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NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

National Research and Development Plan For Aviation Safety, Security, Efficiency, and Environmental Compatibility

Committee on Technology
Subcommittee on Transportation Research and Development

November 1999

THE WHITE HOUSE

WASHINGTON

November 2, 1999

As we approach the centennial of powered flight, the United States continues to lead the world in aviation. We have the safest, most reliable, most efficient, and most productive air transportation system in the world, and our aircraft are second to none. The aviation industry in the United States provides millions of high-quality jobs, and the aircraft manufacturing industry represents one of the Nation's largest export sectors. Worldwide, much of the growth in the $3 trillion-plus global travel and tourism industry stems from innovative United States aviation technology and services. In short, aviation has become central to the way we live and do business, linking people from coast to coast and connecting America to the world.

The Federal government has an important role in shaping the future of global civil aviation--ensuring the continued safe, secure, efficient, and environmentally acceptable operation of the Nation's aircraft and aviation system, and providing leadership and investment in areas critical to the public good. Our response to these challenges will have a profound impact on our national air transportation system, our national security, our environment, and our economy.

For these reasons, it is important that the Nation have a set of clear and unambiguous goals to guide our civil aviation policy as we approach the new millennium. First and foremost, we will continue to place the highest priority on maintaining and strengthening public safety and security in our aviation system. We will also seek to continuously improve our airports and aviation system to increase their efficiency and capacity while fostering their environmental compatibility. Finally, we will maintain U.S. leadership in aviation science and technology to ensure the continued excellence of our aviation system, products and services.

Pursuing and accomplishing these goals requires a coordinated effort at the National level and effective partnerships with State and local governments, industry, and universities. This *National Research and Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility*, developed by the National Science and Technology Council in cooperation with the Federal Aviation Administration, the National Aeronautics and Space Administration and the Department of Defense, charts the right course for continued U.S. leadership in aviation.

Neal Lane

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Assistant to the President
for Science and Technology

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16. Abstract

The National Research and Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility focuses on those areas of research for civil aviation, including concepts exploration and development, that are directly relevants safety, security, National Airspace System efficiency, and impacts of aviation on the environment. This plan serves as the benchmark for future inter-agency cooperative efforts, and to attempts to direct essential government research toward the attainment of critical aviation and air transportation goals established by the Federal government and supported by industry. The report also describes differing functions, technologies, mission responsibilities and key areas of technical expertise involved in reaching goals.

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EXECUTIVE SUMMARY

This plan describes coordinated long-term research initiatives to bring about advances in aviation that will be required in the opening decades of the next century. The White House Commission on Aviation Safety and Security and the National Civil Aviation Review Commission both document the importance of aviation to the nation and the need for investment in research and technology to ensure that the aviation system meets the growing demand for air transportation. This plan serves as the benchmark for the future inter-agency cooperative efforts to optimize essential government research toward the attainment of critical aviation and air transportation goals established by the Federal government and supported by industry. It is a visionary plan presenting cooperative government research and operational solutions in four key areas that otherwise would limit our nation's ability to meet the growing demand for air transportation:

- Safety
- Security
- NAS Efficiency
- Environmental Compatibility

The development of this plan signifies the achievement of a broad consensus as to aviation goals and agency roles, and provides the foundation for developing more integrated program plans in the future. Joint research efforts and goals have been developed among:

- NASA
- FAA
- DoD
- The aviation industry
- The academic community

The research and goals will be further refined and expanded with the involvement of the National Science Foundation, the Environmental Protection Agency and the National Weather Service, and others in the future.

Rapid technological advances fostered by Federal investment in aeronautical research and development have led to air transportation becoming the preferred means of long-distance transportation world wide. The government's role has been a critical factor to this success. The remarkable growth of aviation is a tribute to all those who have contributed to research and technology infusion into the aviation transportation system of the world.

An effective response to the challenges of a rapidly advancing aviation system is needed to assure the continued viability and utility of that system for all users. This response will require applying national scientific and technical resources to a more comprehensive and coordinated program of research, development and implementation leading to improved operational systems, standards, procedures and/or regulations. Many of these resources reside at FAA and NASA. While implementation of the results will rest largely with the FAA and the aviation community, NASA and DoD, on the basis of their technical strength and expertise, play an essential role in this endeavor. It is particularly important that the efforts of FAA and NASA be fully integrated and directed towards well-defined civil aviation goals.

NASA, DoD and FAA researchers have long worked together on specific topics such as human factors, aging aircraft, aircraft icing, airworthiness of new classes of aircraft (e.g., tiltrotor, supersonic and vertical lift), crashworthiness, energy efficiency, and noise reduction. Interagency collaboration between the FAA and NASA has been accomplished through a series of Memoranda of Understanding and facilitated by the R&D coordinating committee since 1980. A 1998 agreement between FAA Administrator Jane Garvey and NASA Administrator Dan Goldin now provides for a strategic alliance between FAA and NASA and a closer collaboration with DoD. This agreement contains an explicit mandate to "maintain a close partnership in the pursuit of complementary goals for aviation and future space transportation and to coordinate their planning and tracking of accomplishments toward achievement of those goals."

The agreement restructures the existing coordinating committee into a new "FAA/NASA Executive Committee," and charters it to oversee the success of the partnership to achieve the goals.[1] One significant change resulting from this newly established joint committee is that, for the future, one council representing the diverse interests of the two agencies at the executive level will be responsible for harmonizing the civil aviation research and implementation efforts of the government.

DIFFERENT RELATIONSHIPS - SAME ROLES

The execution of this plan will be made possible through a positive change in the traditional relationships between the agencies. This strategic partnership will be based on a common vision of the future and a joint commitment at the executive level. This new relationship is critical in order to ensure that research produces real world outcomes, which will meet critical aviation needs. Agency roles are summarized as follows:

- FAA has the mission of providing a safe, secure, efficient and environmentally compatible aerospace system.

- NASA has the complementary role of conducting research, development, verification, and transfer of advanced aeronautics, space and related technologies that enable the long-term major improvements necessary to assure that the aviation system continues to meet the nation's needs.

- In addition to playing a substantial role in aviation research, the Department of Defense is a major user of FAA services, a provider of infrastructure for weather and air traffic services, and a major player in commercial and government space operations.

- There is also a necessary and natural strategic relationship between Federal activities and those of airline operators, aircraft manufacturers, academic research institutions and others who provide services and equipment to aviation operators.

[1]This step responds to recommendations for a re-evaluation and modification of the advisory committee structure made jointly by the NASA and DOT Inspectors General. (Memorandum Report, October 8, 1998)

This plan focuses on those areas of research for civil aviation, including concept exploration and development, that are directly relevant to safety, security, National Airspace System efficiency, and impacts of aviation on the environment. While these are currently the highest priority aviation issues, DoD, FAA and NASA are conducting research that covers a wider set of topics and issues that also need to be addressed in an integrated fashion.

The FAA/NASA Executive Committee in collaboration with DoD is beginning a methodical review of their goals and metrics in order to define a comprehensive set of civil aviation goals and metrics that both FAA and NASA can endorse and support. This will include a process for monitoring progress toward achieving the goals.

Interagency work groups have been established to prepare the more extensive roadmaps and program plans that will be described in future versions of this national plan.

FRAMEWORK AND APPROACH

This national R&D plan is based on the following general approach:

- Implement existing solutions as part of current operational practices wherever possible,
- Develop enabling technologies to generate new solutions, and
- Conduct research in promising areas to provide the foundation for the major advances that will be needed to accomplish the demanding goals that have been defined.

This plan describes differing functions, technologies, mission responsibilities and key areas of technical expertise for each aviation goal. As a result, implementation of the plan takes a somewhat different form for each goal. Unique programs for each of the four goals are described in detail in the plan.

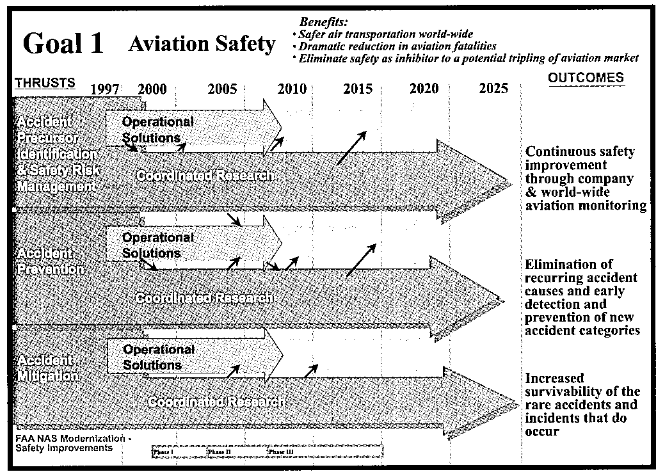
STRATEGIC GOALS: ROADMAPS TO SUCCESS

Top-level roadmaps for four national goals are provided in the plan. Each roadmap includes:

- Thrusts to achieve the goal
- Anticipated long term outcomes
- Related efforts between agencies and interrelationships between activities/programs
- Examples of specific high priority programs
- Real world, national and global steps and solutions to ensure US pre-eminence in technical advancement in aviation

The roadmaps guide cooperative efforts toward innovation and breakthrough technologies. The highlights of the plan for each of the goals are provided here in summary form.

Safety

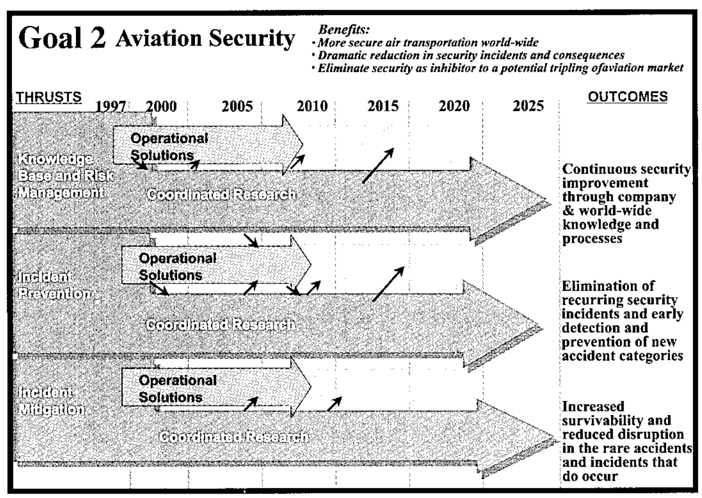


On February 12, 1997 the White House Commission on Aviation Safety and Security proposed a national goal to reduce the fatal accident rate by 80 percent within ten years and conduct research to support the goal. Only through government and industry collaboration to define the goals, identify the focus areas, agree on intervention strategies, and commit to mutual action plans, can the goals be achieved. Safety efforts will be directed toward supporting three thrusts that, in the aggregate, will meet the goal.

Safety Thrusts

- Accident Precursor Identification and Safety Risk Management
- Accident Prevention
- Mitigation of Consequences

Security



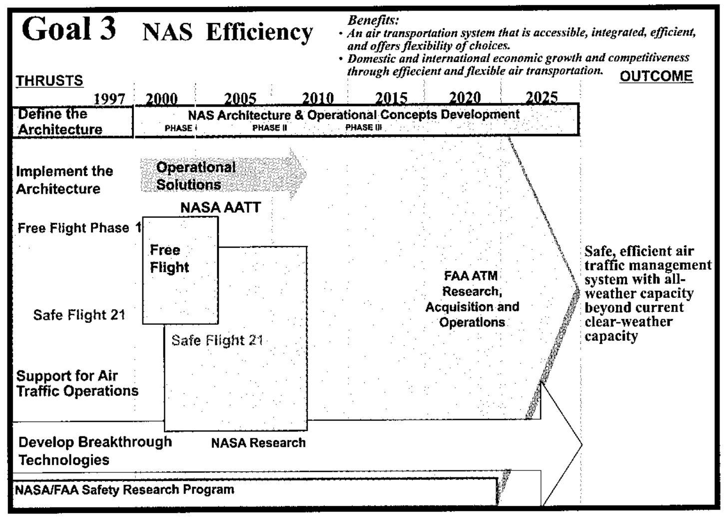
Research and development supportive of the security recommendations of the report of the White House Commission on Aviation Safety and Security can be grouped in a manner similar to those used for the safety goal.

Security Thrusts

- Knowledge Base and Risk Management
- Incident Prevention
- Mitigation of Consequences

NAS Efficiency

The principal focus of this goal is the near- and long-term modernization and evolution of the National Airspace System to meet the needs of users. Modernization includes both the enabling technology and associated operational practices.

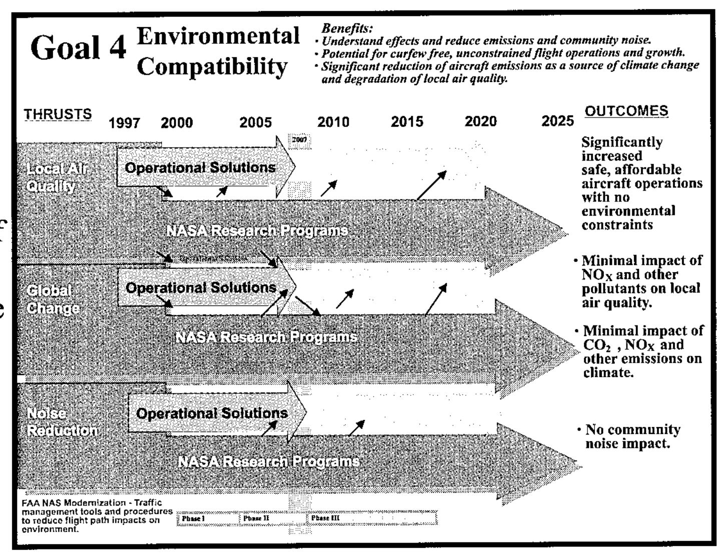


NAS Efficiency Thrusts:

- Architecture Definition and Evolution
- Architecture Implementation
- Support of Air Traffic Operations
- Breakthrough Technologies

Environmental Compatibility

The 1995 NSTC Report *Goals for a National Partnership in Aeronautics Research and Technology* recognized that "Environmental issues are likely to impose the fundamental limitation on air transportation growth in the 21st century." Thus, understanding the effects of aviation on the environment and developing technology for reducing noise and emissions are essential to sustaining aviation's vitality.



Environmental Compatibility Thrusts:

- Local Air Quality
- Global Change
- Noise Reduction

1. INTRODUCTION

PURPOSE

This plan describes the coordinated long-term research initiative to bring about advances in the safety, security, efficiency, and environmental compatibility of the US and global aviation system that will be required in the opening decades of the next century. The plan includes the highest priority aviation goals; operational and research thrusts to achieve the goals; roadmaps to achieve real world outcomes; and a description of the roles of the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), Department of Defense (DoD) and other participants.

This collaborative national research plan accomplishes the following important objectives:

- Establishes a visionary national plan for research based upon cooperative government agency goals and priorities;

- Describes the relationships forged between FAA, NASA and DoD to achieve Civil Aviation Goals;

- Introduces collaborative initiatives for joint venture both within government and between government and industry for critical areas of safety, security, efficiency and environmental compatibility;

- Establishes a top-level roadmap for key mission objectives including:

  – Goals, major thrusts, and anticipated outcomes for research, and

  – Related research efforts and roles of agencies and participants,

  – Examples of specific programs and initiatives to be used as measures of success;

- Illustrates how research and technology development are both linked and critical to achieving real world outcomes; and

- Identifies critical research areas necessary for the US to retain and expand its national and global pre-eminence in aviation technology advancements for aviation.

This plan serves as the benchmark for future inter-agency collaborative efforts to optimize essential government research toward the attainment of critical aviation and air transportation goals established by the Federal government and supported by industry. The development of the plan signifies the achievement of a broad consensus as to goals and agency roles in this undertaking, and provides the foundation for developing more integrated program plans in the future.

BACKGROUND

Air transportation has become an essential element providing mobility for individuals, strengthening the health and vitality of the US economy, and furthering US interests around the world. The United States spans a continent and is the largest single participant in an increasingly global economy. Just as telecommunication technologies have enabled virtually instantaneous, low cost movement of information and convenient personal communications, the aviation system has provided dramatic advances in the movement of people and goods across great distances with speed, convenience and economy. This has enabled rapid growth in global manufacturing, trade, and tourism.

As a result of rapid technological advances, supported by continuous Federal investment in aeronautical research and development, the US has long led the world in aviation. The Federal role in this accomplishment has been a critical factor which allowed this success and is a remarkable tribute to all those in government who have contributed to research and technology infusion into the aviation transportation system in the US and worldwide. However, the energy and creativity that characterized the first century of aviation will have to continue into the next century if the challenges that lie ahead are to be met.

These challenges take many forms. In addition to public expectations for aviation safety, security and environmental compatibility, the value of time (and therefore, doorstep-to-destination speed) will take on increased importance early in the 21st century. As the Information Age unfolds, human and intellectual capital is displacing physical capital as the basis for creation of wealth, increasing the value of time as the scarce commodity.

The FAA has developed an operational concept and system architecture for a modernized National Airspace System (NAS) that will rest on a broad base of sophisticated technology, complex software and new procedures and standards. Congestion and associated delays are already of widespread concern, and the next-generation NAS will have to support a level of passenger traffic likely to grow almost threefold by 2025. Even with larger aircraft and higher load factors, that increased traffic will mean a large increase in the number of crashes and fatalities if the accident rate–which has remained relatively constant for two decades–is not substantially reduced. In addition, the forecast in traffic growth and congestion will further challenge the ability of the current hub-spoke system to meet travelers' expectations for doorstep-to-destination speed. Events in recent years have intensified domestic and world sensitivity to the threat of many types of terrorist and other malicious attacks on the aviation system. Environmental concerns such as noise in the vicinity of airports, emission of air pollutants and gases linked to local air quality, global change, and petroleum usage are also major factors affecting the performance and health of the aviation industry.

In August, 1996, in recognition of the seriousness of these issues, President Clinton established the White House Commission on Aviation Safety and Security, chaired by Vice President Gore. The Commission's final report, issued February 12, 1997, set high goals to be met by the entire aviation community under the leadership of the Department of Transportation (DOT) and FAA and made numerous recommendations addressing the safety and efficiency of the air traffic control system and the security of travelers.

Subsequently, the Assistant to the President for Science and Technology and the Director of the Office of Management and Budget requested that FAA, NASA and DoD work together and develop a joint plan to implement the Commission's recommendation to coordinate R&D investments and definite the role of each agency. This plan has been prepared in response to their request. It describes the substantial progress that has been achieved in shaping a truly integrated and coordinated array of aviation safety, security, efficiency and environmental compatibility programs. In addition, the plan provides a high level plan for meeting the ambitious goals of the White House Commission.

On October 9, 1998, FAA Administrator Jane Garvey and NASA Administrator Dan Goldin signed a formal agreement establishing a partnership between their agencies with the objective of articulating and achieving specific goals in aviation and future space transportation. This agreement, built on a long history of NASA-FAA joint efforts and cooperation, is intended to provide the leadership for defining, developing and deploying the research and technology necessary for the nation's aviation system to meet the difficult challenges of coming decades.

An effective response to these challenges is needed to assure the continued viability and utility of the National Airspace System to all users. This response will require applying the relevant national scientific and technical resources, many of which reside in FAA and NASA, to a more comprehensive and coordinated program of research, development and implementation leading to improved operational systems, standards, procedures and/or regulations. Implementation of the results will rest largely with the FAA and the aviation community. However, NASA and DoD, on the basis of their technical strength and expertise, will play an essential role in this endeavor. It is particularly important that the efforts of FAA and NASA be fully integrated and directed towards well-defined civil aviation goals.

NASA and FAA researchers have long worked together on specific topics such as human factors, aging aircraft, aircraft icing, airworthiness of new classes of aircraft (e.g., tiltrotor, supersonic and vertical lift), crashworthiness, energy efficiency, and noise reduction. Interagency collaboration has been accomplished through a series of Memoranda of Understanding and an R&D coordinating committee since 1980. The Garvey-Goldin agreement now provides for a strategic alliance between FAA and NASA and a closer collaboration with DoD. It contains an explicit mandate to "maintain a close partnership in the pursuit of complementary goals for aviation and future space transportation and to coordinate their planning and tracking of accomplishments toward achievement of those goals." The agreement restructures the existing coordinating committee into a new "FAA/NASA Executive Committee," and charters it to oversee the success of the partnership to achieve the goals.[2] One significant change resulting from this newly established joint committee is that, for the future, one council, representing the diverse interests of the two agencies at the executive level, will be responsible for adopting, executing and fostering the harmonization of civil aviation research efforts of the government.

This effort is being pursued within a broad context in which partnerships with DoD and other stakeholders are recognized as critical mechanisms for achieving national objectives. The National Science and Technology Council (NSTC) has worked energetically to foster cooperation and joint

[2] This step responds to recommendations for a re-evaluation and modification of the advisory committee structure made jointly by the NASA and DOT Inspectors General. (Memorandum Report, October 8, 1998)

programs among Federal agencies in general, and has particularly addressed aviation, as reflected in the 1995 NSTC document *Goals for a National Partnership in Aeronautics Research and Technology* and the establishment of an NSTC Aeronautics and Aviation Subcommittee. The NSTC *Transportation Science and Technology Strategic Plan* (September, 1997) includes specific partnership initiatives addressing aviation safety, security, efficiency and environmental compatibility that are embodied in this program plan.

ROLES

R&D to meet aviation system challenges necessarily involves a wide range of public- and private-sector participants. Many specific subprograms and projects will include close collaboration with air carriers, manufacturers, multiple Federal, state and local agencies, academic researchers, and others. However, the primary participants are the Federal agencies with responsibility for civil aviation and aeronautics: FAA and NASA. Activities of other organizations, primarily DoD, are discussed where their responsibilities entail R&D complementary to the aims of this program.

FAA has the mission of providing a safe, secure, efficient and environmentally compatible aerospace system. To achieve this mission, it develops and implements a regulatory system that promotes aviation safety and security, provides an airway system for the safe operation of a multi-aircraft environment, and conducts supporting research.

NASA has the complementary role of conducting research, development, verification, and transfer of advanced aeronautics, space and related technologies that enable the long-term major improvements necessary to assure that the aviation system continues to meet the nation's needs. NASA's many aeronautics advances (like those of its predecessor, the National Advisory Committee for Aeronautics) include breakthrough-enabling technologies which directly support the aviation community and performance of the system. Other facets of NASA's R&D benefit system users by developing short- and long-term technology advances for implementation by FAA in the National Airspace System.

In addition to playing a substantial role in aviation research, the Department of Defense is a major user of FAA services, a provider of infrastructure for weather and air traffic services, and a major player in commercial and government space operations. It differs from other key stakeholders in the type of aircraft it operates, the risks it encounters, its independence of "market" forces and inflexible funding, and its population of aging aircraft and air traffic control facilities. However, it shares a common airspace and procedures with civil users, and faces the same basic challenges of human and aircraft performance and crashworthiness.

DoD has been dominant in developing and testing advanced aerospace technology and concepts (such as GPS, the Global Positioning System), and has extensive special expertise relating to aeronautical engineering, security and terrorism, aircrew human factors and avionics technologies. DoD also has a strong interest in safety in its own operations, shares the nation's airspace with the civil sector, and is the world's largest user of civil transportation services. Since 1988, NASA has had a Memorandum of Agreement with DoD that establishes the Aeronautics and Astronautics Coordinating Board.

There is also a necessary and natural strategic relationship between Federal activities and those of airline operators, aircraft manufacturers, academic research institutions and others who provide services and equipment to aviation operators. As a result, there exist numerous committees, task forces, and coordinating bodies that provide the network of relationships that will enable the entire aviation community, with Federal partnership, to move forward aggressively to meet known and future challenges.

The execution of this plan will be made possible through a positive change in the traditional relationships between the agencies. This strategic partnership will be based on a common vision of the future and a joint commitment at the executive level.

SCOPE

This plan focuses on those areas of research for civil aviation, including concept exploration and development, that are directly relevant to safety, security, National Airspace System efficiency, and impacts of aviation on the environment. While these are currently the highest priority aviation issues, DoD, FAA and NASA are conducting research that covers a wider set of topics and issues that also need to be addressed in an integrated fashion. The FAA/NASA Executive Committee, in collaboration with DoD, is beginning a methodical review of their goals and metrics in order to define a comprehensive set of civil aviation goals and metrics that both FAA and NASA can endorse and support. This will include a process for monitoring progress toward achieving the goals.

Therefore, specific current and planned programs directed primarily toward other significant aviation system characteristics are not presented in this document. Important areas not covered in this plan include development of advanced aerospace vehicles, commercial space transportation's effect on and integration into the goals for aviation, and operating concepts for commercial and general aviation that could substantially increase the mobility of the American people and the efficient utilization of the airspace. These topics will be considered for inclusion in the future. However, aviation system changes associated with those programs are implicit in this plan.

Even within the topics of safety, security, NAS efficiency and environmental compatibility, this plan is intended only to provide a strategic overview. Specific research topic areas and projects are noted as examples of high priority program content. The descriptions of research programs contained in this report do not represent the full content of individual research efforts, and do not include every topic of relevance and importance to safety, security, NAS efficiency and the environment. That information is available in plans, budget submissions and other formal documents prepared by the performing agencies.

The line between R&D and implementation cannot be drawn sharply. This plan adopts a broad definition of research and development that also includes test, evaluation, and demonstration and fielding of prototype systems. For this reason, some projects and activities described herein, particularly in the efficiency area, may be funded out of budget categories other than R&D, such as capital investment and operations.

2. NATIONAL AVIATION SYSTEM GOALS AND THRUSTS

In the past, aviation R&D activities, such as those addressing weather information, airframe failure modes, explosives detection, or cockpit human factors, have often been shaped in response to accident investigations and aviation system limitations. Applied research programs such as these solve specific problems or exploit opportunities for improvements based on new technology and concepts. These activities have delivered continuing significant advances. However, in order to assure an aviation system that meets the nation's needs in 2025, a more comprehensive, focused approach is required. Desired outcomes must be defined, strategic programmatic goals and research thrusts that will yield those outcomes must be developed, and R&D necessary to support attainment of those goals must be conducted. With a structured approach, critical gaps and shortfalls will be avoided and diverse activities coordinated and integrated. The safety, security, efficiency and environmental strategic goals and associated research thrusts for achieving these goals are summarized below; the approach to be taken in achieving real world outcomes is described subsequently in this plan.

STRATEGIC GOAL: SAFETY

After a long period of steady and dramatic improvement in aviation safety, the accident rate has stabilized at a very low level and remained relatively unchanged for about twenty years. This stability, in a period of rapid growth in air travel, indicates the degree to which problem areas have been successfully addressed and technological advances have been exploited. It also shows the difficulty in further reducing the accident rate. On February 12, 1997, the White House Commission on Aviation Safety and Security proposed a national goal to reduce the fatal accident rate by 80 percent within ten years and conduct safety research to support the goal. Only through government and industry collaboration to define the goal, identify the focus areas, agree on intervention strategies, and commit to mutual action plans, can the goal be achieved. Safety efforts will be directed toward supporting three thrusts that, in the aggregate, will meet the goal.

Thrusts:

- ***Accident Precursor Identification and Safety Risk Management:***
  Identify latent and potential future operational safety issues and correct them before they become accidents through research that supports (1) the comprehensive monitoring, sharing and use of operational aviation safety information and a consequent continuing growth in the understanding of current and emerging accident precursors and direct causes, and (2) immediate operational and technical interventions and decisions at the local, national and international levels.

[3] The FAA and NASA Inspectors General jointly recommended the preparation of "a detailed integration plan that identifies the research and development requirements, roles and responsibilities of each agency." (Memorandum Report, October 8, 1998)

- ***Accident Prevention:***
  Identify and implement interventions which eliminate the highest priority accident categories, primarily through the elimination of recurring accident causes, and early detection and prevention of accidents due to new causes, including introduction of insufficiently validated new technologies or operations.

- ***Mitigation of Consequences:***
  Reduce the risk of injury in the unlikely event of an accident.

STRATEGIC GOAL: SECURITY

Recent events in the United States and overseas have focused considerable attention on the potential for destructive acts of terrorism. Historically, transportation has been among the most visible and frequent targets of attack. Thanks to concerted efforts over the past two decades, the security posture of commercial aviation has been significantly improved. However, as the nature of the threat evolves, the effectiveness of the security program needs continual re-assessment. Research and development supportive of the security recommendations of the report of the White House Commission on Aviation Safety and Security can be grouped in a manner similar to those used for the safety goal.

Thrusts:

- ***Knowledge Base and Risk Management:***
  Research that supports comprehensive monitoring of terrorism trends (including intelligence reports and performance of aviation security systems) to enhance understanding of current and emerging threats and countermeasures needs.

- ***Incident Prevention:***
  Development and application of advanced technologies and improved practices and procedures to enhance the ability to prevent security incidents in aviation environments.

- ***Mitigation of Consequences:***
  Development and application of advanced technologies and improved practices and procedures that can reduce casualties, increase survivability and minimize system disruption and damage in the infrequent aviation-related incidents that do occur.

STRATEGIC GOAL: NAS EFFICIENCY

The focus of this goal is the near- and long-term modernization and evolution of the National Airspace System, to assure that it continues to meet the needs of users. Modernization includes both the enabling technology and associated operational practices. Virtually all elements of programs directed toward aviation efficiency must necessarily address safety as well, and be balanced with programs focused on the safety, security and environmental goals in order to ensure that the inherent tradeoffs are in the highest public interest.

Thrusts:

- ***Architecture Definition and Evolution:***
Detailed definition of the NAS operational concepts and development of associated NAS architecture, and evolution of that architecture over time in response to new opportunities and changed requirements.

- ***Architecture Implementation:***
Fielding of near-term prototype R&D systems to achieve early free-flight benefits, and field demonstrations of emerging communication, navigation and surveillance (CNS) technologies.

- ***Support of Air Traffic Operations:***
Involvement of air traffic controllers in developing new systems, and training and assistance in transition to those new systems. Human factors research is needed to improve controller effectiveness, and for development and implementation of improved infrastructure maintenance management, and enhanced weather services.

- ***Breakthrough Technologies:***
Development of technologies that will enable the NAS to meet growing demand in the 21st century.

STRATEGIC GOAL: ENVIRONMENTAL COMPATIBILITY

The 1995 NSTC Report Goals for a National Partnership in Aeronautics Research and Technology recognized that "Environmental issues are likely to impose the fundamental limitation on air transportation growth in the 21st century." Evidence of this problem is widespread. Every experienced traveler is familiar with the many airport operational restrictions (e.g., curfews) resulting from community noise concerns. Although the phase-in of Stage 3 aircraft is nearly complete, complaints about noise continue in airport communities and restrict expansion or construction of new facilities. Moreover, after completion of the Stage 3 phase-in, the projected growth of aviation services is expected to cause community noise exposure to increase once again.

Similar issues exist for aircraft engine emissions. Increasingly stringent ozone and particulate matter standards under the US Clean Air Act have resulted in local authorities and environmental interest groups demanding action from Federal agencies and the air carriers to mitigate emissions of nitrogen oxides (NOx) (that contribute to ozone production) and other pollutants. The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection also voices worldwide concerns about both local air quality and global change. In particular, the Kyoto Protocol to the UN Framework Convention on Climate Change has drawn growing attention to aviation's emissions of carbon dioxide (CO_2). However, the *Special Report on Aviation and the Global Atmosphere,* published by the Intergovernmental Panel on Climate Change (IPCC) in April 1999, indicates that aviation's impacts on climate possibly also include significant production of ozone (a greenhouse gas) and nucleation of cloudiness. The assessment also includes potential impacts of future supersonic aircraft on stratospheric ozone. Thus, scientific assessment and development of safe and affordable technology options for reducing aircraft noise and emissions are important to protect the environment and to sustain the growth of aviation.

Thrusts:

- ***Local Air Quality:***
  Through research and development of technology, reduce emissions of NOx and other pollutants that endanger public health and the environment.

- ***Global Change:***
  Through research and development of technology, reduce emissions that affect climate or stratospheric ozone.

- ***Noise Reduction:***
  Through research and development of technology, reduce noise levels in the vicinity of airports and in other places where aircraft noise is perceived as disruptive to the environment.

3. R&D PROGRAM STRUCTURE

BASIC PROGRAM FRAMEWORK

Figure 1 shows the programmatic approach developed to achieve an effective integration and coordination of NASA, FAA and DoD R&D activities in pursuing the linked goals of aviation safety, security, efficiency and environmental compatibility. Generally, the approach is to implement existing solutions as part of current operational practices wherever possible. When this does not provide a final solution, enabling technologies are developed to generate new solutions, and research is conducted in promising areas to provide the foundation for the major advances that will be needed to accomplish the demanding goals that have been defined.

The first element, introduction of ongoing improvements into the current aviation system, is based on existing technology, practices and program commitments that are shown in FAA's strategic plan and annual five-year budget. This is illustrated as an ever-advancing five-year FAA Commitment arrow (light pink) in Figure 1 and represents real world decisions and operational regulations, practices, etc. The successful fruition of these near-term efforts will draw on ongoing FAA and NASA research and technical assistance as appropriate, as indicated by the vertical arrow (white) between the NASA & FAA Research and Enabling Technology arrow and the FAA 1-5 Year Commitments arrow. The top arrow (red), Industry Actions, is shown as also strongly interacting with the FAA Commitments arrow, since the overall outcome will also be shaped by specific industry actions, expressed needs and concerns, and technology developments. That pattern, though represented on the chart by the single vertical linking arrow at the left (red crosshatch), will be a continuing interaction throughout the entire process.
However, it is central to meeting each goal that the "current system" continue to change year-by-

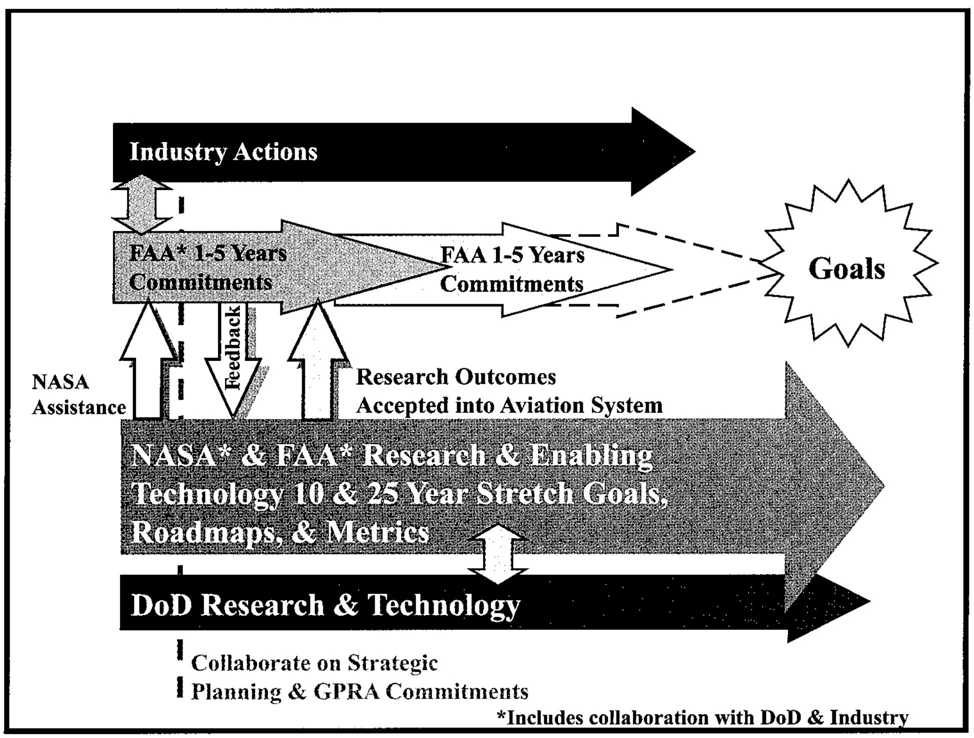


Figure 1. Overall Programmatic Approach to Achieving National Civil Aviation Safety, Security, Efficiency and Environmental Compatibility Goals

year, incorporating not only incremental improvements as described above, but also by adopting major advances made possible by NASA and FAA longer-term research and enabling technology. The crosshatched vertical blue arrow suggests the integration of these advances into the "current system." This technology will enable evolution of the system infrastructure and permit innovative architectural and operational concepts and practices. These advances are shaped by aggressive long-term "stretch" goals, associated technology roadmaps, and metrics with which to monitor progress. As indicated in the figure, this research will make full use of DoD R&D and technology results as they occur, based on existing and future coordination mechanisms, and will similarly be closely linked to industry input.

The continuing acceptance of research outcomes into the system, based on ongoing feedback from the operational "real world," will thus permit the current system to evolve steadily through a sequence of new stages, ultimately reaching as close as possible to the very demanding "stretch" national research goals. The vertical dashed orange line on the left of the figure represents the ongoing collaboration of all parties in strategic planning, coordination of programs, and incorporation of these activities into agency commitments associated with the Government Performance and Results Act. The Federal leadership required to accomplish the activity represented in this figure is the responsibility of the FAA/NASA Executive Committee.

R&D AND THE INNOVATION PROCESS

This plan envisions a period of R&D-enabled innovation in the aviation system that will yield dramatic improvements in highest priority areas. A key aspect of the effort will be strong coupling between coordinated multi-agency basic and focused R&D and the ongoing operational activities under the purview of the FAA. The process of technological innovation and improvement has traditionally been described as occurring in discrete steps of sequential compartmentalized activities: basic research, applied research, development, test and evaluation, and engineering refinement, all leading to final manufacture or deployment of a new product or process.

However, it is increasingly recognized that all elements of the innovation process actually tend to occur continually and simultaneously, rather than intermittently and sequentially. Further, there is typically strong coupling among them, as suggested by Figure 2. In addition to the flow of successive outputs from basic to applied research and on to development, findings at each stage also can a have strong impact on ongoing activities in the preceding elements. For example, the paths followed in basic and applied research are often determined by the results of development and even deployment efforts, as problems are identified and market opportunities are clarified. For topics as general as aviation safety, security, efficiency, and environmental compatibility the search for improvements will continue beyond the goals set in this plan, with no single stage of the process ever complete. The "final" phase of deployment and system operation, particularly in this age of rapid technical advance, is never truly reached. The FAA is keenly aware that requirements must at some point be frozen and a generation of technology delivered into operation. However, changed needs and the availability of new technologies continually redefine what is both possible and required and are the foundation for evolution into the next-generation system.

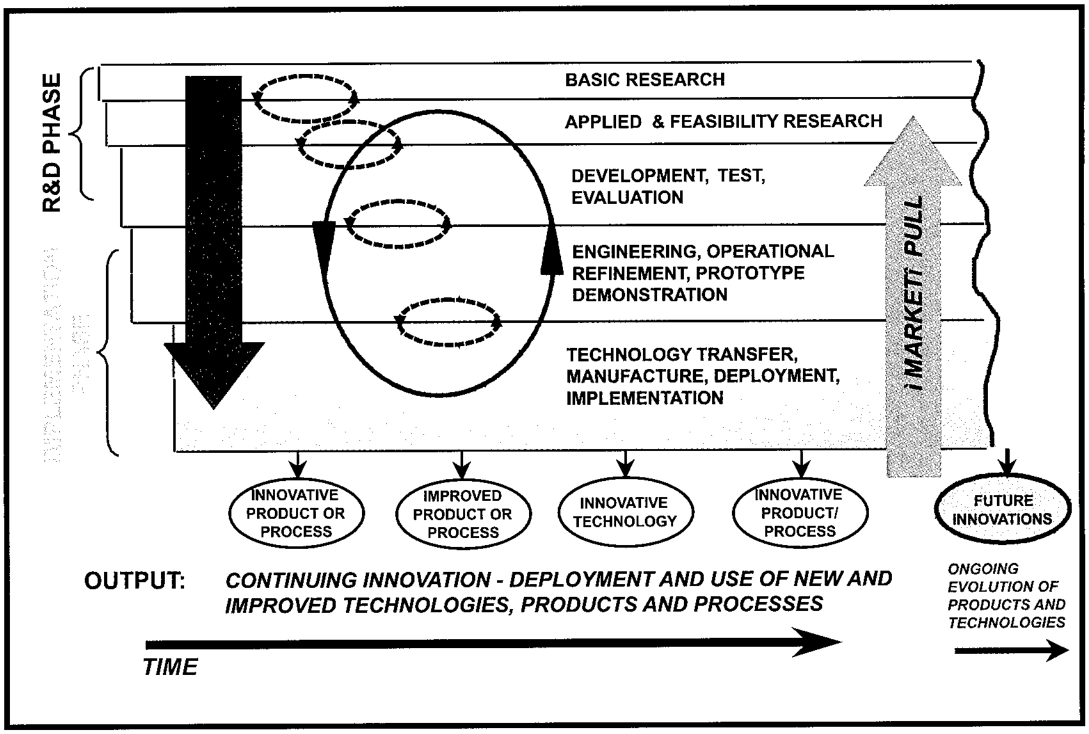


Figure 2. The Innovation Process

Major R&D results can often produce a "technology push" that stimulates individuals and companies to envision and create "products" (including services, such as transportation, as well as equipment) that utilize the new knowledge. On the other hand, changing circumstances can stimulate a "market pull" that motivates innovation to meet demands such as the desire of the American people–expressed through their government–for safe, secure, efficient, and environmentally compatible air travel. These two forces can be complementary and mutually reinforcing, as in the aeronautics case, since the availability of powerful advanced technologies gives credibility to the potential for actually achieving a substantially improved "product." Both forces are currently driving the aviation industry; it is the purpose of the plan described here to respond to the technology push associated with current rapid advance, as well as to the market demand for aviation system improvements.

COMPONENTS OF THE PLAN

This plan describes the relevant functions, technologies, mission responsibilities and key areas of technical expertise for each aviation goal. As a result, implementation of the plan takes somewhat different form for each goal. Specific plans for each of the four goals are described in detail in Sections 4 through 7.

Summary of the Safety Plan. The operators in the aviation system are responsible for the safety of their operations. FAA has the primary responsibility for ongoing safety guidance, regulation, certification, inspection, and monitoring of aviation safety, as well as assuring safety in managing traffic in the National Airspace System. FAA is also active in working with the aviation industry to encourage voluntary actions to enhance safety. Research and development in support of all of these areas is a key to establishing the necessary knowledge base and array of safety interventions.

The FAA "Safer Skies" program is identifying and addressing the highest priority accident causes such as runway incursions, controlled flight into terrain, uncontained engine failures, and weather, for both commercial and general aviation. Joint FAA/industry information sharing programs, including the Flight Operations Quality Assurance (FOQA) program and the Global Aviation Information Network (GAIN), seek to provide information on potential accident precursors to those who can take action to ameliorate them before they lead to accidents.

NASA's research and enabling technology development programs in many key areas of aeronautics and information technology are the primary component of the long-term aviation safety research effort. Through contributions in areas such as information analysis tools, system modeling and simulation, synthetic vision, and a systems approach to crashworthiness, they are seeking breakthroughs that will dramatically reduce the aviation accident rate. NASA, FAA and DoD are cooperatively moving forward on human factors, aging aircraft, fire safety and crashworthiness testing programs. Results of this research will be integrated into FAA operational activities and adopted by industry based on demonstration of their feasibility and potential value.

The detailed Safety Program Plan is provided as Section 4 of this report.

Summary of the Security Plan. It is coming to be appreciated that the nation's basic physical and information infrastructure is increasingly vulnerable to acts of malicious individuals, organized terrorism, and natural or accidental events that can disrupt or disable entire systems, such as the transportation system[4]. This plan focuses on the role that FAA, DoD and NASA R&D programs can play in addressing these concerns. Aviation security involves setting sound rules, regulations, and policies; hiring, training, deploying, and constantly testing a good screening work force; implementation of effective detection and screening technologies and procedures; and gathering and using effective intelligence on potential security threats.

Continuing research is critical to improving effectiveness in all of these areas, and in the achievement of necessary technological advances, particularly in detection systems (including human performance in these systems), aircraft hardening, and identification of future technological threats and countermeasures. The White House Commission recommended that the FAA continue to lead Federal efforts in aviation security R&D. NASA has little direct participation in this area, but its technical expertise will be made available as needed in addressing specific topics. DoD actively supports FAA efforts in bringing to bear military technology and experience in combating emerging threats. FAA also works with other agencies such as US Customs, US Postal Service, Federal Bureau of Investigation, Central Intelligence Agency and various defense agencies.

The detailed Security Program Plan is provided as Section 5 of this report.

Summary of the NAS Efficiency Plan. The FAA is in the midst of a major modernization of the NAS, which will affect virtually every facet of the system. During the next decade, navigation and positioning systems will be largely based on the Global Positioning System (GPS) and specialized augmentations, with advanced communication systems and avionics that provide controllers and aircraft with precise information as to the location of all equipped aircraft. Improved weather data collection, processing, and display will provide more timely, accurate and localized weather information to crews, controllers, airline dispatcher and other users. These and other subsystems, most benefiting from extensive use of automation aids, will increase the ability of users to fly more direct

[4] See, for example, the 1997 Reports of the President's Commission on Critical Infrastructure Protection and the White House Commission on Aviation Safety and Security.

routes, enable more efficient sequencing of arriving and departing aircraft, and permit increased air-to-air situational awareness for crews.

NASA research is developing the breakthrough technologies to support terminal area productivity in the near term and to provide technology for advanced operational concepts in the long-term. In addition they are developing technology to support the development of aircraft such as tiltrotors and personal transportation vehicles which can utilize all of the airspace more efficiently. Products of the NASA-FAA Safety Research Program, such as synthetic vision and data modeling, will also support the efficiency program. At the same time, greater efficiencies must be developed so as not to inadvertently lead to safety problems for less capable aircraft. This will be an ongoing challenge as the National Airspace System evolves in new directions.

The detailed Efficiency Program Plan is provided as Section 6 of this report.

Summary of the Environmental Compatibility Plan. The FAA has responsibility for establishing aircraft noise standards and certifying manufacturer compliance. In general, these standards and certification processes are recommended by ICAO, and then incorporated into US regulations. Public interest and scientific assessment determine the need for noise mitigation, while the application of noise reduction technology is based on cost benefit. Technical feasibility is determined in research and development programs sponsored by NASA and the aeronautical industry. The FAA and NASA have previously co-sponsored noise reduction research under the Advanced Subsonic Technology (AST) and High Speed Research (HSR) programs that developed, in partnership with US manufacturers, a number of technologies to a high state of readiness.

Standards for mitigating the effects of aircraft engine exhaust on local air quality have similarly been recommended by ICAO and incorporated by the Environmental Protection Agency (EPA) under the Clean Air Act, with compliance certified by FAA. Current regulatory standards control emissions of NOx, carbon monoxide (CO), unburned hydrocarbons, and smoke. Engine manufacturers, NASA, and DoD have developed technology for control of these pollutants. NASA is also developing advanced NOx reduction technology that could be applied in the next few years, particularly if justified by cost/benefit considerations.

As noted earlier, an emerging concern about aircraft engine emissions is their effect on climate and stratospheric ozone. With the advice of EPA and FAA, NASA has sponsored a national scientific assessment of the Atmospheric Effects of Aviation, which served as a significant resource for the IPCC Special Report on Aviation and the Global Atmosphere. DoD research facilities have been particularly helpful in determining the chemical and physical characteristics of engine exhaust. Moreover, the previous AST and HSR programs have a number of elements that promise reduction of CO_2, NOx and other exhaust constituents, if scientific assessment and economic reasonableness justify application.

During 1998, NASA conducted a series of workshops that sought to determine needs for further environmental compatibility research and technology. Participation was active and wide, including other Federal agencies, academia, manufacturers, air carriers, airports, and environmental interest organizations. Anticipated new elements are included in the NASA Aeronautics Program plan, and will provide a substantial basis for future reduction of aircraft noise and emissions

The detailed Environmental Compatibility Program Plan is provided as Section 7 of this report.

4. SAFETY PROGRAM PLAN

OVERVIEW

Commercial aviation has established an impressive safety record. That accomplishment has been based largely on advances in the technology, including cockpit automation, simulator training, and air traffic control. The steady long-term improvement has been particularly remarkable in an industry that must adapt continually to a high rate of technological change. However, while the accident rate for scheduled airlines over the last two decades has been very low, it has also been relatively constant. The absence of continuing accident rate reductions is a cause of serious concern. Even with today's very low accident rate, projected growth in air travel will inevitably produce a higher and continually increasing number of accidents as years pass unless the rate can be decreased. If left unchecked, there could be a fatal airline accident somewhere in the world each week in less than two decades. This provides a particularly strong motivation for aggressive efforts to lower the accident rate.

The importance of R&D in this endeavor was noted in a study by the FAA Research, Engineering, and Development Advisory Committee. After identifying several important new technologies, their report said "...the synergy and steady advance associated with all of the above technology areas are creating rapidly succeeding vistas of rich new capabilities. As they combine and specific new applications are developed, we have a critical family of technologies that imply major ... opportunities for safety enhancement..."[5]

At the same time, technological change can be a two-edged sword. In addition to research to exploit potential avenues to increasing safety, continuing R&D is also necessary to assure that new systems and procedures do not inadvertently introduce new hazards. As a 1996 NASA report noted, "The history of aviation is characterized by periods of major quantum jumps in safety brought about by advances in technology, followed by years of marginal improvements. Today we already can see the new technology that may drive the next quantum leap in safety. The challenge is to ensure that our leap in technology to solve past problems does not induce new problems that pose a greater threat. Our next leap must be a leap based on sound research."[6]

In response to the report of the White House Commission, which set the national safety goal, the FAA began a process to define the highest priority safety interventions. The FAA, through its Safer Skies initiative, began to work with NASA, DoD, and the aviation industry to collaborate on identifying the top safety areas through the analysis of past accident and incident data. The goal of this government-industry partnership is to use data to identify high-leverage interventions to address the key safety areas and remain focused on implementing these "critical few" intervention strategies. Many of these strategies will be supported by FAA research initiatives.

In a similar vein, NASA began to address the accident rate by using the Aviation Safety Investment Strategy Team (ASIST). During the spring of 1997, ASIST conducted four workshops involving sub-teams organized around five major accidents categories. These teams defined the current state of technology and future needs from the perspective of each major accident category in order to develop investment options to reduce the fatal accident rate.

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[5]Taken from *Challenge 2000: Impact of Future Technologies, March 6, 1996.*

[6]*Toward a Safer 21st Century: Aviation Safety Research Baseline and Future Challenges,* NASA Report NP 1997-12-231-HQ, December, 1996 (page 15).

The ASIST process involved over 100 organizations, including NASA, FAA, DoD, the Department of Commerce (DOC), the National Transportation Safety Board (NTSB), airlines, aircraft and equipment manufacturers, universities, trade and professional organizations, and other aviation system stakeholders.

One product of this undertaking was the definition of a structured set of key investment areas directed toward accident prevention, accident mitigation and aviation system monitoring and modeling. This formed the basis of NASA's current aviation safety R&D program. The NASA research was defined on the basis of a full knowledge of ongoing industry R&D and FAA's safety research, which is conducted in support of specific FAA mission responsibilities such as regulation and certification.

Within the past year, the FAA, NASA, DoD and industry safety efforts for commercial aviation safety have come together into a Commercial Aviation Safety Team (CAST). As CAST input to Safer Skies matures, the NASA research requirements will be refined based on intervention strategies identified through the CAST process. Flexibility is the key, and is a concept that all CAST members recognize as necessary to achieve the safety goal. A similar effort is underway for General Aviation through the establishment of a Joint Steering Committee.

The national safety effort that resulted from the White House Commission involves many aviation community participants, as shown in Figure 3. Each component of the FAA, the aviation industry, NASA, and DoD, must all work together to make the system safer. As suggested by Figure 3, safety is ultimately the responsibility of the operator.

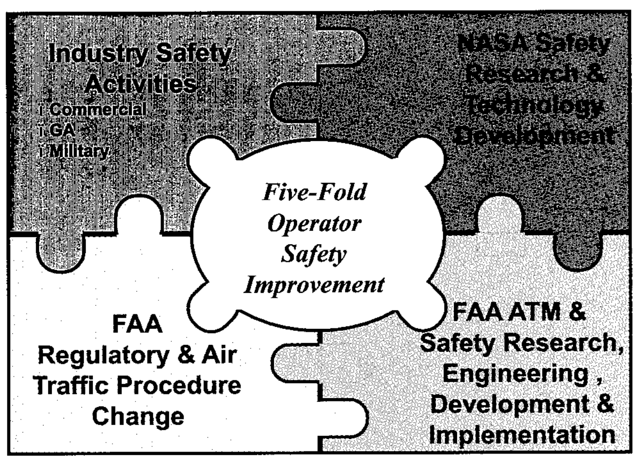

Figure 3. The Aviation Community Working Together

However, the Federal government has a major role to play in guiding and supporting industry safety efforts. The FAA has the Federal leadership role, focusing on regulation and certification, NAS infrastructure, and system surveillance, while NASA's role is development of enabling tools and technology, with implementation to occur through voluntary industry actions as well as incorporation into FAA operational programs and requirements. DoD is primarily concerned with safe operations and transfer of military technology to the civil sector. In addition to having a dominant role in implementation, the industry also plays a major role in identification of issues and as a source of feedback.

AVIATION SAFETY ROADMAP

The Aviation Safety Roadmap is the top level description of the Federal plan to achieve the national goal for safety. Figures 4 through 6 show a progressive elaboration of the roadmap for purposes of explanation, with Figure 6 presenting the greatest detail. As shown in Figure 4, the initiative has three primary thrusts–Accident Precursor Identification and Safety Risk Management, Accident Prevention, and Accident Mitigation. The roadmap depicts these three major thrusts, with two arrows for each thrust representing operational solutions and research efforts respectively. These arrows align with the description of the relationship of operational real-world commitments and R&D activities shown previously in Figure 1. The "Operational Solutions" arrows in the safety roadmap, Figure 4, correspond to the five-year moving FAA Commitment arrow in Figure 1, and the "Coordinated Research" arrows similarly represent the NASA and FAA Research and Enabling Technology element in Figure 1.

The fundamental elements of the aviation safety initiative are shown in Figure 4. This chart shows the three primary thrusts to achieve the goal, the intended outcomes, and the interaction of current operational solutions (pink arrows) with research by the three agencies (wide blue arrows). Figure 5 additionally includes a statement of the basic intent of each thrust, and shows how agency research programs will be shown in the final roadmap (NASA only in blue, FAA only in pink, and joint DoD/FAA/NASA in tan). Figure 6, the final representation, provides additional detail by showing examples of the specific topics associated with the operational solutions and the research programs. The research bars show the time frames for currently defined or anticipated research. In each case there is a 25-year technology outcome noted within the arrowhead with the anticipated real-world outcomes delineated at the right of the roadmap.

The intended real-world outcomes can only result from a combination of research outcomes implemented as future operational solutions. These outcomes cannot become commitments by the FAA until they are shown to be operationally feasible, but they do reflect the current desire for the future. A brief discussion of major elements follows; a more complete description of the safety program will be prepared as a supporting document to this plan. The strategic overview provided here is not intended to be a comprehensive description of specific programs or to represent the totality of relevant research being conducted by the agencies.

ACCIDENT PRECURSOR IDENTIFICATION AND SAFETY RISK MANAGEMENT

Accidents rarely have a single cause. Aviation systems and procedures have been developed to be redundant and failure-tolerant, which tends to mitigate single failures. In most cases, it is the combined effect of a sequence or confluence of circumstances, errors, and equipment failures that causes an accident. Thus, an important path to improved safety is the identification and monitoring of anomalous operating conditions and incidents that are precursors to serious incidents, accidents and fatalities. (This sequence of events is illustrated in Figure 7.) By this means, counter-measures can be developed and systemic changes introduced to eliminate lurking hazards prior to their culminating in a major accident. This safety program thrust particularly exploits the rapid increase in application of information technologies, which permit much closer monitoring and modeling of virtually all aspects of the aviation system.

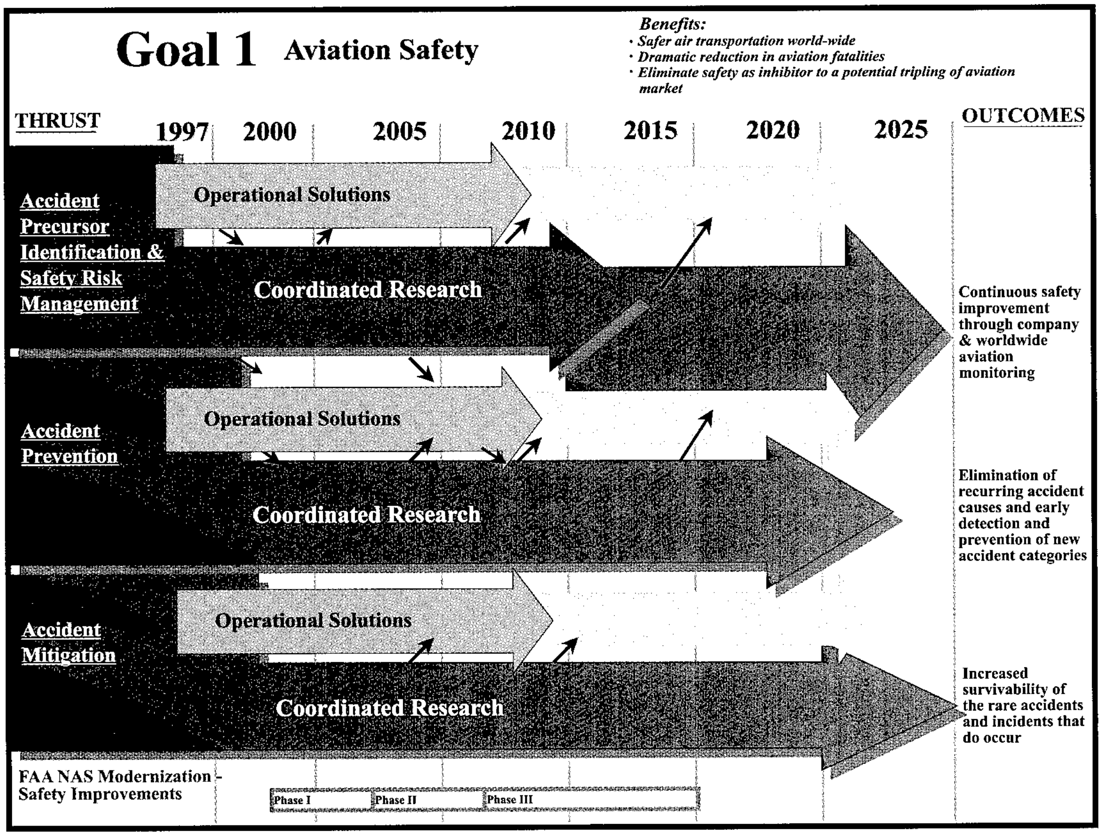

Figure 4. Safety Research Roadmap -- Overview

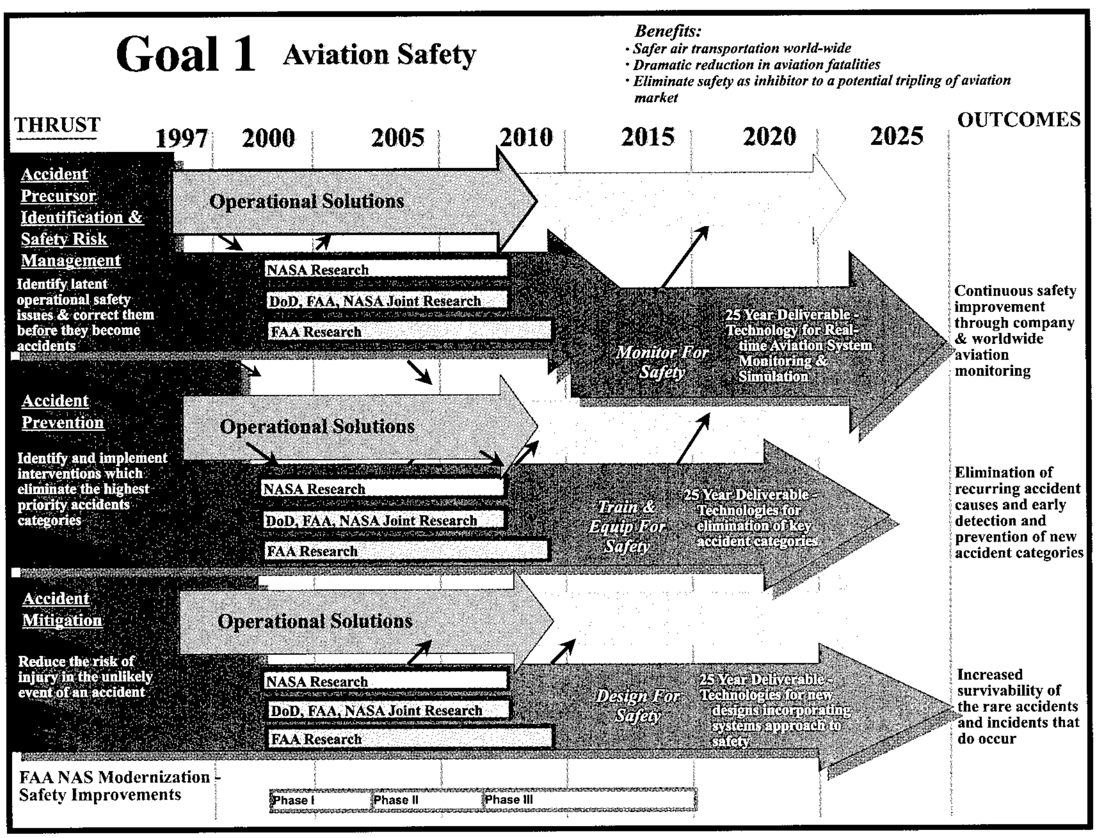

Figure 5. Aviation Safety Roadmap Including Research Overview

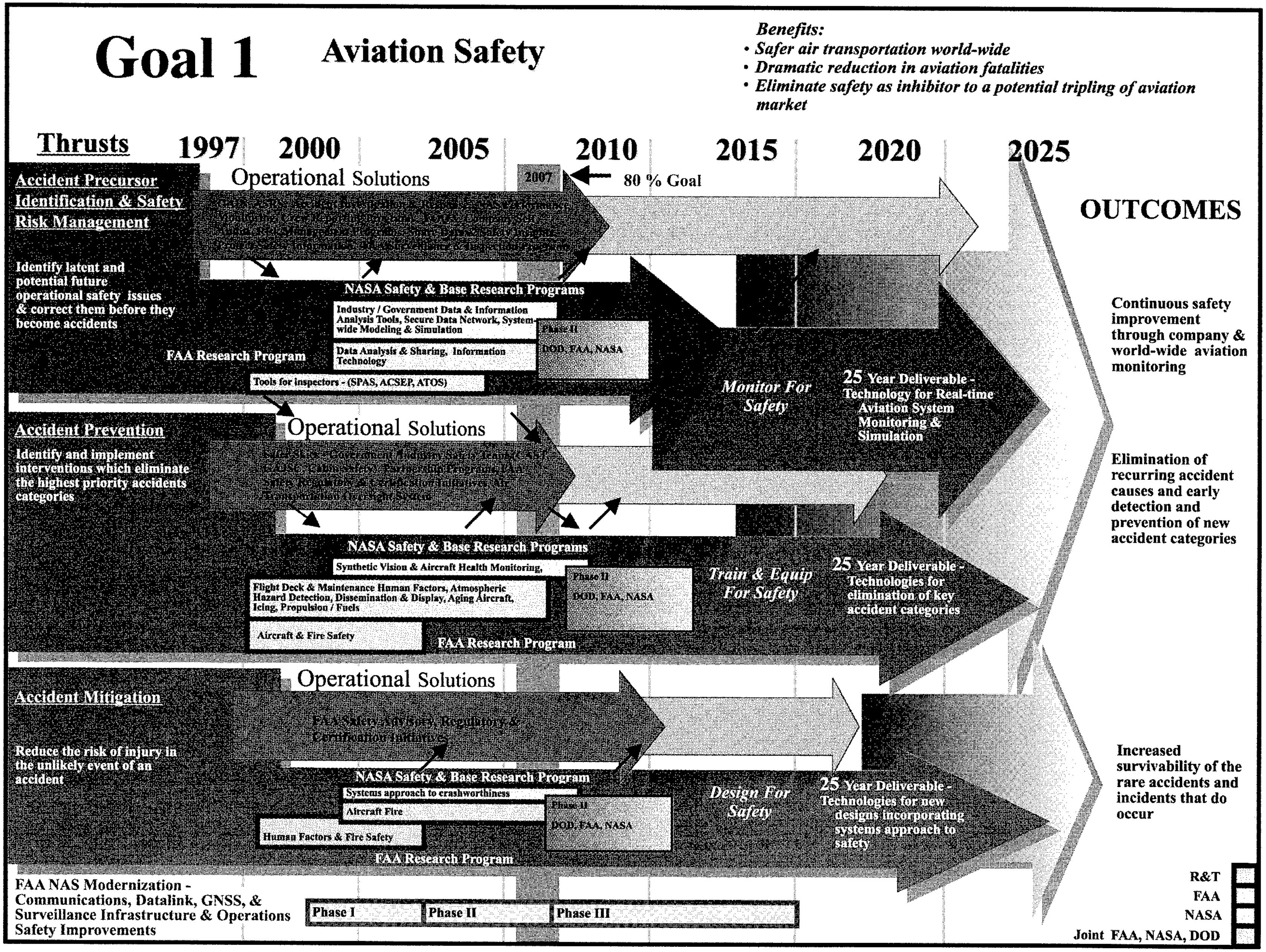

Figure 6. Detailed Aviation Safety Roadmap

More generally, safety risk management involves assuring that safety issues are identified, raised, and resolved by the appropriate aviation decision maker wherever they occur in system design, implementation and operations. In recognition of its importance, the FAA has established a formalized and disciplined process to assure that safety risk management issues are considered in FAA decisions. Policy and guidance are now being developed for building safety risk management into the comprehensive acquisition management process, as well as the processes for other major decisions in the agency. The FAA also has established an agency-wide Safety Risk Management Committee, supported by the staff of the Office of System Safety, to coordinate, focus, and foster safety risk management activities throughout the FAA in all phases of operation and across all organizations.

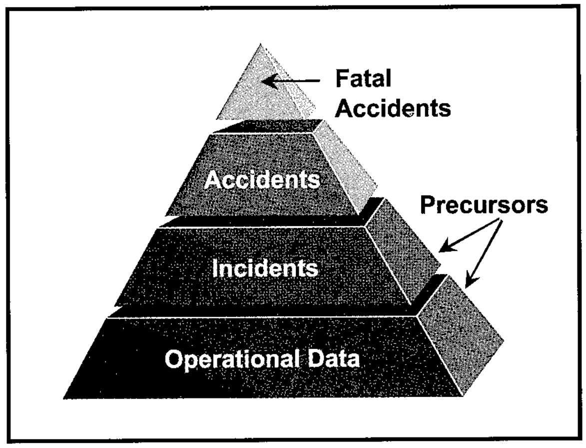

Figure 7. Role of Accident Precursors.

The Department of Defense has mishap prevention programs that include investigation and reporting, accessibility, and sharing of data and concerns. All Services have safety risk management programs, with harmonization and standardization accomplished through the "Joint Service Safety Chiefs" architecture.

Current Operational Solutions

Understanding accident causes and precursors is central to mounting a successful offensive against accidents. However, getting the information and data required for the better understanding of causal factors is difficult. First, there are, statistically speaking, relatively few accidents to investigate. Second, the effectiveness of the current population of accident flight recorders is limited (in terms of the parameter set, the data rate, and reliability, survivability, and operability). To supplement the causal factor data from accident investigations, the Aviation Safety Reporting System (ASRS) was established in 1975 under a Memorandum of Agreement between the Federal Aviation Administration and the National Aeronautics and Space Administration. FAA provides most of the program funding; NASA administers the program and sets policies in consultation with the FAA and the aviation community. The ASRS collects, analyzes, and responds to voluntarily submitted aviation safety incident reports in order to lessen the likelihood of aviation accidents. ASRS data are used to:

- Identify deficiencies and discrepancies in the national aviation system so that the appropriate authorities can take remedial action.
- Support policy formulation and planning for the national aviation system, and improvements to the system.
- Strengthen the foundation of aviation human factors safety research. Human factors are particularly important since two-thirds of all aviation accidents and incidents are attributed to human performance errors.

This information is an important source of understanding of airspace system trends and hazardous situations and as an input to a wide range of analyses. Pilots, air traffic controllers, flight attendants, mechanics, ground personnel, and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which they judge that aviation safety was compromised. All submissions are voluntary. Reports sent to the ASRS are held in strict confidence. More than 300,000 reports have been submitted to date and no reporter's identity has ever been breached by the ASRS. ASRS removes identifiers from reports before entering them into the incident database.

In 1996, the FAA began facilitating the development of a worldwide privately owned and operated information infrastructure, the Global Analysis and Information Network. GAIN is designed to help the aviation industry prevent accidents by making safety information available to aviation professionals worldwide who can use it to improve safety. By learning more about potential problems, the GAIN participants can use the information in their own safety risk management programs to address problems proactively.

In addition to these initiatives, the FAA inspection program is constantly monitoring the safety of certificated operations, maintenance, production, and design. This monitoring is done to anticipate where the safety margin may become compromised with the passage of time or due to a changing environment. The FAA is also continuously improving the system of certificate monitoring. For example, an important source of safety-relevant operational data is airline programs based on retrieval and use of data from flight data recorders, which can reveal anomalous operations for an individual flight or a series of flights. This concept is called Flight Operational Quality Assurance (FOQA). Basic FOQA programs have long been applied by some European airlines and are increasingly being used voluntarily by US carriers. It is expected that DoD commercial equivalent aircraft safety data will be added to the information pool as standards and guidelines for information sharing and protection are formalized.

These data systems, coupled with air traffic control tapes, digital flight data from more-sophisticated flight data recorders, and the NTSB accident data base are shaping a powerful new information architecture to drive both operational programs and R&D. The value of these information resources is critically dependent on the degree to which they are readily available to the participating agencies, the industry, and the entire international aviation community. Accordingly, this element of the safety program includes an explicit component to assure effective data sharing and protection of self-disclosed safety information.

FAA Research

FAA's Aviation Safety and Risk Analysis (ASRA) program builds on the various data systems to support development and enhancement of aviation safety performance measures embedded in FAA analytical systems. Two such programs are the Safety Performance Analysis System (SPAS) and risk-based analytical tools such as the Aircraft Certification Systems Evaluation Program (ACSEP). ASRA focuses on development and enhancement of safety-critical performance measures, advanced analysis and decision support systems, improved monitoring and oversight, and data standards. The improved safety measures will encompass particulars about aircraft design, aircraft maintenance, air carriers, air agencies and air personnel. SPAS, ACSEP and related systems are making it possible for safety inspectors to systematically assess potential risks and take proactive steps to reduce the rate of operational-related accidents or incidents.

NASA Research

Aviation System Data Monitoring and Modeling (ASMM). ASMM addresses the need for a comprehensive, accurate, and insightful method for monitoring continuously the operational performance and health of the national aviation system. Its purpose is to develop the tools and methodologies to obtain a perspective of what is happening today and of the impact of any changes that are introduced into the system. A goal of ASMM is to provide decision-makers of the air carriers, air traffic management, and other air services providers with regular, accurate, and insightful measures of the health, performance, and safety of the national aviation system. ASMM outputs will also provide technology and procedure developers with reliable predictions of the system-wide effects of the changes they are introducing into the aviation system. This capability will enable definition of operational and safety trends and also identification of developing conditions that could compromise the safety of the NAS. Having this capability will allow an industry-wide, and eventually worldwide, proactive approach. The work of ASMM seeks to address the problem of monitoring the aviation system by:

- Developing the tools and methodologies for a dual strategy of complementary capabilities,
- Developing the infrastructure capabilities for sharing information, and
- Utilizing the collected textual and quantitative data to support the development and validation of system-wide models and simulations.

Data Sharing Technology research will provide advanced middleware technologies to link, integrate and distribute aviation data. The target domains that would be supported by the middleware infrastructure would include: System-wide monitoring of the National and Global Air Spaces, Collaborative Decision Making for Free Flight Operations, and Integrated Design Environments.

Methods for Analysis of Systems Stability and Safety (MASSS). Advances in databases and data analysis provide the foundation for development of improved predictive models and simulations that can assist in evaluating alternative solutions and countermeasures, assessing hazards in new situations, and setting of program priorities. The NASA MASSS program, which is intended to model the entire aviation system based on current technology and operations, will enable projections of the health of a future integrated aviation system based on new technologies.

Joint and Coordinated Research

FAA and NASA are working together to develop the Aviation Performance Measuring System (APMS), which includes a comprehensive set of tools which will assist all parts of the aviation community in assessing the safety implications contained, but currently often hidden, in the vast amounts of data collected relating to daily fleet operations. Under APMS, joint NASA-FAA-industry research based on airline FOQA programs is showing great promise as a means to further understand normal operations and thereby identify areas where safety improvements are required.

ACCIDENT PREVENTION

The FAA is responsible for establishing rules, regulations, advisory material, specifications and recommended practices in areas bearing on aviation safety, and for conducting R&D programs in support of these responsibilities. NASA has the role of identifying, developing, and accelerating implementation of integrated applications of on-board, system-wide and weather accident prevention technologies to reduce accident rates in the highest accident categories. In many areas, these roles are complementary and are pursued as joint or closely coordinated research efforts. DoD is responsible for the safety of the military aviation system and provides research results to help out with the civil aviation safety improvements.

Current Operational Solutions

Safer Skies. In 1998, as the result of a comprehensive review of the causes of aviation accidents, the FAA adopted a focused safety agenda to meet the goal of a five-fold reduction in the fatal accident rate. The FAA is concentrating its resources on the most prevalent causes of aircraft accidents and using special teams of technical experts to zero in on the leading causes of aviation disasters and to recommend safety actions. In partnership with DoD, NASA and industry, Safer Skies is analyzing US and global data to find the root causes of accidents and determine the best actions to break the causal chain. At the foundation of the Safer Skies agenda is a partnership between government and industry. This agenda relies on a data-driven approach to determine top focus areas and to identify the key intervention strategies that will make a difference in aviation safety.

The Safer Skies agenda spotlights the leading causes of accidents or incidents in three areas–commercial aviation, general aviation, and cabin safety. Safety research and technology are relevant primarily to the first two. Top accident categories common to both commercial and general aviation are controlled flight into terrain, runway incursions, weather, and loss of control.

Ongoing safety programs also include regulatory and certification initiatives and the Air Transportation Oversight System (ATOS), an improved surveillance process that takes a systems approach. ATOS is targeted to address identified risks, and is based on a dynamic comprehensive surveillance plan for each air carrier which can re-target surveillance as needed.

FAA Research

Propulsion and Fuel Systems. The FAA is working closely with industry in a program to enhance the airworthiness, reliability and performance of civil turbine and piston engines, and of their propellers, fuels, and fuel management systems. This research currently emphasizes design tools for engine rotors that will ultimately be reflected in a design certification standard and will improve turbine rotor structural integrity and reduce the risk of failure. This program area also includes testing related to low-lead aviation fuel formulations to assure safe engine operation and support eventual certification as a replacement fuel.

Aircraft Catastrophic Failure Prevention Research. This area comprises R&D directed toward prevention of aircraft catastrophic failure. It includes assessment of risk and identifying potential causes–defects, failures, and malfunctions in aircraft, aircraft components, and aircraft systems.

The FAA program is aimed principally at known problem areas identified on the basis of historical accident and incident data, such as turbine engine uncontainment events and degradation of the primary flight control system.

Fire Research and Safety. FAA accident prevention R&D also addresses elimination of ignition sources and containing in-flight fires and their consequences. This objective is pursued through research on interior materials that meet tighter fire resistance criteria, improvements in fire detection and suppression, aircraft designs that delay the spread of fire, and test methods and acceptance criteria of relevant materials. As part of this program, the FAA operates the most extensive test facilities in the world for aircraft fires.

Airport Safety Technology. The FAA's airport safety research includes development of new and emerging technologies to support safe and efficient aircraft operations on runway surfaces and for lighting, signing, and marking materials for improved visual control systems.

NASA Research

Synthetic Vision. Reduced visibility conditions can contribute to several of the most important accident causes, including controlled flight into terrain, loss of control, and runway incursions. NASA's Synthetic Vision program has two components directed toward improving a pilot's situation and spatial awareness during low visibility conditions. Synthetic vision systems provide under all conditions, in an intuitive manner, the visual information and cues that a flight crew would have in daylight on a clear day. The visual information and cues are depicted based on precise positioning information within onboard terrain, obstacle and airport databases, and could include weather and traffic information from surveillance sources. This program also includes the development of enhanced head-up displays, through which a "virtual" 3-D world will be visible. The R&D will address systems suitable for light general aviation aircraft as well as for commercial transports.

Aircraft Health Management Technologies. Safety can be significantly enhanced by systems that (1) contribute to the prevention and reduction of malfunctions and failures in aircraft systems and components; (2) enhance the ability of the flight crew to respond correctly when system or component failures occur; and (3) reduce the pilot workload associated with safe flight under system and component failures to prevent related occurrences of controlled flight into terrain. Data from onboard sensors are used as inputs to the controls system, for display to the crew, and to reconfigure and manage redundant components. Solutions of this type will be developed for the propulsion system, the airframe, and various flight systems.

Loss of Control (Upset) Management Technologies. This program is developing advanced guidance and control methods and associated pilot cueing strategies and display formats for the recovery from loss of vehicle control in normal to extreme flight conditions under failure and non-failure states. Systems appropriate to both general aviation aircraft and commercial transports will be developed. NASA's Propulsion Controlled Aircraft program is exploring computer-based systems that would allow the pilot to control the aircraft using the throttles in the case of total loss of control systems; this has been flight tested in the F-15 and in an MD-11 civil transport.

Engine Failure Containment. NASA's engine failure containment project has the objective of reducing engine component failure to an absolute minimum and containing all possible fragments if a failure should occur.

AGATE. Important safety initiatives are included in the agenda of the 70-member Advanced General Aviation Transport Experiments (AGATE) Consortium. This is a cost-sharing industry-university-government partnership initiated by NASA to create the technological basis for revitalization of the US general aviation industry by developing affordable new technology as well as the industry standards and certification methods for next-generation single pilot-light airplanes. A revolutionary means for FAA certification of composites, developed by the AGATE consortium, will reduce the cost of materials certification for crashworthy airframes by 75% and cut the time required by 90%.

General Aviation Propulsion. While not primarily focused on safety issues, NASA's General Aviation Propulsion (GAP) program will play a significant role in increasing safety. The new GAP engines will increase propulsion system reliability, reduce in-flight engine shutdowns, and provide automated engine health monitoring and a single-lever power control, allowing the pilot to focus full attention on flying the airplane and situational awareness.

Joint and Coordinated Research

Aging Aircraft. The FAA, NASA and DoD, as well as the industry, academia, and foreign governments, are working closely together on research to ensure the continued airworthiness of aircraft structures and components in the civil fleet. Interagency agreements on this topic also include the National Institute of Standards and Technology and the Department of Energy. Specific topics being addressed include methodologies to predict the onset of widespread fatigue damage, nondestructive inspection techniques, flight and landing load airworthiness standards, airframe maintenance and repair requirements, crack-growth-based predictive methodologies, and non-structural aging systems.

Flight Safety and Atmospheric Hazards. The FAA-sponsored program in this area has three elements. (1) the FAA, together with NASA, is pursuing development of technologies, information, procedures and practices to minimize adverse consequences of aircraft icing, including de-icing and anti-icing prior to takeoff. Recent NASA R&D in this area has included development of improved, environmentally benign anti-icing fluids, studies of icing effects on flight characteristics, and an innovative ice removal system for general aviation. (2) The FAA is conducting tests and analyses to assist in protecting aircraft electrical and electronic systems against the effects of lightning and high intensity radiated electromagnetic fields. These effects may be caused by airborne, ship-borne or ground emitters, and by portable electronic devices brought on the aircraft by passengers. (3) The safety issues associated with digital flight control and avionics systems are being examined by the FAA, including the special challenges associated with software certification. NASA and the FAA have an explicit interagency agreement covering this area as well as electromagnetic hazard research.

Related NASA programs include use of laser technology to detect atmospheric turbulence, an invisible hazardous and leading cause of in-flight injuries. Tests to date suggest the potential of up to a minute of advance warning. Other NASA research includes modeling of trailing vortices from aircraft wingtips to support better aircraft designs and reduce possible hazards and required separation of aircraft during takeoff and landing. For the longer-term, NASA is considering space-based detection and measurement systems.

NASA is also exploring a variety of topics relating to crew performance, including design of human-centered technologies leading to a truly human-centered flight deck. In addition to "synthetic vision" imaging systems to see through fog and darkness, this research could include systems to monitor stress and fatigue, and enhanced computerized flight management systems sensitive to possible human errors.

Flight Deck Human Factors. The joint FAA, NASA and DoD human factors program is based on the *National Plan for Civil Aviation Human Factors: An Initiative for Research and Application.*[7] Specific areas of coordinated FAA-NASA research include cockpit automation, fatigue, crew resource management, error management, team decision making, air-ground communication, and aviation performance measurement system. DoD participation in joint efforts focuses on fatigue, team performance, and decision making. Additionally, the FAA and NASA are represented on the DoD Human Factors Engineering Technical Advisory Group, a forum for the coordination of research across a variety of technical areas.

NASA's human-automation integration project is developing validated tools and prototyping testbeds for the design and analysis of innovative human-automation systems in air, ground, and integrated airspace operations. The goals are to improve communication and collaboration among system designers and human factors experts; to identify and eliminate or mitigate risk factors during the design phase for automation-related operator error; and to improve operator understanding of automated systems.

DoD research includes programs that, though directed at specific military situations and functions, have clear relevance to many human factors topics, such as crew performance, interaction with automated systems, reduction of fatigue, and communication and display of information for situational awareness.

ACCIDENT MITIGATION

Mitigation of accident consequences in the following areas is central to aviation safety:

- Aircraft crashworthiness
- Occupant protection
- Fire safety
- Evacuation
- Airport emergency services

[7] A national agenda developed by FAA, NASA and DoD to address human factors in aviation; March, 1995.

Each of these areas involves continued research to better understand each factor and develop improved regulations, equipment and procedures, to identify issues associated with changing circumstances, and to exploit technology opportunities for advances. In this way the operational programs work synergistically to achieve mitigation goals and the desired long-term outcomes.

Current Operational Solutions

The FAA has a wide range of standards and regulations that address fire safety, crashworthiness, and aircraft evacuation. In addition, one of the three components of the Safer Skies program is cabin safety, which primarily seeks to assure in-flight safety through precautions such as greater seatbelt use, stowage of carry-on baggage, and use of child restraint systems. Existing military standards are also potentially useful as a point of departure for improvements related to crashworthiness, understanding of fire propagation, and the development of non-ozone-depleting alternative fluids, processes and techniques for fire and explosion suppression. DoD disaster response procedures and capabilities are also relevant, particularly when crash survivability is recognized as being a function of response, as well as of aircraft design.

FAA Research

Aeromedical Research. The FAA's aeromedical research includes assessment of types of injury and death patterns in civilian flight environments, recommendation and development of protective equipment or procedures, and provision of guidance to FAA regulatory and medical certification staff. It includes research to identify human physiological and bioengineering failure modes in both uneventful flight and during civil aircraft incidents/accidents, while simultaneously assessing counteracting measures.

Airport Systems. The airport safety technology program includes consideration of new materials, methods, and equipment to improve the capability and cost-effectiveness of airport rescue and firefighting services.

Joint and Coordinated Programs

Structural Crashworthiness. Research on the minimization of the consequences of an accident fall largely in two categories: crashworthiness and fire safety. The FAA's Advanced Materials and Structural Safety research program has several components. In the materials area, it addresses standardized analysis and test methods for world-wide harmonization, better understanding of the effects of damage and joint configurations on the remaining strength and life of composite aircraft structure, and criteria for acceptable risk in the design of composite aircraft components. The program also includes consideration of improved crash characteristics for aircraft structures, cabin interiors, auxiliary fuel tank systems, and occupant seat/restraint systems.

This work is closely coordinated with related NASA programs, with the FAA focusing on safety and certification topics while NASA has the lead on analysis and design issues, including validation of dynamic analysis software. The FAA is also supporting NASA efforts to develop composite materials for general aviation under the AGATE program, and works on similar topics with the US Army. In the structural area, the FAA, NASA and DoD have cooperative programs relating to crash testing and modeling.

Fire Safety. The FAA fire safety program includes research to mitigate accident consequences by eliminating ignition sources of burning cabin materials as a factor in postcrash survivability, reducing impediments to passenger escape (heat, smoke, toxic gases), new techniques for fire control, and low-flammability fuels. NASA is developing post-crash fire mitigation techniques.

Post-Crash Response. Mitigation of consequences may also result from more effective post-crash communications, response and emergency equipment capabilities. Opportunities for expanded research and development in these areas will be explored with the DoD, the Federal Emergency Management Agency, and civil emergency preparedness organizations to ensure their appropriate integration into the broader framework of national aviation safety mitigation efforts.

5. SECURITY PROGRAM PLAN

OVERVIEW

In 1990 the President's Commission on Aviation Security and Terrorism, formed in response to the bombing of Pan American Flight 103 over Lockerbie, Scotland, recommended that the FAA pursue an intensified program of research, development and deployment to counteract the terrorist threat to the civil aviation system. This mandate was embodied in the Aviation Security Improvement Act of 1990. In 1997, the White House Commission on Aviation Safety and Security noted that "The terrorist threat is changing and growing. Therefore, it is important to improve security not just against familiar threats, such as explosives in checked baggage, but also means of assessing and countering emerging threats."

The FAA Aviation Security Research and Development Service maintains laboratories and research programs exploring advanced technologies applicable to (1) enhanced scanning of luggage; (2) improved devices for walk-through and hand-held equipment to screen passengers for weapons; (3) better image processing and decision-making by screening personnel, including fully automated devices; (4) explosive trace detection technologies for next generation systems; and (5) means of hardening aircraft against explosions. The FAA has long been a world leader in research addressing weapons and explosives detection.

A rapidly-emerging area of concern is information security, which can range from protecting mission-critical computers against intrusion and disruption to countering the possibility of "cyber-warfare"–malicious attacks intended to disrupt or damage the functioning of public infrastructure, or to cause large numbers of casualties. The increasing use and criticality of computer-based communications and information technologies has created a whole new set of threats and challenges with which the aviation system must contend. While this concern can be addressed largely through the application of technologies, tools, and practices being developed by other industries, it is very important that it be well understood. The basic elements of computer security cut across all applications, but their manifestations in aviation must be carefully assessed and countered in the design and upgrading of NAS systems and through a variety of operational programs.

The DoD has great expertise in several areas central to aviation security, and is cooperating closely with the FAA wherever its capabilities are relevant, such as threat assessment, information security, damage characteristics for various explosives situations, and aircraft survivability. The DoD also has basic responsibility for the safety, security and integrity of the GPS system, which will be critical to the nation's civil aviation navigation system in the 21st century.

FAA R&D activities in this area all relate to specific operational programs, including assessment of domestic and foreign air carriers and airports, explosives security, and movement of hazardous goods. A systems approach is being taken in which the elements of security programs are integrated and coordinated among the many participants–domestic and international, public and private. Figures 8 through 10 show the Aviation Security roadmap, which, as for the Safety roadmap, reflects the overall structure previously shown in Figure 1. A complete description of the security program will be prepared as a supporting document to this plan.

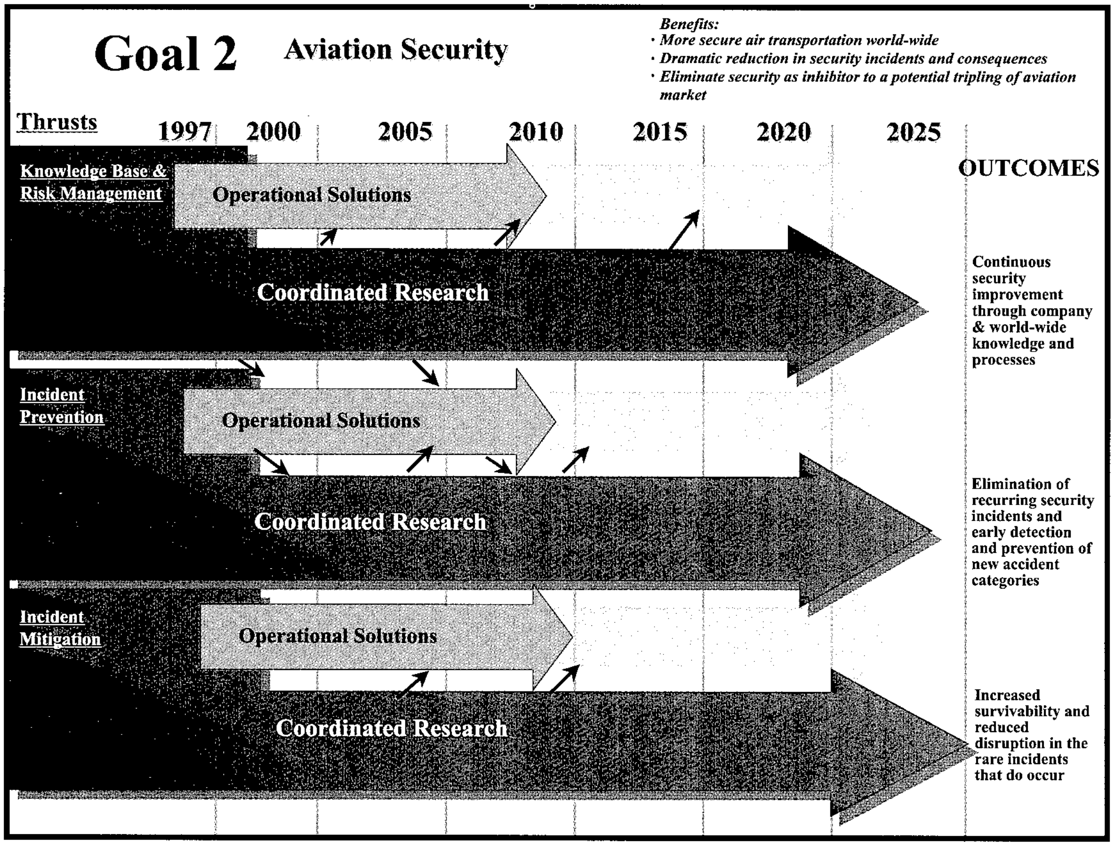

Figure 8. Aviation Security Roadmap -- Overview

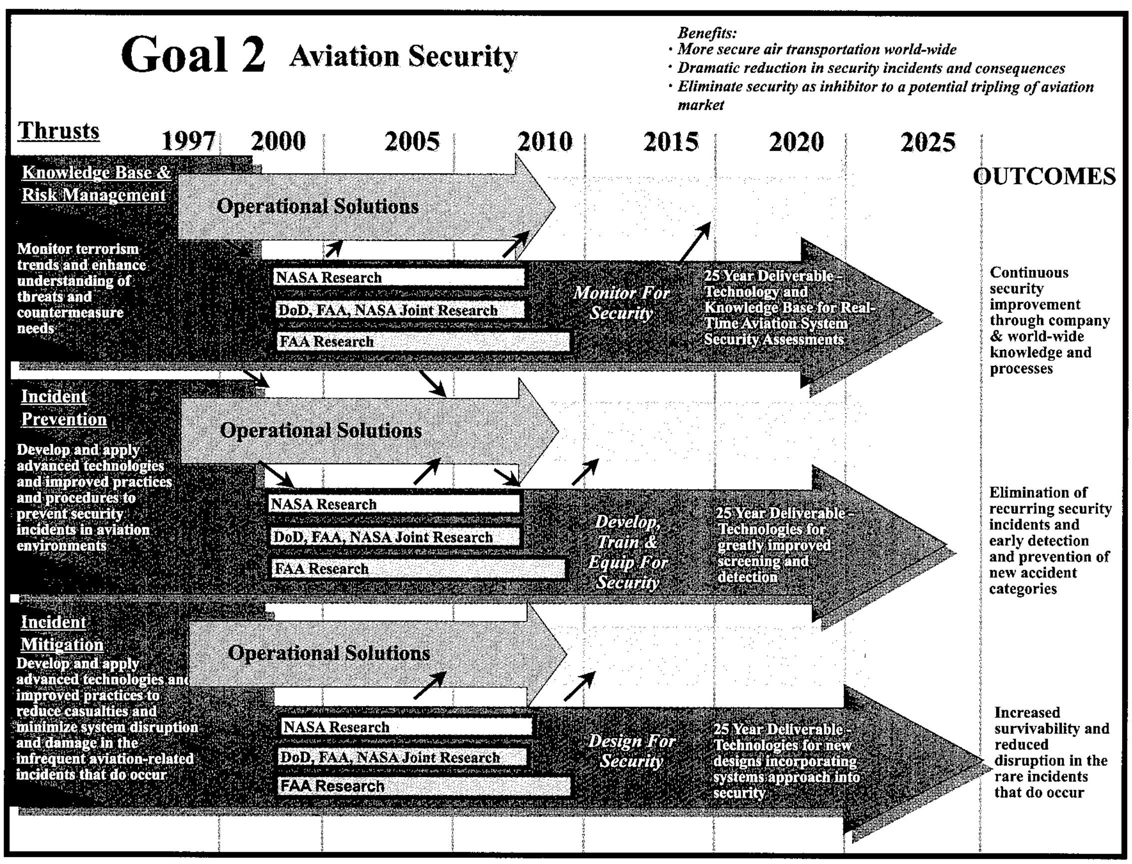

Figure 9. Aviation Security Roadmap Including Research Overview

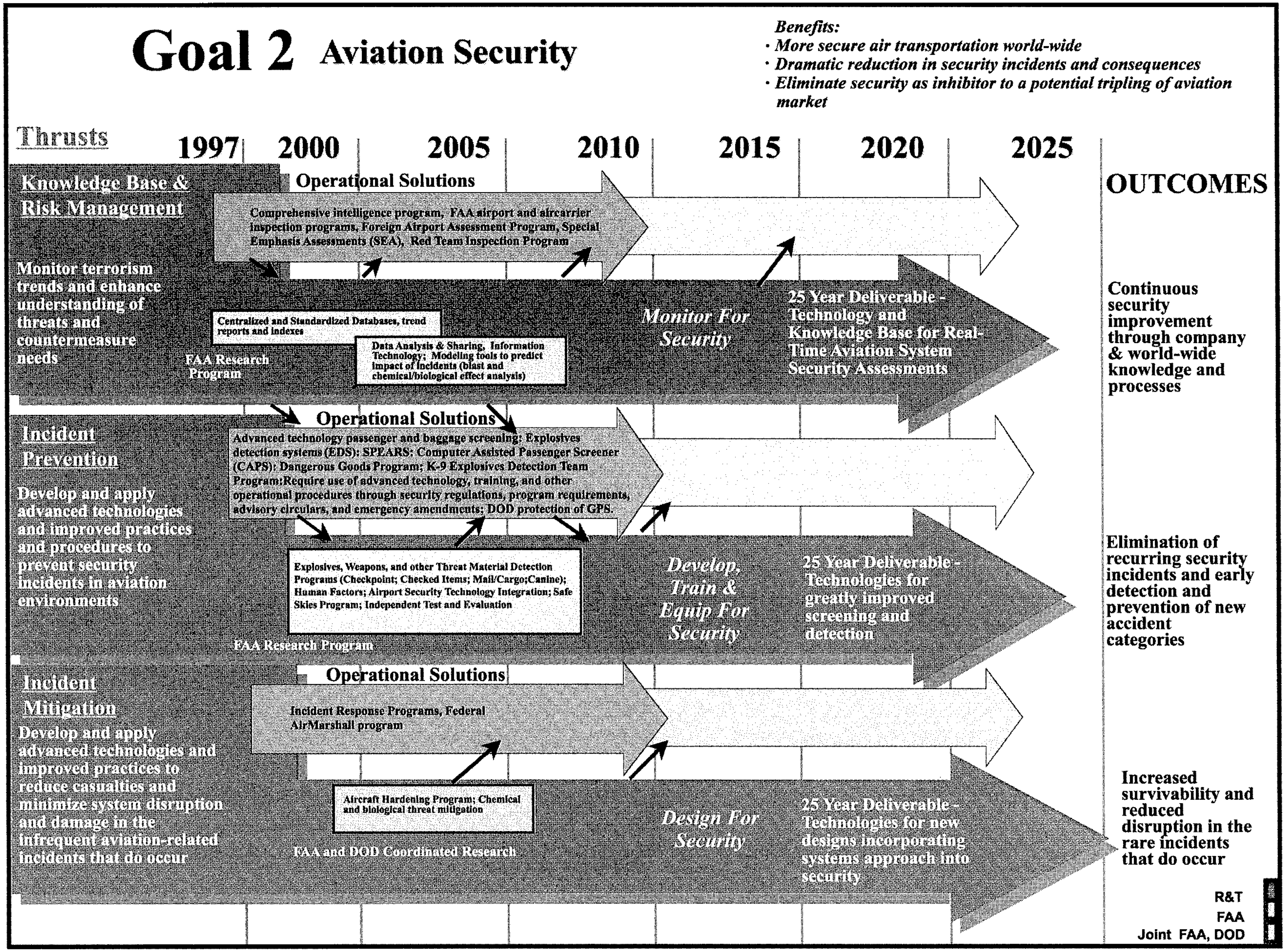

Figure 10. Detailed Aviation Security Roadmap

AVIATION SECURITY ROADMAP

The basic security roadmap in Figure 8, like the overview safety roadmap (Figure 4), shows three broad thrusts, associated outcomes, and a linkage between operational solutions and research. Figures 9 and 10 show increasing levels of detail concerning the role of research and program content.

The Federal Aviation Administration, as the designated lead Federal agency responsible for the safety and security of civil aviation, is charged with promoting safe travel by countering the terrorist threat with technologies and procedures that will prevent, deter, or mitigate any attempts to sabotage civil aviation. Terrorists have demonstrated expertise in the acquisition, development, and deployment of both rudimentary and sophisticated improvised explosive devices. The Civil Aviation Security Research, Engineering, and Development Program addresses these threats as well as non-conventional threats. The aviation security roadmap closely parallels the safety roadmap in having major elements focused on information and risk management, prevention and mitigation. It shows the operational solutions now in place and evolving, with the FAA and joint R&D programs being conducted to enable the operational solutions to advance sufficiently to achieve the desired outcomes. While the research is being performed primarily by the FAA, joint or coordinated efforts the with DoD are also important, and the overall effort draws on NASA technical expertise as appropriate.

KNOWLEDGE BASE AND RISK MANAGEMENT

The great range and varied nature of potential security threats make data and information the first line of defense. Only with data of sufficient breadth, depth, variety and timeliness can the aviation community act effectively and efficiently to prevent or mitigate incidents. Given the wide range of sources and types of data relevant to security, establishment of a comprehensive and accessible information data system continues to be a major undertaking. Its creation and expansion will involve development of well-defined data needs, standard data-exchange protocols, and centralized data bases based on consensus standards agreed to by the many and varied information sources and users.

In addition, ongoing detailed analysis programs are needed to assure that trends and emerging threats are identified as early as possible, in a commonly understood structure, quantified by meaningful indexes that clearly convey findings and their implications to all users. Information must readily be shared with all who need it, while maintaining the controls and secrecy required for highly sensitive data. The large number of data sources will necessitate special efforts to make this information infrastructure truly real-time in its operation and availability so that it can be monitored and used in real-time by command and control centers.

Current Operational Solutions

The intelligence analysis of the threat to civil aviation is the basis for determining the application of aviation security measures. The FAA's Office of Civil Aviation Security Intelligence has four central roles:

- Collection, evaluation, analysis, and dissemination of aviation security information and intelligence
- Coordination of domestic and international aviation security intelligence activities with other Government agencies

- Assessment of the threat of criminal actions against domestic and international aviation and FAA facilities
- Performances of analyses leading to development of criminal trends impacting civil aviation security systems.

The basic regulations for aviation security apply to 165 US air carriers, 164 foreign air carriers, and several thousand cargo forwarders at 459 US airports and 244 foreign airports. FAA aviation security special agents conduct US air carrier inspections both overseas and at home, as well as foreign air carrier inspections at US airports. The FAA performs US airport inspections, facility security inspections, indirect air carrier inspections, and foreign airport assessments overseas. The FAA also participates in vulnerability assessments and developing associated action plans.

The Red Team Testing Special Assessment Program involves unannounced monitoring and testing of the capability of US airports and air carriers to comply with aviation security requirements. During the assessments, special techniques are used to replicate current terrorist or criminal *modus operandi* that pose a threat to civil aviation. The purpose of the program is to give the FAA the ability to assure that its mandated security requirements are being applied by US air carriers and airports when FAA inspectors are not on site conducting a formal and scheduled air carrier station inspection.

FAA Research

The FAA is conducting R&D necessary to respond to operational requirements directly linked to current and anticipated security threats. The FAA security research activities include collaboration with other US government agencies and other governments concerned with similar threats in order to address threats of similar interest in a cost effective and efficient manner. An important element of the program is the identification of technologies that could circumvent or reduce the effectiveness of current detection systems, and of engineering changes, where feasible, to mitigate any potential weaknesses.

In coordination with private industry and the airports, the FAA is developing integrated command and control centers combining airport operational security elements with other airport operation functions. The control center integrates security output and performance information to a central node for analysis and response.

Joint and Coordinated Research

In coordination with the DoD, modeling tools are being developed to predict the impact of a terrorist attack utilizing either explosives or chemical/biological agents. These tools are used in airport design efforts and to evaluate existing facility risk against such attacks and to allow for evaluation of countermeasure effectiveness.

INCIDENT PREVENTION

The primary focus of R&D addressing prevention of security incidents is detection and screening. The FAA's explosives and weapons detection program is intended to eliminate the ability of a terrorist to successfully conceal explosives devices, weapons or other hazardous materials on aircraft.

The purpose of the program is to make improved explosives detection systems and other devices available to airlines and others responsible for airline security, both domestic and international, to reduce the vulnerability of US air carriers and airports to terrorist acts. This research supports, and is implemented through, the FAA's primary operational role of establishing policies and rules for airline compliance with security directives. Much of the R&D is based on integration of data from multiple sensors, and addresses scanning of baggage, cargo and personnel. In addition to achieving improved detection, the research seeks faster, more automated and lower-cost systems that can readily be integrated into the airport environment.

Current Operational Solutions

Security Systems. In 1996, the FAA established an integrated product team to plan, purchase and install sophisticated explosives detection devices and other advanced security equipment. The team includes working representatives of air carriers and airport authorities. The team has been involved in all aspects of the deployment of automated security screening technologies, including the Explosive Detection System, explosive trace detectors, Computer Assisted Passenger Screening, and the Screener Proficiency Evaluation & Reporting System (SPEARS). The FAA sets performance standards for certification of detection equipment. The criterion includes explosive amounts, detection rates, false alarm rates, and system throughput.

The SPEARS Program consists of computer-based training of screeners, tools to aid in evaluating screeners for initial selection, and threat image projection which exposes screeners to threats on a periodic basis thus maintaining screener attention and vigilance. The dangerous goods program focuses on compliance and enforcement efforts involving hazardous materials. The program was initiated as a result of growing hazardous materials incidents involving air transportation and includes inspections of air carriers, aircraft repair stations, air freight forwarder facilities, and air shippers of dangerous goods.

The FAA canine program includes training, evaluation, and certification of explosives detection team dogs and handlers. By the end of 1998, there were approximately 154 canine teams deployed at 40 airports. In addition for being used as a highly mobile system to search bags and cargo, the teams also perform visible patrols and training to increase deterrence.

The intelligence analysis of the threat to civil aviation is the basis for determining the application of aviation security measures. This is accomplished by synthesizing intelligence and threat information into products such as security programs, security directives, information circulars, and threat assessments. These products are needed by the operations and policy and planning offices for ruling on carrier amendments to approved security programs, determinations of foreign airport security effectiveness, and support in changing regulations. Decisions to impose additional security measures result from coordinated effort among operations, policy, and intelligence specialists, US and foreign air carriers, and airport operators.

Information Security. The FAA is currently engaged in a broad and comprehensive effort to ensure that safety- and mission-critical computer-based elements of the National Airspace System are fully protected against intrusion, disruption, damage or incorrect functioning as a result of external attacks. While this is primarily an operational rather than R&D issue, it involves highly specialized knowledge and skills. The new "open" computing environment has highlighted the need to move away from the rigid protection engineering that has been used extensively. The international, industrial, commercial, and government communities have responded to this need by moving to develop and adopt a "common criteria" that will allow for interoperability between systems while providing appropriate protection for them which the NAS Security Architecture.

Selected NAS systems are being analyzed to identify their security needs and to assist in developing a methodology that can be applied across all NAS systems. This will facilitate the development of an overall architecture and a security operational concept. In parallel, assessments of new security products and services will supplement the experience of other government agencies and the private sector to provide a catalog of available security products and services. A management structure for the information security function also will be developed and implemented to efficiently administer the security processes, not only from an operational viewpoint but also to assist in the acquisition phase of the life cycle. This management structure will provide for a combination of centralized and distributed security management.

The NAS Security Architecture will be developed through analyses and tradeoffs with respect to requirements, cost, degree of security, performance, etc. To ensure compatibility and effectiveness of security measures within individual systems, while also securing an appropriate degree of uniformity across NAS systems, a system-wide operational concept will be considered part of these analyses and trades. Interaction with other efforts under the NAS Architecture, such as the Information Architecture, will be essential to ensure consistent, compatible outcomes.

FAA Research

Detection Capabilities. The FAA Explosives, Weapons, and Other Threat Material Detection Program is responsible for developing technologies to prevent explosives, weapons, and other threat materials from being introduced on aircraft. One objective of this program is to develop a "checkpoint of the future," emphasizing technologies able to screen people and their carry-on items efficiently and in a non-intrusive manner. The critical elements are equipment performance, operational issues including human factors, and integration to ensure smooth and timely processing of people and their carry-on belongings.

Another goal is improvement of the performance of checked baggage security systems, particularly with regard to impact on airport and airline operations. That program also addresses human factors considerations in terms of allowing alarm resolution to occur as efficiently and effectively as possible. Another program is focused on providing a level of security for cargo and mail transported on passenger aircraft that is commensurate with that provided for checked and carry-on baggage and passengers.

Research is also being conducted to quantify canine detection capabilities for various classes and quantities of explosives and associated compounds. This data will be used to identify baseline performance capabilities and identify methods to improve canine detection performance.

Human Factors. The people who use and interact with security technology and procedures are a critical element in the success of the overall system. Accordingly, FAA's research includes a specific activity concerned with aviation security human factors. Research is conducted in the human factors area to develop selection, training, testing, and monitoring techniques (including computer-based techniques) for personnel responsible for performing security procedures and/or operating existing or developmental security systems. Human factors input is provided during the design phases for new security procedures and systems.

Technology Integration. The Airport Security Technology Integration Program focuses on the security of the airport environment and the security of FAA facilities, equipment, and communications. The program addresses personnel access, physical security, positive passenger bag matching, advanced threats to the NAS, and decision support tools such as simulation and modeling.

Safe Skies. The Safe Skies Program is a cooperative effort between government, municipal, and industry groups to address civil aviation security issues. The program has provided a public airport test bed for security technologies that are transitioning from research and development to fielded systems. Research is being conducted in human factors, screener assist x-ray equipment, trace explosive detection, and technology integration through the Safe Skies Program.

Security Equipment Evaluation. The Independent Test and Evaluation Program provides objective analysis of security equipment performance, and advises prospective users on deployment strategies, configurations and procedures. The program is responsible for developing and maintaining protocols for tests and evaluations of security devices and systems, and develops and maintains all aspects of the system certification process.

INCIDENT MITIGATION

Although prevention of all incidents is the primary aim of the aviation security program, the possibility of an on-board explosion must be faced for many years to come. In response to this harsh reality, the FAA security research program includes an aircraft-hardening component to protect commercial aircraft from catastrophic structural damage or critical system failure due to an in-flight explosion. This effort focuses on determination of the minimum size explosive that would result in aircraft loss, and the methods and techniques that can be applied to the current and future fleet of commercial aircraft, including baggage and freight containers, to reduce their vulnerability to explosive effects. This work is closely coordinated with DoD, which has extensive experience in aircraft damage reduction, and has also drawn on expertise in NASA and the Department of Energy, as well as the aircraft and container industries.

This program also addresses the vulnerability of aircraft to spurious or high-energy electromagnetic interference to electronic systems, and assesses the threat presented by highly mobile surface-to-air missiles.

Operational Solutions

The FAA Aviation Explosives Security Program provides round-the-clock expert advice on the management of civil aviation security incidents involving actual or suspected explosive devices. The program provides training on emergency procedures involving explosives and explosive devices to FAA, airport, air carrier, and law enforcement personnel.

The Federal Air Marshals (FAMs) are a covert, armed security force capable of rapid deployment and tasked with conducting both anti-hijacking and counter-hijacking operations. FAM teams are deployed on a continuing basis to provide protection for passengers and crews onboard US air carriers on selected domestic and international routes.

FAA Research

The Aircraft Hardening Program develops methods to protect commercial aircraft from catastrophic structural or critical system failures due to in-flight explosions. The program also investigates aircraft vulnerability to spurious electromagnetic or high-energy signal interference with aircraft electronic systems and assesses the threat presented by manually operated, highly mobile surface-to-air missiles.

Research is also being conducted to identify and/or develop technologies to mitigate the threat from chemical and biological agents.

DoD Research

The Global Positioning System, originally designed to serve the needs of US military forces throughout the world, has rapidly evolved into an extremely valuable tool for use in many civil activities, particularly transportation. GPS now plays an important role in a variety of applications across virtually all modes of transportation, and will be at the heart of aviation radio navigation in the early 21st century. The President has issued a directive that specifically recognizes the need to protect the security of space-based assets. The Defense Department, which has responsibility for the system, is conducting research to make the GPS less vulnerable to interference.

6. EFFICIENCY PROGRAM PLAN

OVERVIEW

NASA and the FAA have long worked together on air traffic management systems to enhance the capacity, efficiency, safety and environmental compatibility of the National Airspace System. NASA uses its technical expertise to develop advanced air traffic decision support tools, improve training efficiency and cockpit safety through human factors research, and develop and flight test advanced communications, navigation and surveillance systems. The FAA defines system requirements and applies its operational expertise in these same areas to ensure that the technically advanced airborne and ground equipment, software and procedures developed by NASA are operationally useful, efficient, safe and cost effective. The FAA performs complementary research in the application of new technologies in addressing airborne and ground-based communications, navigation, and surveillance needs and in new decision support tools for strategic management of the system.

Within the context of this plan, the heart of near-term aviation efficiency improvements is the FAA's on-going NAS modernization program, which is providing new systems to enhance capabilities and services for users. At the same time, it will make the critical infrastructure of air traffic control services easier and more cost-effective to operate and maintain. This undertaking, which the White House Commission recommended be completed by 2005, necessarily draws more on past than current research activities. However, once the basic infrastructure is in place, the continuing enhancement and evolution of the system–including powerful automation aids and new operational concepts and procedures–will be shaped in part by the R&D now being conducted by FAA, NASA and DoD. Indeed, these technological breakthroughs will be the key to achieving the levels of performance that will be required in coming decades.

DoD is an important partner in this activity not only through research on the ATC improvements, but also with respect to integration of military aviation into the NAS architecture. The DoD is the world's largest operator of aircraft, and its facilities handle approximately a tenth of all domestic air traffic, including many civil flights.

The basic NAS infrastructure, with respect to both near-term implementation and longer-term research, can be described in terms of seven elements:

- *Communications.* Integration of aviation communications systems into a seamless network using digital technology for voice and data, with electronic data exchange between controllers and cockpit.
- *Navigation.* Satellite-based navigation supporting direct routes and more predictable schedules for users, with declining reliance on ground-based navigation aids. GPS, in conjunction with the Wide-Area and Local-Area augmentations systems (WAAS and LAAS), will become the primary means for en route navigation and instrument approaches.
- *Surveillance.* Gradual transition from current radar systems to digital radar and automatic dependent surveillance (ADS), which, when coupled with broadcast capabilities (ADS-B), will greatly enhance pilot awareness of the surrounding environment, and eventually provide similar information for controllers.[8]

[8]Automatic dependent surveillance (ADS) is a technique in which aircraft position is determined using an onboard global navigation satellite system receiver. ADS-B is an extension of this concept in which each aircraft continually broadcasts its identity, altitude and position directly to ground stations and nearby aircraft.

- *Aviation Weather.* Improved ways to collect, process, transmit, and display weather information, during planning and in flight, based on real-time data from multiple sources. It includes development of improved forecasting and aviation-specific weather products, such as near-term (0-30 minute) prediction of significant terminal-area weather.
- *Avionics.* Aircraft systems that link GPS receivers to digital terrain maps; multi-mode digital communications technology for a wide range of uses; ADS-B to transmit position, velocity and intent to ground stations and other aircraft; multi-functional displays; and an enhanced collision avoidance system.
- *Free Flight Operational Tools.* Tools that give controllers, planners and service operators more complete information about air traffic control and flight operations, including data-link communications using predefined messages, support for collaborative decision-making (CDM) with airlines, and improved sequencing into terminal areas and on the airport surface.
- *Automation Infrastructure.* Infrastructure elements including improved air traffic controller displays and computers capable of supporting and exploiting new sequencing and spacing tools and advanced communications, navigation, surveillance and weather systems. This also includes a system-wide information network that enables users and providers to receive and share common data and jointly make operational planning decisions. These elements will be incorporated into en route, terminal, tower/surface, flight service and oceanic functions.

NAS Modernization is a large, complex, and lengthy program. It is being conducted in three phases with future R&D projects having their greatest impact in Phases II and III. However, current research is also playing an important role in Phase I, particularly with respect to automation aids. The NAS Efficiency roadmap, shown in Figures 11 and 12, indicates the broad thrusts, outcomes and structure of the associated research program.

NAS EFFICIENCY ROADMAP

The NAS Efficiency activity differs from the safety and security efforts in that the air traffic management system is procured and operated solely by the government. The roadmap focuses on the modernization and more efficient use of an existing well-defined infrastructure and on interventions and technological innovations of procedures, aviation systems, and vehicles that operate within the NAS. The foundation of the National Airspace System is a concept of operations and a NAS architecture that supports the concept. This is shown in Figure 11.

The first thrust is the development of an operating concept and architecture. A NAS architecture has been established and is guiding current modernization activities. But as new technologies and operational concepts are developed the architecture will continue to evolve, based on aviation system needs and technical capabilities. The second thrust shown in the roadmap is implementation of the architecture. This thrust includes near-term operational/procedural solutions that bring benefits to users as quickly as possible. Technology enhancements are being delivered through two underlying programs as indicated by the boxes in Figure 11. The Free Flight Phase 1 program will introduce modernization into the national air space incrementally and move toward free flight operations by deploying systems based on current R&D prototypes. Safe Flight 21 is the demonstration and assessment of improved procedures, advanced CNS technologies, and streamlined certification processes.

The third thrust involves initiatives to support FAA Air Traffic Operations in the areas of human factors, facility maintenance and improved weather information for controllers. The fourth thrust focuses on technology breakthroughs. NASA's Advanced Air Transportation Technology program is directed toward improvement of the effectiveness of national and global air transportation systems by development of sophisticated operational decision support automation aids, and its Terminal Area Productivity research which will provide technologies and operating procedures that enable instrument-weather airport capacity to safely match that of clear-weather capacity.

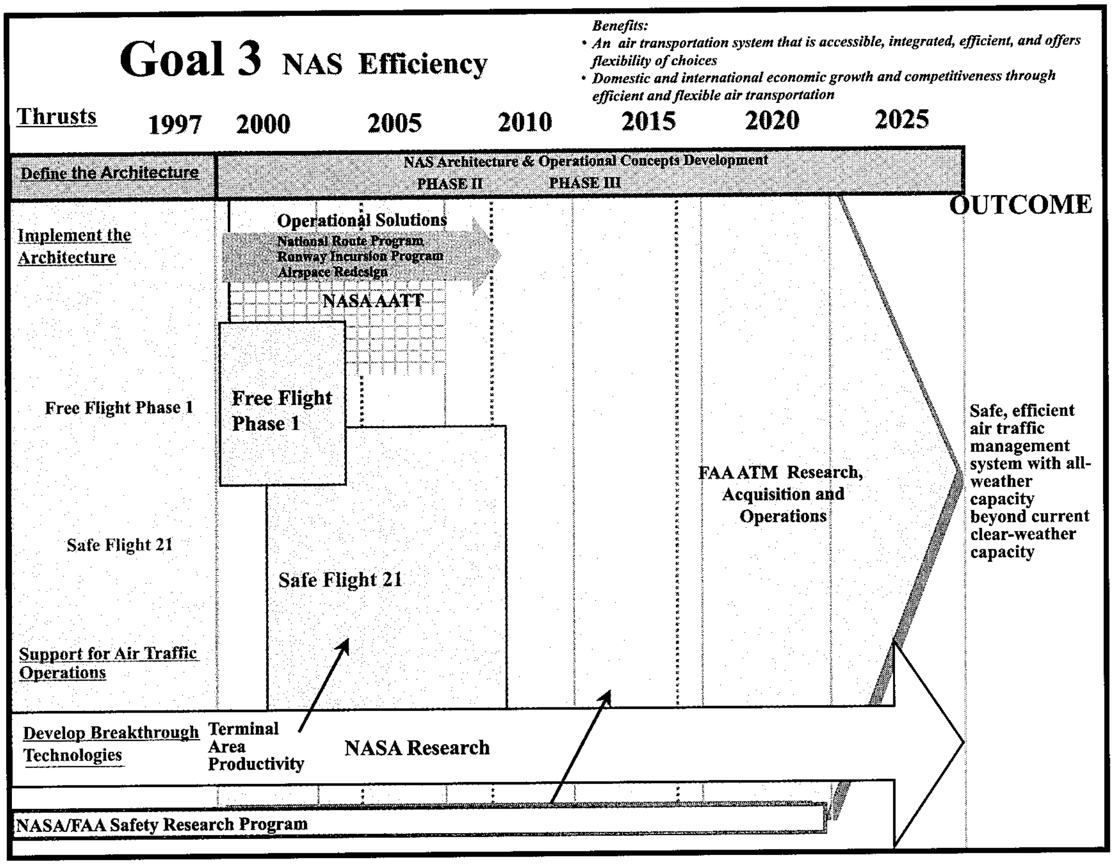

Figure 11. NAS Efficiency Roadmap -- Overview

Figure 12 shows the specific functionalities that will be achieved with these thrusts, as well as specific areas of ongoing research. Cumulatively, all of these build upon and extend current operational solutions: the National Route Program, the Runway Incursion Program, and Airspace Redesign. The blue horizontal bars in Figure 12 indicate the primary building blocks to be implemented. The roadmap also shows three on-going research elements needed to support air traffic operations: human factors, maintenance management, and weather. Beyond the period covered by the currently planned modernization process, FAA's air traffic management research, acquisition, and operational programs will provide continuing steady increase in system capabilities and performance.

NASA's development of the breakthrough technologies needed to extend the NAS modernization foundation to meet the needs of 2025 and beyond is represented by the light arrow extending across the bottom of the figure. NASA's Safety Research Program will also yield innovations that have substantial benefits for NAS efficiency.

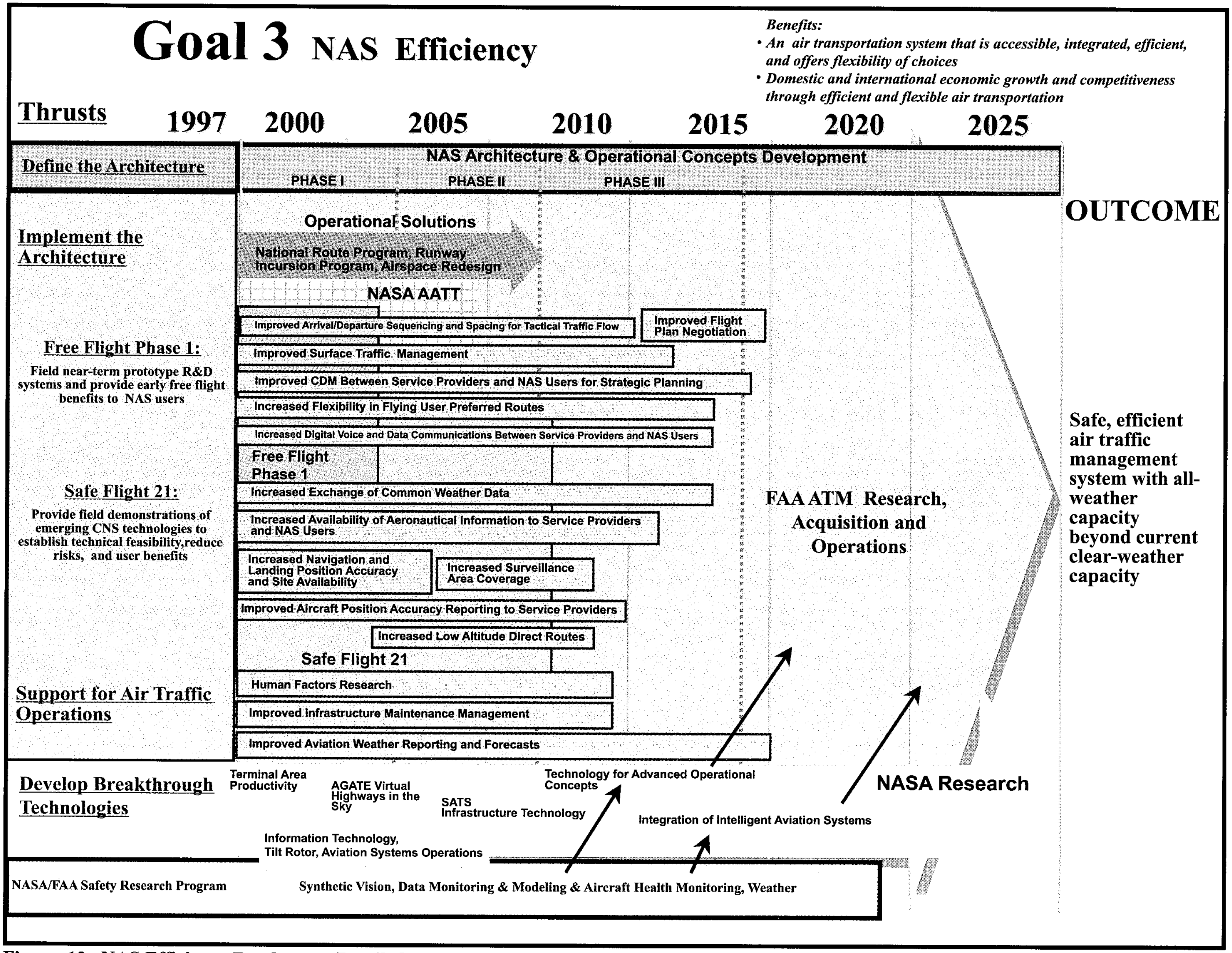

Figure 12. NAS Efficiency Roadmap -- Detailed

DEFINITION OF THE NAS ARCHITECTURE

FAA's NAS Architecture is the nation's blueprint for modernizing the NAS and improving its services and capabilities through the year 2015. The architecture is intended to provide increased benefits to all users while increasing safety through new technologies, airspace changes, and collaboration among users and providers. Version 4.0 of the NAS Architecture, released in January 1999, lays out the integration of equipment, personnel, facilities and procedures to support the joint Government/Industry Operational Concept for the Evolution of Free Flight. It also addresses the key policy and program decisions needed to accomplish modernization through the year 2015. Version 4.0, which incorporates internal and external comments on earlier versions, now establishes the baseline architecture, representing the accepted long-range plan for NAS modernization.

As changes to FAA/industry policy and program decisions are being considered in coming years, architecture impact assessments will be conducted to provide a total picture of the effect of the changes on NAS modernization. Upon approval of changes, the architecture database will be updated accordingly, so that it constantly reflects the current, agreed-upon aviation community approach to NAS modernization. The extent of cumulative changes will determine when new versions of the NAS Architecture document will be issued.

Advanced architecture has been developed in accordance with the NAS Concept of Operations document, which provides a high-level description of NAS air traffic operations as envisioned for the 2005 to 2010 timeframe. Enhanced systems in a modernized NAS will facilitate seamless inter- and intra-facility communication and coordination and provide better information to support decisions. Controllers will be able to draw upon sophisticated decision support systems that reduce their routine burdens while increasing their ability to evaluate and plan for the flow of traffic, increasing both productivity and user flexibility. Other NAS enhancements will increase the accuracy of weather displays and make weather data available in the cockpit.

The Concept of Operations includes a NAS-wide Information System that will provide an exchange of electronic data and increase collaboration between NAS users and service providers so that carriers will be able to adjust their schedules to maximize safety and efficiency. Flight data, including the filed flight profile and amendments and up-to-date flight schedules, will be readily available for NAS users.

IMPLEMENTATION OF THE NAS ARCHITECTURE

Implementation of the NAS components detailed in the architecture will take place in a phased approach from now through the year 2015. There are two major initiatives in this implementation, Free Flight Phase 1 and Safe Flight 21. These initiatives, taken together, will effectively develop, demonstrate, and field an integrated set of systems capabilities of next generation of Air Traffic Management tools and procedures. The individual components of these systems capabilities, are being developed individually in the seven building block areas.

The FAA conducts enabling core research in the seven building block areas of communications, navigation, surveillance, aviation weather, avionics, collaborative decision making tools, and automation infrastructure. These research programs, focused in individual technology areas, provide the requisite data on technology alternatives for allowing the FAA to deliver the anticipated services described in the architecture. Subject to their own development cycles, they demonstrate individual capabilities in the laboratory or in limited scale demonstrations that can serve as the basis for larger systems demonstrations of integrated technologies such as Safe Flight 21.

Supporting these individual research programs, FAA and NASA conduct comprehensive research programs in human factors and operational concept development and validation. These last two linked areas represent some of the most important research being undertaken for two reasons. First, human performance must be addressed in terms of the human role in the future system and the interfaces between the automation programs and display systems that figure so strongly in future NAS development. Failure to do so would raise significantly the risk that the system will fail to perform as intended and that benefits would be greatly reduced. Second, there must be a viable operational concept, which takes human performance into full account, for the use of new technology. Technology cannot deliver by itself the performance required if the NAS is to achieve the goals of free flight and accommodate the projected traffic demands of the future.

Given the central role in the NAS that is planned for an augmented GPS, ongoing DoD research directed toward assuring integrity of the GPS signal by making it less vulnerable to interference is an important contribution to rapid system implementation. Other DoD research of direct relevance to NAS implementation and evolution is the Real Time Information in the Cockpit program, which is intended to leverage and mutually support commercial weather initiatives.

Free Flight Phase 1

The first major step in the implementation of the NAS Architecture is the Free Flight Phase 1 (FFP1) program, an incremental introduction of modernization components into the National Airspace System (NAS). This program takes a "building block" approach to fielding new systems to provide early benefits to users. The goal of FFP1 is to move toward free flight operations by deploying selected low-risk technologies that provide core capabilities needed for free flight. The result will be near-term realization of air traffic management capabilities that have early benefits for service providers and National Airspace System users. These products are:

- User Request Evaluation Tools
- Surface Movement Advisor
- Traffic sequencing and metering tools based on:
  - NASA's passive Final Approach Spacing Tool (pFAST)
  - NASA's Traffic Management Advisor
- Collaborative Decision Making (CDM) tools.

By the close of 2002, FFP1 products will be operational at six terminal radar approach control centers, seven airports, eight air route traffic control centers, the air traffic control system command center, and the airlines-owned, Internet-like communications system connecting the airline operations centers, and will enhance the aviation community's ability to view and optimize all phases of flight, from planning and surface operations to the en route flight.

The FFP1 program will be aided by a Stakeholders Group consisting of representatives from the airline industry, general aviation, business aviation, labor organizations, RTCA Inc., NASA, aviation research centers, and several FAA offices. This group will assist the process of maintaining the previously-established consensus and will resolve new issues as they arise. Emphasis will be placed on introducing new technologies resulting from FAA, NASA and industry research that will reduce delays and costs through limited deployment of core capabilities by the close of 2002.

Safe Flight 21

In parallel with FFP1, Safe Flight 21 will focus on demonstrating the technical feasibility, safety, and other benefits of different operational enhancements for NAS modernization. The emphasis of Safe Flight 21 is on an integrated set of communications, navigation, and surveillance tools that promise to extend the range of capabilities and service beyond that provided today. The nine operational enhancements being evaluated by Safe Flight 21 are:

- Provide weather and other information to the cockpit
- Provide an affordable means to reduce controlled flight into terrain
- Improve the capability for approaches in low visibility conditions
- Enhance the capability to "see and avoid" adjacent traffic
- Enhance the capability to delegate aircraft separation authority to the pilot
- Improve the capability for pilots to navigate on the airport surface
- Enhance the capability for controllers to manage aircraft and vehicular traffic on the airport surface
- Provide surveillance coverage in non-radar airspace
- Provide improved separation standards

Safe Flight 21 will demonstrate new CNS technology and improved procedures; reduce risks for accelerated NAS modernization; evaluate CNS transition issues without a need for mandates; reduce costs by streamlining avionics development, certification, and installation; and develop controller and pilot tools for transition. Alaska is one of the major locations for the program, which is scheduled to be completed by the Spring, 2002. Alaska offers a controlled environment with an affordable fleet size, plus a wide range of weather conditions and rugged terrain to help evaluate the safety benefits. Approximately 200 aircraft will be equipped with compatible avionics and twelve ground stations established for transmitting weather and other data to participating aircraft and for receiving position broadcasts from participating aircraft. A parallel effort is being undertaken with air cargo carriers, currently planned for the Ohio Valley. Aircraft equipage will be voluntarily undertaken by the air cargo carriers operating in this area and the FAA will establish five ground stations to support aircraft operations in the area.

Key issues that this demonstration program will address include the following:

- How can the certification process be streamlined?
- What capabilities and enhancements will improve aircrew and controller awareness, and what will be the impact on overall workload?
- Which of the proposed enhancements will provide the greatest benefits?
- Can system design and integration issues be resolved, especially in the areas of human factors, cockpit display integration, and spectrum usage?
- Can beneficial enhancements be made affordable enough to gain widespread voluntary equipage?

Until new technologies are integrated into the NAS in such a way as to provide quantified benefits and actual costs, users will be reluctant to purchase the new CNS equipment. The Safe Flight 21 infrastructure includes: (1) GPS-based en route navigation and Category I/II/III approaches and landings (using WAAS and LAAS); (2) ADS-B; (3) data link communications across one or more of three candidate data links; (4) flight information services, including cockpit weather information; and (5) cockpit display of terrain and/or traffic.

Safe Flight 21 will ensure that the capabilities with the most promising NAS-wide benefits are identified in collaboration with users for rapid integration into the rest of the NAS. Infrastructure requirements at additional locations will be identified early for quick transition to the rest of the NAS. To that end, this demonstration program will be conducted as a joint program, involving Federal and state agencies, industry groups, individual cargo carriers, airlines, and general aviation operators. A Safe Flight 21 Steering Committee, formed by RTCA, Inc. from the above industry groups, is monitoring and providing guidance on the execution of this program.

SUPPORT FOR AIR TRAFFIC OPERATIONS

Provision of improved weather data, services and product delivery will be an ongoing effort in the future evolution of the NAS, drawing heavily on a wide range of research and coordination among interested agencies and other parties. As part of this effort, FAA has an active research program to significantly improve the accuracy and timeliness of forecasted weather phenomena that impact most heavily on the safety and efficiency of aircraft operation.

Another facet of efficiency is the cost of providing the services. For a large technology-intensive system such as the NAS, management of the infrastructure maintenance becomes a key factor in achieving efficient operations. Technologies for high-reliability systems, remote monitoring and maintenance and convenient software upgrading will be incorporated in system design and planning continually.

BREAKTHROUGH TECHNOLOGIES

The continuous growth of aviation will necessitate a comparable continuing evolution of the NAS, making the fullest possible use of new and advanced technologies and sophisticated systems. The FAA is exploring a wide range of future NAS technologies and concepts at its Center for Advanced Aviation System Development. Research already being pursued or planned in NASA's Terminal Area Productivity, Advanced Air Traffic Technology, and Base R&T Programs will provide and demonstrate (1) technologies to enable terminal area operations at today's clear weather rates under instrument conditions, (2) automated air traffic management decision aids, and (3) a foundation for development and integration of intelligent aviation systems for the future.

Center for Advanced Aviation System Development (CAASD)

CAASD, the FAA's Federally funded research and development center, is pursuing a broad-based research agenda in future technologies and operational concepts for air traffic management. Included in their forward looking efforts are programs in CNS operational capability, navigation system architecture, NAS architecture implementation, airspace design and analysis, user strategic planning and performance assessment, NAS systems integration, and NAS infrastructure management.

Advanced Air Transportation Technology (AATT)

The primary objective of the NASA Advanced Air Transportation Technologies project is to fully exploit the possibilities of the "Free Flight" concept. AATT products will enable substantial increases in the effectiveness of national and global air transportation systems. These increases will be achieved by developing and testing automation aids that can assist in the decision-making process among pilots, air traffic controllers, and dispatchers.

The AATT project is responsible for defining, exploring, and developing advanced air traffic system concepts to a level suitable for pre-production prototype assessment by the FAA which, if successful, will result in full-scale deployment. These decision support tools will allow all airspace users to choose the best flight path for their own purpose within the constraints of safety and the needs of other users. To do this, several goals must be met: (1) allow users to minimize operating costs by making trade-offs between time and routing; (2) improve the effectiveness of high-density operations on the ground and in the air; (3) enable safe operation in a smooth and efficient manner across boundaries of free-flight and capacity-constrained flight regions; (4) provide system improvements that are easily deployable anywhere in the world; and (5) improve the ability to simulate advanced capabilities in the airspace system.

The AATT project is developing computer-based analysis, prediction and display tools to aid air traffic controllers in managing aircraft. Examples include the Surface Movement Advisor that helps balance the traffic assigned to the departing runways and the Traffic Management Advisor and Final Approach Spacing Tool to improve arrival rates. All of the tools are currently being evaluated and enhanced. AATT is also evaluating communication, navigation, and display technologies that will contribute to enabling the flight crew to assume more responsibilities for aircraft separation. AATT decision support tools and airborne systems should allow an increase in throughput per runway at capacity-constrained/multi-runway airports and an increase in controller productivity.

Terminal Area Productivity (TAP)

Terminal Area Productivity research will provide technologies and operating procedures that enable instrument-weather airport capacity to safely match that in clear-weather. In cooperation with the FAA, NASA will develop and demonstrate airborne and ground technology and procedures to safely reduce aircraft spacing in the terminal area, enhance air traffic management and reduce controller workload, improve low-visibility landing and surface operations, and integrate aircraft and air traffic systems to address the problems described above. Given the capabilities of future ATC automation and improved wake vortex knowledge, "dynamic spacing" between pairs of aircraft types in the landing sequence for a given airport runway system is possible and desirable for maximum safety, capacity and efficiency. Flight demonstrations in the TAP project will show the feasibility of increasing single runway throughput by 12 percent; reducing lateral spacing below 3400 feet for independent operations on parallel runways; equivalent instrument/clear-weather arrival traffic flows; and equivalent instrument/clear-weather runway occupancy time and taxi operations.

Technology for Advanced Operational Concepts

This NASA program will begin by studying a variety of ways of making large increases in throughput by using new, innovative operational concepts. No list of candidate concepts exists at present; studies will determine the list of initial candidates, develop feasibility and practicality analyses, and produce an appropriate list of potential technologies for further discussion with industry, the airlines and the FAA. The program for Integration of Intelligent Aviation Systems will follow a course similar to that for the Operational Concepts. Various highly innovative candidate technologies will be analyzed for application.

General Aviation

An important element of the efficiency with which the NAS is used is its availability for general aviation aircraft. Within the AGATE Consortium, the team developing "Highway in the Sky" operating capability will produce a certifiable, graphically intuitive perspective display of flightpath that responds to weather, traffic, terrain, airspace clearance and regulatory constraints. The stated goal of the activity is to "Enable doorstep-to-destination travel at four times the speed of highways to 25% of the Nation's suburban, rural, and remote communities in 10 years, and more than 90% in 25 years." The current R&D investments shown on the roadmap include revolutionary technologies for next generation vehicles for personal and business air transportation.

Two of the first of this new class of vehicles (Cirrus and Lancair) are entering the marketplace in 1999. These technologies form the basis for the Small Aircraft Transportation System, which is intended to extend accessibility within the National Air Transportation System from the few hundred airports with scheduled air carrier service to over 5,000 landing facilities throughout the nation. The 21st century impact of SATS will be to improve mobility, accessibility, quality of life, and economic equity throughout the nation's suburban, rural, and remote communities. The potential exists to utilize a ten-fold increase in currently-untapped NAS capacity in Classes C, D, E, and G airspace (below 18,000 feet altitude) and thousands of small airport facilities across the country.

Tiltrotor

The civil tiltrotor has the potential to increase throughput substantially by off-loading passengers from heavily congested airports onto vertiport-to-vertiport routes or onto routes based on vertiports located at existing airports. NASA's civil tiltrotor research is developing the most critical technologies for overcoming the inhibitors to a civil tiltrotor airliner: an efficient, low-noise proprotor; an integrated cockpit for minimum pilot workload; and a safe and cost effective one-engine-inoperative emergency power capability.

Safety Research

NASA Aviation safety research, although focused on accident rate reduction, will contribute to throughput improvements by greatly enhancing the ability to detect and respond effectively to all types of weather hazards (thereby reducing weather-related delays) and by the introduction of synthetic vision in the cockpit (which will help in eliminating delays due to poor visibility).

7. ENVIRONMENTAL COMPATIBILITY

OVERVIEW

The 1995 White House National Science and Technology Council report, *Goals for a National Partnership in Aeronautics Research and Technology*, recognized that "environmental issues are likely to impose the fundamental limitation on air transportation growth in the 21st century." Thus a key goal of this plan is to "ensure the long-term environmental compatibility of the aviation system." Environmental compatibility addresses mitigation of the impact of aircraft operations on local air quality, community noise, climate change, and stratospheric ozone depletion. The objective is to allow demand-based growth in aviation with minimum environmental impact.

It is important to note that aviation has made tremendous strides in environmental compatibility over the past 30 years. Fuel efficiency has doubled and aircraft noise energy has been reduced by a factor of ten over this time period. Additionally, operational efficiency improvements associated with NAS modernization will also result in reduced fuel consumption and lower aircraft exhaust emissions. For long distance travel, aviation is a very efficient mode of transportation. Nonetheless, in order to counterbalance the growth of aviation, even greater improvements will be required to reduce noise and limit emissions that affect local air quality and climate.

Both noise and emissions are global issues. The International Civil Aviation Organization (ICAO) of the United Nations (UN) is the body responsible for developing worldwide environmental policy and standards. The Kyoto Protocol has also given ICAO the responsibility to deal with greenhouse gas emissions resulting from aviation operations. Globally, governments at both the local and national levels are also considering actions that go beyond current ICAO standards for local air quality. For example, stringent ozone and particulate matter standards under the U.S. Clean Air Act have resulted in local governments and environmental interest groups in the U.S. demanding action by airports and air carriers to mitigate emissions of NO_x and other pollutants.

Therefore, continued scientific assessment and development of safe and affordable technology options for reducing aircraft engine emissions are important to protect the environment and to sustain the growth of aviation. Research and technology objectives are to enable reduction of NO_x emissions by a factor of three within 10 years and by a factor of 5 within 25 years. Additional goals are reduction of CO_2 emissions by 25% within 10 years and 50% within 25 years. These CO_2 goals are particularly responsive to the Special Report on Aviation and the Global Atmosphere, published by the Intergovernmental Panel on Climate Change. The assessment indicates that aviation's impacts on climate possibly also include significant production of the ozone greenhouse gas, resulting from NO_x emissions, and nucleation of cloudiness, from water vapor and aerosol or particulate emissions, in the upper troposphere and lower stratosphere, and that future supersonic aircraft might deplete the stratospheric ozone.

Figure 13, which is from the IPCC aviation assessment report, shows that the possible radiative forcings (a scientific measure of climate change) from ozone and additional cloudiness are the same order of magnitude as for CO_2 alone. However, the level of scientific understanding of these effects, indicated by the ratings at the bottom of Figure 13, ranges from fair to very poor. Further, because of the expected growth of aviation, all of the aviation's climate impacts are expected to increase faster than other sectors. Thus, further scientific studies are essential to improve understanding of these effects.

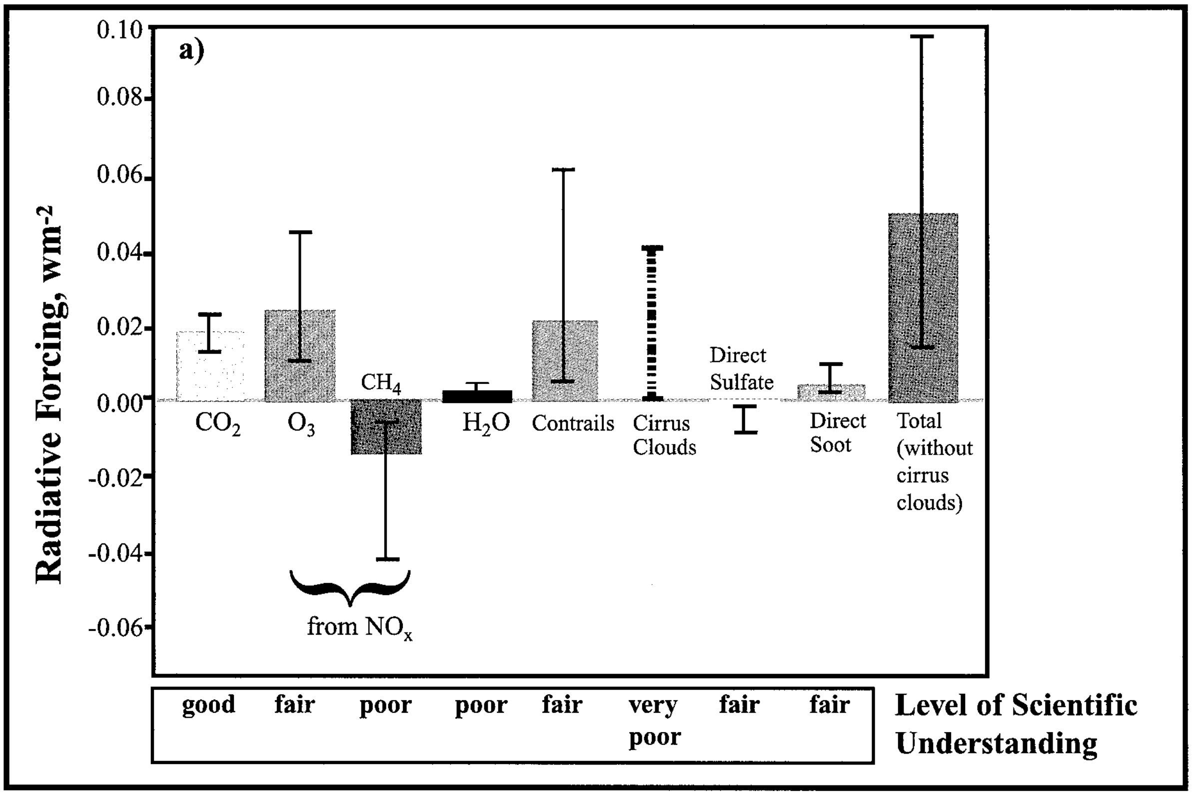

Figure 13. Scientific assessment of the climate impact of aviation in 1992 (Special Report on Aviation and the Global Atmosphere, Intergovernmental Panel on Climate Change, Cambridge University Press, New York, 1999)

NASA, in partnership with the FAA and industry, has already developed breakthrough technology to mitigate aircraft emissions, including technology to enable a 50% reduction in NOx compared with current standards. Programs to develop technologies to reduce aircraft emissions even further are being planned by NASA, FAA and other Government agencies. The Ultra Efficient Engine Technology program, starting in FY 2000, will reduce NOx by 70% (factor of 3) and CO_2 by 15%. The program will focus on developing low emissions, efficient combustors operating at high-pressure ratios and temperatures, while maintaining high levels of operability and maintainability. Overall engine efficiency and related CO_2 improvements will also be sought, for example, through performance improvements and weight reductions resulting from fewer compressor and turbine stages, advanced materials, and supporting subsystems.

Community noise impacts result from the level of noise from individual aircraft and the frequency of aircraft operations. With the mandated phase-out or hush-kitting of noisier Stage 2 airplanes by the year 2000, the number of people impacted by noise will be reduced. Moreover, the phase-in of new aircraft in replacement of hush-kitted or older Stage 3 aircraft over the next several years will tend to counter the noise impact of increased frequency of aircraft operations due to growth. However, community noise impacts from aircraft operations is a continuing issue. Local noise restrictions have grown from 119 airports in 1980 to 595 in 1998 worldwide, and in a growing number of cases, these include restrictions to the quieter Stage 3 airplanes. Noise issues are also inhibiting expansion or construction of new facilities.

The Environmental Protection Agency has established that a Day-Night Average Level of 55 decibels (dB) is "requisite to protect the public health and welfare with an adequate margin of safety." Therefore, the long-term NASA and FAA vision includes a noise-constraint-free air transportation system that would contain the 55 dB contour to within airport boundaries. This represents a 20 dB reduction in aircraft noise from the 1997 state-of-the-art.

Again, NASA, in partnership with the FAA and industry, has already achieved excellent progress in the development of noise reduction technologies. By 2001, this National partnership will have developed technology to enable a 5 dB reduction relative to the 1997 baseline.

ENVIRONMENTAL COMPATIBILITY ROADMAP

The top level Environment Compatibility Roadmap provided in this National plan shows enhancement of the capability to mitigate aircraft emissions and noise by developing enabling technologies. Both current and planned programs for reducing aircraft emissions and noise are shown in the roadmap. The Base Research & Technology Programs continue well beyond FY 2000, and are generally directed toward goals at a 25-year horizon. The overarching objective of this Federal plan is an aviation system that is unconstrained by environmental issues.

The Roadmap, Figure 14, shows a progression of activities in the following three thrusts:

- **Local Air Quality:** Through research and development of technology, reduce emissions of NOx and other pollutants that endanger public health and the environment. NOx reduction will minimize impact on local air quality and the ozone layer through advanced engine design and more efficient operations. Long-term technology goals are to enable a 70% reduction (3X) in NOx relative to 1996 ICAO standards by 2007 and 80% (5X) by 2022.
- **Global Change:** Through research and development of technology, reduce emissions that affect climate or stratospheric ozone. Developing efficient aircraft and engine systems, using alternate fuels and more efficient operations will achieve carbon dioxide emissions reduction or elimination. Long-term technology goals are to enable a 25% reduction in CO_2 by 2007 and 50% by 2022.
- **Noise Reduction:** Through research and development of technology, reduce aircraft noise levels in the vicinity of airports and in other places where aircraft noise is perceived as disruptive to the environment. The noise reduction thrust is to minimize impact on local population. The primary focus is on developing mitigating options in three areas: 1) Engine Systems, 2) Aircraft Systems, and 3) Operational Procedures. Long-term technology goals are to enable noise reduction by at least 5 dB and up to 10 dB by 2007 and up to 20 dB by 2022.

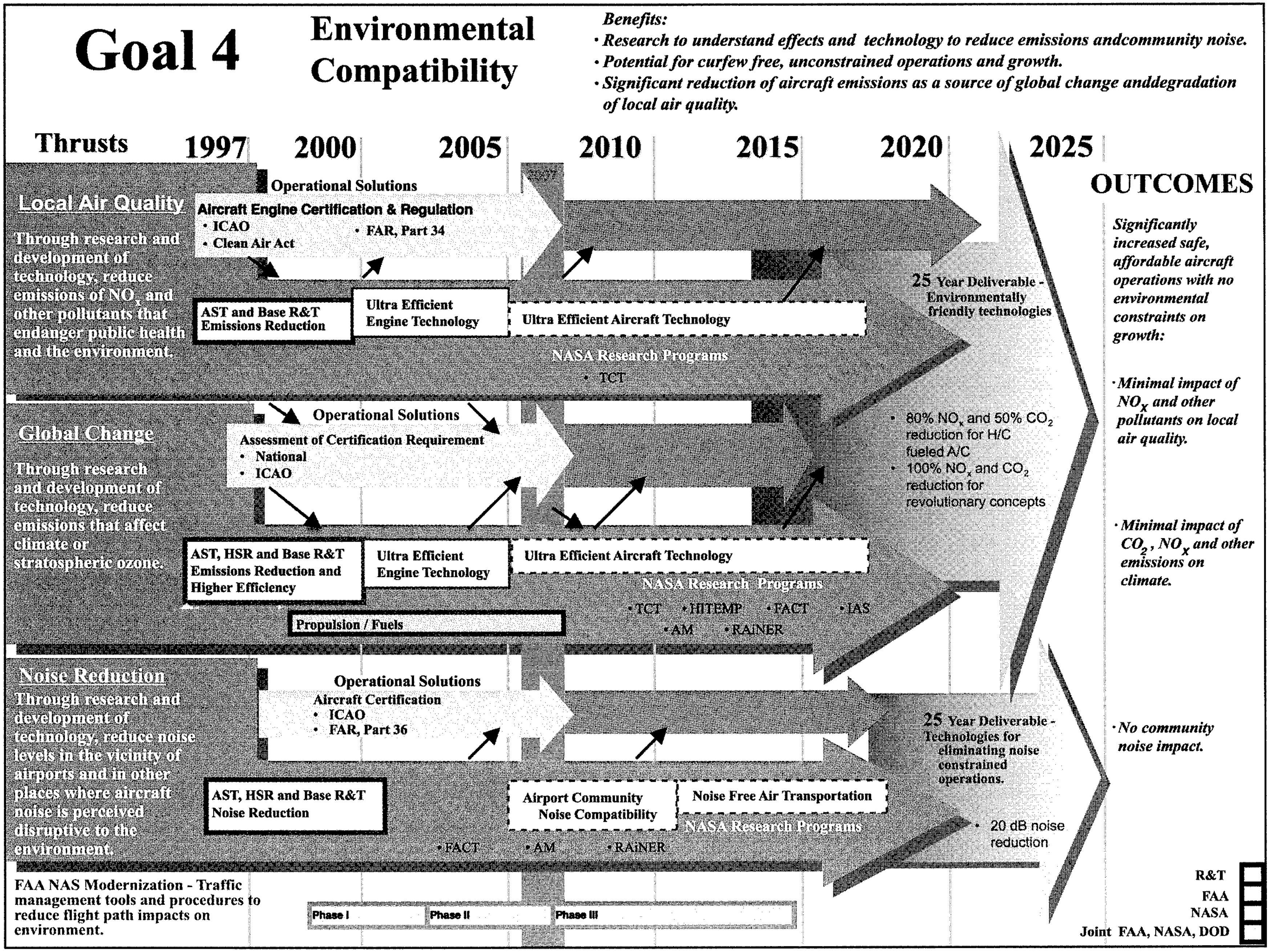

Figure 14. Environmental Compatibility Roadmap

The contribution of Operational Solutions, associated with the Efficiency goal, is implied in each case, and a schedule for NAS modernization is shown as well. The FAA's principal functions in the areas of Local Air Quality and Noise Reduction are certification and regulation, as continually reviewed at national (e.g., Clean Air Act) and international (e.g., ICAO) levels. A related research function is described in a later section. At this time, the FAA's role in the Global Change area is to participate with other agencies in national and international assessments and forums considering the possible need for regulation of high altitude emissions.

In general, NASA's contributions are considered breakthrough technologies that are "pre-competitive" in character, but have varying levels of technology readiness, primarily dependent on the level of investment. A high level of technology readiness implies a relatively lower technical risk for further market development and investment by manufacturers. A low level of technology readiness implies relatively greater technical risk. This matter of technology readiness is especially important in the environment area because a "market pull" often does not exist for potential products having no readily discernible economic market benefit. Therefore, establishing a need for emissions or noise reduction based on scientific assessment is a critical element of environmental research. This is generally a government responsibility, along with demonstrating technical feasibility of mitigation concepts. Implementation of the concepts is often based on economic feasibility, an evaluation likely requiring considerable collaboration of government and industry decision-makers. Although collaboration in this instance is important, it also may be difficult because of the possibility of government regulation and resulting additional costs of product and/or operations.

Although not explicitly shown on the roadmap, the contributions of the Environmental Protection Agency and DoD are noteworthy. EPA has a very important role in establishing the need for emissions reduction to benefit local air quality, and determining the economic reasonableness of potential regulatory standards. EPA also is a primary participant in national and international considerations of global change and the possible need for mitigation measures. Through formal and informal relationships between agency investigators, as well as direct transfer to industry, DoD research and technology has continued to provide important advances for civil application. Materials development for engines and airframes, and increased pressure ratios for efficient core engines are just two examples of DoD technologies that are likely to benefit civil aircraft environmental compatibility in the future.

In addressing the environmental goal, the primary distinction between the roles of the FAA and NASA, is that FAA deals with each of these areas through certification, standards, and operational considerations and NASA develops revolutionary aeronautics technologies to address all three thrusts in an integrated fashion. Thus, the following discussion is structured around agency programs, rather than treating each thrust area separately.

FAA PROGRAMS

Strategies and Coordination

The FAA has adopted the following strategies to provide strong international leadership in mitigating aviation's adverse impact on the public consistent with an effective aviation system:

- Lead a cooperative development effort that balances noise reduction with adequate airport capacity

- Manage FAA activities to understand and minimize adverse environmental consequences and comply with all Federal statutes
- Stimulate private industry and Government sponsored research to reduce noise, emissions, and energy consumption by the aviation sector
- Harmonize international aircraft noise and engine emissions certification standards

Using its regulatory authority, the FAA must serve as an advocate for both the environment and industry. Through an optimal mix of aircraft and engine certification standards, operational procedures, compatible land use, and abatement technology, the FAA intends to:

- Reduce the impact of aircraft noise by 64% (based upon population) by the year 2000 and prevent any increase[9], and
- Minimize the global, regional, and local impact of aircraft exhaust emissions.

The FAA uses a unified regulatory and R&D approach, working closely with other Federal agencies, industry, and foreign governments to assess environmental concerns, to plan R&D, to shape technical requirements, to identify feasible abatement technologies or other mitigation actions, and to implement aircraft and engine certification regulations to mitigate the potential impacts. The following arenas are used for collaboration on aviation environmental issues:

- The Aviation Regulatory Advisory Committee (ARAC) is a formal standing committee, composed of representatives from aviation associations and industry. Established by the FAA, ARAC provides industry input in the form of recommendations, advice, and information to be considered in the full range of FAA rulemaking activities. The harmonization working groups under ARAC have been tasked to ensure that the certification regulations impacting both domestic and foreign parties do not impose different standards in each country involved.

- The FAA participates, as the United States member, on the International Civil Aviation Organization Committee on Aviation Environmental Protection (CAEP) along with representatives of other civil aviation authorities and observers from the aviation industry. The purpose of CAEP is to assess the adequacy of the international aviation environmental standards, especially in the areas of aircraft noise and engine exhaust emissions standards.

- The FAA and other interested Federal agencies established the Federal Interagency Committee on Aviation Noise (FICAN) to provide forums for debate over needs for future aviation noise research and to encourage new development efforts in this area. FICAN conducts annual public forums in different geographic regions to solicit general input on aviation noise impacts with the intent to better align research with the public's concerns.

Research

The FAA aviation environmental research program is composed of the following major disciplines that form a cohesive system of projects to support Federal actions that will identify, control, and mitigate the environmental consequences of aviation activity with the focus on noise and engine exhaust emissions:

[9]Measured against a 1995 baseline.

Aircraft Noise Reduction and Control. FAA's aircraft noise reduction and control program produces research findings that become the noise standards, procedures, and recommended practices for the certification of new and modified airframe and engine designs. It includes research on the identification of feasible noise abatement technologies and the evaluation of more efficient certification procedures leading to lower costs for manufacturers and the FAA.

Engine Emissions Reduction and Control. FAA's engine emissions reduction and control program produces research findings that become the exhaust emissions standards, procedures, and recommended practices for the certification of new and modified aircraft and engine designs. It includes research on the identification of feasible abatement technologies and the evaluation of more efficient certification procedures leading to lower costs for manufacturers and the FAA.

Aviation Environmental Analysis. The aviation environmental analysis program develops the computer models and impact criteria for civil aviation authorities to use in the environmental assessment of proposed actions. It includes the research and development of new aircraft noise and emissions prediction methodologies to enable the FAA to quantify and accurately evaluate current and future issues affecting the environment.

NASA RESEARCH

The Environmental investment area addresses the issues of aircraft emissions and noise with the objective of mitigating their effects so as to allow airport operations to continue and potentially grow without degrading the quality of life or safety of the local population.

Emissions Reduction

Local Air Quality:

Ultra-Efficient Engine Technology (UEET) Program. UEET will continue advances made in past programs to reduce emissions. This is a new five-year effort to begin in FY 2000. The overall objective is to dramatically increase turbine engine performance and significantly reduce NO_x emissions. UEET will fulfill past commitments to enable a 50% reduction in NO_x and will further develop technology for a 70% (3X) NO_x emissions reduction for take-off and landing conditions. The UEET program will provide validation of low emissions combustor technologies through sector and full annular combustor testing based on 1996 ICAO standards by 2004.

Further requirements beyond the current UEET program will be to validate the component technology for a 70% NO_x reduction in a realistic engine environment. Additional efforts on new combustor concepts and technologies will also be required at the 80% (5X) NO_x reduction that is required to meet the 25-year goal. A radical new approach and a revolutionary set of combustor technologies will likely be needed to meet this challenge.

Global Change:

Ultra-Efficient Engine Technology (UEET) Program. UEET will also address the challenge of reducing greenhouse gases (CO_2) and stratospheric ozone depleting NO_x from engine emissions. The CO_2 objective is to improve an engine fuel consumption 15%. To achieve high fuel efficiency, the unprecedented targets are an overall pressure ratio of 55 and turbine rotor inlet temperatures of

3100°F. Thus, technologies are to be developed for high temperature turbomachinery components, materials and structures, and will also include novel concepts for significantly improved propulsion airframe integration through advanced technology. These technologies can also lead to weight reductions by allowing the number of compressor and turbine stages to be cut by half. Reduction of NOx emissions for aircraft that operate in the stratosphere will be accomplished through continuing development and demonstration of lean-premixed-prevaporized (LPP) combustor concepts.

Further requirements beyond the current UEET are the development of airframe technologies for weight savings and efficiency improvement to achieve the overall 25% fuel burn reduction (including contributions from the propulsion system in UEET) to meet the 10-year, 2007 goal. Beyond this near-term effort, development of integrated engine and airframe system technologies will be required to meet the 25-year goal of 50% CO_2 reduction or elimination. Any further reduction of aircraft emissions from the 25% level will require the use of alternate fuels. To achieve this goal, low carbon fuel such as methane may be used. This alternative would require evaluation of fuel in terms of availability and characteristics, propulsion effects and aviation infrastructure. To completely eliminate aircraft emissions, non-hydrocarbon fuel alternatives will be considered. This would require major consideration of infrastructure effects, impact on future fleet and technology insertion. The future technologies will rely on advancements in the Emissions Base R&T programs where revolutionary technologies and concepts will be assessed and evaluated.

Aircraft Noise Reduction:

Base R&T Program: The Noise Reduction element of the Base R&T Program is developing technology in three areas: engine system, aircraft system, and operational procedures. Significant progress has been made under past programs and NASA expects to fulfill its near-term commitment in noise reduction through its FY 2001 objective of reducing community noise impact by 5 dB relative to 1997 technology. To achieve a 10 dB perceived noise reduction relative to the 1997 baseline would require technology for an additional 5 dB noise reduction. Furthermore, to achieve the 25-year goal to contain objectionable noise within airport boundaries will necessitate up to an additional 10 dB, i.e., 20 dB perceived noise reduction relative to the 1997 baseline. Current studies indicate this is challenging, but feasible in the long-term through reductions in airframe noise, engine noise and advanced operational procedures.

Additional, Long-Term NASA Base Research & Technology (R&T) Programs in Support of 25-Year Environmental Goals

The Base R&T program is an essential element of the NASA AeroSpace Enterprise, for it is here that new technologies that lead to future advanced aerospace products are conceived. Base R&T provides a strong foundation for the fundamental understanding of a broad range of physical phenomena, development of computational methods to analyze and predict physical phenomena, and experimental validation of key analytical capabilities. Base R&T also produces revolutionary concepts and tools that can reduce the development time and risk of advanced aerospace systems and high performance aircraft. These programs are focused toward long term, i.e., 25 years, and have the goal of maintaining US superiority in aircraft and airbreathing engine development. The programs include research activities in both emissions and noise reduction that ensure the long-term environmental compatibility of aviation systems. Several projects are pertinent:

Zero CO_2 Propulsion Research: This is a newly established Base R&T program that will provide system-oriented technologies to assess alternate fuels and propulsion systems for future aircraft. These alternatives, such as fuel cells, can provide revolutionary change to aviation operation in order to achieve the long term zero emissions goal.

Turbomachinery & Combustion Technology (TCT). The Turbomachinery and Combustion Technology effort develops technologies that will reduce environmentally harmful emission levels of future aircraft. It looks beyond the current Advanced Subsonic Technology (AST) program to further reduce NO_x, and in addition seeks to reduce CO_2 emissions through lower overall fuel consumption. The latter is achieved through turbomachinery loading and efficiency improvements, more optimal component operability, and overall cycle thermal efficiency improvement. A recently identified need for aviation to also consider particulate and aerosol emissions is being addressed through development of specialized measurement techniques, characterization experiments, and modeling. Some specific technologies pursued include lean direct injection combustion, active combustor 0control, active/passive compressor stability enhancement, oil-free turbomachinery, coolant flow management, and wave rotor technology for topping cycles.

High-Temperature Engine Materials & Structures Project (HITEMP). The HITEMP program focuses primarily on advanced alloys and lightweight composite materials to reduce engine component weight and to allow increases in operating temperature of engines. These improvements lead to a lighter-weight vehicle, which translates to lower fuel burn and lower CO_2 emission. Higher allowable operating temperatures enable higher peak temperatures and/or lower cooling requirements, both of which also translate into higher thermal cycle efficiency, lower fuel burn, and lower CO_2 emissions. A number of technologies are pursued under HITEMP for engine component applications. Polymer matrix composites are being developed for use in fans, compressors, casings, ducts, and engine control systems. Advanced alloys and metal matrix composites are being investigated for compressor and turbine disks, blades, and vanes. Ceramic matrix composites are being pursued for extremely high temperature hot-section applications.

Futuristic Airframe Concepts and Technologies (FACT). This program emphasizes technologies required by a wide variety of subsonic commercial/cargo unconventional configurations, which in general are also applicable to military configurations. The project addresses barrier technology in structures, material, aerodynamics, airframe/propulsion integration, and acoustics to significantly expand design options for future subsonic transports. The technical approach involves developing and validating improved analyses and advanced technologies and concepts, integrated with ground and flight experiments.

Integral Airframe Structure (IAS). The Integral Airframe Structure project will develop technologies required to demonstrate the feasibility of manufacturing large, integral structures to reduce the cost of metal airframes. Key issues that will be addressed are application and scale-up of advanced materials processes, analysis methodology development, demonstration of the durability and damage tolerance of integrally stiffened structure, and verification of cost assessment tools. Results will be validated through the fabrication and evaluation of an integrally stiffened panel component. An assessment of the applicability of integral metallic structure for advanced transport configurations will be made.

Aircraft Morphing (AM). The primary objective of the Aircraft Morphing project is the development of smart devices with active components to increase aircraft efficiency and affordability. The focus is devices with dynamic actuation, local sensing, and feedback control. For many applications, these devices will modify local phenomena to support a macroscopic strategy, such as flow separation control for advanced, high-lift systems. Aircraft Morphing is an inherently multi-disciplinary project and is built around a core discipline-based structure. Technologies will be developed to address the following: advanced health monitoring, active structural damping, active noise reduction, and active separation control.

Revolutionary Airframe Noise and Emissions Reduction (RAiNER). The goal of RAiNER is to apply revolutionary airframe systems technologies to produce radical improvements in environmental compatibility through significant reduction of noise and emissions. Technologies addressed will include concepts to reduce the noise of the airframe itself, including noise from high lift systems, landing gear cavities and enclosures; propulsion airframe integration; and concepts that address the noise emanating from flow impingement on pylons and engine components. RAiNER will also address technology concepts that reduce the emissions of the aircraft by the reduction of fuel burn through increased aerodynamic performance and innovative flight operation.

Ultra Low NO_x Emissions Technology: This R&T Base program is directed at 80% NOx Reduction to meet the 25-year National Goal. New concepts and technologies will be developed at a lower maturity level. Flame tube and limited sector experiments at different operating conditions will be required to provide preliminary down-selection and validation of technologies beyond UEET to demonstrate 80% NOx emissions reduction, based on 1996 ICAO standards.

APPENDIX A - REFERENCES

Goals for a National Partnership in Aeronautics Research and Technology, National Science and Technology Council, White House Office of Science and Technology Policy, August 1995.

Report on FAA/NASA Research and Development Coordination Efforts, NASA and DOT Inspectors General. Joint Memorandum Report, October 8, 1998.

Report of the White House Commission on Aviation Safety and Security, February 1997.

1998 Research, Engineering & Development (R, E&D) Plan, FAA.

Aeronautics and Space Transportation Technology Annual Progress Report 1997-98, NASA.

Toward a Safer 21st Century Aviation - Safety Research Baseline and Future Challenges, NASA Report NP 1997-12-2321-HQ, December, 1996.

Aviation in the Next Millennium, Draft report prepared for the NSTC by the RAND Science and Technology Policy Institute, October 1998.

Avoiding Aviation Gridlock & Reducing the Accident Rate, Final Report of the National Civil Aviation Review Commission, December, 1997.

The Impact of National Airspace Systems (NAS) Modernization on Aircraft Emissions, FAA Report Number DOT/FAA/SD-400-98/1, September 1998.

*Defense Science and Technology Strategy, Director of Defense Research and Engineering, May, 1996.**

*Joint Warfighting Science and Technology Plan, Director of Defense Research and Engineering, January, 1998.**

*Defense Technology Area Plan, Director of Defense Research and Engineering, January, 1997.**

*Defense Technology Objectives of the Joint Warfighting Science and Technology Plan and the Defense Technology Area Plan, Director of Defense Research and Engineering, January, 1998.**

*Available at www.dtic.mil/dstip/index.htm

APPENDIX B - ACRONYMS

AATT	Advanced Air Transportation Technology Program
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
AGATE	Advanced General Aviation Transport Experiments
AM	Aircraft Morphing Program (NASA Base R&T Program)
APMS	Aviation Performance Measuring System
ARAC	Aviation Regulatory Advisory Committee
ASIST	Aviation Safety Investment Strategy Team
ASMM	Aviation System Data Monitoring and Modeling
ASRA	Aviation Safety and Risk Analysis
ASRS	Aviation Safety Reporting System
AST	Advanced Subsonic Technology Program
ATOS	Air Transportation Oversight System
CAEP	Committee on Aviation Environmental Protection (ICAO)
CAST	Commercial Aviation Safety Team
CDM	Collaborative Decision Making
CMC	Ceramic Matrix Composite
CNS	Communication, Navigation and Surveillance
DOC	Department of Commerce
DoD	Department of Defense
DOT	Department of Transportation
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FACT	Futuristic Airframe Concepts and Strategies Program (NASA Base R&T Program)
FAM	Federal Air Marshall
FFP1	Free Flight Phase 1
FICAN	Federal Interagency Committee on Aviation Noise
FOQA	Flight Operational Quality Assurance
GAIN	Global Analysis and Information Network
GAP	General Aviation Propulsion Program
GPS	Global Positioning System
HCST	High Speed Civil Transport
HITEMP	High-Temperature Engine Materials & Structures Project (NASA Base R&T Program)
HSR	High Speed Research Program
IAS	Integral Airframe Structure Project (NASA Base R&T Program)
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental Panel on Climate Change
LAAS	Local Area Augmentation System
MASSS	Methods for Analysis of Systems Stability and Safety
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NSTC	National Science and Technology Council
NTSB	National Transportation Safety Board
pFAST	passive Final Approach Spacing Tool

RAiNER	Revolutionary Airframe Noise and Emissions Reduction (NASA Base R&T Program)
R&D	Research and Development
R&T	Research and Technology
SATS	Small Aircraft Transportation System
SPAS	Safety Performance Analysis System
SPEARS	Screener Proficiency Evaluation and Reporting System
TAP	Terminal Area Productivity
TCT	Turbomachinery and Combustion Technology Program (NASA Base R&T Program)
TRL	Technology Readiness Level
WAAS	Wide Area Augmentation System

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