue promising solutions. A program of this nature will enable the necessary major innovations in how FAA missions are performed, now and decades in the future, and will expand the knowledge and tools available to the entire aerospace community for advancing safety, efficiency, and environmental compatibility.

2. Aviation System Overview

During the next 10-15 years, the period addressed by this strategy, the aviation system will continue to be essential to the U.S. national security, economy, and quality of life for U.S. citizens, and is expected to continue its current pattern of growth. As early as 2013, U.S. enplanements are projected to reach nearly 1.1 billion passengers a year – 50 percent more than they carried in 2001. The projected increase in passengers and aviation activity will further strain a system that, prior to September 11, 2001, was already perceived as near full capacity. Over the next decade it will be critical to increase both capacity and efficiency in the NAS. In the period 2003-2013, demand for aerospace transportation services is projected to increase at average annual rates of 3.8 percent for domestic enplanements and 5.5 percent for cargo services.[4]

In addition, the aerospace enterprise will continue to evolve in important ways in seeking to satisfy and profit from this demand. In what has become a truly global marketplace, competitive forces and popular insistence on efficient government will continue a trend toward deregulation of air carriers and privatization of nationally owned airlines. Regardless of public or private ownership, the need for global reach has generated a varied and extensive set of cooperative arrangements and alliances among carriers seeking to provide convenient and seamless service anywhere in the world. A similar process is visible in the linking of major airlines with regional airlines and commuter services that can serve many localities for both direct and feeder flights.

For at least the next several years, security issues will be a central part of the aviation environment. Security initiatives will generally affect costs, aviation system processes and procedures, and overall system performance and convenience during the transition to new ways of operating. Depending on the success with which future terrorist attacks are prevented, higher costs and traveler concerns could significantly constrain near-term growth. However, it is assumed here that the global response to the tragic events of September 11 will be sufficiently successful that, in the long run, security impacts on air transportation supply and demand will be relatively modest.

The aerospace environment is increasingly dynamic. The fleet of regional jets is growing rapidly. One major manufacturer is planning a new airliner seating more than 500 passengers, and another is designing a transport to travel at nearly the speed of sound. Some industry observers see higher enplanements as driving a move back toward increased direct flights and less reliance on hub-and-spoke operations. Expanded use of smaller airports, facilitated by satellite-based navigation and landing systems and continued expansion of the regional and business jet fleet, will be widespread. Carrier strategies relating to routes, aircraft size, schedules, and other matters will be varied and volatile, driven in part by mergers and alliances, including international agreements.

Fuel cost is a large component of airline expense, and major changes in the price of petroleum

[4] *FAA Aerospace Forecasts Fiscal Years 2002-2013,* March 2002.

can have a significant impact on seat miles offered, or ticket prices, and ultimately on passenger demand. The competitive environment for airlines is reflected in the FAA forecast of declining yield (revenue per passenger mile), which could put continuing pressure on service quality and ability to make improvements that could relieve congestion pressures.

Although currently in abeyance, the steady growth in demand in recent years has already strained airspace system capacity. There are many impediments to the FAA's ability to significantly increase capacity. Equally important are the decisions by airlines, airport operators, and Congress as to how the available capacity should be managed and used. The closer the airspace comes to maximum usable capacity, the more the system is vulnerable to any deviation from nominal conditions, such as adverse weather, with consequences and delays that can quickly spread across the entire network. Schedules planned around capacity under good conditions, and recovery flexibility, will inevitably suffer when those conditions do not prevail.

A key characteristic of this evolving industry structure is a continual search for new business strategies and relationships suited to a highly competitive free market environment. At the same time, this freedom has also had the consequence of removing constraints that previously played an important role in allocating system capacity—gates, landing slots, airspace, etc.—so that it is proving a difficult challenge to find means of avoiding or mitigating congestion and the resulting delays. Under these circumstances there is widespread concern that modernization of the NAS, development of improved procedures, and revised air carrier operational strategies will not be sufficient to relieve current problems, and will not be able to respond to the steadily growing level of traffic. Similar issues can be expected on a global scale.

Safety

Outlook

As the aviation system grows, so, too, do concerns for safety, which will remain a critical and highly visible government responsibility. The growth of transportation activity, even with level or declining accident rates, could yield a significant and highly visible increase in the absolute number of incidents, deaths, and injuries. To a large degree, countermeasures have been developed for the historically dominant accident causes, leaving the more difficult challenges, as well as new emerging problems, still to be addressed.

Over the past several decades, dramatic progress has been made in aviation safety (see Figure 2-1). While encouraging, the actual outcome of trends cannot be predicted with certainty. The data indicate a possibility that the rate of improvement could be slowing compared to that experienced in earlier years, emphasizing the magnitude of the challenge implied by the FAA goal of an 80 percent reduction by 2007 from the 1996 level. A similar pattern is seen for general aviation (GA) (see Figure 2-2).

Technological advances, particularly in communication, information, and automation systems, offer the potential to contribute significantly to a continued decline in the accident rate for both commercial and GA. Systems already deployed, or now being developed will enhance situational awareness (ground proximity, runway incursions and airborne collision situations) for GA pilots, commercial flight crews, and controllers.

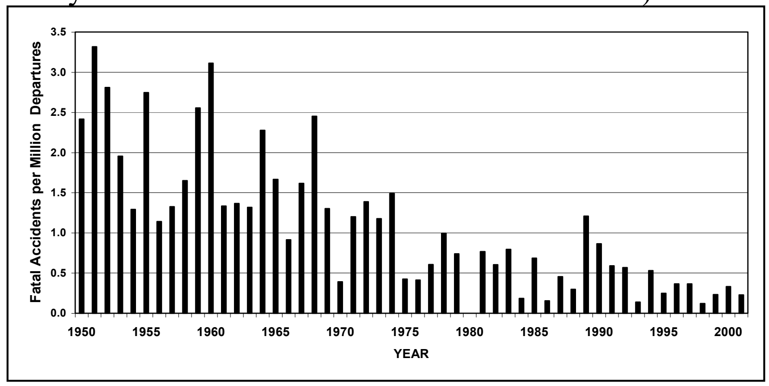

Figure 2-1. Fatal accidents per million departures for U.S. Part 121 scheduled service airlines, 1950-2001. Accidents due to sabotage are not included. (Source: Air Transport Association.)

Future development of technological aids—e.g., better weather information, advanced avionics, on-board flight management systems, aircraft "health" monitoring systems, and other automation aids, all reflecting principles of human-centered design—can prevent many other types of accidents, as will the growing understanding of aircraft component and system failure modes.

A growing role will be played by sophisticated data collection and analysis systems that make accident precursors much more visible. This will enable more effective and timely introduction of technological, operational, maintenance, and inspection-related remedies.

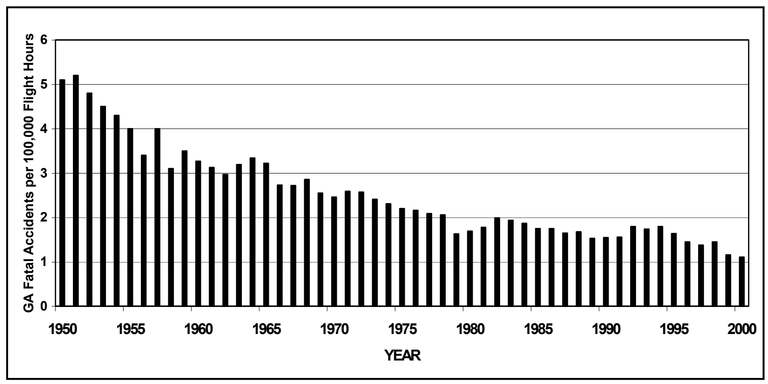

Figure 2-2. Fatal accidents per 100,000 flight hours for general aviation, 1950-2000. (Source: Aircraft Owners and Pilots Association, based on FAA and National Transportation Safety Board data.)

However, it will be of the utmost importance to remain alert to the possibility of new failure modes and "learning-curve" problems associated with these changes. Timely validation, certification, and industry-wide equipage of highly sophisticated software-based safety-critical systems pose a daunting challenge, and similar concerns accompany use of any other new or advanced equipment, materials, designs, and procedures which may be associated with airspace system modernization and the introduction of new aircraft and subsystems. The response to these challenges will require R&D to develop full understanding of the system components, testing and inspection tools, software validation processes, human factors considerations, and focused failure mode analyses.

Globalization and changes in industry structure and practices could also compromise safety. The partitioning among many external parties of maintenance and other functions traditionally performed by a single airline, or global alliances among many carriers, could blur responsibilities and diminish oversight capabilities. A similar issue arises with respect to an increased level of overseas design and manufacture. Vigorous competition, if unconstrained, and associated pressures for lowering costs, might have adverse safety consequences if monitoring and oversight are not sufficient. Overall, harmonization of standards, practices, and procedures will require substantial effort.

As in other industries, aviation could be hard-pressed to find a workforce fully qualified to deal with new technologies, particularly in the automation and computer areas. Still another complicating factor is the likelihood of a significantly broader mix of air traffic—from enhanced general aviation aircraft and a rapidly growing fleet of business and regional jets to tiltrotors, unmanned air vehicles, dirigibles, and space vehicles.

Current and Future Issues, Challenges, and Opportunities

Topics of significance to aviation safety and associated R&D in the next decade include:

- The potential for terminal area and airport surface collisions.
- The introduction and certification of new technologies, with special emphasis on software reliability and failure modes in critical highly automated applications.
- New concerns associated with aging aircraft, e.g., mechanical and electrical systems, and "aging software," particularly in embedded systems.
- Human factors issues regarding the integration of increased flight deck and ground automation.
- New human-centered designs in cockpit/flight deck and air traffic control and management systems.
- The roles and responsibilities of flight crews and controllers in high-technology automation-rich environments.
- The need to collect and analyze safety-relevant operational data.
- The introduction of new technologies with possible new failure modes.
- The unintended adverse safety consequences associated with security countermeasures.
- An increase in the numbers of commercial space launches and landings, and associated sites, and increased complexity of space launch vehicles.
- The need to protect, detect, respond and recover from malicious cyber attacks.

System Efficiency

Outlook

Modernization of the NAS and its global counterpart, with the continued evolution of sophisticated technology and the introduction of new operational concepts, holds the potential to permit significant safe reduction of aircraft separation standards in some circumstances, reduce the consequences of adverse weather conditions, and permit more flexible and efficient use of en route airspace. In the future, automation tools will support greater optimization in system-wide traffic management. Collaboration among controllers, airline flight dispatchers, and flight crews in key decisions will enable more effective use of the airspace.

The potential for dispersal of some air travel to less crowded and smaller airports by direct-flight regional jets, small transports, and business aircraft will be enhanced by use of GPS-based navigation and positioning systems and other avionics equipment. Advances in technology could lead to significantly expanded GA activity, making greater use of controlled airspace. Additionally, the move from turbo-prop to jet aircraft by regional carriers will continue to increase demand for entry into the high-level en route sectors.

The lengthier, high-traffic routes will continue to be served predominantly by relatively large aircraft, with some, primarily on intercontinental routes, potentially carrying more than 500 passengers. Shorter routes, in particular, are likely to see increased use of smaller aircraft, which offer the market advantage of greater frequency of flights. The ability of hub-and-spoke route structures to provide attractive schedules for a large number of smaller cities would assure a continuation of this basic strategy, though the number of routes on which direct flights are offered is likely to increase with enplanements and further penetration of regional jet aircraft. The high rate of growth of international aviation could contribute to a similar trend toward direct flights to and from many inland cities, rather than the current high concentration in a few gateway airports.

This growth will occur in the context of an airport and air traffic management system that is already perceived as substantially overloaded, contributing to frequent and sometimes widespread congestion and delays in response to adverse weather and other circumstances. To meet the currently projected demand in 2010 and beyond, it will be necessary not only to respond to today's problems, but also to nearly double the traffic handled. A substantial shortfall in the capacity of the aviation system, and in its performance characteristics, would have serious implications for personal mobility and the economic health of the nation, and would be especially detrimental in particular localities. Given the time required to develop, test, and implement innovative solutions, the foundation of meeting the post-2010 challenges must be initiated within the next few years.

The problem is not confined to en route and terminal airspace traffic management. Congestion on taxiways and at gates is an additional source of delays and inefficiencies. Other relevant constraints include environmental limits associated with noise and other emissions, uncertainty concerning localized near-term weather conditions, and avoidance of wake vortices. Runway capacity is a critical limitation, with expansion virtually precluded at many airports as a result of environmental concerns and lack of available land. From the perspective of air travelers focusing on door-to-door travel time, the availability and capacity of ground transportation access and services at airports, and of the terminals themselves, will also affect the convenience, ease, and speed of air travel.

Solutions to this challenge must be consistent with the absolute requirement that safety not be compromised by any changes in operational strategies and procedures, equipment, software, and other system elements. Implementation of innovative technology and operational strategies will require a lengthy period for user training and for installation of sophisticated avionics not only in the commercial aviation sector, domestic and international, but also for more than 200,000 general aviation aircraft and over 300,000 pilots. A high degree of global compatibility and interoperability will be required, implying a need to obtain international consensus and collaboration.

Overall, the goal of providing a level of system capacity and performance meeting the needs of users through 2010 will require a major effort and large investments. To make the necessary continuing improvements for traffic anticipated in the decade beyond 2010 is truly a daunting undertaking. To increase capacity and better match available capacity to demand for air travel, fundamental changes will be required in operating procedures, technology, airspace design, and airport infrastructure. Dramatic advances will be required in airport arrival/departure rates, airspace congestion, and reduction of the effects of weather conditions, both en route and at airports. Long-term success in this endeavor will require that the FAA Operational Evolution Plan[5] (OEP) be supported with the fullest identification and exploitation of relevant technologies and associated operational concepts.

Current and Future Issues, Challenges, and Opportunities

System Efficiency topics with a potential bearing on R&D in the next decade include the need to:

- Reduce system delays.
- Improve system performance in bad weather, especially low ceilings and visibility.
- Increase the flexibility and adaptability of system architecture to allow for data sharing to support collaborative decision making and common situational awareness.
- Increase system capacity to meet domestic and global demand.
- Improve the rate of technical and procedural evolution of the air traffic management system:

Implementation.
Human performance and limitations.

- Improve pavement design and construction standards.
- Provide air traffic services for a wider range of aircraft—dirigibles, unmanned air vehicles, next-generation general aviation aircraft, high-performance business jets, jumbo airliners, space vehicles, and payloads.
- Update and apply satellite-based navigation and positioning system technology, and ensure the FAA's role in shaping and exploiting that evolution.
- Increase power and affordability of information technologies, particularly with respect to automation applications.

[5] *Operational Evolution Plan Version 4.0*, FAA, Dec. 2001.

Environmental Compatibility

Outlook

Environmental compatibility is an area in which public sensitivity is already high and may well increase further. Five years ago the National Science and Technology Council predicted "environmental issues are likely to impose the fundamental limitation on air transportation growth in the 21st century."[6] The apparent accuracy of this assessment has not changed in the intervening years.

The noise associated with aircraft operations will continue to be a contentious issue into the future, delaying or precluding construction of new runways in some cases, in spite of the phase-in of significantly less noisy aircraft. Similar objections will continue to arise in response to attempts to institute or expand air carrier service in the smaller airports that are currently underused.

Compliance with air quality standards is a major focus for many airports, and will be a growing challenge in coming years as air traffic, and associated landside emission sources grow. Responses to this concern will affect aircraft operations as well as the movement of service vehicles, airport access, and other activities. Other constraints include land use and local road traffic issues, which often preclude expansion of facilities, or at least make it a difficult, expensive, and lengthy process. Cumulatively, environmental issues can be expected to pose a significant constraint on airport expansion throughout the next decade.

Given the increasingly global scope of air transportation, handling challenging environmental issues will be made even more complex and difficult by the need to develop solutions that can achieve international agreement and deployment. The starting point for meeting these challenges is a solid foundation of scientific data and analysis, coupled with a comprehensive understanding of airport operations.

Current and Emerging Future Issues, Challenges, and Opportunities

Topics of significance to environmental compatibility, and to associated R&D, in the next decade include the need to:

- Create an environmentally friendly global air transportation system.
- Harmonize U.S. and international standards.
- Conduct comprehensive environmental assessments, including both airside and landside through models and data.
- Analyze and simulate alternative mitigation strategies, including economic factors and stakeholder impacts.

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[6] *Goals for a National Partnership in Aeronautics Research and Technology,* NSTC, 1995.

- The impacts caused by the large growing variances between expected computational power and the capability to effectively transport exponentially increasing amounts of data and information.

Technology Considerations

New aviation technologies are being introduced into the NAS at a rapid rate. Perhaps the most visible area of advance is information and digital electronics technology. Computational power and memory capacity has for decades been doubling every 18 months, yielding a ten-fold increase over a 5-year period. If this rate of improvement continues, as is widely expected, the result would be a 1,000-fold increase by 2015. It is difficult to predict specific consequences of an advance of this magnitude, but dramatic changes are very likely in power and affordability of specific technologies and in the functionalities they enable. Communications technology, based in large part on digital electronics, will be similarly affected, as will applications of displays, sensors and actuators, and other components.

In the next decade these technologies will enable virtually any individual to have convenient, low-cost, and accurate knowledge of his or her position and environment, to communicate that and other information to any other entity, and to access, either locally or at a distance, enormous data resources. Satellite-based navigation positioning will be particularly critical for aerospace applications. Voice recognition and synthesis will be a common form of human-system interface. Enhanced vision technology, automated data link, and advanced surveillance information (e.g., non-radar-based solutions) will move rapidly from the laboratory to operations.

The availability of greater communications, sensing, and computer power will enable pattern recognition and functional automation far beyond anything previously possible. A variety of technologies offer the potential of a much tighter coupling—both input and output—between humans and the systems they operate or monitor. These technological changes will enable a broad range of new concepts, functions, and designs. Some will ultimately transform specific systems, activities, and even behavioral patterns.

When large-scale changes to capabilities or affordability of technology occur the results are not simply better performance, but also lower cost for systems. However, implementation of such advances is often disruptive of existing practices. (This effect has been highly visible in the information technology arena.) They yield conceptually new products and applications, created by the existence of new functionalities, innovative ways of operating, evolving institutional realignments, and changed markets. It is seldom possible to predict in advance the nature and magnitude of the long-term impacts of emerging technologies. Many fail, and those that are successful often evolve in ways and serve markets not anticipated even by their champions.[7] Other unintended consequences can be the introduction of new risks and failure modes derived from the complex interaction of innovations in systems and processes. This pattern, which is

[7] This concept is developed in Clayton Christensen's 1997 book, *The Innovator's Dilemma*, published by the Harvard Business School Press.

becoming increasingly characteristic of the times, will undoubtedly be an important factor in the course of transportation and aerospace in coming decades.

Innovations, disruptive or not, will contribute to the development of vehicles with improved operational characteristics, operating in a framework of dramatically enhanced traffic management technology. Many challenging issues and complications, including the following, however, will accompany the improvements:

- Safe and effective integration of humans and automated systems.
- Attainment of a solid understanding of the properties and failure modes of new materials and components prior to application.
- Full characterization and understanding of the operation and failure modes software-based large-scale distributed systems.
- System designs that are suited to the continued incorporation of improved technology, and facilitate evolution to alternative operational concepts.

3. FAA R&D Goals, Objectives, Challenges, and Strategies

As shown in the Figure 3-1, the FAA has developed a strategic framework to ensure that R&D activities remain focused on the agency's mission goals. Those goals are subdivided into specific **Derived Goals** that represent the critical outcomes central to achievement of the mission goals. Each Derived Goal is then further subdivided into one or more specific and potentially measurable **Performance Objectives**, each of which addresses a different aspect of the Derived Goal. In general, achievement of each Performance Objective will depend upon knowledge, tools, technical advances, or other research products, and thus implies a specific **R&D Challenge** to be met by the FAA R&D program. With the R&D Challenges thus defined, specific **R&D Strategies** are developed to meet them. The strategies are realized through the development and performance of the projects that comprise the FAA R&D program.[8]

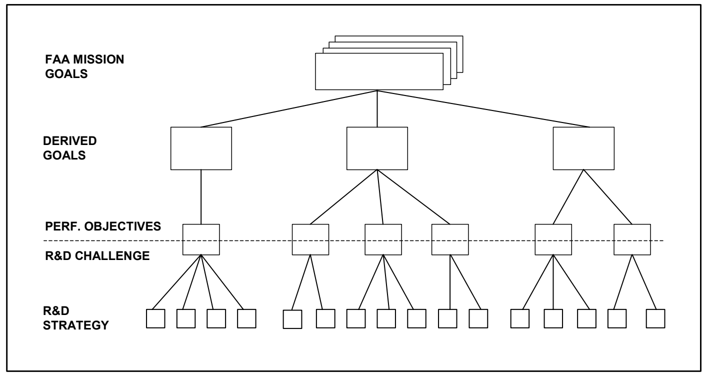

Figure 3-1 Goal-Performance Objective-Strategy Hierarchy, Showing Links to R&D Program

These Derived Goals, Performance Objectives, R&D Challenges, and R&D Strategies will shape and guide FAA research activities during the next 5 years, subject to refinement based on agency and aviation system needs and interim R&D findings. Cumulatively, implementation of these cross cutting strategies will provide the research products necessary to meet agency goals.

Safety

Derived Goals

The FAA safety goal is to reduce fatal accidents in both commercial and general aviation. Accidents can be prevented by establishing and maintaining a broad framework of regulations and standards, developing a better understanding of accident causes and countermeasures, introduction of new technology, and leading and participating in cooperative programs with the aviation community. These activities enhance safety in three ways: (1) identification and prevention of accidents due to emerging or previously unrecognized causal factors; (2) reduction of the recurrence of accidents associated with known causes (e.g., weather, human error); and (3)

[8] Details of the projects that comprise the full R&D program can be found in the annual FAA *National Aviation Research Plan,* the FAA budget submission, and other FAA planning documents. This strategy document has a 5-year perspective. The specific strategies are intended to guide evolution of the R&D program over that time frame, and, therefore, are not necessarily fully realized in current research activities.

protecting passengers and crew by mitigating the consequences of a crash or in-flight incident, thereby increasing survivability. These approaches are reflected in three derived goals:

- ***Reduce the occurrence of aviation system accidents caused by new or previously unrecognized factors.***
- ***Reduce the recurrence of aviation system accidents due to known risks or causal factors.***
- ***Increase the survivability of aviation system accidents and incidents.***

Modern aviation is also vulnerable to attacks involving communication, navigation, and other information technology, electronic, and software-based systems. At a NAS-wide level, successful attacks of this nature could pose a serious threat to passengers and crews, and an extended disruption or shutdown of air transportation would be most serious. Hence, a fourth derived safety goal is to:

- ***Prevent successful attacks on the integrity and availability of critical NAS-information systems.***

Finally, there is increasing recognition of the potential for a variety of long-term health effects on transport aircraft passengers and flight crews. Assessment of the level of risk and the value of alternative countermeasures is implicit in the FAA safety mission, leading to an additional derived safety goal:

- ***Prevent adverse health impacts on air passengers and flight crews.***

Performance Objectives, Challenges, and R&D Strategies

Derived Goal: Reduce the occurrence of aviation system accidents caused by new or previously unrecognized factors.

Performance Objective: Reduce hazards by developing increased aviation community knowledge and understanding of current operations and potential accident causes.

R&D Challenge: *Safety Information Sharing and Analysis* - Develop and apply data and analytical tools for use by FAA and industry in identifying potential accident causes and developing effective safety programs and countermeasures.

Many hazardous conditions can be identified, and preventive actions taken, by exploiting the means now available for monitoring and analyzing flight operations on a large scale. However, for this approach--implemented in collaboration with the entire aviation community--to obtain the level of success that is potentially possible, substantial advances are needed in the availability of analytical tools. Comprehensive analyses are also required with accompanying special efforts to incorporate the results in safety programs.

R&D Strategies:

1. Develop and apply data systems and risk management and decision support tools and methodologies to monitor and analyze the aviation system operations and safety risks that encompass air carriers, aircraft design, aircraft maintenance, aviation training schools, and personnel.

2. Develop a broadened understanding of biomedical, toxicological, and human performance factors that can contribute to accidents through research studies and results of FAA's role in performing toxicological and other biomedical analyses for aviation and other transportation accidents.

Performance Objective: Prevent any degradation of safety associated with the introduction of new technologies, operational practices, or other changes in the global aviation enterprise.

R&D Challenge**:** *System Safety and Risk Management* - Develop and apply knowledge and analytical tools to assess the safety implications of innovative technologies and operational procedures planned or proposed for implementation in the airspace system.

The NAS is increasingly interconnected and automated, and relies on software for many safety-critical functions. Tools will be evolved that will assist and enhance human design and analytic capabilities, support human reasoning about the properties of complex systems, and lead to efficient creation of more robust and trusted systems. Application of advanced technologies, particularly communication, navigation, and surveillance (CNS) and automation, will enable new and evolving operational concepts, procedures, and allocation of responsibilities for operational use in the NAS.

Although new technologies and procedures are intended to improve the safety, security, efficiency, and environmental compatibility of the airspace system, it is always possible that a particular change or innovation could interact with other system elements in ways that could increase risk. One example is increased reliance on digital software-based aircraft systems, which will increasingly require additional or revised certification criteria be developed and updated. To prevent any degradation of safety in this process, a system safety perspective needs to be incorporated throughout civil aviation. Only in this way can potential adverse interactions and incompatibilities among the system elements, training, equipment, maintenance practices, etc., be detected and countermeasures be developed before an accident occurs.

R&D Strategies:

1. Develop tools to support the efficient design, development, validation, production, and certification of high confidence software and systems in safety-critical NAS functions and aircraft avionics. Develop knowledge and tools to facilitate the ability to assess and develop certification criteria for the continually expanding use of digital software-based aircraft systems.

2. Assess and develop responses to the safety implications of the greater use of new composites, alloys, and other materials, and associated structures and fabrication techniques. Develop a

comprehensive understanding of the aging process and failure modes associated with the incorporation of new materials into aircraft structures and systems, and of appropriate maintenance and inspection practices, to assure that the potential for improved performance and cost characteristics is not accompanied by any degradation of safety, and that opportunities for safety enhancements are fully exploited.

3. Assess and address the safety implications of evolving operational procedures and practices, specifically including potential impacts of measures to enhance aviation security. Detailed examination of failure modes, anomalous situations, human performance considerations, and other safety-related matters will be conducted in close partnership with industry.

Derived Goal: Reduce the recurrence of aviation system accidents due to known risks or causal factors.

Performance Objective: Reduce the number of accidents associated with weather, icing conditions, and other aspects of the flight environment.

R&D Challenge: *Hazards of the Flight Environment* - Characterize potential hazards of the flight environment and develop the knowledge base and technologies needed to eliminate or reduce those hazards.

A variety of hazards exist in the flight environment, producing threats to aircraft safety even in the absence of any equipment malfunction or human error. Severe weather is the most common of these hazards. Flight crews must be aware of icing conditions and know countermeasures for mitigation of in-flight and ground icing. Turbulence, whether arising naturally or from the wake of aircraft en route or in terminal operations, can also pose a significant threat. In addition, other serious flight environment risks, such as electromagnetic fields from ground sources or passenger-carried sources, could conceivably cause malfunction of sophisticated and critical avionics equipment.

R&D Strategies:

1. Improve understanding, predictability, and the ability to deal with adverse weather, icing conditions, and other atmospheric hazards, and improve the delivery of weather products to pilots and aircrews. Conduct tests, perform analyses, and develop and apply more accurate algorithms that improve the clarity, specificity, and timeliness of weather information provided to traffic controllers, flight crews, general aviation pilots, and airline dispatchers.

2. Develop guidance concerning flight hazards associated with electromagnetic fields. Develop the means to characterize risks and protect aircraft electrical and electronic systems against the effects of lightning and high intensity radiated fields that may come from airborne, ship borne, and ground-based emitters, including portable electronic devices that may be carried aboard by passengers.

Performance Objective: Reduce the number of accidents associated with the failure of aircraft structures, components, and systems.

R&D Challenge: *Failures of Aircraft Structures and Systems* - Develop knowledge, criteria, tools, technologies, and practices to improve reliability and prevent or reduce failures of aircraft structures and systems.

Standard analysis and test methods, based in part on better understanding of failure mechanisms, are needed to support regulatory responsibilities in the area of aircraft structures and materials. It is important to incorporate new materials and associated structural design and construction practices that can reduce or eliminate known risks. Similar considerations arise in connection with the failure of turbine rotors, general aviation engines, and with issues related to aircraft fuels. Assurance of the continued airworthiness of aging aircraft requires information, technologies, techniques, and inspection systems to ensure the safe operation of aircraft electrical, mechanical, and fuel systems. A high level of understanding, as well as identification of possible regulatory actions or potential specific countermeasures, are needed in key areas of catastrophic failure, such as turbine engine uncontainment events, uncontrollable in-flight fires, fuel tank explosions, and other propulsion system malfunctions.

R&D Strategies:

1. Develop improvements in aircraft fuel tank explosion protection.

2. Develop knowledge, inspection tools, techniques, and strategies to address safety hazards associated with the aging of airframe structures, engine components, and mechanical and electrical systems.

3. Assess the use of improved processing and manufacturing techniques for critical engine components to eliminate engine failures

4. Assess the use of advanced materials to protect aircraft critical systems and passengers in the event of catastrophic engine failures.

5. Assess the safety implications of changes to aviation fuels used for both commercial and general aviation.

Performance Objective: Reduce the number of accidents associated with the performance of pilots and aircrews, controllers, maintainers, and others who fill roles important to the safety of the NAS.

***R&D Challenge*:** *Human Performance* - Develop knowledge, guidance, and standards to improve the performance and structure the roles and working environments of the people who play critical roles in aviation safety.

Human error is frequently a contributing or causal factor in aviation accidents and incidents. Errors of this nature can arise from limitations of training materials and programs, design of displays and controls, fatigue, or sensory and cognitive impairment of individuals, as well as other issues relating to human behavior and performance. Improvements in all of these areas depend on availability of scientifically validated information and guidance concerning means of enhancing the performance of a wide range of people who play critical roles in aviation safety:

air carrier crews; general aviation pilots; aviation maintenance and inspection personnel; air traffic controllers; and NAS system maintenance specialists. Key interventions supported by human factors research include more effective training techniques, tools and materials; application of the principles of human-centered design to displays and controls; new or revised operational practices; and application of human factors considerations in certification of new aircraft and in equipment design and modification.

R&D Strategies:

6. Develop knowledge, guidance, and standards for the design and use of automated support systems. Develop and apply human factors concepts and guidelines in the design, development, evaluation, and certification of advanced-technology control and display systems for flight deck, air traffic control, and airway facilities applications to address issues associated with: workload; situational awareness (particularly in the context of using advanced automation equipment); recovery from automation failures; skill retention and dependency on automation; and alternative human-computer interfaces in aviation applications.

7. Develop and apply increased understanding of the relationship between human abilities and aviation task performance to:

    - Assess the appropriate knowledge, skills, abilities, and characteristics needed to excel in highly automated environments;

    - Develop guidelines for effective training materials and instructional delivery systems applicable to complex working environments;

    - Evaluate countermeasures to stressors (e.g., fatigue) that affect alertness and performance; and

    - Assess the impact of new technologies and operational circumstances (e.g., longer-duration intercontinental flights) on job characteristics and requirements, as well as on the associated consequences for selection and training.

8. Develop knowledge, guidance, and standards for human performance assessment. Identify the intrinsic characteristics of individuals and teams that determine how well they are able to perform aviation tasks, characterize the impact of environmental (external and internal) and individual factors on human performance, and improve and standardize methods for measuring human performance. Develop more effective methods for investigating, reporting, analyzing, and mitigating human error.

9. Develop knowledge, guidance, and standards for information management and display. Identify the most efficient and reliable ways to display and exchange information, determine what, when, and how one might best display and transfer information to system components, design the system to reduce the frequency of information transfer errors and misinterpretations, and minimize the impact when errors do occur.

10. Develop knowledge, guidance, and standards for bioaeronautical factors. Enhance personal performance and safety by enabling commercial aviation crews and general aviation pilots to better understand and become more aware of health and physiological integrity issues, including spatial disorientation, visual illusions, and hypoxia.

Performance Objective: Reduce aircraft accidents and incidents associated with air and ground operations on the airport surface and surrounding airspace.

R&D Challenge: *Terminal Area Safety* - Develop technologies and evaluate strategies to increase pilot and controller situational awareness in the terminal area, reduce wildlife interactions, and assure compatibility of airport designs and infrastructure with new types of aircraft.

Runway incursions continue to occur at an unacceptably high level. While serious accidents due to incursions have been rare in the United States, the potential for a catastrophic event has made this a high-priority program. Assurance of pilot and controller situational awareness is key to reducing these accidents. Aircraft and vehicle detection and alerting technologies and systems are important countermeasures, as are clear signs and markings to minimize the possibility of human error or misperceptions. Another growing concern in the terminal environment is the possibility of collision of aircraft with birds and other wildlife attracted by the favorable conditions often found near airports.

R&D Strategies:

1. Develop technology and standards to increase pilot, controller, and vehicle operator awareness of potential runway incursions and other airport surface traffic hazards:

   - Develop, evaluate, demonstrate, and validate–in an operational environment–advanced technology and systems for surface detection, secondary surveillance, conflict-alerting and data fusion, cockpit displays, and runway status lights to increase pilot and controller situational awareness; and
   - Develop and apply advanced light sources and applications, addressable signs, and ground marker communications, accompanied by development of a computer-based simulation system, to evaluate new visual guidance systems and procedures, particularly during low visibility conditions.

2. Conduct evaluations and assessments of means to reduce bird-strike and other wildlife-related risks. Develop effective means of habitat management to reduce bird activities around airports, and identify active and passive techniques that can reduce the presence of birds and other wildlife at airports.

3. Conduct tests and analyses to assure compatibility of airport design with new larger aircraft, particularly with respect to airport pavements and design, to assure that safety is not compromised as these aircraft come into common use.

<u>Performance Objective:</u> Prevent any threat to public health and safety in the testing, operation and use of Reusable Launch Vehicles (RLV).

R&D Challenge**:** *Safety of Reusable Launch Vehicles* - Determine best practices for commercial space transportation operations and develop criteria for assessing the safety of RLVs.

The potential for a significant increase in commercial space operations, particularly involving reusable launch vehicles, carries with it the responsibility for FAA to establish plans, regulations, guidance, and licensing approaches to assure the health and safety of the public. The safety of space launch and landing sites also needs to be addressed, including assurance of coordination with NAS operations.

R&D Strategies:

1. Identify best practices for commercial space transportation operations and maintenance. Analyze and assess standards and processes applicable to commercial RLV operations and maintenance activities to assure that they provide adequate public safety, with emphasis on applicability of relevant NASA and aircraft industry best practices.

2. Establish criteria to define a "proven" RLV. Develop criteria for a basic methodology to assist in determining when an RLV has progressed from "unproven" to "proven" status and for judging the public safety relevance of methodologies associated with proven RLVs.

3. Assess effects of RLV maneuverability characteristics on public safety. Increase understanding of safety issues regarding reentry of RLVs and reentry vehicles with respect to maneuverability of vehicles reentering from space and differentiation between maneuverable and non-maneuverable vehicles.

Derived Goal: Increase the survivability of aviation system accidents and incidents.

<u>Performance Objective:</u> Reduce the occurrence of aircraft fires and the consequences of any that do occur.

R&D Challenge: *Aircraft Fire Safety* - Develop standards and specifications for fire-resistant materials used in aircraft.

Fire, whether in-flight or as the result of a crash, can lead to many casualties in cases that would otherwise have been a survivable event. Rigorous, but practical, test criteria must be applied to all materials on aircraft, accompanied by rules and a comprehensive aircraft fire knowledge-base to support reduction of ignition sources and provide effective fire detection and suppression systems.

R&D Strategies:

1. Develop materials and standards to reduce the likelihood of ignition of aircraft fires and the severity and toxicity fires that do occur in flight and as a result of crashes. Evaluate ultra-

fire-resistant materials to eliminate burning cabin materials as a cause of death in aircraft accidents.

2. Develop improved fire detection and fire suppression systems. Develop technologies, procedures, test methods, and criteria for preventing accidents caused by hidden in-flight fires through improved fire detection and suppression systems and interior materials fire test methods and criteria.

Performance Objective: Increase crash survivability by enhancement of aircraft crashworthiness and evacuation practices.

R&D Challenge: *Aircraft Crashworthiness and Crash Survival* - Develop knowledge, tools, and standards to improve the crashworthiness of aircraft structures and systems and the effectiveness of evacuation procedures.

If fire is adequately controlled, aircraft crash situations can sometimes be survivable for many or even all occupants. However, this will depend to a large degree on crashworthiness of the aircraft structure, including interior elements, such as the passenger seats, and the effectiveness of evacuation procedures. FAA certification and guidance to industry are key means to assure that full advantage is taken of new materials and manufacturing processes. Similar considerations apply to assuring that aircraft design and configuration, as well and cabin crew training, rapid and safe evacuation capabilities and post-evacuation actions.

R&D Strategies:

1. Conduct tests and analyses and develop standards to guide design and manufacture of aircraft structures, cabin interiors, auxiliary fuel tank systems, and occupant seat and restraint systems with improved crashworthiness.

2. Develop knowledge, design, procedural guidelines, and recommendations for safe evacuation routes through various aircraft cabin configurations, particularly addressing designs for the very large aircraft now being planned.

Performance Objective: Increase crash survivability by enhancing the effectiveness of airport crash response capabilities.

R&D Challenge: *Airport Crash Response Capabilities* - Develop knowledge, tools, standards, information and guidance to support regulatory actions and improved operational practices related to post-crash response to accidents, particularly for the large aircraft now being planned.

The survivability of crashes or other incidents occurring on the airport surface can depend on the speed and effectiveness of airport rescue and firefighting actions. Planned new aircraft with multiple levels and high-density seating will complicate this process. FAA information, guidance, and regulatory actions in this area are important in influencing the equipment, facilities, training (including simulators), and practices employed.

R&D Strategy:

Develop knowledge, tools, and standards to improve airport rescue and fire-fighting efforts. Test and evaluate improved firefighting systems for use in controlling both external and internal cabin fires, and develop new methods, procedures, and firefighting chemicals to fight fires in future larger aircraft that will use advanced materials, such as carbon-based composites.

Derived Goal: Prevent successful attacks on the integrity and availability of critical NAS information systems as well as providing protection to FAA administrative and support systems.

Performance Objective: Protect the NAS and supporting information infrastructure systems against current and future cyber threats, detect and respond to those threats, and assure that those systems can be reconstituted quickly if necessary.

R&D Challenge: *Protection of Information Infrastructure* - Develop the technical foundation for incorporation of high-performance cybersecurity technology and procedures into the existing NAS and at the design level for new NAS elements.

Assurance of the integrity of FAA information systems and data, and the availability of service, are central to carrying out the agency's mission. Ever more serious threats are being developed, requiring more robust system defenses. Reduction of the vulnerability of the NAS and its users, as well as protection of FAA's administrative and support systems, requires that solutions be found to extraordinarily difficult technical problems. Further, as NAS modernization proceeds and the system continues to evolve, within an overall information technology context that is also continually changing, it is critical to guard against the possibility of vulnerabilities being created in the implementation of new or revised software and systems. Use of the Global Positioning System, for example, introduces a new and critical element of potential risk. New mechanisms must be developed to address both insider and outsider threats and vulnerabilities to key information systems.

R&D Strategies:

1. Develop and deploy improved technology for intrusion protection, detection, response, and recovery capabilities of critical information systems, focusing on a rapidly evolving threat base, achieving minimal false alarms, and guaranteeing continuity of service while under denial-of-service attacks.

2. Develop and incorporate new architectural approaches and improved cybersecurity capabilities into the NAS design and modernization process to assure continual protection. Develop architectural approaches to insure that, as the NAS evolves, the most vulnerable points in the very large and complex FAA information infrastructure are protected. Develop public key infrastructure technologies and procedures to enable secure transactions over public and other networks.

3. Develop and evolve technologies to enhance integrity and confidentiality in the mobile environment. As NAS systems evolve towards more autonomous digital control and communications, new techniques must be developed to address improved integrity and confidentiality in the dynamic and mobile environment created by digital wireless communications in both wide and local area environments.

4. Undertake collaborative R&D efforts with DoD, NSF, NASA, other organizations and industry to identify new and emerging technologies that can be employed to reduce the risks to the integrity and availability of critical systems and data. It is understood that effective protection in the evolving networked environments that will exist in the future can only be obtained by close collaborative and timely communication of existing threat and attack information while addressing the impacts of security actions on organic and non-organic IT resources.

5. Conduct research necessary to enhance the protection of GPS from unintentional or intentional interference, including development of improved interference direction-finding equipment and appropriate studies to further define the problem, assess impacts, and identify and characterize protection and mitigation strategies.

Derived Goal: Prevent adverse health impacts on air passengers and flight crews.

Performance Objective: Identify and reduce adverse health impacts associated with the cabin environment.

R&D Challenge: *Cabin Environment Health Impacts* - Develop understanding of health risks in the cabin environment sufficient to assess the need for remedial actions and provide the scientific basis for developing them.

A variety of threats to the health of passengers and flight crews can exist in the cabin environment, including poor cabin air quality, sudden decompression, and, for very high altitude flights, cosmic radiation. In general, these possible hazards are difficult to assess quantitatively to determine the reality and magnitude of the threat and the preferred means of addressing it.

R&D Strategy:

Develop knowledge, recommendations, and guidelines to minimize health risks to cabin occupants and aircraft crews and assure health maintenance of cabin occupants with respect to possible hazards, including poor air quality, cosmic and other radiation, and sudden decompression.

System Efficiency

Derived Goals

The FAA efficiency goal is to provide an aerospace transportation system that meets the needs of the users and is efficient in the application of FAA and aerospace resources. This goal requires that a proper balance be achieved among three NAS attributes: level of service to the user community; costs to the users, insofar as they are affected by NAS performance and capabilities; and costs incurred by the FAA in providing those services. The first component of this objective matches the focus of the OEP-- meeting the basic service needs of users of the NAS by providing sufficient system capacity to prevent significant user delays, and greatly reducing the impact of adverse weather on operations. Minimization of the NAS-related costs to users requires increasing the predictability of NAS performance and increasing the operational flexibility offered NAS users. Finally, the agency is charged with minimizing the cost of providing the NAS infrastructure and operating the system. A key role of System Efficiency R&D is to explore and support the introduction of existing technologies into the aviation system. The complex and demanding requirements associated with aviation applications can require extensive R&D efforts to assure successful, timely and safe innovation.

The three System Efficiency Derived Goals are:

- ***Match system capacity to the traffic demands of users of the NAS.***
- ***Minimize the costs to users of the NAS.***
- ***Reduce the cost of providing NAS infrastructure and operations.***

Performance Objectives, Challenges, and R&D Strategies

Derived Goal: Match system capacity to the traffic demands of users of the NAS.

Performance Objective: Provide sufficient airport arrival/departure capacity to meet demand.

R&D Challenge: *Increased Airport Arrival/Departure Rates* - Develop and evaluate technologies, practices, and operational procedures that support accelerated design and construction of runways and full exploitation of their capacity.

Many of the busiest airports currently are unable to meet peak arrival/departure demand; future growth in aviation activity will exacerbate this situation. By itself, construction of new runways is unlikely to resolve this problem. Expanded runway capacity must be accompanied by improvements in airspace design, technology, decision support aids, procedures, and standards to make the fullest possible use of available runway and other surface infrastructure.

R&D Strategies:

1. Facilitate surface infrastructure design, construction practices, and efficient operational surface movement.

2. Provide terminal airspace standards, procedures, and tools that support improved terminal airspace and route design and permit full use of available runway capacity.

Performance Objective: Provide sufficient en route capacity to meet demand.

R&D Challenge**:** *Increased En Route Capacity* - Develop operational concepts, standards, and tools that increase flexibility in responding to changing circumstances and better matching airspace design and capacity and demand.

When demand exceeds capacity in one or several sectors, the resulting congestion can quickly affect other airspace, sometimes leading to near-gridlock conditions. Increases in physical capacity and reductions in controller workload are critical to providing the flexibility needed to prevent congestion from arising, and to respond quickly and effectively to that which does occur.

R&D Strategies:

1. Develop tools and analyses to design and evaluate airspace design and reduce separation standards without compromising safety.

2. Develop tools and validate procedures for strategic collaborations between users and providers to resolve tactical congestion problems.

3. Develop and validate improved controller-pilot communication technologies.

4. Develop human-machine interface and system-to-system coordination to support controller-to-controller communication, improved planning and reduce uncertainty through increased current and future situational awareness.

Performance Objective: Minimize adverse impacts of adverse airport weather conditions on operational capacity.

R&D Challenge**:** *Reduced Airport Weather Impacts* - Develop and evaluate technologies, tools, and procedures to achieve near optimum runway acceptance rates without regard for meteorological conditions.

Airport arrival and departure rates can be lowered substantially under adverse weather conditions, by limiting the use of runways and increasing spacing between flights. Cockpit tools and enhanced navigation aids could extend the range of conditions under which visual operations can be conducted.

R&D Strategies:

1. Develop and validate new NAS services, based on surveillance and navigation technologies and procedural improvements, to enable continued arrival operations as weather deteriorates from visual meteorological conditions (VMC) to instrument meteorological conditions (IMC).

2. Validate new cockpit tools and displays to achieve VMC throughput capacity in all weather conditions.

3. Develop and evaluate tools and procedure, and improved weather prediction capabilities to

facilitate efficient runway reconfiguration at the onset and conclusion of hazardous weather conditions.

Performance Objective: Minimize adverse impacts of en route severe weather conditions on operational capacity.

***R&D Challenge*:** *Reduced En Route Weather Impacts* - Develop and evaluate the means to generate and deliver more specific and timely weather information to users, and the means for providers and users to respond effectively and rapidly to hazardous weather.

Adverse en route weather can block access to key sectors and shift traffic in ways that create new congestion points. The result is significant reduction of the capacity of portions of the system, with delays and service cancellations quickly spreading across the nation. When the system is already operating at a point near capacity, poor en route conditions can produce a dramatic reduction in the overall level of service and efficiency of the NAS. Severe weather cannot be prevented, but provision of comprehensive, accurate, location-specific, and timely predictions can enable airlines, aircrews, controllers, and airline dispatchers to work together to develop and implement more effective tactics and strategies for dealing with weather events.

R&D Strategy:

1. Develop means for improved weather prediction and timely dissemination to all aerospace system users.

2. Develop means for greater integration of common weather information into the air traffic management process, including collaborative adjustment of routes.

Performance Objective: Expand NAS services in areas lacking Air Traffic Control (ATC)/Air Traffic Management (ATM) infrastructure.

***R&D Challenge*:** *Expanded Access and Service Availability* - Develop and validate technologies to enable instrument approaches at remote and low-traffic airports.

Improvement of the NAS level of service may offer limited benefit to those who live in relatively remote or low population-density regions and, thereby, are unable to access the system because of a an economically-driven lack of infrastructure (radar, approach systems, etc.). Technology advances offer the possibility of significantly broadening the availability of NAS services.

R&D Strategy:

Develop alternatives to fixed terrestrial facilities as a means of rapidly introducing improved NAS services in remote areas.

Performance Objective: Identify and develop capacity enhancements that will meet the post-2010 needs of users.

R&D Challenge: *Future Capacity Enhancements* – Explore and apply system architectural concepts, technologies, and procedures that will make possible NAS capacity increases sufficient to meet traffic demand beyond 2010.

Long-term growth of air transportation will require not only that current capacity limitations be eliminated, but also that performance of the system be continually enhanced to accommodate the projected expansion of aviation activity and associated demand for NAS services. This will pose a very demanding challenge requiring implementation of system architecture responsive to evolving patterns of user needs and operational strategies, availability of increasingly powerful technology options, and development of innovative ways of operating the airspace system. This endeavor will require close collaboration with the aviation and technology communities.

R&D Strategy:

1. Develop a NAS architecture to serve as the framework for a flexible and adaptable air traffic management system that (a) is based on the paradigm of timely and efficient delivery information to all actors; (b) can rapidly and efficiently be reconfigured in response to changing user needs and patterns of operation; (c) facilitates evolutionary incorporation of technology improvements and innovations; and (d) fosters exploration and validation of alternative operational tools, procedures and strategies.

2. Undertake structured collaborations with NASA, other organizations, and the industry to identify air traffic management concepts and provide technical analyses and evaluations to guide their incorporation into the NAS and accelerate exploitation of new technologies required to enable those concepts.

Derived Goal: Minimize the costs to users of the NAS.

Performance Objective: Increase the predictability of NAS performance.

R&D Challenge**:** *Improved NAS Predictability* - Provide users with improved current and projected status information in an operational environment.

When congestion and delays upset airline schedules, the process of adjusting (e.g., through cancellation of flights) can be costly, especially if the disruption is widespread and lengthy. The consequences of these events can be reduced by communicating to all users accurate and timely system status information and the projections they need to make timely adjustments to their plans and implement collaborative solutions.[9]

R&D Strategies:

1. Identify, develop, and validate improved technology and processes for communication to users of current and projected NAS status and performance. Demonstrate and validate

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[9] The predictability Performance Objective will also be supported by all of the activities undertaken to achieve the Derived Goal of maximizing the level of providing system capacity to match traffic demand.

advanced technology and procedures in an operational environment to accelerate their application to provide NAS users with highly specific and accurate indications of current status and any projected constraints or uncertainties.

2. Identify and develop tools for knowledge capture of operational experience with respect to actual performance and decisions made in order to support post-analysis that will facilitate lessons learned, improved training and repeatability of "best practices," and longer–term strategic planning.

Performance Objective: Increase system flexibility to allow users to adapt operations to changing conditions.

R&D Challenge**:** *Greater NAS Flexibility* - Validate performance and safety of technologies critical to implementation of Free Flight.

The concept of Free Flight, in which operators have the freedom to select their path and speed in real time, will permit much greater flexibility for airlines and FAA controllers in maximizing use of available airspace and responding to adverse weather or other factors that constrain capacity and predictability. Significant cost benefits for users are expected to result, as well as other operational advantages. Realization of Free Flight and full exploitation of its potential will require extensive evaluation efforts to validate alternative strategies and procedures.

R&D Strategies:

1. Accelerate application of specific CNS technologies critical to Free Flight and related procedures that enhance user flexibility.

2. Demonstrate and validate advanced technologies and procedures in an operational environment to accelerate the implementation of capabilities that expand the operational freedom of users and involve them in setting system strategies.

Derived Goal: Reduce the cost of providing NAS infrastructure and operations.

Performance Objective: Enhance the operational reliability and reduce the life-cycle cost of the infrastructure that supports provision of all NAS services.

R&D Challenge**:** *Reduction of the Cost of Providing NAS Services* - Design and evaluate infrastructure technologies that minimize life-cycle costs, and develop tools to accelerate the development of software systems.

A major portion of the cost of providing NAS services is associated with ongoing investment in system modernization and evolutionary upgrades, and with maintenance of installed facilities and equipment. Minimization of these costs can be achieved only by incorporating analyses of life-cycle costs in the design of system elements. Control of the cost of software development is a particularly important consideration, requiring development and tools for efficient and effective construction of NAS systems based on the new architectures.

R&D Strategies:

1. Perform analyses and design subsystems for implementation in the NAS infrastructure that fully incorporate consideration of costs of initial construction and deployment, operations, repair, and maintenance, and workforce requirements.

2. Develop means for ensuring that Commercial Off-The-Shelf (COTS) software is safe and will function as required, including identifying and developing practices for safety-related systems using COTS software.

3. Develop software design and development tools and techniques to enable more efficient management and accelerated deployment of key NAS software systems using reusable and common components for a new FAA standards-based architecture.

4. Develop new verification and validation techniques that will increase overall system quality while reducing the time and costs associated with existing methods.

Performance Objective: Reduce the cost and improve the life of airport pavement, and increase capacity, operational and functional efficiency, and groundside access of airports.

R&D Challenge**:** *Reduction of Airport Surface and Terminal Infrastructure Cost* - Develop guidance and standards for pavement design and construction and airport design and layout.

Very substantial public funds from the Airports and Airways Trust Fund are invested in airport construction and improvements, particularly for runways and other pavements. The functional demands on airport pavements are substantially different from the highway situation, posing unique technical issues. Airport design and layout can be a critical factor in efficient operation and in ability to respond to changing patterns of use.

R&D Strategy:

Collect operational data and conduct analyses to support development of guidelines and standards relating to pavement design and construction, airport and terminal design and layout, including consideration of changing fleet mix (new large aircraft, regional jets, etc.), and integration of ground transportation linkage. These R&D products will contribute significantly to reduced costs and less interference of construction with airport operations.

Environment

Derived Goals

The FAA enabling goal for environment is to prevent, minimize, and mitigate adverse environmental impacts associated with aviation activity. Aircraft and airport operations affect the environment in many ways. Public concerns over the environmental affects of aircraft and airport operations, as well as those requirements embodied in laws and regulations, can severely constrain the ability of the aviation system to meet the nation's need for mobility and economic growth.

The nature of environmental impacts, and the means by which they can be reduced or eliminated, generally involve complex and multi-disciplinary science, and draw on a wide range of operational and technology choices. Effective and practical FAA environmental programs and actions require a sophisticated understanding of specific aerospace-related environmental issues and the development of tools to characterize accurately those impacts. It is then necessary to apply that understanding to the control and reduction of environmental impacts of aircraft and airport operations.

The FAA also has a responsibility to quantify and mitigate environmental impacts of its facilities and activities. However, at present this imperative is being met through known technologies and practices, and does not imply a significant need for research and development. It is therefore not included as a Derived Goal in this strategic framework.

There are two Derived Goals for Environment:

- ***Increase understanding of current and potential environmental consequences of aviation-system operation and alternative countermeasures.***
- ***Control and reduce environmental impacts of aircraft and airport operations.***

Performance Objectives, Challenges, and R&D Strategies

Derived Goal: Increase understanding of current and potential environmental consequences of aerospace system operation and alternative countermeasures.

Performance Objective: Characterize and assess aviation environmental impacts and countermeasures.

R&D Challenge: *Enhanced Knowledge Base* - Enhance the knowledge base and array of planning tools available for designing and implementing programs to reduce environmental impacts.

Improved analytic and planning tools are necessary to achieving a better understanding of aviation's environmental impacts, and providing insight into the consequences of alternative courses of action. Enhanced analytical tools and simulation models must accompany improved understanding of relevant physical, chemical, and biological processes if impacts are to be accurately characterized and effective and efficient countermeasures designed and implemented. Noise certification stringency needs to be increased as technology allows. At present, noise and air quality impacts in the vicinity of airports are the primary area of concern. However, the very broad issue of global climate change also must be addressed, and possible impacts associated with commercial space transportation operations may also require focused R&D.

R&D Strategy:

> Develop and validate methodologies and models to assess aircraft-related noise exposure, aviation emissions and impact on air quality, and greenhouse gas emissions. The capability to estimate the effect of operational and technology changes, as well as introduction of specific countermeasures, is central to FAA decisions relating to aerospace environmental impacts. Thus, development of comprehensive and validated computer models and application data is an essential component of meeting FAA responsibilities with respect to aircraft noise, air quality impacts, and contribution to production of greenhouse gases. These tools are also needed by the aviation community to support environmental assessments.

Derived Goal: Control and reduce environmental impacts of aircraft and airport operations.

Performance Objective: Minimize aviation noise impacts on the population.

R&D Challenge: *Minimization of Noise Impacts* - Develop, apply and disseminate knowledge and tools to support international harmonization and optimization of the mix of noise-related aircraft certification standards, operational procedures and abatement technology.

In many locations, control and reduction of terminal-area noise is the major environmental issue limiting the efficiency and growth of air transportation. The scientific assessment and development of safe and affordable options for mitigating the impacts of aircraft noise are important not only to protect the environment, but also to sustain the continued expansion of air transportation. FAA efforts to address this complex issue include creating a cooperative development effort that balances noise reduction with adequate airport capacity, managing FAA activities to understand and minimize adverse environmental consequences, stimulating private industry and government research to reduce noise created by the aviation sector, and harmonizing international aircraft noise certification standards.

R&D Strategies:

1. Develop data, requirements, standards, rules, and technical guidance addressing certification of new and modified designs for reduction of aircraft noise.

2. Prepare technical documentation and training materials for use by aircraft manufacturers and others.

3. Provide computer models and impact criteria for use by civil aviation authorities in

environmental assessments. These activities provide the technical basis for internationally harmonized noise certification regulations.

Performance Objective: Minimize the impact of aviation engine emissions.

R&D Challenge: *Minimization of Air Quality Impacts* - Develop, apply, and disseminate knowledge and tools to support international harmonization and optimization of the mix of emissions-related aircraft certification standards, certification test procedures, and abatement technology.

Emissions from aircraft engines and airport operations, including generation of carbon dioxide and other greenhouse gases, is a rising challenge for the aviation community and, just as is the case for noise, could impose a significant limit on the growth and performance of the air transportation system. The scientific assessment and development of safe and affordable options for mitigating the impacts of aircraft engine emissions are necessary to address this concern. Additionally, to understand and minimize adverse environmental consequences, a knowledge base and effective tools are needed to reduce emissions by the aviation sector and to harmonize international engine emissions certification standards.

R&D Strategies:

1. Develop data, requirements, standards, rules, and technical guidance addressing certification of new and modified designs for reduction of aircraft emissions.

2. Prepare technical documentation and training materials for use by aircraft manufacturers and others.

3. Provide computer models and impact criteria for use by civil aviation authorities in environmental assessments. These activities provide the technical basis for internationally harmonized engine emission certification regulations.

Summary

The R&D Challenges and Strategies described above are summarized in the following table.

Safety

R&D Challenges	R&D Strategies
Derived Goal: Reduce the occurrence of aviation system accidents caused by new or previously unrecognized causal factors.	
Safety Information Sharing and Analysis *- Develop and apply data and analytical tools for use by FAA and industry in identifying potential accident causes and developing effective safety programs and countermeasures.*	(1) Develop and apply data systems and risk management and decision support tools and methodologies to monitor and analyze aviation system operations and safety risks. (2) Develop broadened understanding of biomedical, toxicological, and human performance factors that can contribute to accidents.

System Safety and Risk Management *- Develop and apply knowledge and analytical tools to assess the safety implications of innovative technologies and operational procedures planned or proposed for implementation in the airspace system.*	(1) Develop tools to support the creation and introduction of high confidence software and systems in safety-critical NAS functions and aircraft avionics. (2) Assess and address the safety implications of new composites, alloys and other materials, and associated structures and fabrication techniques. (3) Assess and develop responses to the safety implications of evolving operational procedures and practices, including measures to enhance aviation security.

Derived Goal: Reduce the recurrence of aviation system accidents due to known risks or causal factors.

Hazards of the Flight Environment *- Characterize potential hazards of the flight environment and develop the knowledge base and technologies needed to eliminate or reduce those hazards.*	(1) Improve understanding, predictability and ability to deal with adverse weather, icing conditions, and other atmospheric hazards, and improve the delivery of weather products to pilots and aircrews. (2) Develop guidance concerning flight hazards associated with electromagnetic fields.
Failures of Aircraft Structures and Systems *- Develop knowledge, criteria, tools, technologies, and practices to improve reliability and prevent or reduce failures of aircraft structures systems.*	(1) Develop improvements in aircraft fuel tank explosion protection. (2) Develop knowledge, inspection tools, techniques, and strategies to address safety hazards associated with the aging of airframe structures, engine components, and mechanical and electrical systems. (3) Assess the use of improved processing and manufacturing techniques for critical engine components to eliminate engine failures (4) Assess the use of advanced materials protect aircraft critical systems and passengers in the event of catastrophic engine failures. (5) Assess the safety implications of changes to aviation fuels used for both commercial and general aviation.
Human Performance *- Develop knowledge, guidance, and standards to improve the performance and to structure the roles and working environments of the people who play critical roles in aviation safety.*	Develop knowledge, guidance and standards for: (1) Design and use of automated support systems. (2) Personnel selection and training. (3) Human performance assessment. (4) Information management and display. (5) Bioaeronautical factors.
Terminal Area Safety *- Develop technologies and evaluate strategies to increase pilot and controller situational awareness in the terminal area, reduce wildlife interactions, and assure compatibility of airport designs and infrastructure with new types of aircraft.*	(1) Develop technology and standards to increase pilot and controller awareness of potential runway incursions and other hazards. (2) Conduct evaluations and assessments of means to reduce bird-strike and other wildlife-related risks. (3) Conduct tests and analyses to assure compatibility of airport design with new larger aircraft.
Safety of Reusable Launch Vehicles *- Determine best practices for commercial space transportation operations, develop criteria for assessing the safety of RLVs.*	(1) Identify commercial space transportation operations best practices. (2) Establish criteria to define a "proven" RLV. (3) Assess effects of RLV maneuverability characteristics on public safety.

Derived Goal: Increase the survivability of aviation system accidents.

Aircraft Fire Safety *- Develop standards and specifications for fire-resistant materials used in aircraft*	(1) Develop materials and standards to increase aircraft fire resistance. (2) Develop improved fire detection and fire suppression systems.
Aircraft Crashworthiness and Crash Survival *- Develop knowledge, tools, and standards to improve the crashworthiness of aircraft structures and systems and the effectiveness of evacuation procedures.*	(1) Develop knowledge, tools, and standards to improve the crash characteristics of aircraft structures and systems. (2) Develop knowledge, design and procedural guidelines to enhance the effectiveness, speed, and safety of aircraft evacuation.

Airport Crash Response Capabilities *- Develop knowledge, tools, standards, information, and guidance to support regulatory actions and improved operational practices related to post-crash response to accidents.*	(1) Develop knowledge, tools, and standards to improve airport rescue and fire-fighting efforts. (2) Test and evaluate improved firefighting systems for use in controlling both external and internal cabin fires, and develop new methods, procedures, and chemicals to fight fires in future aircraft that use advanced materials.
Derived Goal: Prevent successful attacks on the integrity and availability of critical NAS information systems.	
Protection of NAS Information Infrastructure *- Develop the technical foundation for incorporation of high-performance cybersecurity technology and procedures into the existing NAS and at the design level for new NAS elements.*	(1) Develop high-performance intrusion protection, detection and response capabilities for incorporation into the NAS. (2) Develop and incorporate into the NAS architectural approaches and improved cybersecurity capabilities design and modernization process. (3) Develop and evolve technologies to enhance integrity and confidentiality of communications in the mobile environment. (4) Undertake collaborative R&D with DoD, NSF, NASA, and others to identify new and emerging technologies that can be employed to reduce the risks to the integrity and availability of critical systems and data. (5) Conduct research to enhance the protection of GPS from unintentional or intentional interference.
Derived Goal: Prevent adverse health impacts on air passengers and flight crews	
Cabin Environment Health Impacts *- Develop understanding of health risks in the cabin environment sufficient to assess the need for remedial actions and provide the scientific basis for developing them.*	Develop knowledge, recommendations, and guidelines to minimize health risks to cabin occupants and aircraft crews and assure health maintenance of cabin occupants with respect to possible hazards, including poor air quality, cosmic and other radiation, and sudden decompression.

Efficiency

R&D Challenges	***R&D Strategies***
Derived Goal: Match system capacity to the traffic demands of users of the NAS.	
Increased Airport Arrival/Departure Rates *– Develop and evaluate technologies, practices, and operational procedures that support accelerated design and construction of runways and full exploitation of their capacity.*	(1) Facilitate surface infrastructure design, construction practices, and efficient operational surface movement. (2) Provide terminal airspace standards, procedures, and tools that support improved terminal airspace and route design and permit full use of available runway capacity.
Increased En Route Capacity *- Develop operational concepts, standards, and tools that increase flexibility in responding to changing circumstances and better matching airspace design and capacity and demand.*	(1) Develop tools and analyses to design and evaluate airspace design and reduce separation standards without compromising safety. (2) Develop tools and validate procedures for strategic collaborations between users and providers to resolve tactical congestion problems. (3) Develop and validate improved controller-pilot communication technologies.

Reduced Airport Weather Impacts - *Develop and evaluate technologies, tools, and procedures to achieve near optimum runway acceptance rates without regard for meteorological conditions.*	(1) Develop and validate new services, based on surveillance and navigation technologies and procedural improvements, to enable continued arrival operations as weather deteriorates from visual to instrument meteorological conditions. (2) Validate new cockpit tools and displays to achieve VMC throughput capacity in all weather conditions. (3) Develop and evaluate tools and procedure, and improved weather prediction capabilities to facilitate efficient runway reconfiguration at the onset and termination of hazardous weather conditions.
Reduced En Route Weather Impacts - *Develop and evaluate means to generate and deliver more specific and timely weather information to users, and means for providers and users to respond effectively and rapidly to hazardous weather.*	(1) Develop means for improved weather prediction and timely dissemination to all aerospace system users. (2) Develop means for greater integration of common weather information into the air traffic management process, including collaborative adjustment of routes.
Expanded Access and Service Availability - *Develop and validate technologies to enable instrument approaches at remote and low-traffic airports.*	Develop alternatives to fixed terrestrial facilities as a means of rapidly introducing improved NAS services in remote areas.
Future Capacity Enhancements – *Explore and apply concepts, technologies and procedures that will make possible NAS capacity increases sufficient to meet traffic demand beyond 2010.*	(1) Develop a NAS architecture to serve as the framework for a flexible ATM that is based on the paradigm of timely and efficient delivery information to all actors, can readily be reconfigured in response to changing patterns of operation, facilitates evolutionary improvement, and fosters exploration of alternative procedures and strategies. (2) Undertake structured collaborations with NASA and others to identify improved ATM concepts and foster their incorporation into the NAS.
Derived Goal: Minimize the costs to users of the NAS.	
Improved NAS Predictability *- Provide users with improved current and projected status information in an operational environment*	(1) Identify, develop and validate improved technology and processes for communication to users of current and projected NAS status and performance. (2) Identify and develop tools for knowledge capture of operational experience with respect to actual performance and decisions made to support post-analysis that facilitates lessons learned, improved training and repeatability of "best practices," and longer–term strategic planning.
Greater NAS Flexibility *-Validate performance and safety of technologies critical to implementation of Free Flight.*	(1) Accelerate application of CNS technologies critical to Free Flight. (2) Demonstrate and validate advanced technologies in an operational environment to accelerate availability of capabilities that involves users and removes operational constraints.
Derived Goal: Reduce the cost of providing NAS infrastructure and operations.	
Reduction of the Cost of Providing NAS Services *- Design and evaluate infrastructure technologies that minimize life-cycle costs, and develop tools to accelerate the development of software systems.*	(1) Perform analyses and design NAS subsystems that reflect costs of deployment, operations, repair and maintenance, and workforce needs. (2) Develop means for ensuring that Commercial Off-The-Shelf (COTS) software is safe and will function as required. (3) Develop tools and techniques for efficient development and deployment of NAS software systems.
Reduction of Airport Surface and Terminal Infrastructure Cost *- Develop guidance and standards for pavement design and construction and airport design and layout.*	Collect operational data and conduct analyses to support development of guidance and standards for pavement design and construction and airport design and layout.

Environment

R&D Challenges	R&D Strategies
Derived Goal: Increase understanding of current and potential environmental consequences of aviation-system operations, and alternative countermeasures.	
Enhanced Knowledge Base *- Enhance the knowledge base and array of planning tools available for designing and implementing programs to reduce environmental impacts.*	Develop and validate methodologies and models to assess aircraft noise exposure, aviation emissions and impact on air quality, and greenhouse gas emissions.
Derived Goal: Control and reduce environmental impacts of aircraft and airport operations.	
Minimization of Noise Impacts *- Develop, apply and disseminate knowledge and tools to support international harmonization and optimization of noise-related aircraft certification standards, operational procedures and abatement technology.*	(1) Develop data, requirements, standards, rules, and technical guidance addressing certification of new and modified designs for reduction of aircraft noise. (2) Prepare technical documentation and training materials for use by aircraft manufacturers and others. (3) Provide computer models and impact criteria for use by civil aviation authorities in environmental assessments.
Minimization of Air Quality Impacts *- Develop, apply, and disseminate knowledge and tools for international harmonization and optimization of emissions-related aircraft certification standards, test procedures, and abatement technology.*	(1) Develop emission reduction data, requirements, standards, rules, and technical guidance for certification of new and modified designs. (2) Prepare technical documentation and training materials for use by aircraft manufacturers and others. (3) Provide computer models and impact criteria for use by civil aviation authorities in environmental assessments.

4. Resources

Introduction

The FAA possesses significant internal capability for managing and conducting aviation-related research and development programs. The bulk of this capability is located at the William J. Hughes Technical Center (located at the Atlantic City International Airport, Atlantic City, New Jersey) and the Civil Aerospace Medicine Institute (located at the FAA Mike Monroney Center, Oklahoma City, Oklahoma). The balance of the agency's internal capability is resident with the staff of the FAA Headquarters' organizations (Washington, D.C.) and at the FAA Air Traffic Control System Command Center (Herndon, Virginia). All of these organizations are staffed by dedicated researchers, engineers, software developers, analysts, and other specialists, skilled in their disciplines and highly experienced in aviation technology and operations. They are the critical resource essential in the development, effective management, and performance of agency research and development.

The FAA's research workforce provides the required capabilities to:

- Conduct Internal R&D
- Conduct External R&D
  - Provide oversight and review, as appropriate, of our partners' research efforts, including:

    – Contract or grant management
    – Technical performance
    – Deliverable acceptance on behalf of the government

- Manage the R&D Program
  - Program management
  - Technical management
  - Program planning and budgeting
  - Communication and dissemination of program goals, plans, progress, and research results among all parties

The FAA also relies heavily on the work of R&D partners to provide the skills and capabilities necessary to perform all the research and associated activities necessary to support the FAA's mission. These partners, coming from industry, academia, and other government organizations, augment internal capabilities and supply needed capabilities outside of agency core needs.

External Partnerships

NASA

Safety

In August 2000, NASA and the FAA signed the first *FAA-NASA Integrated Safety Research*

Plan,[10] which builds on existing FAA-NASA relationships to assure ongoing communication and coordination of safety research and establish a strategy for the two agencies to make complementary, coordinated research investment decisions. That plan includes the FAA-NASA Safety Investment Strategy, which has four objectives: coordinate strategic assessments and investment portfolios; synchronize communication opportunities based on individual agency budget cycles; integrate implementation plans; and assess work in progress. NASA's role in aviation safety research is the development of enabling tools and technology, with implementation to occur through industry actions as well as incorporation into FAA operational programs and requirements.

Efficiency

The FAA/NASA Interagency Air Traffic Management (ATM) Integrated Product Team (IAIPT) coordinates research directed toward air traffic control technologies and the development of procedures for their safe and efficient use.[11] The IAIPT is comprised of the major stakeholders in the planning, execution, and outcome of ATM R&D programs, throughout the FAA and NASA. Its work teams execute research activities in six areas:

- *System/Cross-Cutting*: System-wide initiatives, including the initial definition of concepts and use of human factors and modeling assessment methodologies and demonstrations.
- *Traffic Flow Management*: Strategic resource allocation and flow management.
- *Surface*: Operations on an airport's surface.
- *Terminal*: Operations in airspace surrounding one or more closely spaced airports where a TRACON or a comparable military facility provides services.
- *En route*: Operations in airspace between airports where an Air Route Traffic Control Center (ARTCC) provides services and transition airspace between the en route and terminal environments.
- *Oceanic*: Operations in airspace over international waters where an oceanic ARTCC provides services.

The IAIPT also maintains collaborative partnerships with Federally-Funded Research and Development Centers, industry, academia, Department of Defense, EUROCONTROL, the Center of Excellence in Operations Research, and the National Weather Service. IAIPT research is accomplished at the following research facilities: FAA William J. Hughes Technical Center,

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[10] *FAA-NASA Integrated Safety Research Plan,* prepared in March 2000 and periodically updated.

[11] *Integrated Plan for Air Traffic Management Research and Technology Development*, Jan. 2000.

NASA Ames Research Center, NASA Langley Research Center, MITRE Center for Advanced Aviation System Development (CAASD), Massachusetts Institute of Technology (MIT) Lincoln Laboratory, Volpe National Transportation Systems Center, and NASA North Texas Research Station.

The FAA/NASA Joint University Program

The FAA/NASA Joint University Program for Air Transportation Research (JUP) is a long-term cooperative research partnership among three universities to conduct scientific and engineering research. The JUP provides grants to Massachusetts Institute of Technology, Ohio University, and Princeton University to support research covering a broad range of relevant technical disciplines that includes human factors, satellite navigation and communications, aircraft flight dynamics, avionics, and meteorological hazards. The universities gain informed comment on their research, as well as proposed new avenues for investigation, via periodic reviews and interactions with FAA and NASA aviation and technical experts. Through this program, NASA and the FAA leverage their resources, enabling them to achieve better high-priority goals. They benefit directly from the results of specific research projects, and, less formally, from valuable feedback from university researchers regarding the goals and effectiveness of government programs. An additional benefit is the creation of a talented cadre of engineers and scientists who will form a core of advanced aeronautical expertise in industry, academia, and Government.

Current JUP research topics include:

- Runway operations planning and control;
- Investigation of information requirements in the future NAS information architecture;
- Modeling of human performance of runway incursions;
- Voice recognition for controller/pilot data link communications;
- GPS-related application issues and technologies;
- Flight control systems;
- Intelligent aircraft/airspace system; and
- Coordinated flight of uninhabited air vehicles.

Center for Advanced Aviation System Development (CAASD)

CAASD, an operating center of the not-for-profit MITRE Corporation, is a federally funded research and development center sponsored by the FAA to perform essential research and development in the area of air traffic control and management. It serves as an essential component of the FAA research program, providing in-depth operational knowledge and technical sophistication, extensive capability in aviation-related technologies, and laboratory systems that support system development. CAASD's work for FAA focuses on high-level system architectures and CNS/ATM research and development, particularly in the areas of navigation and surveillance and traffic flow management.

Technology Sharing, Transfer, and Cooperative Agreements

Technology transfer activities enhance the resource base for performance of FAA R&D by addressing the need for government-private sector cooperation by enabling companies, institutions of learning, and federal laboratories to work together to develop innovative technologies and marketable products.

Cooperative Research Development Agreements (CRDAs) have proven highly effective in facilitating technology transfer. The CRDA allows the FAA to share facilities, equipment, services, and personnel resources in cooperation with private industry, academia, or state/local government agencies. It is implemented to develop an idea, prototype, process, or product for direct application to the civil aviation community and/or indirect application for commercial exploitation. The FAA has made extensive use of this mechanism over many years to foster advances in all of its mission goal areas. The breadth and relevance of CRDAs is illustrated by a sampling of recent and current examples:

- Maintenance, inspection, and structural design and integrity of aging aircraft;
- Damage prediction models for aircraft hardening against explosions;
- Collision avoidance warning systems;
- Detection systems for weapons and explosives;
- Advanced weather information systems with graphical display products;
- Means of detecting and predicting the presence of ice on aircraft surfaces;
- Soft ground arresting system to safely stop aircraft that overrun the available length of runway;
- Measurement of in-flight thrust of gas turbine engines;
- Use of GPS technology to generate an acceptable Local Area Augmentation System that will meet Category III precision approach requirements;
- National Airport Pavement Test Machine airport pavement technology; and
- New oxygen mask/regulator technology.

Another facet of technology sharing is FAA's participation in the Small Business Innovation Research (SBIR) program, which seeks to use small business as effectively as possible in meeting federal research and development objectives, and to contribute to the commercialization of innovative ideas. Small contracts are awarded on the basis of responses defining areas of specific interest to FAA and other DOT agencies. After small business contractors complete the second phase of the SBIR cycle, they can often participate in CRADA's with the FAA to facilitate successful commercialization of their research products.

Air Transportation Centers of Excellence

Air Transportation Centers of Excellence are established through cooperative agreements among academic institutions and the FAA to assist in mission-critical research and technology areas. After 10 years of FAA funding, they are expected to be self-supporting. FAA research organization staff work closely with the Centers of Excellence in shaping the R&D, incorporating results into FAA programs, and disseminating findings. Currently there are four Centers:

- Airworthiness Assurance: 28 university members--working with more than 100 academic, industry, and government institutions--conduct research in the major areas of:
  - Maintenance, inspection and repair;
  - Crashworthiness;
  - Propulsion and fuel systems performance and safety; and
  - Advanced materials.
  - Operations Research: This team[12], which includes ten university affiliates and twenty industrial partners, focuses on:
    - Traffic management and control;
    - Human factors;
    - System performance and assessment measures;
    - Safety data analysis;
    - Scheduling;
    - Workload management and distribution;
    - Navigation;
    - Communications;
    - Data collection and distribution; and
    - Aviation economics.
- Airport Pavement Research: This Center, established at the University of Illinois (Urbana-Champaign) and supported by Northwestern University, focuses on new technologies to handle the high pavement loads of the largest current aircraft and those anticipated in the future. The research includes rehabilitation and non-destructive testing and evaluation of existing pavement.

[12] The team is led by University of California (Berkeley), Massachusetts Institute of Technology, Virginia Polytechnical Institute, and the University of Maryland (College Park)

- General Aviation: This Center,[13] established in 2001, is developing synergistic relationships among academia, industry, and government. It is significantly enhancing opportunities for innovation in general aviation research.

R&D Funding

The first and foremost resource for R&D is the budget authority provided by the Congress. This authority provides the financial wherewithal to sustain the internal R&D staff and facilities and to procure the goods and services necessary to augment internal efforts in achieving R&D goals.

Funding for FAA research programs is provided by the Congress in three different appropriations: the Research, Engineering and Development (R,E&D) appropriation, the Facilities and Equipment (F&E) Appropriation, and the Operations (Ops) Appropriation. In FY 2001, the R,E&D appropriation accounted for two-thirds of R&D funding with substantially all of the balance coming from the F&E Appropriation. The Ops Appropriations, used for a small R&D program supporting Commercial Space Transportation regulatory issues, provided substantially less than one percent of the total.

From a historic high in FY 1995, there was a significant drop in appropriated R&D funding in FY 1996. The budget remained relatively stagnant until FY 2001. Adjusted for inflation (current year dollars), current funding still lags behind that high in terms of purchasing power. (Figure 4-1)

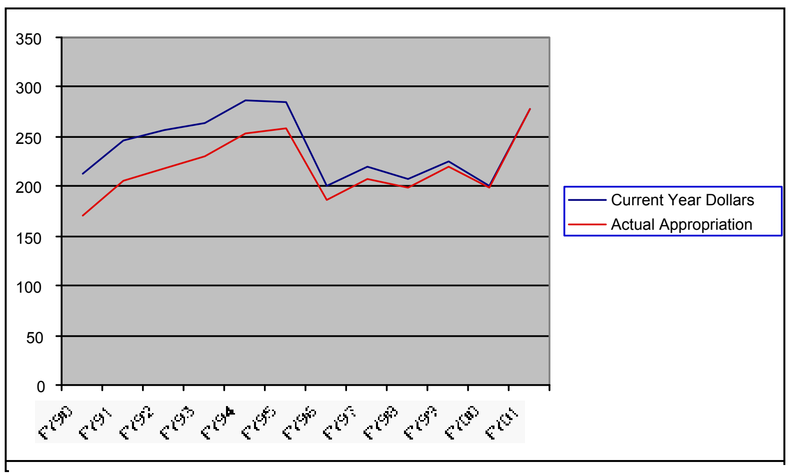

Figure 4-1. Total FAA R&D Funding ($M)

All R&D was funded through the R,E&D Appropriation through FY 1998. Beginning in FY 1999, the Congress moved a substantial portion of the funding for Air Traffic Management R&D and all of the Airport Technology R&D to the F&E Appropriation (Figure 4-2). The F&E funding was provided in two separate budget line items, Advanced Technology Development and Prototyping and Safe Flight 21.

With one exception, the projections for funding shown in Figure 4-2 are based upon OMB planning figures through FY 2006 and 3 percent growth for the following years. The exception is the Safe Flight 21 Program, a technology integration demonstration, which is funded only through FY 2007. All projections shown are planning figures derived for the purpose of developing the research strategies. *They are not commitments by either the Department of Transportation or the Congress to specific funding levels and, hence, are subject to change*.

[13] Members include Embry-Riddle Aeronautical University, Wichita State University, University of North Dakota, Florida A&M University, and the University of Alaska.

There is also an active R&D program for commercial space transportation, which has been budgeted at a relatively modest level of $100,000 per year and funded through the Operations Appropriation. These amounts are not depicted in Figure 4-2.

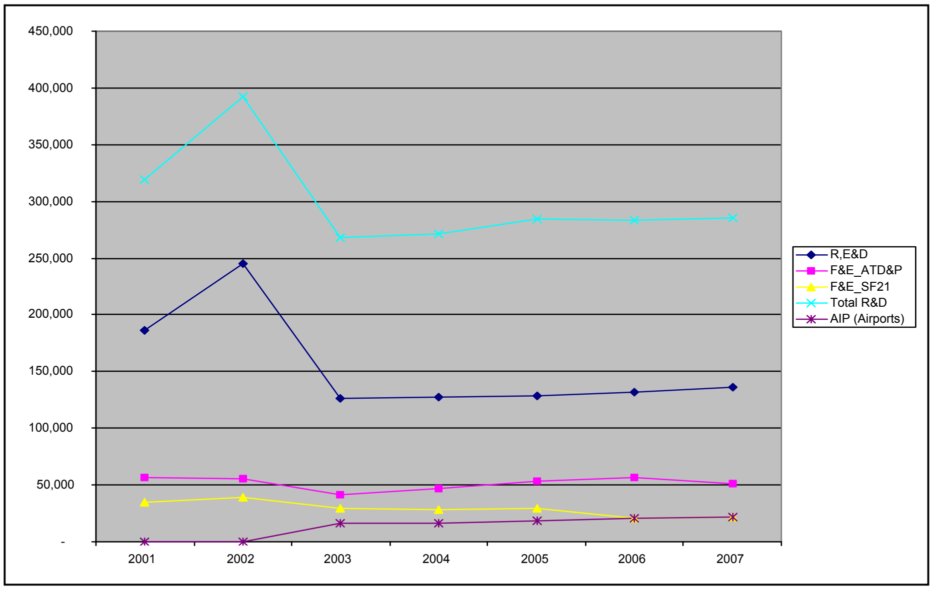

Figure 4-2. Funding Outlook by Appropriation ($K)

Taken alone, absolute funding levels show only a partial view of FAA R&D funding resources. Figure 4-3 offers an alternative presentation, based on the goal-oriented structure of the R&D Strategy. It indicates how the funding was distributed in fiscal years 2001 and 2002 across the mission and enabling goals of the FAA Strategic Plan. (As noted previously, funding assigned to a specific goal also may be supportive of one or more of the other goals; the assignment is based on the primary affected goal.)

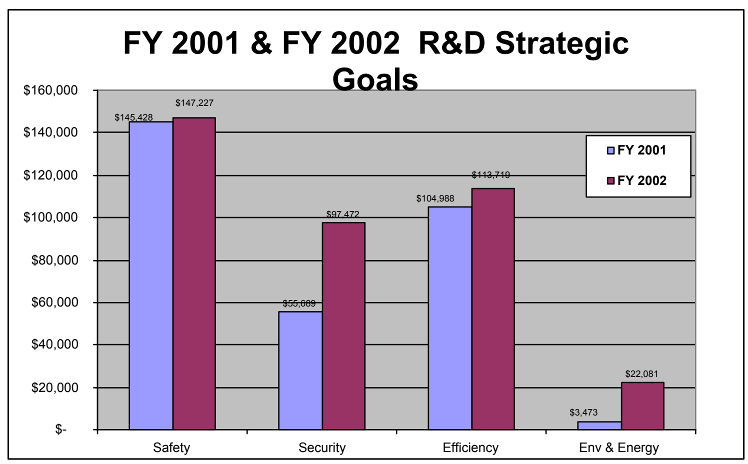

Figure 4-3. Funding by Strategic Goal ($K)