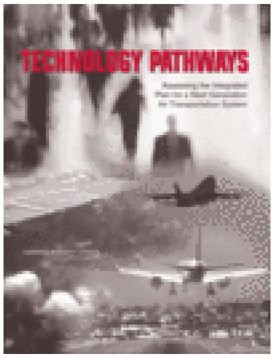

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Committee on Technology Pathways: Assessing the Integrated Plan for a Next Generation Air Transportation System, National Research Council

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Assessing the Integrated Plan for a Next Generation Air Transportation System

Committee on Technology Pathways:
Assessing the Integrated Plan for a Next Generation Air Transportation System

Aeronautics and Space Engineering Board

Division on Engineering and Physical Sciences

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Preface

Federal legislation created the Next Generation Air Transportation System (NGATS) Joint Planning and Development Office (JPDO) in December 2003. Tasks assigned to the JPDO include planning the development of an air transportation system capable of meeting potential air traffic demand by 2025 as well as overseeing and coordinating necessary research among federal agencies and private industry. Completing all of the tasks assigned to the JPDO will be a difficult challenge that goes beyond the limited authority and fiscal resources possessed by the JPDO. The JPDO staff have met this challenge in part through the establishment of nine integrated product teams (IPTs), which are serving as a vehicle both to involve other agencies with an interest in the U.S. air transportation system and to ensure that responsibility for improving the system rests with agencies and government officials with the authority and resources to make the necessary changes. The IPT approach has the potential to address the complexity of NGATS and facilitate an integrated approach that involves private stakeholders and federal agencies. However, the committee recommends that the IPTs be reduced in number and restructured to focus on the operational products that NGATS will require for success. In addition, the committee encourages the JPDO to implement the committee's recommendations through modifications to the Integrated Plan, to IPT documents, or to both.

Some of the recommendations in this report are directed to the secretary of transportation, the administrator of the Federal Aviation Administration, and the administrator of the National Aeronautics and Space Administration because they are members of the Senior Policy Committee that oversees the JPDO.

Michael Hudson, *Chair*
Committee on Technology Pathways:
Assessing the Integrated Plan for a
Next Generation Air Transportation System

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the Report Review Committee of the National Research Council (NRC). The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

George L. Donohue, George Mason University
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Agam Sinha, MITRE Corporation
Richard W. Taylor, Boeing (retired)
Ray Valeika, Delta Airlines (retired)
Bill G.W. Yee, Pratt & Whitney (retired)

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert J. Hermann, Global Technology Partners, LLC. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Executive Summary

Transforming the air transportation system is essential to meet the needs of the traveling public and other system users, to sustain the nation's economic growth, and to help the United States maintain continued global aviation leadership. The Vision 100—Century of Aviation Reauthorization Act of 2004 (see Appendix B), which directs the secretary of transportation to establish the Next Generation Air Transportation System (NGATS) Joint Planning and Development Office (JPDO) within the Federal Aviation Administration (FAA), creates the opportunity for all federal agencies with a stake in aviation to bring their resources to bear on this critical issue. Previous initiatives to modernize the U.S. aviation system have enjoyed limited success. The JPDO's multiagency approach affords new possibilities for overcoming the substantial barriers inherent in the significant undertaking of developing and deploying an NGATS. The secretary of transportation and the FAA administrator have both been supportive of the JPDO through public statements and through direct involvement in the Senior Policy Committee, which oversees the work of the JPDO and provides interdepartmental coordination.

The National Research Council was asked to form a committee to assess the first edition of the NGATS Integrated Plan, which the JPDO submitted to Congress in December 2004 (see <www.jpdo.aero>). The assessment committee met with staff from the JPDO and some of the integrated product teams (IPTs) that the JPDO has formed. This report is the result of that assessment.

The assessment committee considers the timely preparation of the first edition of the Integrated Plan to be a positive first step. Even so, substantial improvements in the Integrated Plan and the method by which it is being implemented are essential.

The next edition of the Integrated Plan should clearly state that increased demand is the key driver that mandates implementation of NGATS. The JPDO should redirect its efforts to focus on development of a systematic, risk-based approach for achieving the primary objective, which is to resolve demand issues and increase capacity, while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness. The Integrated Plan should make sure that secondary objectives, such as alignment of existing interagency efforts, do not overshadow the primary objective of meeting increased demand.

The JPDO should define operational concepts to satisfy future demand by phase of operation:

- airport operations
- terminal area operations
- en route and oceanic operations

Operational concepts for airport operations will be needed for flight operations during approach, landing, and takeoff; for ground operations; and for curb-to-gate processing of passengers within the terminal.

Operational concepts for terminal area operations will be needed for flight operations between the last en route waypoint and the initial approach waypoint at major airports. This includes multicenter operational concepts for terminal areas that are so close together that responsible traffic control centers should take a collaborative approach to traffic flow management.

Operational concepts for en route and oceanic operations will be needed for aircraft operating between the terminal areas at their points of origin and destination, including aircraft operating in oceanic airspace. Operational concepts at this level should also encompass national traffic flow management.

Even though the current IPTs have multiagency membership, they are functioning primarily as experts in specific disciplines rather than as cross-functional, integrated, multidisciplinary teams organized to deliver specific products that will improve operational capabilities of the air transportation system. To better support the core goal of meeting increased demand in each phase of operation, the JPDO's IPT structure should be realigned and simplified. All of the current IPTs (except for the Master IPT) should be disbanded and replaced with three new IPTs, one for each of the above operational concepts. Safety, security, weather, and other elements of the existing IPTs should be embedded in each of the three new IPTs, as appropriate, and the JPDO should establish goals related to cost, schedule, and level of performance that can be quantified using appropriate figures of merit.

Adequate support for all core technologies and processes that will be included in NGATS is crucial to validate the Integrated Plan. In particular, the NASA administrator should continue—and the Senior Policy Committee and the JPDO should advocate for continuation of—research on core NGATS technologies and processes. Likewise, the JPDO itself must receive adequate resources. The members of the Senior Policy Committee should ensure that the federal agencies they direct or represent allocate funding and staff to (1) provide the JPDO with the resources it needs to define NGATS and draw up an appropriate implementation plan and (2) ensure departmental and agency research in civil aeronautics is consistent with plans developed by the JPDO and endorsed by the Senior Policy Committee to enable and implement new operational concepts.

The first edition of the Integrated Plan has little to say about implementation other than to acknowledge that the IPTs will need to address implementation and transition issues. Successful implementation of NGATS requires an Integrated Plan that does the following:

- Clearly addresses the needs of the traveling public, shippers, and other system users, which vary with fluctuations in the economy.
- Establishes a source of stable funding suitable for development, implementation, and operation of NGATS, including capital improvements.
- Proposes reforms in governance and operational management that assure accountability and limit the effect of traditional external influences. The interests of individual stakeholders should be balanced with the common good in a way that expedites the deployment of optimal technologies and procedures and achieves the primary goal of meeting increased demand.
- Defines an NGATS that efficiently interfaces with the rest of the global air transportation system.

The secretary of transportation, as chair of the Senior Policy Committee, and the FAA administrator, as a member of the Senior Policy Committee, should help the JPDO accomplish each of the above goals by, for example, supporting jointly funded, collaborative research to define NGATS operational concepts suitable for global implementation. They should also lead the development of a proposal to adequately fund the development, implementation, and operation of NGATS.

The assessment committee's overall guidance is summarized in the following recommendation:[1]

Summary Recommendation. The secretary of transportation, the FAA administrator, the rest of the Senior Policy Committee, and the JPDO should invigorate development, implementation, and operation of the Next Generation Air Transportation System, especially with regard to the development of core technologies and processes, as follows:

- Focus the work of the JPDO on development of a systematic, risk-based approach for achieving the primary objective, which is to resolve demand issues and increase capacity while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness.
- Restructure the JPDO as a product-driven organization with three coordinated operational concepts and three IPTs focused on (1) airport operations, (2) terminal area operations, and (3) en route and oceanic operations (plus the Master IPT for systems integration and oversight).
- Consistently provide the JPDO and its IPTs with strong, fully involved leadership and program management capabilities, along with more full-time staff.
- Draw up a plan to establish a viable source of stable funding and a governance structure suited to the Next Generation Air Transportation System.
- Undertake a more vigorous effort to collaborate with foreign governments and institutions, to include jointly funded, collaborative research to define operational concepts suitable for global implementation.

[1]A complete list of the committee's findings and recommendations appears following Chapter 6.

1

Introduction

The Vision 100—Century of Aviation Reauthorization Act, which was enacted on December 12, 2003 (see Appendix B), directed the secretary of transportation to form the Next Generation Air Transportation System (NGATS) Joint Planning and Development Office (JPDO) as an office within the Federal Aviation Administration (FAA). The JPDO was charged with creating and implementing an integrated plan for NGATS, as well as overseeing and coordinating relevant research and technology development plans, programs, and priorities. The JPDO is jointly managed by the FAA and the National Aeronautics and Space Administration (NASA), and it is supported by staff from NASA, the FAA, other parts of the Department of Transportation, and other involved agencies: the Departments of Commerce, Defense, and Homeland Security and the White House Office of Science and Technology Policy.

The Century of Aviation Reauthorization Act also directed the secretary of transportation to establish and serve as the chair of a senior policy committee consisting of the heads of each of the agencies involved in the JPDO (or their designees). The Senior Policy Committee oversees the work of the JPDO by providing policy guidance and advice "regarding the national goals and strategic objectives for the transformation of the nation's air transportation system to meet its future needs." The Senior Policy Committee is also charged with identifying resource needs and making legislative proposals regarding the future of the air transportation system.

The JPDO is focused on the transformation of the air transportation system.[1] The JPDO defines transformation as "technologically-enabled change that simultaneously meets seemingly conflicting requirements in the face of increasing demand—e.g., greater security and greater efficiency" (NGATS JPDO, 2005, p. 1).[2] The Integrated Plan issued by the JPDO in December 2004 documents the progress the JPDO has made in defining its goals for transforming the air transportation system and developing strategies to achieve those goals. The Integrated Plan anticipates that efforts to achieve the future vision for air transportation will involve "collaboration among federal, state, and local governments and private industry" and "will be coordinated through eight major strategies that broadly address the goals and objectives for the NGATS" (NGATS JPDO, 2004, p. 15).

As described in the Integrated Plan, the JPDO has formed an integrated product team (IPT) to define and implement each of the transformation strategies, which are as follows:

- Develop airport infrastructure to meet future demand.
- Establish an effective security system without limiting mobility or civil liberties.
- Establish an agile air traffic system (i.e., a system that accommodates future requirements and readily responds to shifts in demand from all users).
- Establish user-specific situational awareness.

[1]In terms of customer satisfaction, the overall effectiveness of air transportation for passengers and cargo is a multimodal problem encompassing the entire trip, from point of origin to the departure airport and onward to the arrival airport and the final destination. However, the scope of the JPDO's Integrated Plan—and this report—is limited to transportation issues under the purview of federal agencies that are directly responsible for aviation: from the curb of the terminal at the departure airport to the curb of the terminal at the arrival airport.

[2]The assessment committee uses demand generally to refer to both consumer demand (the amount of air transportation services purchased, in terms of revenue passenger miles and revenue cargo ton miles) and the load imposed on the National Airspace System (in terms of aircraft operations). Demand reflects the response of consumers to prices and the shape of the air transportation demand curve. Consumer demand is closely linked to demand on the National Airspace System, as individual airlines adjust routes, schedules, levels of service, prices, etc., to both stimulate and satisfy consumer demand.

- Establish a comprehensive, proactive safety management approach.
- Develop environmental protection that allows sustained aviation growth.
- Develop a systemwide capability to reduce weather impacts.
- Harmonize equipage and operations globally.

The organization of the JPDO and the Senior Policy Committee is summarized in Figure 1-1. To facilitate stakeholder involvement, the JPDO is establishing the NGATS Institute to assist in the selection of experts from industry and academia to participate on the IPTs and conduct analyses in support of the IPTs and JPDO. The JPDO has approximately 50 government and contractor staff, including the heads of the IPTs, some of whom are working with the JPDO on a part-time basis.

The secretary of transportation and the FAA administrator have both been supportive of the JPDO, as shown by their direct involvement in the work of the JPDO and their public statements. The involvement of senior executives from other departments as members of the Senior Policy Committee indicates the importance that other departments place on this activity.

In early 2004, NASA requested that the National Research Council (NRC) establish the Committee on Technology Pathways: Assessing the Integrated Plan for a Next Generation Air Transportation System (referred to hereinafter as the assessment committee). The assessment committee was directed to study the JPDO's Integrated Plan, and it was given the option of discussing and commenting on the JPDO process for developing and implementing the Integrated Plan. The scope of the committee's work included research and technology components of civil aviation, homeland security, and national security flight operations involving airlines, air taxis, helicopters, general aviation, and unmanned aerial vehicles, as well as the work of the IPTs. However, the IPT approach was approved during the first year of the JPDO's existence, and the IPTs were still developing their individual plans during the course of this study. As a result, the assessment committee had limited opportunity for substantive interaction with the IPTs: Committee members met

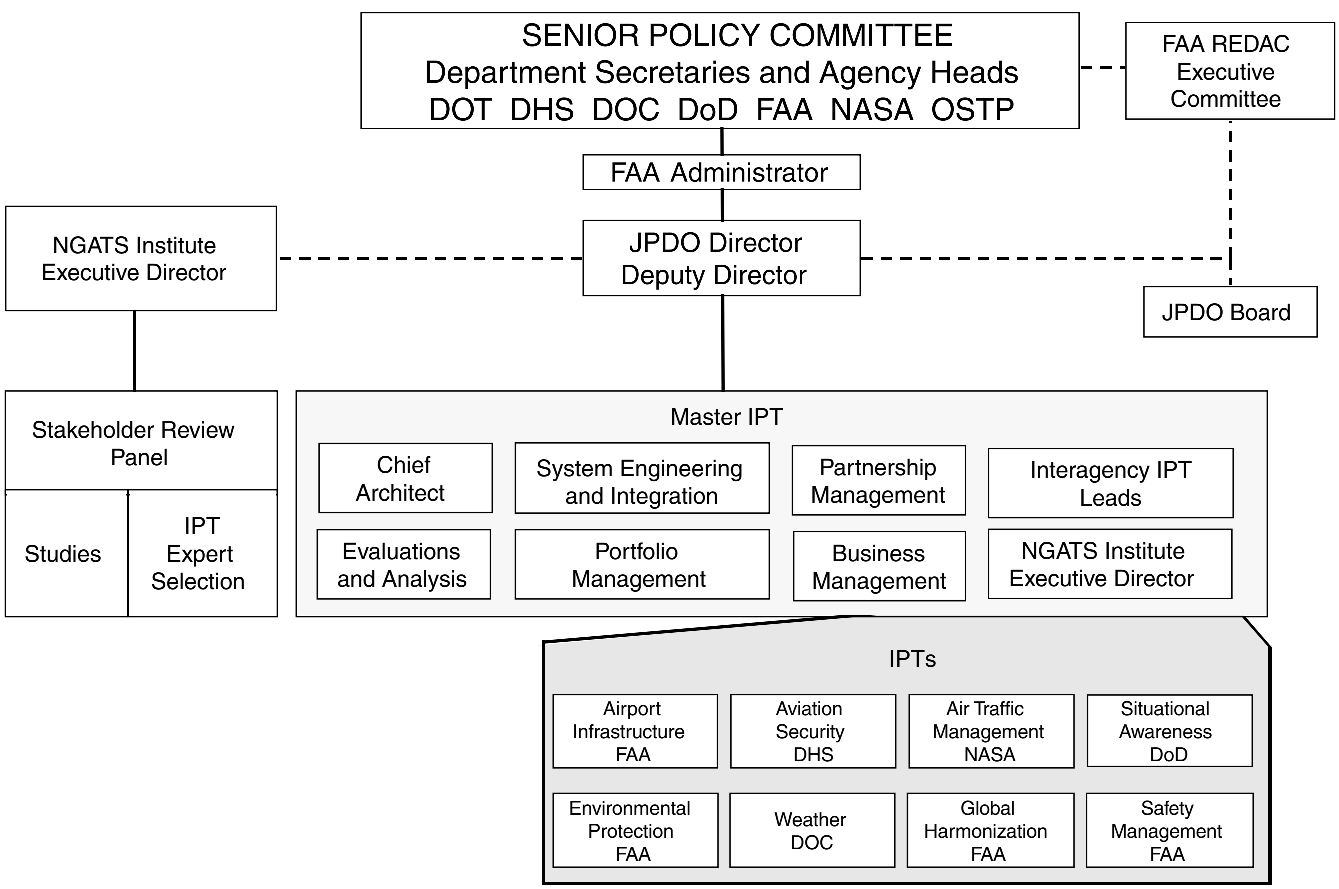

FIGURE 1-1 Organization of the JPDO and the Senior Policy Committee. DOT, Department of Transportation; DHS, Department of Homeland Security; DOC, Department of Commerce; OSTP, Office of Science and Technology Policy; REDAC, Research, Engineering, and Development Advisory Committee. SOURCE: JPDO.

with the heads of four IPTs, and the committee received a five-page summary of the plans being made by one IPT. In addition, because much of the detailed technology planning and technical analysis that otherwise might have been included in the Integrated Plan is being created and documented by the IPTs, the JPDO has prepared the Integrated Plan at a higher level than would be anticipated from a reading of the legislation that established the JPDO and mandated the creation of the Integrated Plan. Likewise this report, which assesses the content of the Integrated Plan, is somewhat less technical in nature than would be anticipated from a reading of the statement of task for this study.

This chapter briefly describes key elements of the Integrated Plan and the importance of taking a demand-based approach to improving the air transportation system. Chapter 2 suggests a new vision for the JPDO, describes the importance of establishing quantitative system goals, and urges the use of a risk-based approach to achieve those goals. Chapter 3 describes how the operational concepts in the Integrated Plan could be improved by grouping them according to the operational phases of the air transportation system. Chapter 4 recommends reducing the number of individual transformation strategies and IPTs by having each IPT correspond to a group of operational concepts. Chapter 4 also emphasizes the importance of research to develop core technologies and processes, suggests a list of technologies and processes that should be included in this core group, and recommends more vigorous action related to global collaboration and harmonization. Chapter 5 addresses issues associated with implementation, including resources and funding. Chapter 6 provides a summary recommendation and is followed by a complete listing of all findings and recommendations.

Appendix A contains the table of contents of the Integrated Plan. Appendix B contains sections 709 and 710 of Public Law 108-176, which established the JPDO and the Senior Policy Committee. Appendix C tabulates the key elements that Congress directed the JPDO to include in the Integrated Plan and shows where these elements appear in the Integrated Plan. Appendix D presents the statement of task and study approach used by the assessment committee. Appendix E offers brief biographies of the members of the committee. Appendix F describes an approach developed by the committee for assessing goals and policies. Appendix G contains a planning document prepared by the Environmental IPT. Appendix H lists acronyms and abbreviations.

OVERVIEW OF THE INTEGRATED PLAN

The Next Generation Air Transportation System Integrated Plan, which was delivered to Congress in December 2004, is available online at <www.jpdo.aero>. The Plan's table of contents appears in Appendix A.

The Integrated Plan begins by describing three factors that the JPDO believes are key determinants of the future performance of the U.S. air transportation system (NGATS JPDO, 2004, pp. 3-5):

- *Security.* "We need to find ways to secure aviation without detracting from the affordability, speed, and predictable advantages we desire in air transportation."
- *Gridlock.* "Aviation's own success will erode the unique speed, predictability, and affordability benefits of air travel if the air transportation system does not expand and adapt at the same pace as the market demands."
- *Global leadership.* U.S. leadership in aviation "is a result of the energy and creativity of America's private sector. . . . Unless we establish a vision and framework that encourages and enables further private sector innovation, our competitiveness in aviation is likely to diminish."

The Integrated Plan then provides the following as a national vision for air transportation in 2025: "A transformed air transportation system that provides services tailored to individual customer needs, allows all communities to participate in the global economy, and seamlessly integrates civil and military operations" (NGATS JPDO, 2004, p. 6).

The Integrated Plan describes six system goals and performance characteristics as the basis for achieving the vision:

- Retain U.S. leadership in global aviation.
- Expand capacity.
- Ensure safety.
- Protect the environment.
- Ensure our national defense.
- Secure the nation.

In the chapter "Operational Concepts," the Integrated Plan discusses the following five areas:

- security operations
- safety assurance
- airport operations
- aircraft operations
- air traffic management (ATM) operations

The plan includes a high-level (two-page) roadmap for 2005 to 2025, with a single line item and about four key milestones for each of the eight strategies. The plan also identifies seven key policy and technical challenges that must be overcome for these strategies to succeed:

- alignment of responsibilities and decision making across stakeholders
- alignment of investments and coordination of transition
- definition of equity and contribution toward national goals

- innovation in managing the safety effects of changes
- responding to future demand and complexity
- creative treatment of a mixed legacy and future fleet
- assessing the merits of transformation

The Integrated Plan continues by describing an approach to transformation that includes changes in government–private sector interactions and changes within government, such as establishment of the JPDO and the Senior Policy Committee.

The Integrated Plan's chapter "Approach to Transportation" describes specific IPT responsibilities, including the following:

- managing the planning and execution of all relevant work to complete the assigned strategy
- conducting analyses and trade studies to select and validate implementation alternatives
- analyzing changes currently under way, identifying gaps, and establishing the required government and/or industry research and development activities to close the gaps
- identifying nontechnical approaches such as policy, regulation, and operational procedures
- establishing detailed requirements for individual mission areas
- conducting advanced concept and technology demonstrations
- creating a transition plan for implementation of products
- creating public–private partnerships

The most detailed part of the Integrated Plan revisits the eight transformation strategies (see first page of this chapter). For each strategy, the Integrated Plan describes (1) how the strategy ties into the overall objectives, (2) the mission of the IPT that has been assembled to implement the strategy, (3) the transformation direction, and (4) linkages with other strategies.

The Integrated Plan concludes with a one-page summary of next steps. The summary states that, during fiscal year (FY) 2005, the IPTs will focus on

> identifying those on-going efforts that are essential to the success of the program. Through the IPT activities we will determine how to leverage the existing resources from all activities by coordinating and restructuring the programs of record, consistent with the developed architectures and identified requirements so as to maximize the return on the investments. The need for funding augmentation will be determined as part of the Senior Policy Committee oversight of the program activities during fiscal year 2005/2006 and addressed as part of the administration's budget process. The initial actions of the IPTs will be to refine the options for future solutions, assess existing programs and plans, leverage what is available, and identify gaps and key questions for further research and development. System engineering/integration work will begin in earnest to support the architecture and IPT planning. These more detailed plans will be reflected as annexes to the second edition of this plan, and will be reflected in the fiscal year 2007 budget submission. (NGATS JPDO, 2004, p. 35)

DEMAND IS THE KEY

The Integrated Plan provides a comprehensive description of the future challenges faced by the air transportation system and the actions necessary to address these challenges. Given the wide scope of the challenges and the limited resources available, the assessment committee believes that the effectiveness of the Integrated Plan would be enhanced if future editions prioritized the challenges to make sure that the key goal of satisfying future demand is adequately addressed. Research efforts should be limited to what is necessary and sufficient, even if that means passing up the opportunity to conduct research that is interesting but expected to be of limited value. In particular, the committee concurs with another NRC report that examined the future of the U.S. air transportation system: *Securing the Future of U.S. Air Transportation: A System in Peril.* That report concluded that "increased demand is the most critical long-term issue facing all aspects of the air transportation system. Issues associated with safety and security, capacity, environmental protection, and consumer satisfaction are all exacerbated by greater demand" (NRC, 2003, p .9). Vigorous new research in each of these areas is needed to create an NGATS that can satisfy future demand. The report warns that "business as usual is likely to result in an air transportation system where growth in demand has been greatly curtailed by undercapacity, environmental effects, customer dissatisfaction, and/or factors related to safety and security" (NRC, 2003, p. 10).

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2

Vision and Goals

VISION AND CAPACITY

Civil aviation accounts for about $900 billion of the U.S. gross domestic product and about 11 million jobs (DRI-WEFA, 2002). An inefficient air transportation system harms the U.S. economy by driving up costs to consumers and taxpayers. Congestion and inefficiencies in the National Airspace System increase fuel consumption, engine emissions, aircraft and crew costs, FAA staffing needs, and passenger delays and frustration.

> The process of improving the long-term performance of the air transportation system—and organizing a corresponding long-term research and technology program—should start with a unified, widely endorsed, national vision that specifies goals in each key area of interest to the commercial aviation community. The vision should establish goals related to safety and security, the capacity of the air transportation system, environmental protection (noise, emissions, and local water quality[1]), the satisfaction of consumer needs, and industrial competitiveness. It should include a clear set of guiding principles and a strategy for overcoming transitional issues. (NRC, 2003, p. 11)

The Integrated Plan puts forth a broad vision of the future air transportation system, but the traveling public, shippers, and other users of the air transportation system of the future will not be well served by an approach that assumes or implies that all issues are of equal importance. The Integrated Plan would be improved by explicitly identifying guiding principles that managers at all levels could use in making decisions about priorities and the direction of specific programs. In particular, increased demand is the single most important factor with which the future air transportation system must cope. The FAA projects that demand for commercial passenger air travel in the United States (in terms of revenue passenger miles) will increase by 58 percent from 2005 through 2016. During that same time, the demand for air cargo (in terms of revenue cargo ton miles) will increase by 70 percent and the total number of instrument flight rule (IFR) aircraft operations handled by the FAA's National Airspace System will increase by 27 percent (FAA, 2005). Growth in demand for air travel will stress every part of the air transportation system, especially airports. Demand already exceeds capacity at 5 of the 35 largest U.S. airports. Even if all of the improvements anticipated in the FAA's Operational Evolution Plan are implemented, in 2013 demand will exceed capacity at 15 of the busiest airports.[2] By 2020, even with improvements in technology and procedures and with the completion of runway construction projects not yet included in the Operational Evolution Plan, demand will exceed capacity at 18 major airports (FAA, 2004).

The secretary of transportation and the FAA administrator highlight the importance of demand in the second paragraph of the cover letter in the Integrated Plan: " . . . travelers are returning to the [air transportation] system in large numbers. We must be prepared to accommodate this growing demand in the years ahead. Failure to do so will result in costly travel delays throughout the system and will almost certainly compromise our ability to create jobs and grow the economy." The importance of demand is also highlighted in

[1]To protect local water quality, airports must ensure that storm-water runoff complies with standards established by the Environmental Protection Agency and other state and local agencies for contamination by chemicals used to deice aircraft and runways, fuel spills, and other pollutants.—Ed.

[2]The National Airspace System includes all ATM systems operated by the FAA. The Operational Evolution Plan is the FAA's plan for modernizing the National Airspace System to accommodate an increase in demand of approximately 30 percent over the next 10 years (see <www.faa.gov/programs/OEP>). The work of the JPDO is intended to complement the Operational Evolution Plan by preparing for system improvements over the longer term.

paragraph b-1 of the JPDO implementing legislation, which directs the JPDO to include in the integrated plan "a national vision statement for an air transportation system capable of meeting potential air traffic demand by 2025." The text of the Integrated Plan often mentions the importance of meeting increased demand, but often as just one item among many, and sometimes the need to meet increased demand is lost altogether. For example, the Plan's vision mentions customer needs, the global economy, and integration of civil and military operations but does not directly address the challenge of increased demand.

Meeting increased demand is difficult because capacity must be increased while also satisfying enabling, interrelated requirements related to safety, security, environmental protection, consumer satisfaction, and industrial competitiveness. The difficulty of meeting performance goals in each of these other areas would be mitigated if demand were stagnant or declining, but it will be exacerbated if demand increases substantially, as it is projected to do. In other words, improvements in virtually every aspect of the air transportation system are required to meet a substantial increase in demand. Accordingly, the highest priority should be given to research and technology development that is most likely to facilitate large increases in capacity (in terms of passenger miles and cargo ton miles), especially for airspace and airports that are currently at or near capacity limits. The assessment committee drafted a vision statement consistent with these concerns:

> *Create a U.S. air transportation system that meets the growing demand of the traveling public, shippers, and other system users while encouraging continuous improvement in capacity, efficiency, safety, security, competitiveness, environmental protection, and consumer satisfaction.*

GOALS

> The future vision for the air transportation system should be supported by research and technology goals leading to improved performance. Measurable long-term targets supported by sound analyses should be established to assess progress toward the goals. Research should support the establishment of quantifiable goals in areas where progress is difficult to measure. (NRC, 2003, p. 7)

The statement of system goals and performance characteristics in the Integrated Plan helps provide some specificity to the JPDO's vision by identifying qualitative objectives related to U.S. leadership, capacity, safety, environmental protection, national defense, and the security of the air transportation system. However, each of the descriptive goal statements in Chapter 3 of the Integrated Plan would be improved by adding quantifiable goals to the generic exhortations to do better in each area. Goals may be difficult to quantify in some areas, particularly with regard to the long-term future, but they are an essential input for evaluating operational concepts, research proposals, and technologies. The process of developing quantifiable goals will also help achieve the JPDO's legislative mandate to explain how it derived performance characteristics for the future air transportation system.

The description of goals related to capacity declares unequivocally that the system will include aircraft operator employees at over 5,000 airports. Infrastructure limitations and environmental concerns at small airports, however, are a serious impediment to the expanded use of many small airports. As of 2001, there were 5,025 public use airports in the United States. However, fewer than 3,900 public use airports had runways at least 3,000 feet long, and fewer than 3,600 public use airports had paved runways with runway lighting. Furthermore, the 213 busiest public airports (4.2 percent of the total number) accounted for 98.8 percent of all passenger enplanements. In addition, shifting a significant portion of the traveling public onto small aircraft compatible with small airports could increase airspace congestion and environmental effects. Heavy reliance on small aircraft carrying just a few passengers each would require more aircraft operations to carry the same number of travelers and increase total aircraft emissions. More than 80 percent of domestic intercity trips of 100 miles or longer begin or end in one of the nation's 160 largest metropolitan areas, and so a substantial increase in the use of small aircraft as a means of intercity travel would tend to exacerbate congestion at large airports that in many cases have little or no spare capacity (NRC, 2002). The assessment committee acknowledges that efforts to distribute traffic to airports with unused capacity may help meet increased demand, but it seems premature to commit to a highly decentralized air transportation system that relies on 5,000 airports as a solution to the key challenge of increased demand. Quantifiable goals are worthwhile, but only if supported by credible analyses.

The Integrated Plan misses the opportunity to establish consumer satisfaction as an area of direct interest to the agencies involved in developing NGATS. This omission stands in contrast to the situation in Europe, where the aviation community as a whole (not just industry) puts goals related to consumer satisfaction on a par with goals related to other factors such as safety, security, and capacity (NRC, 2003).

The description of goals related to national defense should discuss the value of reducing the impact of special-use airspace on civil operations and capacity. This discussion should also address the importance of a smooth transition of the ATM system in time of crisis from civil to military operational control. On 9/11, there was no plan, and the process did not go smoothly. Also, the national defense goal ("Ensure our national defense") and the objectives related to national defense are overly broad, given the supporting role that NGATS plays in national defense. The objectives are also inconsistent with the supporting discussion in the Integrated Plan.

RISK-BASED APPROACH

One way for the JPDO to carry out its mandate to coordinate priorities among federal agencies and industry would be through the systematic use of risk management and trade studies to help set research and technology priorities, with the highest priority placed on activities that will help the system meet increased demand. Requirements should likewise be based on a systematic approach to resolving issues related to increased demand, through the creation and assessment of multiple candidate scenarios and operational concepts. In the long run, a systematic, coordinated effort is essential to maximize efficiency and avoid delays, cost overruns, and duplicative research and technology development, all of which could be enormously expensive on such a mammoth undertaking.

The assessment committee acknowledges that the goal of developing an air transportation system with the flexibility to efficiently support increased operations by all types of users, including general aviation aircraft, military aircraft, rotorcraft, and small jets is generally attractive. However, while overall demand for passenger and cargo services is certain to increase, the commercial viability of large fleets of small jets or unmanned air vehicles (UAVs) is speculative, and plans to improve the air transportation system should take this distinction into account. In other words, it may be *helpful* for the future air transportation system to accommodate a large growth in small jets and UAVs, but it is *essential* for it to accommodate a large increase in conventional transports, because they will be an essential component of efforts to double or triple the capacity of the air transportation system over the next 20 years. Trying to build a system that can do everything for everyone increases the risk that the solutions ultimately defined will be unaffordable and take too long to implement. Even so, the JPDO should strive to develop a system that meets the needs of existing users and has the flexibility to respond to changing requirements and technologies.

Allocation of resources should be guided by quantified risk assessments that are based on sound models, simulations, and figures of merit related to the risk that research will fall short in terms of cost, schedule, and/or its contribution to the performance of the air transportation system. This is especially important when it comes to security measures, which too often are focused on the problems of the past or the desire to increase public confidence, even if they involve deploying systems and procedures of questionable effectiveness, rather than the essential tasks of reducing current and future security threats and educating the public to understand security concerns and what is being done to address them.

ASSESSING GOALS AND POLICIES

In general, the appropriateness of a strategy to improve the performance of a large system can be determined by testing the proposed goals and polices for consistency and compatibility with key implementation and operational factors (see Appendix F). The next edition of the Integrated Plan should elevate increased demand to the primary challenge and ensure that each IPT is focused on helping to meet this challenge. The work of the IPTs should be organized accordingly. As described in the Integrated Plan, the mission of some IPTs is to achieve new or improved capabilities in specific areas, while the mission of others is more generic or is limited to program coordination and alignment of resources. For example, the Integrated Plan describes the following missions for the Security IPT:

- Serve as the central activity to ensure alignment—operational effectiveness and suitability—of appropriate processes, policies, and technologies in the transformation to NGATS.
- Ensure program coordination with stakeholders in the aviation industry, airports, operators, service industries, academia, and related associations.
- Align resources necessary for timely development of candidate security systems.
- Align resources necessary to ensure timely acquisition, deployment, and life cycle support of transformational security systems. (NGATS JPDO, 2004, p. 26)

The above missions fail to acknowledge that security measures continue to suppress business travel that historically has been the key to the profitability of the airline industry.

> Security concerns continue to reduce the propensity for business travel, especially over shorter distances. Since the September 11th attacks, the advantage of air travel versus other modes of transport for short-haul travel has been reduced due to concerns about the increased processing time. For shorter haul trips this processing time is a significant percentage of the total travel time and as this percentage increases, more business travelers will use substitutes. (FAA, 2005, p. III-18)

The ability to rapidly screen passengers—and to convince business travelers that screening times will be consistently short—could have a major impact on overall demand, the profitability of the airline industry, and even the survival of some carriers. Consistently short screening times are also likely to increase consumer satisfaction of all travelers. The mission of the security IPT should reflect these realities.

Finding 2-1. Demand. The health of the U.S. economy is dependent upon an air transportation system that efficiently satisfies demand for passenger travel and air cargo. Anything that limits the ability of the air transportation system to efficiently satisfy demand is harmful to air transportation providers, users of the air transportation system, and the national economy as a whole. The JPDO Integrated Plan discusses the importance of demand, but often in the context of other objectives that are given equal or greater weight.

Recommendation 2-1. Demand. The Integrated Plan should clearly state that increased demand is the key driver that mandates implementation of the Next Generation Air Transportation System. The JPDO should refocus its efforts on development of a systematic, risk-based approach for achieving the primary objective, which is to resolve demand issues and increase capacity, while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness. The Integrated Plan should make sure that secondary objectives, such as alignment of existing interagency efforts, do not overshadow the primary objective. The JPDO should establish goals related to cost, schedule, and level of performance that can be quantified using appropriate figures of merit. Multiple candidate scenarios and operational concepts should be defined and assessed in terms of the risk that they will fail to achieve these goals.

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3

Operational Concepts

The Integrated Plan's discussion of operational concepts describes the performance of the future air transportation system in five areas:

- security operations
- safety assurance
- airport operations
- aircraft operations
- ATM operations

Safety and security are best achieved when they are viewed as inherent in each operational phase, when they are integrated into each phase from the beginning, and when they are considered an integral component of system reliability and efficiency. Safety and security are less effective when they are patched onto technologies and processes by an outside group after the process of developing operational technologies and processes is well under way. In addition, just as safety is enhanced through the use of multiple, redundant systems, security can be enhanced through the use of a layered system in which multiple security features are connected and provide backup for one another (NRC, 2002). Layered security is effective, however, only if it is guided by a risk-based approach that quantifies the cost of each layer and its contribution to overall goals for the mitigation of security risks.

The other three performance areas described in the Integrated Plan—airports, aircraft, and ATM—reflect how responsibilities for the manufacture, ownership, and operation of physical assets are distributed among different organizations, but they do not correspond to distinct phases of operation. As discussed further in the next chapter, implementation of NGATS would be easier if each IPT corresponded to one group of operational concepts. With such an approach, each set of operational concepts would encompass integrated operations by pilots, air traffic controllers, and all of the other people and equipment involved in a particular phase of operation.

The systems-oriented grouping of operational concepts currently in the Integrated Plan should be replaced by a functional grouping of operational concepts that corresponds to how the air transportation system actually operates:

- airport operations
- terminal area operations
- en route and oceanic operations

Operational concepts for airport operations will be needed for flight operations during approach, landing, and takeoff; for ground operations; and for curb-to-gate processing of passengers within the terminal.

Operational concepts for terminal area operations will be needed for flight operations between the last en route waypoint and the initial approach waypoint at major airports. This includes multicenter operational concepts for terminal areas that are so close together that responsible traffic control centers should take a collaborative approach to traffic flow management.

Operational concepts for en route and oceanic operations will be needed for aircraft operating between the terminal areas at their points of origin and destination, including aircraft operating in oceanic airspace. Operational concepts at this level should also encompass national traffic flow management.[1]

[1] ATM responsibilities for airspace over international waters is delegated to various countries; the United States is responsible for much of the oceanic airspace over the Atlantic, Pacific, and Arctic oceans. Implementation of new operational concepts for oceanic airspace would require collaboration with the International Civil Aviation Organization, which is responsible for setting ATM standards and procedures for oceanic airspace.

This approach—of grouping operational concepts by phase of operation—corresponds naturally to the way that aircraft operate as they move from the departure gate to the arrival gate. In addition, this approach would greatly simplify the interfaces between operational concepts compared with the complex interfaces needed in the Integrated Plan, which implies the creation of five sets of operational concepts—one for aircraft operations, one for ATM, one for safety, etc.

Future versions of the Integrated Plan would also be improved by defining both the goals that must be achieved by each operational concept and the process or approach by which those goals will be accomplished. Specific technological solutions should be viewed as speculative until they have been demonstrated to be the best means available to implement a particular operational concept. Therefore, it is important to develop the tools needed to assess operational concepts that will meet the primary objective of resolving demand issues and increasing capacity while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness. Until that assessment is complete, the Integrated Plan should avoid prescribing specific solutions that may be too limiting. For example, the Plan's discussion of security operations states that "sensor technology and countermeasures will be used to detect and render man-portable air defense systems ineffective" (NGATS JPDO, 2004, p. 11). Developing, deploying, and maintaining missile defense systems on commercial aircraft would be very expensive and may not represent the most cost-effective solution to this problem, even if one assumes that small missiles will become a significant security threat in the future.

The need for an integrated, systematic approach to operational concepts is further illustrated by the discussion of remote piloting capabilities in the aircraft operations section. This capability is mentioned as a possible means for enabling "ground intervention in case of pilot incapacitation or for security reasons." This discussion does not seem to consider that remote piloting capabilities also create the potential for remote hijacking of multiple aircraft by terrorists who have taken over a traffic control facility. The Integrated Plan should more carefully consider the strengths and weaknesses of specific technological and procedural approaches (e.g., remote control of aircraft by ground controllers) as they relate to the stated goals (e.g., to be more secure).

Changes in the airline industry that have occurred since it was deregulated in 1978 demonstrate the futility of trying to predict whether the air transportation system of 2025 will be dominated by point-to-point or hub-and-spoke route systems and by jumbo jets or regional jets. However, no matter what types of users dominate the future air transportation system, operational concepts for in-transit operations should strive to satisfy increased demand for passenger and cargo traffic, with safe separation between aircraft and with the ground, in all types of weather.

As soon as possible, the JPDO should use available analytical capabilities to define guiding principles for the development of new operational concepts. The guiding principles that are ultimately adopted by the JPDO should also be reflected in the NGATS vision and goals. Four possible guiding principles are described below, for purposes of illustration:

- *Use precise information.* The current air transportation system is based on certain assumptions about the availability and precision of information related to aircraft position and velocity, atmospheric conditions, etc. In recent decades, the accuracy and timeliness of this information has improved by orders of magnitude. Therefore, one guiding principle could be that NGATS will take full advantage of precise information about aircraft performance and flight status, adverse weather, wake vortices, and the state of the air transportation system that is quickly disseminated to improve situational awareness and support effective decision making by all system users. Such an approach could increase safety, reduce vertical and horizontal separation, eliminate operational restrictions on closely spaced runways, enable operation of more than one aircraft on a runway at a time, and eliminate the adverse effect of reduced visibility on system capacity. Such a guideline would promote research to safely increase system capacity by making better use of existing runways and airspace, and it would improve the performance of the air transportation system regardless of which aircraft types dominate the airspace or which route structures are employed by the airlines.
- *Use existing flight management system capabilities.* Another guiding principle could establish that NGATS will take full advantage of the flight management systems, the Global Positioning System (GPS), traffic collision avoidance systems (TCAS), and terrain alerting and warning systems (TAWS) that are installed in more than 4,000 air transport aircraft. More than 20,000 aircraft in the worldwide fleet will be equipped with these systems by 2025. Operational concepts that take full advantage of these performance-based capabilities could be implemented much more quickly and more economically than concepts that require new equipment to be retrofitted into all aircraft in the fleet. Taking full advantage of the advanced navigation capabilities and other precise information that current systems provide could dramatically improve the situational awareness of system users. The FAA is already taking a step in this direction in the form of the Required Navigation Performance Program. This program is establishing aircraft performance standards that would allow aircraft to use already installed technology to break free of the traditional ground-based navigation system. In addition, operational concepts could be developed, based

on the performance capabilities of current air transport aircraft, that allow simultaneous, independent, parallel approaches to closely spaced runways in low visibility conditions.

- *Reduce the impact of aviation on local communities.* Operational concepts for NGATS should be designed to improve operational efficiency while reducing community impacts (noise and emissions). For example, trajectory-based flight operations would, among other things, allow continuous descents and eliminate the need for adding power to level off during approaches. This would reduce emissions, fuel consumption, community noise, and travel time. Continuous descent approaches would also minimize level flight at low altitudes, which produces more noise and requires a higher thrust setting than descending flight. Continuous descent approaches also keep aircraft at higher altitudes during most of the approach to landing, which increases noise attenuation (NASA, 2004).
- *Increase the productivity of air traffic controllers.* Another guideline might establish the principle that new technologies, systems, and procedures will increase capacity by increasing the productivity of controllers (rather than rely on a business-as-usual approach that strives to double or triple the capacity of the air transportation system by doubling or tripling the number of controllers). For example, one way to increase the productivity of controllers in crowded airspace would be to have controllers monitor the placement of an aircraft route "tube" between two cities or waypoints, while relying on aircraft to self-separate within the tube.

Whatever approach is ultimately used to define and assess operational concepts—and the operational roles that human beings should play—it should focus on the area of greatest importance to the future of the air transportation system, which is satisfying increased demand, while also satisfying enabling, interrelated requirements regarding safety, security, environmental effects, consumer satisfaction, and industrial competitiveness.

The operational concepts developed by the IPTs will help sharpen the focus of the entire effort by clearly defining the end state toward which all other investments in research, development, facilities, equipment, procedures, etc., should be directed, in both the short and long term. It is still too early to know what the air transportation system of 2025 will look like in detail, in part because it is impossible to anticipate with certainty the impact of anomalous changes in the world, such as the rise of computer technology over the last 30 years, the rise of the Internet over the past 15 years, or the rise of international terrorism over the last 5 years. However, much information about the air transportation system of 2025 can be deduced from (1) current knowledge about those elements of the existing system that are expected to still be in place, (2) knowledge of short-term improvements that are being or soon will be implemented, and (3) analysis of future operational concepts.

Finding 3-1. Operational Concepts. The Integrated Plan implies that it will develop separate operational concepts for security operations, safety assurance, airport operations, aircraft operations, and ATM operations. Safety and security are inherent in the execution of the latter three, and operational concepts that integrate safety and security considerations from the beginning are more likely to satisfy system requirements than concepts that have safety and security imposed later in the development process.

Recommendation 3-1. Operational Concepts. The JPDO should define operational concepts to satisfy future demand by phase of operation:

- airport operations
- terminal area operations
- en route and oceanic operations

Safety and security risk management systems should be embedded in each of the above operational concepts, not set apart as separate considerations. The Integrated Plan should describe an iterative process for defining and assessing operational concepts as they relate to quantifiable system performance goals. The process should involve discussions with stakeholders and progressively more detailed modeling and simulation to assess performance and identify problems and guiding principles. The JPDO should support research to enhance and assess modeling and simulation capabilities.

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4

Research and Development Roadmap and Integrated Product Teams

ROADMAP

The Integrated Plan includes a high-level roadmap running from 2005 to 2025 with one line item and about four key milestones for each of the eight transformation strategies. To create the timeline, the JPDO estimated how soon key milestones could be achieved, while considering the need to coordinate action in different areas. The roadmap was developed late in the preparation of the Integrated Plan and does not include detailed supporting plans. The JPDO intends to include a much more detailed roadmap in the next edition of the Integrated Plan. To be useful, the roadmap should also be based on sound program management techniques, incorporate critical path scheduling, and show linkages among the different strategies in terms of information flow and interdependencies among various milestones.

INTEGRATED PRODUCT TEAMS

Organization

The JPDO has established an IPT to prepare and execute detailed plans for each of the eight transformation strategies. The FAA leads four of the IPTs. Each of the other key agencies involved in the JPDO (NASA, the Department of Homeland Security, the Department of Defense, and the Department of Commerce) leads one IPT, as follows:

- *Airport Infrastructure IPT (FAA lead).* Develop airport infrastructure to meet future demand.
- *Aviation Security IPT (Department of Homeland Security lead).* Establish an effective security system without limiting mobility or civil liberties.
- *Air Traffic Management IPT (NASA lead).* Establish an agile air traffic system.
- *Situational Awareness IPT (Department of Defense lead).* Establish user-specific situational awareness.
- *Safety Management IPT (FAA lead).* Establish a comprehensive, proactive safety management approach.
- *Environmental Protection IPT (FAA lead).* Develop environmental protection that allows sustained aviation growth.
- *Weather IPT (Department of Commerce lead).* Develop a systemwide capability to reduce weather impacts.
- *Global Harmonization IPT (FAA lead).* Harmonize equipage and operations globally.

The JPDO has also formed a Master IPT with the goal of coordinating and integrating the work of the focused IPTs.

The JPDO has an annual budget of $10 million, half from NASA and half from the FAA. The agency leading each IPT is responsible for its funding, and in most cases the IPT heads are government executives who have significant budgetary influence within their own agencies, or they work directly for someone who does. Given that the JPDO itself does not have budgetary authority, this approach substantially increases the amount of resources available to develop NGATS. Already, the total staff effort involved in the JPDO and the IPTs far exceeds what the JPDO could fund itself.

Even so, the current IPT organization creates some difficulties. As described in the following section, linkages among the IPTs are numerous, and they must be carefully managed. In addition, there is a mismatch between how the operational concepts and the IPTs are organized. NGATS research, development, and implementation would be more effective if they were focused on key items necessary to assess and implement the operational concepts. As with the operational concepts, safety and security would be enhanced if they were incorporated into the other IPTs.

The current IPT structure—having one IPT for each transformation strategy—accomplishes three objectives:

- Facilitates the distribution of IPT responsibilities among the agencies involved in the JPDO.

- Clearly shows that the JPDO recognizes the importance of safety, security, weather, and other key elements of an air transportation system.
- Provides a convenient forum for all of the parties involved in each element of the air transportation system to exchange information.

Nonetheless, this structure hinders and is inconsistent with an optimal, *product*-oriented approach for organizing an air transportation system research and acquisition program. The current structure also works against the idea of forming multidisciplinary *integrated* product teams, in that most of the IPTs are discipline-specific. Furthermore, the second and third objectives listed above could be accomplished more effectively in other ways. For example, many aviation safety groups already exist in government, industry, and academia. The JPDO could rely on one or more of these as a center of excellence for aviation safety management, and the Master IPT and/or the NGATS Institute could include representatives of centers of excellence in safety, weather, etc., to provide expertise and advice. Quick action to restructure the IPTs is needed to prevent the current structure from becoming institutionalized and incorporated into the long-term plans of the federal agencies involved in the JPDO.

In addition, the Master IPT seems to function primarily as an administrative coordinating body. Successful development and implementation of NGATS is unlikely unless the JPDO develops a stronger system engineering and integration function and a larger permanent staff for the Master IPT and the eight subordinate IPTs. In almost all cases, the IPT heads work only part-time on JPDO activities, and in some cases they still carry a full workload from the departmental positions they held before they were appointed as IPT heads. Asking senior departmental officials to serve as IPT heads increases the likelihood that departments and agencies involved in the JPDO will support the plans of the IPTs. On the other hand, it makes it impossible for the IPT heads to devote themselves fully to the difficult task of developing and implementing IPT plans.

Finding 4-1. IPT Organization. Even though the current IPTs have multiagency membership, they are functioning primarily as experts in specific disciplines rather than as cross-functional, integrated, multidisciplinary teams that can deliver specific products to improve operational capabilities of the air transportation system.

Recommendation 4-1. IPT Organization. As soon as possible, the JPDO's IPT organization should be modified to better support the core goal of meeting increased demand in each phase of operation by structuring the IPT organization to match the structure recommended for the operational concepts. All of the current IPTs (except for the Master IPT) should be disbanded and replaced with three new IPTs:

- Airport Operations IPT
- Terminal Area Operations IPT
- En Route and Oceanic Operations IPT

Linkages

Sections 7.1 through 7.8 of the Integrated Plan describe the IPTs and the transformation strategy associated with each IPT. Included in the description of each IPT is a list of cross-strategy linkages. Table 4-1 shows all of these linkages. An "O" marks the strategy for which an IPT in the leftmost column is responsible. Each "X" in the row for a particular IPT shows what other strategies/IPTs that IPT will coordinate

TABLE 4-1 IPT Linkages Depicted in Chapter 7 of the Integrated Plan

	NGATS Transformation Strategies							
IPT	7.1 Airport Infrastructure	7.2 Security System	7.3 Agile Air Traffic System	7.4 Situational Awareness	7.5 Safety Management Approach	7.6 Environmental Protection	7.7 Reduce Weather Impacts	7.8 Harmonize Globally
7.1	O	X	X	X	X	X	X	X
7.2		O	X	X	X	X		X
7.3	X		O	X	X	X	X	X
7.4		X	X	O	X		X	X
7.5	X	X	X	X	O	X	X	X
7.6	X		X			O		X
7.7	X	X	X	X	X		O	X
7.8	X	X	X		X	X	X	O

NOTE: "O" indicates the strategy for which the particular IPT is responsible; "X" indicates the cross-strategy linkage with the other IPT strategy areas to coordinate work.

with (according to the Integrated Plan). Table 4-1 shows that each IPT is expected to interface with and is dependent on the progress made in virtually every other IPT. And in some cases where linkages are not shown, they should be. For example, the IPT described in section 7.2 (Security System) has an open box under column 1, Airport Infrastructure, meaning there is no linkage between security and airport infrastructure. But IPT 7.1 (Airport Infrastructure) has an "X" under column 2 (Security System), meaning there is a linkage between these two IPTs/strategies. Inconsistencies such as these should be identified and corrected.

The current situation, in which every IPT interacts with almost every other IPT, means that interactions among the IPTs, as they are currently organized, are both exceedingly important and potentially very complex. A considerable effort may be needed to ensure that each of the existing IPTs is effectively coordinated with the other IPTs.

In addition to the many interactions among the IPTs, the potential exists for a large amount of overlapping work. As described in the Integrated Plan, many of the IPTs are addressing the same issues, such as security, situational awareness, global and national standards, policies and procedures, airport infrastructure, weather, communication and navigation systems, and regulatory authorities. Without effective coordination, multiple IPTs could address the same issues independently, creating study groups and research projects that duplicate efforts and waste time and money. These problems would be mitigated by consolidating the eight existing IPTs into three IPTs, consistent with the recommended scheme for restructuring the operational concepts. In any case, the Integrated Plan would be improved if it described how the IPTs will work together to manage overlapping areas of interest and avoid redundancies. In particular, it is essential that the JPDO's Master IPT provide a strong system integration and engineering function and work effectively with the other IPTs in setting IPT requirements. At a minimum, this requires that the head of each IPT have the skills needed to manage an interdisciplinary project, and the head of the Master IPT should possess the skills, expertise, and system-of-systems experience typical of the program manager for a major aerospace product development program.

Finding 4-2. IPT Linkages. As currently organized, none of the IPTs interact sufficiently with all of the other IPTs with which they have shared responsibilities. The current IPT structure creates a potential for substantial overlap and duplication of effort. The recommended restructuring of IPTs would solve this problem.

CORE TECHNOLOGIES AND PROCESSES

In general, new technologies and processes should be tailored to meet the needs of validated operational concepts, but some are certain to be of value regardless of the operational concepts ultimately selected, and their development should proceed even as the operational concepts are being defined and assessed. Examples of these generally applicable technologies and processes are as follows:

- Automation technologies applicable to fully automated systems; decision aids; and information systems for communication, visualization, situation assessment, and the prediction of future conditions.
- Technologies that support distributed, collaborative decision making and foster coordination and interactions among multiple human and automated elements of the system.
- Methods and technologies for moderating and abating the impact of noise and emissions locally, regionally, and globally.
- Methods and technologies for predicting or directly sensing the magnitude, duration, and location of wake vortices, to support the goal of reducing separation standards without compromising safety.
- Methods for identifying (1) the information required for situational awareness when humans are assigned novel (untried) tasks in future operational concepts and (2) sensor, computing, and display technologies for better supporting situational awareness, judgment, decision making, and planning. Relevant technologies may include synthetic vision, cockpit and controller displays for novel ATM functions, fast-time simulation and computational functions for predicting future conditions, and alerting systems. These methods and technologies should be investigated for their potential to (1) reduce separation standards without compromising safety and (2) enable changes in the roles of humans within the system.
- Systems-engineering methods that are (1) capable of conceiving and analyzing systems as complex as the air transportation system and (2) suitable for governing the design, testing, and implementation of these systems.
- Avionics technologies that will provide ubiquitous and transparent communication, navigation, and surveillance capabilities; enable cost-effective, reliable ATM; and contribute to the reduction of separation standards without compromising safety (NRC, 2002).

Finding 4-3. Core Research. Adequate support of all core technologies and processes upon which the Next Generation Air Transportation System will be built is crucial to validate the Integrated Plan.

Recommendation 4-2. Core Research. The NASA administrator should continue—and the Senior Policy Committee and the JPDO should advocate for continuation of—research on core technologies and processes, including automation and human factors, necessary to develop the Next Generation Air Transportation System.

AUTOMATION AND HUMAN FACTORS

A wide range of research, including basic research, proof-of-concept testing, and simulation and modeling, is needed to maximize the benefit of automation technologies, in part by more clearly articulating the role of humans vis-à-vis automation. Research should be used to increase both the capabilities of automated systems and the understanding of how and when automated systems can be profitably employed as well as the conditions under which they should be avoided. Automation should be designed into systems in ways that lead to high reliability and graceful degradation when system components fail.

Like safety and security, human factors should be incorporated into the operational concepts and the restructured IPTs from the beginning. This would ensure, for example, that the tasks assigned to pilots, controllers, and other system operators are reasonable and appropriate, that interfaces with automated systems are well conceived and executed, and that efforts to improve situational awareness are likely to succeed. System designers must resist the temptation to provide more automated features and give more information to system operators just because they can; more automation does not always increase safety or reliability, and more information does not always improve situational awareness or operational decisions.

RESEARCH AND TECHNOLOGY LEVELS

In some research and technology areas described in the report, the state of the art is so advanced that industry could quickly begin product development. In other areas, basic research is needed to acquire necessary knowledge and technological capabilities. In each area of planned research, the gap between the status of current technology and the status envisioned by NGATS should be understood and a plan developed to bridge that gap. In some areas, this could be a substantial problem, given the well-documented problem that basic research programs often do not mature promising new technologies to the point where managers in industry are ready and willing to take over responsibility for advanced research and product development. This can also be a problem when transitioning technology from a federal agency focused on research (such as NASA) to another federal agency focused on operations (such as the FAA). The IPTs should develop a transition plan with clear criteria defining states of technological readiness for each technology that may encounter this problem.

AIRPORT IMPROVEMENTS

The Integrated Plan's transformation strategy for airports is titled "Develop Airport Infrastructure to Meet Future Demand." This title expresses both the goal (enable airports to meet future demand) and the approach (develop new infrastructure). As described in the Integrated Plan, the associated Airport Infrastructure IPT will focus on infrastructure improvements and expansion of airports. By omission, these plans seem to discount the ability to increase the capacity of existing airports by procedural changes such as those enabled by (1) the timely dissemination of precise information related to the position and velocity of aircraft, adverse weather, wake vortices, and the state of the air transportation system and (2) aircraft and ground facilities equipped to use this information effectively. Building new airports and new runways (especially if current procedural constraints on separation standards between parallel runways do not allow new runways to fit on existing airport property) is extraordinarily expensive and can take decades to complete. And in many areas, land for airport expansions and new airports is simply unavailable. Environmental issues also limit the ability of airports to expand their infrastructure. During the 1990s, environmental issues forced 12 of the nation's 50 busiest commercial airports to cancel or indefinitely postpone expansion projects (GAO, 2000). Thus, solutions that substantially increase the capacity of existing runways are potentially quite advantageous. Large payoffs would also result from the ability to conduct independent flight operations on closely spaced parallel runways in limited visibility using the performance-based area navigation and flight management capabilities in many existing aircraft.

Eighteen of the nation's 35 busiest airports are already at capacity limits or will reach capacity limits sometime in the next 15 years (FAA, 2004). One aspect of the effort to enable airports to meet higher demand might be to conduct an airport-specific analysis of impediments to higher capacity at these airports. The analysis would investigate solutions that are (1) generally applicable or (2) must be tailored to individual airports. The latter will tend to be more expensive than the former on a per airport basis, but both types of solutions should be considered. In general, the most effective solutions are likely to involve an integrated approach that involves aircraft and ATM technologies, procedures, and standards, including those related to required navigation performance (RNP) and area navigation (RNAV) capabilities.

AIRCRAFT NOISE, EMISSIONS, AND WATER QUALITY

Notwithstanding changes in demand, the air transportation system must continue to satisfy environmental requirements related to aircraft noise, local and global impacts of engine emissions, and water quality. Efforts to satisfy higher demand should include a balanced strategy for improving technologies, operational procedures, and policies related to environmental performance of the air transportation system. Achieving these improvements would be facilitated by the development of (1) improved metrics that better reflect the impacts of technologies, operational procedures, and policies and (2) improved tools that facilitate the assessment of interdependencies and trade-offs. The environmental strategy should also include a global perspective, because commercial aircraft are manufactured for a global market and buyers expect them to be compatible with the global air transportation system.

Research to improve the environmental performance of aircraft will likely remain the domain of domestic and foreign aircraft and engine manufacturers, research institutions, and government agencies, such as NASA and the Department of Defense. The environmental strategy should recognize that aircraft and engine manufacturers generally respond to four major drivers:

- safety and reliability issues
- legislation and regulatory standards, including standards for noise and emissions
- competitive and economic pressures on fuel consumption, noise, maintainability, etc.
- customer needs and field service issues

The assessment committee received a five-page summary of plans under development by the Environmental Protection IPT for FY 2007 to 2011. This summary, which appears in Appendix G, describes a strategy that is well thought out, appropriate, and consistent with the above guidance. Although the information contained in the summary is preliminary, it describes a credible way forward and should be incorporated into future editions of the Integrated Plan. Further, the Environmental Protection IPT is to be commended for adopting a process that begins by defining initial goals, key uncertainties and risks (including uncertainties in the NGATS architecture), programmatic priorities, and the other topics included in its plan.[1] The general processes employed by this IPT and the structure of its plan would serve as useful models for the other IPTs.

GLOBAL HARMONIZATION

Global harmonization of NGATS will require that harmonization issues be considered in the development of each operational concept and each IPT. A willingness to maximize the use of existing technologies and procedures, including foreign technology, even when that technology must be licensed for use by the U.S. air transportation system, would facilitate the development of new capabilities by reducing costs and schedule (relative to an approach that duplicates research that has already been completed overseas) and by building in harmonization (to the extent that technologies and procedures already in use by other countries are adopted into the U.S. air transportation system). Failure to collaborate would reduce the international competitiveness of U.S. aircraft and ATM technology if standards sponsored by foreign organizations became the global standard. Global harmonization is a high priority and cannot be accomplished by a small interdepartmental office such as the JPDO without the active involvement of other federal agencies, including the FAA and NASA, and the support of both the administration and the U.S. Congress.

Finding 4-4. Global Collaboration. U.S. leadership in fostering a substantial increase in collaboration with foreign organizations in Europe, Asia, and elsewhere would facilitate development of the Next Generation Air Transportation System and help ensure the competitiveness of U.S. aircraft and air traffic management technology.

Recommendation 4-3. Global Collaboration. The FAA administrator and the secretary of transportation should immediately undertake a more vigorous effort to lead development of the Next Generation Air Transportation System in collaboration with foreign governments and institutions. This should include jointly funded, collaborative research to define NGATS operational concepts suitable for global implementation.

REFERENCES

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[1]The Environmental Protection IPT has also estimated funding requirements for FY 2007 to 2011, but that information was not provided to the assessment committee.

5

Implementation

Numerous efforts have been made during the last 10 years to improve the performance of the U.S. air transportation system. Lessons learned from these efforts include the following:

> ATC [air traffic control] system development and implementation are chronically delayed, in large part due to shortcomings in analyzing and establishing operational requirements. . . . Key criteria necessary for more effective ATC system development include stable leadership within the organization, multidisciplinary development teams that cross organizational and public-private boundaries, and a commitment and understanding throughout the organization that ATC system development must be more operationally driven than technology driven. . . . Modernization efforts [for the National Airspace System] have most often been held up by inadequate understanding of operational and procedural issues, rather than by insufficient technological expertise. (OTA, 1997, pp. 4, 17, 28)

> Expanding capacity is not only a function of technology, infrastructure, and design; it is also directly related to how air traffic services are managed and implemented. . . . While technology and procedures will make [a higher] capacity goal functionally possible, it is continued collaboration between government and the aviation community that will make it happen. (FAA, 2005c, pp. 3, 13)

> The proposed schedule for modernization [of the National Airspace System] is too slow to meet projected demands and funding issues are not adequately addressed. (Gore, 1997)

> FAA's organizational culture has been an underlying cause of the agency's acquisition problems. Its acquisitions were impaired because employees acted in ways that did not reflect a strong commitment to mission focus, accountability, coordination, and adaptability. . . . In reporting on FAA's acquisitions, several observers have found that accountability was not well-defined or enforced for decisions on requirements and oversight of contracts—two essential responsibilities in managing acquisitions. (GAO, 1996, pp. 3, 5)

> The FAA estimates that it will need $13 billion over the next 7 years to continue its modernization program. However, persistent acquisition problems raise questions about the agency's ability to field new equipment within cost, schedule, and performance parameters. (GAO, 1996, p. 2)

> Appropriations [for the FAA] should be made on a multiyear basis. . . . This process will promote better overall business planning and provide greater stability for the FAA's safety, security and public use functions. (Mineta, 1997, p. 35)

> The current funding level of FAA's capital account is not sustainable. This is a result of the combined effects of increased operations costs (salaries) and the fact that modernization projects have suffered so much cost growth that there is little room for new initiatives. This explains why most of FAA's efforts now focus on keeping things running, or "infrastructure sustainment." And this is why there is so much discussion about how to finance new air traffic management initiatives. (DOT-IG, 2005, p. 4)

> The challenge for the Operational Evolution Plan [to modernize the National Airspace System] is to find ways to continue to develop National Airspace System capacity in collaboration with an aviation community that is hard-pressed to invest in new avionics, test new systems, and commission new runways, and to do so when the agency's own resources are limited. (FAA, 2005c, p. 3)

> The future of U.S. aviation is global. International safety and environmental regulations and ATC standards and

> operational procedures are becoming increasingly important to U.S. aviation industry economics. (OTA, 1997, p. 13)

The Integrated Plan has little to say about implementation other than to acknowledge that the IPTs will need to address implementation and transition issues. For example, Chapter 6 of the Integrated Plan, "Approach to Transformation," contains only a short section on changes in interactions between the government and the private sector, and the discussion is quite general. Much more work is needed to enable successful implementation of NGATS.

The Integrated Plan acknowledges that "the ability to manage effectively across government agencies and fuel government/industry partnerships as the engine of transformation has never been more critical to this country. . . . Planning and executing a transformational program through partnership requires identifying the key partners, establishing an organizational framework, and implementing processes that support their collaboration" (NGATS JPDO, 2004, p. 22). The assessment committee believes the JPDO's implementation approach should use organizational collaboration and focus on development of operational products. Successful implementation of NGATS requires an Integrated Plan that does the following:

- Clearly addresses the needs of the traveling public, shippers, and other system users, which vary with fluctuations in the economy.
- Establishes a source of stable funding suitable for development, implementation, and operation of NGATS, including capital improvements.
- Proposes reforms in governance and operational management that assure accountability and limit the effect of traditional external influences. The interests of individual stakeholders should be balanced with the common good in a way that expedites the deployment of optimal technologies and procedures and achieves the primary goal of meeting increased demand.
- Defines an NGATS that efficiently interfaces with the rest of the global air transportation system.

OUTREACH AND INCENTIVES FOR CHANGE

Most airspace congestion problems in the United States disappeared on 9/11 because of the large decline in commercial air travel. Demand is now recovering to pre-9/11 levels, however, and substantial airspace congestion will recur if modernization efforts do not increase capacity quickly enough. The situation would be exacerbated if the use of small IFR aircraft for intercity travel increases substantially, as the JPDO projects.

The JPDO and the Integrated Plan should clearly and convincingly define the problems that the air transportation system faces and how the changes proposed by the Integrated Plan will solve those problems. Because of the divergent self-interests of different members of the community, reaching consensus will require consistently strong, high-level leadership.

One of the most difficult implementation challenges will be motivating stakeholders to accept change that may lead to an uncertain future in terms of the costs that each stakeholder must bear and the benefits that will accrue. This will be especially difficult where stakeholders are asked to look past their self-interest to improve the air transportation system in ways that primarily benefit others. In some cases, the government can simply mandate change and require industry and other stakeholders to comply, but such an approach is not always appropriate, helpful, or even possible. Economic incentives can be effective and should be considered, though they are often difficult to implement equitably. Even within the federal government, it is often difficult to get action unless a situation is in crisis, yet the goal of the JPDO is to avoid an air transportation crisis rather than wait for one to act as the engine for change. As part of the JPDO's outreach effort, it is working with state aviation organizations and FAA staff involved with the FAA's Operational Evolution Plan.

The Integrated Plan states on page 24 that the Senior Policy Committee and JPDO "must create a new model of collaboration throughout government and industry." Currently, Europe seems to be advancing faster than the United States in many areas covered by the Integrated Plan. Factors contributing to European success include the following:

- The Europeans recognize the traveling public as the primary customer for the system.
- A powerful champion (a former vice president of the European Commission) has supported changes to the current system.
- Europe has been much more willing to mandate some changes than the United States. For example, despite having comparably complex airspace system, Europe implemented reduced vertical separation minima from 2,000 feet to 1,000 feet long before these changes were implemented in the United States.
- Government-industry cooperation has been more effective than in the United States, in part because it is so difficult for U.S. airlines and other important stakeholders to reach consensus on key issues. Moving forward will be very difficult in the United States without a process that (1) fairly balances the need to create an air transportation system that can meet future demand while avoiding undue hardship for any particular element of the air transportation system and (2) ensures that changes endorsed by a majority of the U.S. air transportation community acting in the national interest cannot be thwarted by the opposition of a vocal minority acting out of self-interest without due regard for the national interest.

- European efforts to improve their transportation system have not tried to do everything for everybody—an approach that is facilitated by (1) the relatively small size of the business aviation community in Europe and (2) the virtual absence of general aviation and recreational aviation activities.

The Master IPT should identify policy and research decisions that the JPDO will need to investigate in coordination with the policy office of the FAA and other agencies.

SYSTEMS INTEGRATION AND PROGRAM MANAGEMENT

Neither the Senior Policy Committee nor the Master IPT will effectively substitute for or diminish the importance of having a competent systems integration capability directed by a strong, fully involved program manager to create and carry out NGATS development and implementation. The JPDO's scope makes systems integration a difficult challenge—a challenge that is exacerbated by the current IPT organization, in which the IPTs (1) are not aligned with functional requirements and (2) are headed by five different agencies. Effective systems integration requires that the program manager lead the systems integration organization in defining system goals and the path toward implementation. The capabilities of the Master IPT, which has been designated as the JPDO's systems integrator, must be substantially enhanced to accomplish the above.

The Master IPT should establish an explicit strategy for the use of a shared modeling and simulation capability by all IPTs so that their results can be tested within the overall operational concepts and system architecture using common assumptions and common goals. This modeling and simulation capability should be used in a cost-effective manner, starting with high-level assessments that evolve to later support high-fidelity, detailed assessments over a broad scope.

The systems integration process should also ensure that safety, security, and human factors are considered from the beginning by each of the operational IPTs, to ensure these important factors are considered throughout the development of new technologies, systems, and procedures. Human factors planning during the development of operational concepts, regulations, and system architecture should include consideration of the role of humans and requirements related to personnel selection, training, and information and control.

CERTIFICATION

As the NGATS operational concepts and system definition are developed, certification requirements for aircraft, ground systems, procedures, pilots, and other system operators must be contemporaneously identified to ensure that implementation is not unduly delayed. The JPDO should explicitly incorporate certification requirements into the Integrated Plan and the plans of the IPTs in a timely manner. The JPDO should also support efforts to foster a systems-oriented approach to certification and other efforts to reduce the time and cost required for certification of new equipment and procedures.[1]

RESOURCES

Funding the development and implementation of NGATS is a major challenge for the FAA and the aviation community as a whole. One measure of the near-term success of the JPDO will be the extent to which the funding and staff allocated by each federal department and agency involved in the JPDO are consistent with JPDO efforts to implement NGATS. For example, some of the proposed reductions in NASA's aeronautics budget, especially with regard to environmental research, are not consistent with the JPDO's research goals and would threaten the ability of the JPDO to develop NGATS as described in the Integrated Plan.

Successful implementation of the NGATS vision, goals, and concepts of operations requires the following:

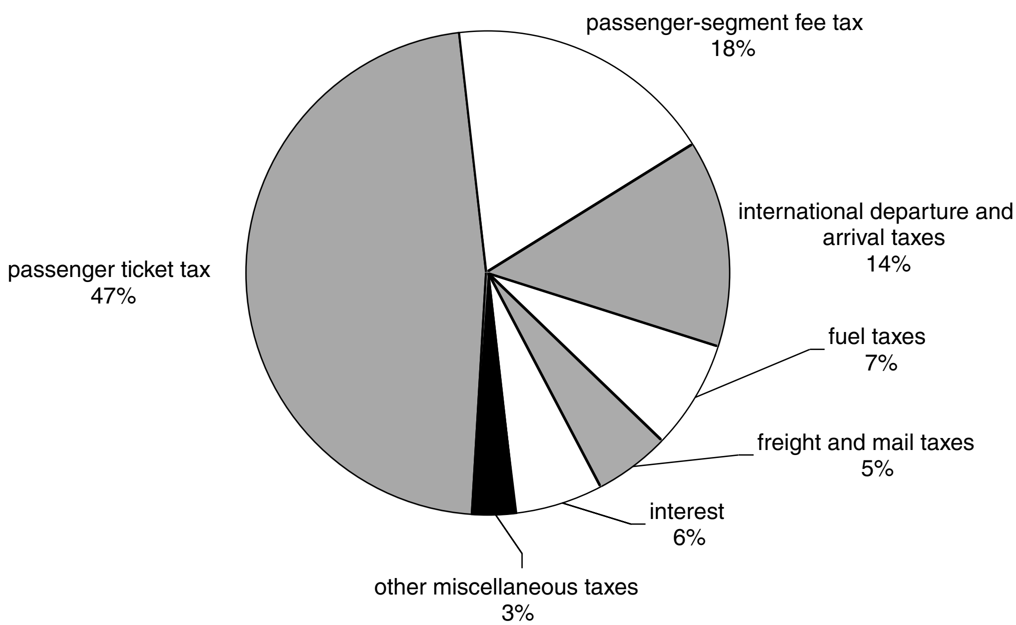
- a source of stable funding
- broad support by air transportation system stakeholders to build the public support needed to generate and sustain congressional support for aligning the federal budget with the Integrated Plan and for making other necessary changes
- an acquisition and implementation plan that is consistent with (1) the ability of all users of the air transportation system to provide revenue and (2) whatever additional funding federal and state governments may choose to provide in recognition of the contribution that the air transportation system makes to national and local economies and public well-being

The current version of the Integrated Plan does not describe the anticipated annual cost of carrying out NGATS research and development activities, because detailed plans are still being prepared by the IPTs. The cost of developing, implementing, and operating NGATS is important because the total costs will be quite substantial, and government and industry resources are expected to be scarce. This is especially true for the airline industry, which is the primary source of revenue and taxes that fund the air transportation system. Operation, maintenance, and modernization of the National Airspace System are funded primarily by the Airport and Airway Trust Fund and, to a lesser extent, by general appropriations from the federal budget. Industry also

[1]Certification issues related to modernization of the air transportation system are addressed in greater detail in the final report of RTCA Task Force 4, issued February 1999 by the RTCA Certification Task Force. Available online at <www.rtca.org/doclist.asp>.

invests heavily in aeronautics research, and the FAA has authorized many airports to collect a passenger facility charge of up to $4.50 per departing passenger to help fund local airport improvements. Nevertheless, the burden of funding development and implementation of NGATS will likely fall primarily on the Airport and Airway Trust Fund and whatever general appropriations are made available for NGATS activities by the FAA, NASA, and other federal agencies.

The Trust Fund's single largest source of income is a 7.5 percent tax on airline tickets (see Figure 5-1), so Trust Fund revenue is closely tied to average ticket price and airline



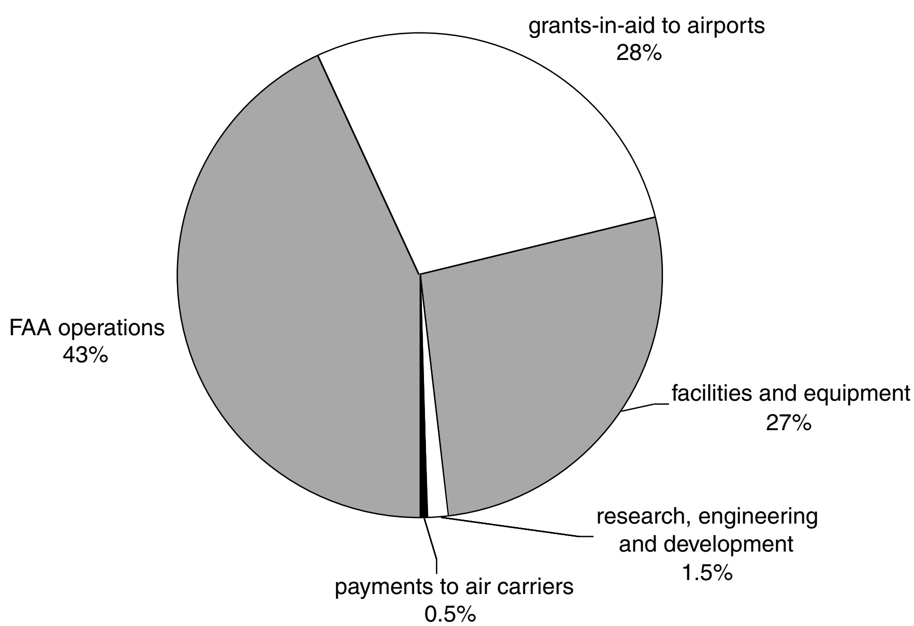


FIGURE 5-1 Airport and Airway Trust Fund: income (*top*) and expenditures (*bottom*). In FY 2004, income totaled $9.7 billion and expenditures totaled $10.4 billion. SOURCES: OMB, 2005; DOT-IG, 2005.

TABLE 5-1 Trust Fund Income and FAA Operational Expenses per IFR Operation, FY 2003 and 2004

	FY 2003	FY 2004	Change (%)
Number of IFR operations	17,041,146	17,975,226	5.5
Total Trust Fund income	$9,372,000,000	$9,687,000,000	3.4
Trust Fund income per operation	$550	$539	–2.0
FAA operational expenses (budget authority)	$7,023,000,000	$7,479,000,000	6.5
Cost per operation (budget authority)	$412	$416	1.0
Cost of IFR operations (actual outlays)	$7,144,000,000	$7,186,000,000	0.6
Cost per operation (actual outlays)	$419	$400	–4.6
Total FAA budget authority	$13,540,000,000	$14,109,000,000	4.2
Cost per IFR operation (total FAA budget)	$795	$785	–1.2
Total FAA outlays	$12,560,000,000	$12,835,000,000	2.2
Cost per IFR operation (total FAA outlays)	$737	$714	–3.1
Trust Fund expenditures (outlays)	$9,618,000,000	$10,415,000,000	8.3
Trust Fund expenditures per operation	$564	$579	2.7

SOURCES: OMB, 2004, 2005; FAA, 2005d.

revenue. In recent years, however, the airline industry has lost much of its economic vitality as intense competition from low-cost airlines dramatically reduced average airfares and curtailed airline income and profitability. During 2004, U.S. commercial airlines experienced an 11 percent growth in demand (in terms of revenue passenger miles), and total demand (along with load factors) exceeded pre-9/11 levels by 3 percent. Nonetheless, during 2004 U.S. airlines as a whole experienced operating and net losses of $3 billion and $6 billion, respectively. Many major carriers remain at the brink of bankruptcy, are in bankruptcy, or recently emerged from bankruptcy (FAA, 2005b).

Early in FY 2004, the FAA was reorganized as a single, performance-based organization. Because of reduced ticket prices, Trust Fund income per IFR operation in 2004 was 2 percent less than in 2003. Total income increased, however, because the total number of IFR operations increased by 5 percent. In addition, the cost of FAA operations per IFR flight increased only slightly in 2004 (by 1 percent, if cost is assumed to equal the allocated budget for FAA operations), or it decreased by 5 percent (if cost is assumed to equal actual outlays) (see Table 5-1).

The Trust Fund had a balance of $12.4 billion at the beginning of FY 2004. A continuation of (1) current funding practices by the federal government and (2) current pricing policies and economic conditions in the airline industry is almost certain to deplete the Trust Fund. The balance could be reduced to $10.9 billion by the end of FY 2006 (OMB, 2005) and to $4.4 billion by the end of FY 2009 (FAA, 2005a), and the Trust Fund could be facing a cumulative deficit of more than $12 billion by 2025 (Cordle and Poole, 2005). Given ongoing concerns about the size of the federal budget deficit, it is problematic to assume that general tax revenues will be readily available to pay for whatever expenses the Trust Fund cannot cover. In addition, increased appropriations (or higher aviation tax rates, or other sources of funding) will be needed to preserve the Trust Fund to the extent that the substantial cost of developing and implementing NGATS exceeds currently planned budgets for modernization of the National Airspace System.

On the other hand, the Trust Fund's financial situation will be improved to the extent that trust fund income exceeds expectations (e.g., as a result of increases in the quantity of air travel and/or average ticket prices). In any case, Trust Fund balances for future years cannot be predicted with confidence because of the many uncertainties that affect Trust Fund income and expenditures. In particular, the aviation taxes that sustain the Trust Fund will expire in September 2007. Even if one assumes that the taxes will be renewed in FY 2008 by the next FAA authorization act, it is impossible to know what the future tax rates will be. For example, the tax rate on airline tickets has been 7.5 percent since FY 2000, but for most of the 1990s the rate was 10 percent, and during the 1980s it varied from 5 percent to 8 percent. Since the ticket tax accounts for about one-half of Trust Fund income, the accuracy of projected Trust Fund balances beyond 2007 is heavily dependent on the accuracy of current assumptions about future aviation tax rates.

The financial picture is further complicated by the federal system of budgeting, because the uncertainty of annual appropriations makes it more difficult to develop and carry through on long-term plans and commitments.

Long-term projections of Trust Fund balances also presume that the means of funding FAA operations will remain essentially unchanged, despite ongoing efforts by the FAA and others to substantially change the FAA funding model. The assessment committee did not evaluate funding mechanisms and takes no position on the appropriateness of various options, except to note that the implementation of NGATS will require a reliable source of adequate funding, and this challenge will obviously be mitigated if costs can be reduced. The FAA expects ongoing business problems in the airline industry to create additional pressure on the FAA to "improve productivity, manage costs, and cut back on services that provide little value" because "near-term funding is threatened by the decreasing balance of the Airport and Airway Trust Fund, and trends within the aviation industry strongly suggest diminishing contributions to the Fund in the years ahead"; in addition, the FAA "must address both badly needed modernization and one-for-one replacement of experienced retirees at a time when the workload is growing more complex." To succeed, the FAA believes that stakeholders "will have to collaborate in meaningful, forward-thinking ways, setting aside narrow interests and focusing on a future that best serves all" (FAA, 2005d, p. 51). The assessment committee concurs, with the caveat that changes in governance and operational management of the National Airspace System may be needed to limit the ability of individual, self-interested stakeholders to slow or put a stop to proposed changes in the sources of funding or in the design or operation of the National Airspace System. The assessment committee would endorse efforts to cut costs, for example, through closure of nonessential activities and facilities, perhaps using a process similar to the Department of Defense Base Realignment and Closure (BRAC) process.[2] In addition, incorporating cost data into the planning process would help prioritize requirements and improve the focus of IPT research and objectives.

Finding 5-1. JPDO Resources. Sufficient resources are not currently available to the JPDO for it to successfully define the Next Generation Air Transportation System and an appropriate implementation plan.

Finding 5-2. Funding Stability. Development, implementation, and operation of the Next Generation Air Transportation System require a plan to assure adequate, stable funding.

Recommendation 5-1. Funding Allocation. The members of the Senior Policy Committee should ensure that the federal agencies they direct or represent allocate funding and staff to (1) provide the JPDO with the resources it needs to define the Next Generation Air Transportation System and draw up an appropriate implementation plan and (2) ensure departmental and agency research in civil aeronautics is consistent with JPDO plans to enable and implement new operational concepts. Reductions in NASA's aeronautics program that would significantly curtail research necessary to achieve goals related to environmental protection and other core research identified by the JPDO should be avoided and/or corrected.

Recommendation 5-2. Funding Model. The secretary of transportation and the FAA administrator should lead the development of a proposal to adequately fund the development, implementation, and operation of the Next Generation Air Transportation System. This proposal should consider a wide range of options for providing necessary funding, both public and private, and for eliminating unnecessary costs.

Recommendation 5-3. Cost Reductions. The implementation plan for the Next Generation Air Transportation System should explicitly address ways to reduce the cost of system implementation and operation.

[2]The basic goal of the BRAC process is to eliminate excess physical capacity to reduce the costs of operating, sustaining, and recapitalizing Department of Defense facilities. BRAC also has the potential to better align infrastructure with overall agency strategy and improve operational capabilities and efficiency.

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6

Summary

The assessment committee considers the timely preparation of the first edition of the Integrated Plan to be a positive first step. The plan recognizes the critical importance of air transportation to the nation's well-being and acknowledges that importance by including a wide variety of stakeholders in the process of developing NGATS. Even so, substantial improvements in the Integrated Plan and the method by which it is being implemented are essential.

Summary Recommendation. The secretary of transportation, the FAA administrator, the rest of the Senior Policy Committee, and the JPDO should invigorate development, implementation, and operation of the Next Generation Air Transportation System, especially with regard to the development of core technologies and processes, as follows:

- Focus the work of the JPDO on development of a systematic, risk-based approach for achieving the primary objective, which is to resolve demand issues and increase capacity while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness.
- Restructure the JPDO as a product-driven organization with three coordinated operational concepts and three IPTs focused on (1) airport operations, (2) terminal area operations, and (3) en route and oceanic operations (plus the Master IPT for systems integration and oversight).
- Consistently provide the JPDO and its IPTs with strong, fully involved leadership and program management capabilities, along with more full-time staff.
- Draw up a plan to establish a viable source of stable funding and a governance structure suited to the Next Generation Air Transportation System.
- Undertake a more vigorous effort to collaborate with foreign governments and institutions, to include jointly funded, collaborative research to define operational concepts suitable for global implementation.

Findings and Recommendations

A complete list of the committee's findings and recommendations appears below, in the order in which they appear in the report.

Finding 2-1. Demand. The health of the U.S. economy is dependent upon an air transportation system that efficiently satisfies demand for passenger travel and air cargo. Anything that limits the ability of the air transportation system to efficiently satisfy demand is harmful to air transportation providers, users of the air transportation system, and the national economy as a whole. The JPDO Integrated Plan discusses the importance of demand, but often in the context of other objectives that are given equal or greater weight.

Recommendation 2-1. Demand. The Integrated Plan should clearly state that increased demand is the key driver that mandates implementation of the Next Generation Air Transportation System. The JPDO should refocus its efforts on development of a systematic, risk-based approach for achieving the primary objective, which is to resolve demand issues and increase capacity, while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness. The Integrated Plan should make sure that secondary objectives, such as alignment of existing interagency efforts, do not overshadow the primary objective. The JPDO should establish goals related to cost, schedule, and level of performance that can be quantified using appropriate figures of merit. Multiple candidate scenarios and operational concepts should be defined and assessed in terms of the risk that they will fail to achieve these goals.

Finding 3-1. Operational Concepts. The Integrated Plan implies that it will develop separate operational concepts for security operations, safety assurance, airport operations, aircraft operations, and ATM operations. Safety and security are inherent in the execution of the latter three, and operational concepts that integrate safety and security considerations from the beginning are more likely to satisfy system requirements than concepts that have safety and security imposed later in the development process.

Recommendation 3-1. Operational Concepts. The JPDO should define operational concepts to satisfy future demand by phase of operation:

- airport operations
- terminal area operations
- en route and oceanic operations

Safety and security risk management systems should be embedded in each of the above operational concepts, not set apart as separate considerations. The Integrated Plan should describe an iterative process for defining and assessing operational concepts as they relate to quantifiable system performance goals. The process should involve discussions with stakeholders and progressively more detailed modeling and simulation to assess performance and identify problems and guiding principles. The JPDO should support research to enhance and assess modeling and simulation capabilities.

Finding 4-1. IPT Organization. Even though the current IPTs have multiagency membership, they are functioning primarily as experts in specific disciplines rather than as cross-functional, integrated, multidisciplinary teams that can deliver specific products to improve operational capabilities of the air transportation system.

Recommendation 4-1. IPT Organization. As soon as possible, the JPDO's IPT organization should be modified to better support the core goal of meeting increased demand in each phase of operation by structuring the IPT organization to match the structure recommended for the operational concepts. All of the current IPTs (except for the Master IPT) should be disbanded and replaced with three new IPTs:

- Airport Operations IPT
- Terminal Area Operations IPT
- En Route and Oceanic Operations IPT

Finding 4-2. IPT Linkages. As currently organized, none of the IPTs interact sufficiently with all of the other IPTs with which they have shared responsibilities. The current IPT structure creates a potential for substantial overlap and duplication of effort. The recommended restructuring of IPTs would solve this problem.

Finding 4-3. Core Research. Adequate support of all core technologies and processes upon which the Next Generation Air Transportation System will be built is crucial to validate the Integrated Plan.

Recommendation 4-2. Core Research. The NASA administrator should continue—and the Senior Policy Committee and the JPDO should advocate for continuation of—research on core technologies and processes, including automation and human factors, necessary to develop the Next Generation Air Transportation System.

Finding 4-4. Global Collaboration. U.S. leadership in fostering a substantial increase in collaboration with foreign organizations in Europe, Asia, and elsewhere would facilitate development of the Next Generation Air Transportation System and help ensure the competitiveness of U.S. aircraft and air traffic management technology.

Recommendation 4-3. Global Collaboration. The FAA administrator and the secretary of transportation should immediately undertake a more vigorous effort to lead development of the Next Generation Air Transportation System in collaboration with foreign governments and institutions. This should include jointly funded, collaborative research to define NGATS operational concepts suitable for global implementation.

Finding 5-1. JPDO Resources. Sufficient resources are not currently available to the JPDO for it to successfully define the Next Generation Air Transportation System and an appropriate implementation plan.

Finding 5-2. Funding Stability. Development, implementation, and operation of the Next Generation Air Transportation System require a plan to assure adequate, stable funding.

Recommendation 5-1. Funding Allocation. The members of the Senior Policy Committee should ensure that the federal agencies they direct or represent allocate funding and staff to (1) provide the JPDO with the resources it needs to define the Next Generation Air Transportation System and draw up an appropriate implementation plan and (2) ensure departmental and agency research in civil aeronautics is consistent with JPDO plans to enable and implement new operational concepts. Reductions in NASA's aeronautics program that would significantly curtail research necessary to achieve goals related to environmental protection and other core research identified by the JPDO should be avoided and/or corrected.

Recommendation 5-2. Funding Model. The secretary of transportation and the FAA administrator should lead the development of a proposal to adequately fund the development, implementation, and operation of the Next Generation Air Transportation System. This proposal should consider a wide range of options for providing necessary funding, both public and private, and for eliminating unnecessary costs.

Recommendation 5-3. Cost Reductions. The implementation plan for the Next Generation Air Transportation System should explicitly address ways to reduce the cost of system implementation and operation.

Summary Recommendation. The secretary of transportation, the FAA administrator, the rest of the Senior Policy Committee, and the JPDO should invigorate development, implementation, and operation of the Next Generation Air Transportation System, especially with regard to the development of core technologies and processes, as follows:

- Focus the work of the JPDO on development of a systematic, risk-based approach for achieving the primary objective, which is to resolve demand issues and increase capacity while also satisfying enabling, interrelated requirements for safety, security, environmental effects, consumer satisfaction, and industrial competitiveness.
- Restructure the JPDO as a product-driven organization with three coordinated operational concepts and three IPTs focused on (1) airport operations, (2) terminal area operations, and (3) en route and oceanic operations (plus the Master IPT for systems integration and oversight).
- Consistently provide the JPDO and its IPTs with strong, fully involved leadership and program management capabilities, along with more full-time staff.
- Draw up a plan to establish a viable source of stable funding and a governance structure suited to the Next Generation Air Transportation System.
- Undertake a more vigorous effort to collaborate with foreign governments and institutions, to include jointly funded, collaborative research to define operational concepts suitable for global implementation.

Appendixes

A

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In less than a century, aviation went from spectacle to spectacular. Today, Americans rely on aviation not just for transportation but for recreation as well.

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- 1.2 Gridlock
- 1.3 Global Leadership

Chapter 2 A National Vision for Air Transportation in 2025 6

Transforming the system to meet the needs of the 21st century will ensure U.S. leadership in the global economy. However, major changes are involved in the process.

Chapter 3 System Goals and Performance Characteristics 7

To achieve our vision we need to define the system goals and performance characteristics that will serve as its foundation.

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- 3.2 Expand Capacity
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The Next Generation Air Transportation System will be well equipped to adapt to future demands by using new concepts, technologies, networks, policies, and business models.

- 4.1 Security Operations
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NOTE: The entire Next Generation Air Transportation System Integrated Plan is available online at <www.jpdo.aero>.

Chapter 5 The Next Generation Air Transportation System Roadmap for Success 15
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B

The Vision 100—Century of Aviation Reauthorization Act Public Law 108-176, Sections 709 and 710

SECTION 709. AIR TRANSPORTATION SYSTEM JOINT PLANNING AND DEVELOPMENT OFFICE

(a) ESTABLISHMENT—

(1) The Secretary of Transportation shall establish in the Federal Aviation Administration a joint planning and development office to manage work related to the Next Generation Air Transportation System. The office shall be known as the Next Generation Air Transportation System Joint Planning and Development Office (in this section referred to as the "Office").

(2) The responsibilities of the Office shall include—

(A) creating and carrying out an integrated plan for a Next Generation Air Transportation System pursuant to subsection (b);

(B) overseeing research and development on that system;

(C) creating a transition plan for the implementation of that system;

(D) coordinating aviation and aeronautics research programs to achieve the goal of more effective and directed programs that will result in applicable research;

(E) coordinating goals and priorities and coordinating research activities within the Federal Government with United States aviation and aeronautical firms;

(F) coordinating the development and utilization of new technologies to ensure that when available, they may be used to their fullest potential in aircraft and in the air traffic control system;

(G) facilitating the transfer of technology from research programs such as the National Aeronautics and Space Administration program and the Department of Defense Advanced Research Projects Agency program to Federal agencies with operational responsibilities and to the private sector; and

(H) reviewing activities relating to noise, emissions, fuel consumption, and safety conducted by Federal agencies, including the Federal Aviation Administration, the National Aeronautics and Space Administration, the Department of Commerce, and the Department of Defense.

(3) The Office shall operate in conjunction with relevant programs in the Department of Defense, the National Aeronautics and Space Administration, the Department of Commerce and the Department of Homeland Security. The Secretary of Transportation may request assistance from staff from those Departments and other Federal agencies.

(4) In developing and carrying out its plans, the Office shall consult with the public and ensure the participation of experts from the private sector including representatives of commercial aviation, general aviation, aviation labor groups, aviation research and development entities, aircraft and air traffic control suppliers, and the space industry.

(b) INTEGRATED PLAN—The integrated plan shall be designed to ensure that the Next Generation Air Transportation System meets air transportation safety, security, mobility, efficiency, and capacity needs beyond those currently included in the Federal Aviation Administration's operational evolution plan and accomplishes the goals under subsection (c). The integrated plan shall include—

(1) a national vision statement for an air transportation system capable of meeting potential air traffic demand by 2025;

(2) a description of the demand and the performance characteristics that will be required of the Nation's future air transportation system, and an explanation of how those characteristics were derived, including the national goals, objectives, and policies the system is designed to further, and the underlying socioeconomic determinants, and associated models and analyses;

(3) a multiagency research and development roadmap for

creating the Next Generation Air Transportation System with the characteristics outlined under clause (ii),[1] including—

(A) the most significant technical obstacles and the research and development activities necessary to overcome them, including for each project, the role of each Federal agency, corporations, and universities;

(B) the annual anticipated cost of carrying out the research and development activities; and

(C) the technical milestones that will be used to evaluate the activities; and

(4) a description of the operational concepts to meet the system performance requirements for all system users and a timeline and anticipated expenditures needed to develop and deploy the system to meet the vision for 2025.

(c) GOALS—The Next Generation Air Transportation System shall—

(1) improve the level of safety, security, efficiency, quality, and affordability of the National Airspace System and aviation services;

(2) take advantage of data from emerging ground-based and space-based communications, navigation, and surveillance technologies;

(3) integrate data streams from multiple agencies and sources to enable situational awareness and seamless global operations for all appropriate users of the system, including users responsible for civil aviation, homeland security, and national security;

(4) leverage investments in civil aviation, homeland security, and national security and build upon current air traffic management and infrastructure initiatives to meet system performance requirements for all system users;

(5) be scalable to accommodate and encourage substantial growth in domestic and international transportation and anticipate and accommodate continuing technology upgrades and advances;

(6) accommodate a wide range of aircraft operations, including airlines, air taxis, helicopters, general aviation, and unmanned aerial vehicles; and

(7) take into consideration, to the greatest extent practicable, design of airport approach and departure flight paths to reduce exposure of noise and emissions pollution on affected residents.

(d) REPORTS—The Administrator of the Federal Aviation Administration shall transmit to the Committee on Commerce, Science, and Transportation in the Senate and the Committee on Transportation and Infrastructure and the Committee on Science in the House of Representatives—

(1) not later than 1 year after the date of enactment of this Act,[2] the integrated plan required in subsection (b); and

(2) annually at the time of the President's budget request, a report describing the progress in carrying out the plan required under subsection (b) and any changes to that plan.

(e) AUTHORIZATION OF APPROPRIATIONS—There are authorized to be appropriated to the Office $50,000,000 for each of the fiscal years 2004 through 2010.

SECTION 710. NEXT GENERATION AIR TRANSPORTATION SENIOR POLICY COMMITTEE

(a) IN GENERAL—The Secretary of Transportation shall establish a senior policy committee to work with the Next Generation Air Transportation System Joint Planning and Development Office. The senior policy committee shall be chaired by the Secretary.

(b) MEMBERSHIP—In addition to the Secretary, the senior policy committee shall be composed of—

(1) the Administrator of the Federal Aviation Administration (or the Administrator's designee);

(2) the Administrator of the National Aeronautics and Space Administration (or the Administrator's designee);

(3) the Secretary of Defense (or the Secretary's designee);

(4) the Secretary of Homeland Security (or the Secretary's designee);

(5) the Secretary of Commerce (or the Secretary's designee);

(6) the Director of the Office of Science and Technology Policy (or the Director's designee); and

(7) designees from other Federal agencies determined by the Secretary of Transportation to have an important interest in, or responsibility for, other aspects of the system.

(c) FUNCTION—The senior policy committee shall—

(1) advise the Secretary of Transportation regarding the national goals and strategic objectives for the transformation of the Nation's air transportation system to meet its future needs;

(2) provide policy guidance for the integrated plan for the air transportation system to be developed by the Next Generation Air Transportation System Joint Planning and Development Office;

[1] Section 709 contains no clause (ii). This sentence should probably refer to "subsection (c)".—Ed.

[2] Date of enactment: December 12, 2003. See <www.whitehouse.gov/news/releases/2003/12/20031212-4.html>.—Ed.

(3) provide ongoing policy review for the transformation of the air transportation system;

(4) identify resource needs and make recommendations to their respective agencies for necessary funding for planning, research, and development activities; and

(5) make legislative recommendations, as appropriate, for the future air transportation system.

(d) CONSULTATION—In carrying out its functions under this section, the senior policy committee shall consult with, and ensure participation by, the private sector (including representatives of general aviation, commercial aviation, aviation labor, and the space industry), members of the public, and other interested parties and may do so through a special advisory committee composed of such representatives.

C

Integrated Plan Inventory

The following table lists key elements that should appear in the Integrated Plan according to the Vision 100—Century of Aviation Reauthorization Act, Public Law 108-176, Section 709, Part b. The table also shows where these elements appear in the Integrated Plan.

Key Elements That Should Appear in the Integrated Plan	Where These Elements Appear in the Integrated Plan
1. National vision statement for an air transportation system capable of meeting potential air traffic demand in 2025	See Chapter 2, A National Vision for Air Transportation in 2025.
2. Description of system demand and performance requirements (e.g., safety, security, mobility, efficiency, capacity, quality, affordability, noise, and emissions)	See Chapter 3, System Goals and Performance Characteristics. System goals are as follows: • Retain U.S. leadership in global aviation • Expand capacity • Ensure safety • Protect the environment • Ensure our national defense • Secure the nation
a. How system performance requirements were derived	A justification for each system goal is described, but there is no explicit description of how they were derived.
b. National goals, objectives, and policies the national vision would support	These are generally included in the justification for each system goal described in Chapter 3. See also Chapter 1 discussion of three factors that "threaten the ability of aviation to grow and continue to serve the nation": • Security • Gridlock • Global leadership
c. Underlying socioeconomic determinants	Socioeconomic determinants that underlie the system goals are not mentioned in the plan.
d. Associated models and analyses	Models and analyses associated with the system goals are not described in the plan.

Key Elements That Should Appear in the Integrated Plan	Where These Elements Appear in the Integrated Plan
3. Operational concepts with the potential to meet system performance requirements for all system users	See Chapter 4, Operational Concepts.
a. Scale to accommodate and encourage substantial growth	Not explicitly addressed in Chapter 4, but see • Section 7.1, Develop Airport Infrastructure to Meet Future Demand • Section 7.3, Establish an Agile Air Traffic System
b. Build on current initiatives	Not explicitly addressed in Chapter 4, but see Chapter 6, Approach to Transformation.
c. Integrate data streams from multiple agencies and sources (e.g., ground-based and space-based communications, navigation, and surveillance systems) to improve situational awareness and facilitate seamless global operations	Not explicitly addressed in Chapter 4, but see • Section 7.4, Establish User-Specific Situational Awareness • Section 7.8, Harmonize Equipage and Operations Globally
d. Use the design of airport approach and departure flight paths to reduce public exposure to noise and emissions	Not addressed in the plan.
4. A multiagency research and development roadmap	See Chapter 5, The Next Generation Air Transportation System Roadmap for Success, and Chapter 7, Transformation Strategies.
a. Timelines through 2025 to develop and deploy the system	See Chapter 5, pages 18 and 19, for a very high-level timeline.
b. Most significant technical obstacles and the research and development activities necessary to overcome them, including the role of each federal agency, corporations, and universities for each activity	Information at this level of detail is not included in the Integrated Plan.
c. Technical milestones that will be used to evaluate activities	Information at this level of detail is not included in the Integrated Plan.

D

Statement of Task and Study Approach

STATEMENT OF TASK

The Aeronautics and Space Engineering Board (ASEB) will study the integrated plan for a next generation air transportation system (see <www.jpdo.aero>). The plan has been developed by the Next Generation Air Transportation System Joint Planning and Development Office (JPDO). This study will conduct a technical assessment of the research, development, and technology components of the integrated plan that leads to publication of a study report.

Inputs from the private sector, including representatives of commercial aviation, general aviation, aviation labor groups, aviation research and development entities, aircraft and air traffic control suppliers, and the space industry, will be considered as part of the assessment. The assessment may also discuss and comment upon the process that the JPDO is using to develop and implement the integrated plan, in the context of lessons learned from past air transportation system planning efforts. In particular, the committee may also review planning documents generated by the integrated product teams (IPTs) established by the JPDO, to the extent that the IPT plans provide additional details on how the JPDO intends to achieve its goals and objectives.[1]

The committee will hold approximately three meetings to review the integrated plan and issue a report summarizing key findings and recommendations for improving research and technology development.

The scope of this project includes research and technology components of civil aviation, homeland security, and national security flight operations involving airlines, air taxis, helicopters, general aviation, and unmanned aerial vehicles. The scope does not include the accuracy of cost estimates that may appear in the integrated plan.

[1]As this report was being prepared, the IPTs were in various stages of formation. Most had not yet completed much work, and the committee did not have the opportunity to examine whatever products the IPTs may have generated (except for the Environmental IPT; see Appendix G).

STUDY APPROACH

The committee may comment specifically on four key elements that Congress directed the JPDO to include in the Integrated Plan (see Appendix B: The Vision 100—Century of Aviation Reauthorization Act, Public Law 108-176, Section 709). These elements are as follows:

1. national vision statement for an air transportation system capable of meeting potential air traffic demand in 2025
2. description of system demand and performance requirements (e.g., safety, security, mobility, efficiency, capacity, quality, affordability, noise, and emissions)[2,3]
   a. how system performance requirements were derived
   b. national goals, objectives, and policies the national vision would support
   c. enabling, interrelated socioeconomic determinants
   d. associated models and analyses
3. operational concepts with the potential to meet system performance requirements for all system users

[2]Section 709 of the Act contains two lists of system characteristics, each with five parameters. Both lists include safety, security, and efficiency. The list in ¶709.b has mobility and capacity. The list in paragraph ¶709.c.1 includes quality and affordability. All seven of these items are listed here in the statement of task, along with two other important factors (noise and emissions) that are mentioned elsewhere in Section 709.

[3]Section 709 does not explain what "quality" means, apart from the other eight system characteristics.

a. scale to accommodate and encourage substantial growth
b. build on current initiatives
c. integrate data streams from multiple agencies and sources (e.g., ground-based and space-based communications, navigation, and surveillance systems) to improve situational awareness and facilitate seamless global operations
d. use the design of airport approach and departure flight paths to reduce public exposure to noise and emissions

4. a multiagency research and development roadmap
   a. timelines through 2025 to develop and deploy the system
   b. most significant technical obstacles and the research and development activities necessary to overcome them, including the role of each federal agency, corporations, and universities for each activity
   c. technical milestones that will be used to evaluate activities

E

Biographies of Committee Members

S. MICHAEL HUDSON, *Chair*, recently retired as vice chairman of Rolls-Royce North America. After Allison Engine Company was acquired by Rolls-Royce, Mr. Hudson served as president, chief executive officer, chief operating officer, and a member of the board of directors of Allison Engine Company, Inc. Previously, during his tenure at Allison, he served as executive vice president for engineering, chief engineer for advanced technology engines, chief engineer for small production engines, supervisor of the design for Model 250 engines, chief of preliminary design, and chief project engineer in vehicular gas turbines. Mr. Hudson has good insight into propulsion engineering issues, related business issues, and the European perspective on aviation issues. He has served on five other NRC committees, including the Committee on Aeronautics Research and Technology for Environmental Compatibility, and is a member of the Aeronautics and Space Engineering Board.

THOMAS M. COOK (NAE) is currently chief executive officer of TCI, a small analytical consulting firm specializing in applying operations research to significant business problems. Previously, Dr. Cook was chairman and chief executive officer of CALEB Technologies, an airline software firm, and he served as senior counselor to McKinsey & Company, Inc., focusing on the transportation sector. Prior to working with McKinsey, he developed large-scale information systems for Ling Temco Vought, Inc.; he taught operations research and computer science at both graduate and undergraduate levels for the University of Tulsa and Boston University and consulted with Arthur Young and Company. The majority of Dr. Cook's career was spent with AMR Corporation, starting as director of operations research for American Airlines. He founded and was president of American Airlines Decision Technologies, the world's largest airline software and consulting firm. He concluded his career at AMR as president of Sabre Technology Solutions, a $1 billion information technology services division of Sabre, Inc. Dr. Cook holds a doctorate in operations research from the University of Texas at Austin, a master's degree in business from Southern Methodist University, and a bachelor's degree in mathematics from Grinnell College. He was inducted into the National Academy of Engineering and cited for his leadership in advancing operations research and decision-support technologies within the transportation industry. He is the past president of the Institute of Management Sciences, the Airline Group of the International Federation of Operations Research Societies, and the Institute for Operations Research and the Management Sciences (INFORMS). He has also served as associate editor of *Operations Research*, *Transportation Science*, and *Interfaces*.

VAUGHN CORDLE is chief executive officer and chief analyst of AirlineForecasts, LLC, an independent research firm that specializes in airline industry research and forecasting. Mr. Cordle attended executive education programs at Kellogg and Wharton business schools and received the chartered financial analyst designation from the CFA Institute. He holds an airline transport pilot license and is typed in the following Aircraft: LrJet, CE-500, A320, B727, B737, B747-4, B757, B767, and B777.

JERALD M. DAVIS completed a 37-year career in military and civil service in increasingly demanding positions in military and civil aviation organizations. His last civil service duties were as manager of the Technical Programs Division, Flight Standards Service, FAA Headquarters. Mr. Davis holds an airline transport pilot certificate with type ratings in A300-600, A310, A320, B727, and CE-500. He holds a flight navigator certificate with 20 years' experience in international operations in large turbojets. He has extensive experience in operational proof-of-concept testing, operational research, and the development of national policies, standards, criteria, and procedures for operational evaluation and approval of sophisticated, complex, and controversial flight technical programs for jet aircraft. He directed national FAA policy for all-weather operations, instrument flight procedures, navigation systems, approach and landing systems and minima, collision avoidance systems, and aviation weather and determined the operational suitability of ATC procedures, airport capacity and delay concepts, new aircraft and navigation systems, and pilot training programs. Mr. Davis has a B.S. in electrical engineering from Clemson University. He is currently working as a consultant to Airbus Industrie and the FAA associate administrator for regulation and certification.

JOHN B. HAYHURST recently retired as president of Boeing Air Traffic Management and senior vice president of the Boeing Company after 33 years at Boeing and $3^1/_2$ years in this position. Previously, Mr. Hayhurst was vice president of business development for the Commercial Airplane Services business unit of Boeing Commercial Airplanes Group (BCAG). Prior to this assignment, Mr. Hayhurst served as vice president and general manager of 737 programs. In addition, he was general manager of the BCAG production site in Renton, Washington. Before that, he served as vice president for the Americas and was responsible for the Boeing business relationships with airline customers in North America and Latin America and for the sale of Boeing commercial airplanes to customers in those regions. Mr. Hayhurst joined Boeing in 1969 as a customer support engineer. He held positions of increasing responsibility related to commercial airplanes and in 1987 was promoted to vice president of marketing. In this position, he played a significant role in the launch of the Boeing 777. Subsequently, he was responsible for leading teams planning the design, development, and manufacture of aircraft larger than the Boeing 747. He then served as vice president-general manager of the Boeing 747-500X/600X program. Mr. Hayhurst is a fellow of the Royal Aeronautical Society and holds a bachelor's degree in aeronautical engineering from Purdue University. He received a master's degree in business administration from the University of Washington in 1971. In 1998, Mr. Hayhurst was awarded an honorary doctorate in engineering by Purdue University.

RICHARD MARCHI is senior vice president, technical and environmental affairs, for the Airports Council International-North America (ACI-NA). He is responsible for overall supervision, direction, and coordination of the staff and activities of the ACI-NA Technical and Environmental Affairs Department. The department provides staff support to five ACI-NA committees: Technical Affairs, Environmental Affairs, Small Airports, Business Information Technologies, and Public Safety and Security. He is also responsible for the development, coordination, and presentation of technical, security, telecommunications, and environmental policies for consideration by the ACI-NA board of directors, for the preparation of responses to governmental issues of concern to airports, and for the development of airport testimony on technical matters. He is the association's focal point representative in preparations for International Civil Aviation Organization (ICAO) technical and environmental matters affecting member airports. Mr. Marchi is an active member of several FAA advisory committees and task forces, including the FAA Free Flight Select Committee, the FAA New Large Aircraft Facilitation Group, and the FAA Research, Engineering and Development Advisory Committee, where he serves as chairman of the Airport Technology Research Subcommittee.

AMY R. PRITCHETT is an associate professor in the School of Aerospace Engineering and a joint associate professor in the School of Industrial and Systems Engineering at the Georgia Institute of Technology. Her research encompasses cockpit design, including advanced decision aids; procedure design as a mechanism to define and test the operation of complex, multiagent systems such as ATC systems; and simulation of complex systems to assess changes in emergent system behavior in response to implementation of new information technology. Dr. Pritchett is the editor of *Simulation: Transactions of the Society for Modeling and Simulation* for the air traffic area; associate editor of the American Institute of Aeronautics and Astronautics (AIAA) *Journal of Aerospace Computing, Information, and Communication*; technical program chair for the aerospace technical group of the Human Factors and Ergonomics Society; and co-chair of the 2004 International Conference in Human-Computer Interaction in Aerospace (HCI-Aero).

EDMOND L. SOLIDAY was employed by United Airlines for over 35 years as a pilot, human factors instructor, flight manager, and staff executive. For the last 11 years with United, he served as vice president of safety, quality assurance, and security, and he was responsible for flight safety, aircraft cabin safety, occupational safety, environmental compliance, operational quality assurance, security, computer security, and emergency response. Captain Soliday made significant contributions in the development of emergency response methodologies, flight crew human factors safety initiatives, enhanced ground proximity warning devices, flight operations quality assurance programs (digital performance monitoring and analysis), union-management occupational safety initiatives, code share and express carrier auditing, implementation of aviation industry security screening technology, and risk analysis methodologies. Captain Soliday has served on numerous aviation safety advisory boards and commissions, including the Gore Commission's Aviation Security Baseline Working Group, the Flight Operations Quality Assurance Advisory Rulemaking Committee, the IATA Flight Safety Committee, and the Air Transport Association Environment Executive Subcommittee. He chaired the Commercial Aviation Safety Team, the Air Transport Association Safety Council, the Star Alliance Safety Committee, and the Environmental Committee of the Air Transport Association of America. Captain Soliday currently serves on the executive board of the Flight Safety Foundation, the Massachusetts Institute of Technology Global Airline Industry Program Advisory Group, the Adler Planetarium board of trustees, and the Trinity International University board of regents. In addition, Captain Soliday teaches an introduction to aviation safety and security course at the George Washington University Aviation Institute. He most recently served as a consultant to the Rand Corporation, the Boeing Company, and Greenbriar Equity, LLP. He has been awarded the Bendix Trophy, the Vanguard Trophy, the Laura Tabor Barbour International Air Safety Award, FBI and FAA Distinguished Service Awards, the Distinguished Flying Cross, two Bronze Stars, and the Purple Heart.

HANSEL E. TOOKES II retired as president of Raytheon International, Inc. Mr. Tookes joined Raytheon in September 1999 as president and chief operating officer of Raytheon Aircraft and became chairman and chief executive officer in 2000. Mr. Tookes joined Raytheon from Pratt & Whitney's Large Military Engines Group, where he served as president since 1996. In 1980, Mr. Tookes joined United Technologies Corp. and held increasingly responsible leadership positions at its Norden Systems and Hamilton Standard Division, including executive vice president of aircraft products and vice president of business planning. Mr. Tookes earned a bachelor's degree in physics from Florida State University in 1969, a masters in aeronautical systems from the University of West Florida in 1971, studied quantitative methods at Louisiana State University, and completed the Advanced Management Program at Harvard University.

IAN A. WAITZ is a professor at the Massachusetts Institute of Technology, where he is deputy head of the Department of Aeronautics and Astronautics and a member of the MIT Gas Turbine Laboratory. His principal fields of interest include propulsion, fluid mechanics, thermodynamics, reacting flows, aeroacoustics, and, in particular, aspects of the above that relate to environmental issues associated with aircraft design and operation. Professor Waitz currently directs a variety of experimental and computational research in these areas. He has written approximately 50 technical publications, holds three patents, and has served as a consultant for 25 different organizations and as an associate editor of the AIAA *Journal of Propulsion and Power*. Professor Waitz is the director of PARTNER: The Partnership for Air Transportation Noise and Emissions Reduction, which is the FAA/NASA center of excellence for aircraft noise and aviation emissions mitigation. In 2003 Professor Waitz received a NASA Turning Goals Into Reality Award for Noise Reduction. He is an associate fellow of the AIAA, a member of the American Society of Mechanical Engineers (ASME) and the American Society for Engineering Education, and currently teaches graduate and undergraduate courses in the fields of thermodynamics and energy conversion, propulsion, fluid mechanics, and environmental effects of aircraft. He received MIT's 2002 Class of 1960 Innovation in Education Award and was appointed as a MacVicar Faculty Fellow in 2003. Dr. Waitz served on the NRC's Committee on Aeronautics Research and Technology for Environmental Compatibility in 2002.

DAVID C. WISLER (NAE) has held positions of increasing responsibility for conducting and managing advanced technology programs at GE Aircraft Engines (GEAE) during the last 33 years. He is recognized as an international expert in turbomachinery aerodynamics technology and is currently the manager of University Programs and Aero Technology Laboratories at GEAE. He is responsible for implementing and coordinating research programs in a broad area of technologies, and he serves as the GEAE representative on a number of university advisory boards. He is the research and technology alliances team leader on the Industry-University-Government Roundtable on Enhancing Engineering Education. Dr. Wisler is an invited lecturer at numerous colleges and international conferences and holds adjunct professorships at the Ohio State University, Tsinghua University in Beijing, and the University of Cincinnati. He recently published several papers on critical areas of lifelong learning for engineering professionals. Dr. Wisler is a fellow of the ASME and the only three-time winner of the ASME Melville Medal (1989, 1998, and 2003), which is awarded for the best technical paper in all divisions of ASME. He is the vice president of ASME and the editor of the ASME *Journal of Turbomachinery*. He has a B.S. in aerospace engineering from Pennsylvania State University (1963), an M.S. in aerospace engineering from Cornell University (1965), and a Ph.D. in aerospace engineering from the University of Colorado (1970).

F

An Approach to Assessing Goals and Policies

In general, the appropriateness of a strategy to improve the performance of a large system can be determined by testing the proposed goals and organizational polices for consistency and compatibility with key implementation and operational factors. Although the process below may be intuitively clear, answering the questions may require a great deal of penetrating analysis.

- Internal consistency
  - —What assumptions must be made for the recommended strategy to make sense?
  - —Are the goals mutually achievable?
  - —Do the key policies address the goals and reinforce each other?
- Context
  - —What are the key factors for success and the important opportunities and threats?
  - —Do the goals and policies adequately deal with organizational resources and trends?
    - – What are the capabilities and limitations of key agencies and other organizations?
    - – Do the goals and polices match resource requirements to the organizations that will have to provide the funding?
    - – Does the timing of the goals and policies reflect the ability of involved organizations to change or adapt the strategy recommendations?
  - —Are the goals and policies responsive to broader societal concerns?
  - —Is available managerial capability sufficient to foster effective implementation?
  - —What important governmental, social, and political factors affect the likelihood of success?
  - —What are the feasible strategic alternatives given the analysis above?
- Communication and implementation
  - —Are the goals well understood by the key implementers?
  - —Is there enough congruence between the goals, polices, and values of the key implementers to ensure commitment?
  - —Strategic choice: Which alternative best relates the JPDO's policies and goals to external opportunities and threats?

G

Draft Plans by the Environmental Integrated Product Team

FY 2007 TO 2011 PLANS AND BUDGET REQUIREMENTS FOR DEVELOPMENT OF ENVIRONMENTAL PROTECTION THAT ALLOWS SUSTAINED AVIATION GROWTH

Background

In developing the initial plans, policies, and resource estimates for the environmental portion of the Next Generation Air Transportation System (NGATS) plan, the following are the initial goals identified by the Environmental Integrated Product Team (EIPT):

- Reduce the impacts of significant aviation noise to community well-being in absolute terms, notwithstanding the growth in aviation.
- Reduce the significant local air quality impacts of aviation on local communities in absolute terms, notwithstanding the growth in aviation.
- Develop the appropriate metrics and models to measure aviation's environmental impacts for the system of 2025.
- Gain sufficient knowledge of the particulates and hazardous air pollutants effects of aviation to determine significant impact.
- Gain sufficient knowledge of climate change effects of aviation to enable appropriate means to mitigate these effects.
- Reduce significant levels of water runoff from airports to minimize impacts on local community water resources.
- Foster communication, ideas, and joint action between the EIPT and communities around airports.
- Facilitate global leadership in developing operational, technology, and policy options to address mobility and environmental needs.
- Advance capacity growth at the key airports by fostering capabilities and processes to streamline environmental reviews.
- Ensure standards exist in a timely fashion to enable new operations, such as domestic supersonic flights, space launches, low-altitude reconnaissance, alternative-fuel air vehicles, etc.

In assessing the ability to deliver on these outcomes, the EIPT understands that the initial national air transportation system architecture for the system of 2025 proposes an approach that relies on net-centric information services available both nationwide and globally that ensure real-time information flows from a variety of governmental and nongovernmental sources. To achieve threefold capacity growth in the next 20 years, the air traffic system architecture would allow dynamic airspace configuration management and differentiated service levels aligned with user abilities, would rely on management by trajectory, with block-to-block coverage and NAS (National Airspace System)-wide, time-based metering, and would develop superdense operations at selected airports.

Critical to achievement of this plan is reducing environmental impacts, especially as aircraft noise and local air quality emission concerns remain strong (and growing) constraints on system capacity. Over the past decade, such issues have caused plans to expand airport capacity to be canceled, delayed, and downscaled. "Air portals"—whatever the eventual number developed in NGATS—will need to deal with the current environmental concerns of the communities surrounding them. Further, depending on ongoing research, additional local air quality and climate change issues could

NOTE: This information was provided to the assessment committee by Carl Burleson, Director, Office of Environment and Energy, Federal Aviation Administration, who is head of the Environmental IPT.

surface that pose additional challenges to capacity expansion. Finally, this is not only a commercial aviation issue, as military readiness is also being challenged by restrictions on training and operations. These effects will be exacerbated by aviation growth.

Compounding the environmental issues is the fact that aviation has features that distinguish it from other transportation modes and industries. The high premium placed on safety demands the incorporation of only proven and technically sound environmental technologies in aircraft, as well as on the ground (e.g., deicing for aircraft and airport runways). Aircraft are expensive and have a long life span, requiring long lead times for new technologies to be widely incorporated in the fleet and close attention to financial feasibility. Airborne systems must be lightweight and fuel-efficient. Noise, local and regional air quality, and potential climate effects are engendered by an interdependent set of technologies and operations, so that action to reduce impacts in one area (e.g., aircraft engine noise) can increase the impacts in another (e.g., nitrogen oxides emissions). All these factors combine to make it challenging to quickly incorporate new technologies, rapidly change fleets, or manage multiple environmental impacts without trade-offs.

Key Uncertainties in NGATS Architecture

In developing the environmental roadmap for implementing the draft NGATS architecture, a number of uncertainties remain that will have a large influence on the success of tackling the environmental dimension in delivering the NGATS plan. Some critical ones include:

- *Capacity results.* It is uncertain whether the draft architecture will produce the targeted three times growth in capacity of the NGATS endeavor. Further, it is not clear what the definition is for capacity—whether it's measured in passengers or operations. Both these factors will have a large influence on potential environmental impacts and whether the current plans and initiatives have any prospect of success.
- *Number and location of "air portals."* It is not clear at this juncture whether NGATS will be delivering aircraft in the same airport patterns of today or something vastly different. Will the majority of traffic involve the top 50 airports, or will it spread to hundreds or thousands of air portals? The potential environmental footprint of aviation—and hence the investments required to shrink that footprint—will be vastly different depending on this number.
- *Required environmental performance.* It remains to be developed how to work in the environmental performance requirements for air traffic services, aircraft, and airports in a system that operates on multiple, differentiated service levels aligned with each user's ability to meet different levels of Required Total System Performance. Further, given the capabilities that new technologies may offer, a balance between applying these abilities in expanding capacity versus minimizing environmental impacts will need to occur.
- *Cost and timing of delivery.* There are (understandably) significant gaps in information on the costs of implementation and timing of delivery of capabilities in the transition from the existing mode of NAS operations to the planned architecture. Both the scale of costs, especially in terms of enabling technology—e.g., GPS overlay procedures and fleet retrofitting—and timing issues will have large potential impacts on the ability to manage the resulting environmental impacts.
- *Identification of choke points in the system.* The initial architecture has focused on managing traffic through the sky. Given the early stage of development, it is not surprising that the key choke points have not yet been identified. However, just as important will be identification of the choke points in NGATS, to ensure correct targeting of investment in different aspects of the plan to provide the necessary capacity growth.

Other Key Uncertainties

- *Environmental targets for 2025.* The required scope of reduction in both noise and local air quality emissions for the system of 2025 has yet to be determined. While we have committed to absolute reductions in both areas, the investments actually required will again depend on how aggressive we are in changing these metrics. It is also unclear what additional impacts may arise from improved scientific understanding of aviation's influence on climate change. Finally, it is uncertain what new requirements may arise from potential introduction of new aircraft types—for example, supersonic business jets—or new environmental concerns—for example, high-altitude noise over national parks.
- *Composition and environmental performance of the aircraft fleet.* The large, subsonic commercial aircraft fleet we have today will—without intervention—in large part be the fleet we have in 2025. This poses a significant obstacle to improved environmental performance, especially for a system that expands threefold. For example, while navigation capabilities can be upgraded relatively quickly and cheaply through plug and play, changing the environmental performance of an aircraft is a more costly and difficult task given the safety and operational issues. Further, the role and size of other aircraft—very light jets, very large jets, UAVs, supersonic business jets, etc.—in the system of 2025 are unclear.
- *Technological research funding gap.* The next 5 to 7 years of research and development are critical for the fleet of 2025 given the long lead times involved in

maturing and incorporating technological innovation in the U.S. fleet. The reduction in NASA's aeronautics budget, especially in the vehicle systems program, undercuts the ability to deliver near-term noise and emissions innovations in airframes and engines. This, in turn, will hamper the ability to meet any increase in the stringency of noise and emissions metrics.

Plans and Priorities for 2007-2011

- Pursue aviation operational changes to reduce environmental impacts:
  —Implement pilot programs in improved air traffic procedures to reduce aircraft noise and fuel burn/emissions to mitigate environmental impacts on communities around airports.
  —Implement programs to improve airport and taxiing operations to reduce aircraft noise and fuel usage in airport operations.
- Continue near-term mitigation strategies to reduce environmental impacts:
  —Foster voluntary efforts to accelerate conversion of airport ground support equipment to alternative and low-emission fuels to reduce emissions in air quality nonattainment areas.
  —Explore development of new technologies and procedures to minimize deicing runoff into local watersheds.
  —Initiate a process to develop land use approaches in communities around airports that would improve compatible land use and reduce future encroachment.
  —Carry out noise reduction activities such as the soundproofing of residences and buildings used for educational or medical purposes near airports, the purchase of buffer zones around airports, residential relocation, and noise reduction planning.
  —Facilitate communication with community roundtables to better educate the public on noise and emissions issues.
- Develop the analytical tools to address impacts, interrelationships, and cost-effectiveness:
  —Develop databases and modeling to obtain a baseline for understanding the impacts and interrelationships of aviation environmental factors with emphasis on noise criteria, pollutants that impact local air quality, and emissions from aircraft operations during cruise that correlate with existing scientific information on climate change.
  —Develop models to allow the cost-effective management of aviation's environmental impacts by establishing a portfolio of policy, technological, and market-based options.
  —Foster acceptance of improved models and tools within the international community.
- Foster research to mature near-term technologies and develop future technologies:
  —Foster the maturing of near-term technologies in engines and airframes that could be readily incorporated and retrofitted in the existing commercial and military aircraft fleet to reduce noise and emissions over the next 5 to 7 years.
  —Foster sufficient and targeted investment in long-term research in technologies for airframes, more efficient engines, advanced propulsion concepts, and new fuels and materials to reduce source noise and emissions. Invest sufficiently to advance these technologies to the maturity level necessary for incorporation into the fleet.
- Develop and incorporate new policy approaches:
  —Explore the use of environmental management systems as an overall approach.
  —Develop key policy proposals for FAA reauthorization in 2007.
  —Recognize and develop ways to incorporate environmental interrelationships in policies and approaches based on new models and tools.
  —Consider use of market-based options, incentives, and other policy approaches to reduce environmental impacts.
  —Investigate new financing schemes to develop and implement noise and emissions abatement technologies and operational measures.
  —Develop more effective metrics and methods to communicate aviation's environmental impact to communities.
  —Develop a U.S. aviation environmental policy document.
- Provide the best science-based information support to assess aviation's environmental impact and critical metrics:
  —Provide science-based knowledge to develop metrics that better represent the health and welfare impacts of NGATS on the environment.
  —Provide science-based knowledge to the other EIPT panels to create an integrated environmental and cost/benefit analysis of all mitigation activities, including technology, policies, and operations.

Funding Requirements

The estimated investment profile for the environmental plans and initiatives is contained in the attached charts.[1] Information has been provided to date only by FAA and NASA. The committee is still awaiting information from the

[1] The IPT estimated funding requirements for FY 2007 to 2011, but that information was not provided to the committee and the charts referred to do not appear in this appendix.

Department of Commerce (NOAA), the Department of Defense, EPA, and the National Park Service. Resource estimates are provided based on current plans as well as on the above estimated investment profile, which reflects the needs identified by the various agencies but not currently programmed by them over the FY 2007-2011 time period.

Key Risks

- *Failure to agree on metrics.* There is a wide diversity of perspectives today on what the right metrics should be for both noise and emissions. There is no guarantee—even with the additional research under way—that a very diverse group of stakeholders will be able to translate general agreement on direction (absolute reductions) into quantitative targets. Further, any agreement among stakeholders will only be the first step, as changes in legislation will be required.
- *Legislative risks.* Beside metrics, a number of potential issues could come up requiring legislative changes or mandates, especially in the policy area.
- *New environmental impacts.* There are three potential categories of risk in this area. First, current research in local and global emissions may provide information that dramatically changes the current view of the risks—and need for mitigation—of particular environmental impacts. Second, new kinds of aircraft—UAV or supersonic—could introduce new types of environmental impacts and issues in the national system. Finally, new sets of expectations for environmental improvements—e.g., "natural quiet in national parks"—could give rise to pressure for significant changes in how aviation's environmental impacts are managed.
- *Federal research and development funding.* As this paper has highlighted, large increases are required, especially for NASA, if technology is to be developed, matured, and incorporated into the U.S. fleet in a manner to meet likely environmental performance requirements. The trends in NASA's aeronautics budget, especially in the vehicle systems program, makes this significantly more challenging.
- *Failure to deliver environmental technology innovation.* Funding is not equivalent to delivery of innovation and its implementation in the system. The next 5 to 7 years of environmental technology innovation is critical if we are to make a difference in the fleet of the next 20 years.
- *Industry financial pressure.* The industry is headed to losing $35 billion since 2000, remains financially fragile, and has continuing pressures for regulatory spending, especially security. Environmental spending tends to take a back seat to spending on both safety and security. Even if new technology is developed, the industry may not be in a position to make a rapid incorporation of these technologies—through purchase of new aircraft or through retrofitting of existing aircraft—due to weak balance sheets and operating prospects as well as competing federal requirements.

H

Acronyms and Abbreviations

ATC	air traffic control
ATM	air traffic management
BRAC	base realignment and closure
FAA	Federal Aviation Administration
GPS	Global Positioning System
IFR	instrument flight rules
IPT	integrated product team
JPDO	Joint Planning and Development Office (for NGATS)
NASA	National Aeronautics and Space Administration
NGATS	Next Generation Air Transportation System
NRC	National Research Council
TAWS	terrain alerting and warning system
TCAS	traffic collision avoidance system
UAV	uninhabited air vehicle