Assessing the Research and Development Plan for the Next Generation Air Transportation System: Summary of a Workshop

Deborah A. Boehm-Davis, Rapporteur, National Research Council

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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 National Research Council's (NRC's) Report Review Committee. 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:

Michael Ball, University of Maryland,
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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the statements presented in the report, nor did they see the final draft of the report before its release. The review of this report was overseen by Adib Kanafani, University of California, Berkley. 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 author and the institution.

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Summary

The U.S. aviation industry, airline passengers, aircraft pilots, airports, and airline companies are all facing challenges. The air transportation system is experiencing unprecedented and increasing levels of use, with air traffic expected to increase two- to threefold by 2025. The federal government understands the critical need to update the U.S. air transportation system and is taking steps to do so by planning for a new, satellite-based air traffic control system intended to increase the efficiency of airport and air space use in the United States.

> The Next Generation Air Transportation System (NextGen) is . . . an example of active networking technology that updates itself with real-time shared information and tailors itself to the individual needs of all U.S. aircraft. NextGen's computerized air transportation network stresses adaptability by enabling aircraft to immediately adjust to ever-changing factors such as weather, traffic congestion, aircraft position via GPS, flight trajectory patterns, and security issues. By 2025, all aircraft and airports in U.S. airspace will be connected to the NextGen network and will continually share information in real time to improve efficiency, safety, and absorb the predicted increase in air transportation.[1]

On April 1-2, 2008, in response to a request from the Federal Aviation Administration's (FAA's) interagency Joint Planning and Development Office (JPDO) (see Appendix A), a workshop was held at the National Academies' Beckman Center to gather observations on the research and development aspects of the baseline Integrated Work Plan for the Next Generation Air Transportation System (NextGen) being prepared by JPDO (JPDO, 2008). The workshop was not conducted as a consensus-building activity intended to produce a formal assessment. Instead, the purpose of this report is to summarize the main points made at the 2-day workshop and to capture the themes of the discussions. Thus this workshop report does not present consensus findings or recommendations.

Chaired by John K. Lauber, senior vice president and chief product safety officer (retired), Airbus S.A.S., the workshop organizing committee planned sessions featuring experts from JPDO and invited guests from government, industry, and academia who were familiar with air traffic management (see Appendixes B and C).

The workshop opened with an overview of the NextGen concept of operation, presented by Robert Pearce, deputy director of the JPDO, and Jay Merkle, chief architect, JPDO. This overview was followed by a series of presentations by JPDO working groups on the following topics:

- Airport operations and support;
- Environmental management;
- Air navigation operations,
- Air navigation support, and flight operation support;
- Positioning, navigation, and timing services and surveillance;
- Weather information services;
- Safety management;

[1] Joint Planning and Development Office (JPDO). 2008. Integrated Work Plan for the Next Generation Air Transportation System (IWP). Joint Planning and Development Office, Washington, DC. See http://www.jpdo.gov/nextgen.asp. Accessed May 15, 2008.

- Network-centric infrastructure services and operations; and
- Layered adaptive security.

Based on information contained in version 0.2 of the JPDO's Integrated Work Plan, the presentations focused on the description of the concept of operation, the operational improvements to be offered by the technologies in each working group area, and requirements for implementation of these capabilities. Each presentation was followed by a discussion. Over the course of the discussions, a number of themes became apparent:

- The sense of a lack of urgency on the part of the JPDO;
- The perception of an inability to clearly articulate the goals of the NextGen program;
- A concern with the narrow boundaries and with the inward focus (viz., on FAA and NASA) of the program;
- A concern that readability and format issues make it difficult to understand the NextGen program as it was presented in version 0.2 of the Integrated Work Plan;
- A concern that the JPDO has not developed an adequate transition plan with test implementations, demonstration projects, and so on, and does not have either the resources or the organizational authority to execute such a plan;
- A concern with the ability of the organization to make difficult (politically charged) decisions; and
- An awareness that NextGen faces technical challenges and risks in the research and development that needs to be undertaken.

In addition, a number of specific research-related questions raised by individual workshop participants are listed in Chapter 3 of this report for consideration by JPDO for the next version of the Integrated Work Plan.

1

Introduction

THE NEXT GENERATION AIR TRANSPORTATION SYSTEM AND THE JOINT PLANNING AND DEVELOPMENT OFFICE

To meet the challenges faced by the U.S. aviation industry, airline passengers, aircraft pilots, airports, and airline companies as a result of unprecedented and increasing levels of use of the air transportation system, the federal government is planning for the development of the Next Generation Air Transportation System (NextGen).

> NextGen is an example of active networking technology that updates itself with real-time shared information and tailors itself to the individual needs of all U.S. aircraft. NextGen's computerized air transportation network stresses adaptability by enabling aircraft to immediately adjust to ever-changing factors such as weather, traffic congestion, aircraft position via GPS, flight trajectory patterns, and security issues. By 2025, all aircraft and airports in U.S. airspace will be connected to the NextGen network and will continually share information in real time to improve efficiency, safety, and absorb the predicted increase in air transportation.[1]

> Enacted in 2003 by President George W. Bush and Congress under VISION 100 – Century of Aviation Reauthorization Act (P.L. 108-176), the NextGen initiative is being headed by the Joint Planning and Development Office (JPDO), which is responsible for managing a public-private partnership to bring NextGen online by 2025. The JPDO is the central organization that coordinates the specialized efforts of the Departments of Transportation, Defense, Homeland Security, Commerce and the FAA, NASA, and the White House Office of Science and Technology Policy.

In 2006, the Joint Planning and Development Office (JPDO) estimated that federal spending on NextGen from its initiation to 2025 will total between $15 billion and $22 billion.[2] NextGen plans to utilize satellite navigation and control—for example, the Global Positioning System (GPS). A key component of NextGen is the automatic dependent surveillance-broadcast (ADS-B), which broadcasts aircraft position, altitude, velocity, and intent to other aircraft as well as controllers on the ground. NextGen will use digital nonvoice communication, advanced networking, and network-enabled and network-centric operation, both on the ground and in the air. The system will assimilate real-time weather information and provide broad-area precision navigation to enable shifting of decision making from ground controllers to pilots, and allow aircraft trajectory-based operations based on four-dimensional trajectories (which incorporate altitude, position, time, and other aircraft positions and vectors). NextGen is intended to permit higher-density aircraft and airport operations, while also reducing the environmental impact of operations ranging from those of aircraft in flight to those of airports. It will employ layered adaptive security to "help reduce the overall risk of a threat causing harm to the system."[3]

[1] See the JPDO Web site at http://www.jpdo.gov/nextgen.asp. Accessed May 15, 2008.
[2] See the JPDO Web site at http://www.jpdo.gov/faq.asp#22. Accessed June 2, 2008.
[3] See Eight Key Capabilities at http://www.jpdo.gov/key_capabilties.asp. Accessed May 16, 2008.

Clearly, NextGen will require participation by federal, state, and local governments. Furthermore, NextGen "is not solely a government program. To ensure that industry plays a role at every stage of NextGen's development, Congress directed steps to create a close relationship with private sector partners."[4]

The JPDO has the task of facilitating NextGen activities, "to create and carry out an integrated plan for NextGen."[5] The JPDO is governed by a Senior Policy Committee and Board of Directors. The Senior Policy Committee is chaired by the Secretary of Transportation and staffed by senior representatives of each of the participating agencies. The Board of Directors also is staffed by senior representatives of the participating agencies. Within the JPDO, there are six division directors, with responsibilities in systems modeling and analysis, enterprise architecture and engineering, policy, portfolio management, partnership management, and business management. Within those divisions are several working groups, each of which represents a key technology needed to enable NextGen. These working groups are staffed with government officials and industry representatives.

PURPOSE AND CONDUCT OF THE WORKSHOP

In mid-2007, the National Research Council (NRC) was asked by the JPDO to organize a workshop to discuss the JPDO's research and development (R&D) plan for NextGen. The NRC formed an ad hoc workshop organizing committee, chaired by John K. Lauber, under the auspices of the Aeronautics and Space Engineering Board (ASEB). The organizing committee's statement of task is given in Appendix A.

On February 15, 2008, the JPDO issued version 0.2 of its Integrated Working Plan (IWP), reflecting "the NextGen vision as defined by the concept of operations and the Enterprise Architecture."[6] The IWP serves "as a master planning document that presents a summary view of what is required to achieve the NextGen vision." IWP version 0.2 is "a preliminary draft version of the final document to describe how NextGen will improve safety, security, mobility, efficiency, and capacity to transform the nation's air transportation system. It will continually be refined and enhanced to reflect current priorities, budgets, and programs."[7]

On April 1-2, 2008, a workshop was held at the National Academies' Beckman Center to provide a forum for observations on the research and development aspects of the IWP. The agenda for the workshop is given in Appendix B. Workshop participants included staff and speakers from the JPDO, members of the workshop organizing committee, and invited guests from government, industry, and academia who were familiar with air traffic management issues. About 50 people attended; see Appendix C for a list of the participants. The workshop was not a consensus-building activity. This report is intended to summarize the main points made in the workshop's discussions and to capture the related themes. It does not provide consensus findings or recommendations.

The workshop provided an opportunity for the JPDO to present the R&D plans in the current IWP (version 0.2) and to solicit feedback on these plans from a broad audience. First on the agenda was an overview of the NextGen concept of operations, presented by Robert Pearce, deputy director of the JPDO, and Jay Merkle, chief architect, JPDO. Their overview was followed by a series of presentations by JPDO staff and working group members on the following topics:

[4] See Next Generation Air Transportation System in Brief at http://www.jpdo.gov/library/In_Brief_2006.pdf. Accessed May 16, 2008.

[5] See Frequently Asked Questions at http://www.jpdo.gov/faq.asp#3. Accessed May 16, 2008.

[6] For the latest revision of the IWP, see http://www.jpdo.gov. In addition, the JPDO has published several pertinent reports: NextGen Business Case, version 1.0; Enterprise Architecture, version 2.0; NextGen Concept of Operations, version 2.0; NextGen Security Annex, version 2.0; Weather Concept of Operations; and 4D Weather Functional Requirements for NextGen. See http://www.jpdo.gov/library.asp. Accessed May 5, 2008.

[7] For the latest revision of the IWP, see http://www.jpdo.gov.

- Airport operations and support;
- Environmental management;
- Air navigation operations, air navigation support, and flight operation support;
- Positioning, navigation, and timing services and surveillance;
- Weather information services;
- Safety management;
- Network-centric infrastructure services and operations; and
- Layered adaptive security.

To focus the discussion of the IWP R&D plan, the organizing committee sent several questions to the speakers prior to the workshop:

- What is the JPDO's most significant research or technological challenge in this area?
- What are the most important R&D activities listed?
- Do the R&D activities form or fit into a structured, coherent program?
- Are there critical R&D activities missing?
- What are the R&D priorities in terms of timing, funding, efficiency, safety, importance, readiness, and so on?
- Are the R&D activities adequate, sufficient, or excessive in terms of achieving the JPDO objectives?
- Is the critical path to NextGen clear?

The presentations (available on request from the ASEB office) were based on the R&D plans contained in the IWP and focused on a description of the concept of operation, the operational improvements to be offered by the technologies in that working group area, and the key enablers for implementation of these capabilities. Each of the nine workshop presentations was followed by a discussion. The issues raised during those discussions are summarized by topic area in Chapter 2. A general discussion followed the last presentation; at that time, workshop participants were given the opportunity to raise any issues they felt should be communicated to the JPDO. Specific observations made and questions raised by individual workshop participants are listed in Chapter 3.

2

Key Issues

Over the course of the workshop discussions a number of themes became apparent, although, by design, the workshop was not a consensus-generating activity.

URGENCY AND PRIORITIES

The issue of a sensed lack of urgency on the part of the Joint Planning and Development Office (JPDO) was mentioned most often by workshop participants. There clearly are economic pressures to move quickly, and the rest of the international aviation world is moving forward, particularly in Europe. However, the JPDO is still proposing research and development (R&D) that needs to be done rather than articulating a clear program. Several participants stated that if the Next Generation Air Transportation System (NextGen) is to be implemented by the targeted dates, applications and development need to be started immediately, with proposed completion dates set for individual pieces of the program.

Several participants stated that outreach for NextGen is important and that more aviation professionals, pilots, and even the public need to be made aware of NextGen. One participant suggested that NextGen should be proposed as the next "Apollo project," with funding dedicated to implementing NextGen within the next 10 or 12 years rather than by the JPDO goal of 2025. However, to do so, several participants noted that the JPDO needs to be more certain and more explicit about the benefits to be gained through implementation of the program. One participant stated that at present, the JPDO is confident of achieving less than half of its goals. Some participants felt it is urgent to model the whole program to determine the extent of the benefits that can be realized. These benefits then could be incorporated into clear statements of goals to be achieved. This information is critical to the JPDO's ability to encourage other federal entities, such as the Department of Defense (DOD), to increase their participation, as well as to convince Congress to invest in this program.

Tied to the concern about the lack of clearly stated goals is the concern that prioritization of the individual pieces of the program has not been done. It is important to consider how best to spend limited research dollars and to determine the likely payoff for particular investments. Most participants felt that it is important to determine whether the proposed work will allow NextGen to meet the challenge of handling the projected system capacity.

Many participants also expressed a realization that the task of prioritization is overwhelming, especially because each of the many operational improvements outlined in the plan represent a scope of activity that would be handled by a government agency. However, many participants felt strongly that the JPDO should identify what elements are the most time-critical and who should decide these issues. Several participants also advocated the development of a process to determine whether the solutions proposed can solve the problem. One participant suggested specifically that JPDO develop a process to identify the human resources needed to do the research, design the systems, and demonstrate them. Further, another participant suggested that the JPDO map the proposed R&D on a critical path and then determine if there are gaps that will prevent the program from succeeding. If so, additional R&D would have to be added to the program, or plans for mitigating these gaps would have to be developed. From there, it will be necessary to determine who is responsible for executing each R&D element and for

ensuring that the work proceeds on schedule. The concern on the part of these workshop participants was that if this prioritization is not done, the bulk of the work that will be done will be non-priority work or that the work will focus only on marginal improvements.

ARTICULATION OF FOCUS, SPECIFIC GOALS, AND OUTCOMES

A second issue raised by many of the participants was the JPDO's inability to articulate the goals of the NextGen program. The JPDO outlined a large number of excellent research tasks in its presentations, most of which will likely be required to support future U.S. airspace system needs. However, many participants felt that there was a lack of focus on the most important future needs: airspace and airport capacity. Further, they felt that the JPDO had not done an adequate job of stating specific, real improvements that could be gained through implementation of the program. Several participants also felt that the JPDO had not been clear in expressing what would be achieved. For example, in stating that NextGen would increase throughput two- to threefold, it was not immediately clear to some participants whether the JPDO was referring to an increase in flights or in passengers carried. They felt that the next version of the Integrated Working Plan (IWP) would benefit from further clarification.

Several participants also suggested that some of the difficulty in articulating the benefits to be achieved could reflect the lack of a baseline against which to measure improvements. In this regard, a number of concerns were raised:

1. Some participants noted an overreliance on modeling as a mechanism for predicting improvements.
2. Modeling of the component systems that carry out functions is necessary for success at the broad enterprise level. Many participants felt that the JPDO may need to move to the systems level and make some assumptions about specific systems to get enough detail to make decisions about the best path to take.
3. Several participants reminded the JPDO about the need to consider impacts broadly across a full life cycle; sometimes long-term impacts are not considered when short-term benefits look attractive (e.g., the large-scale use of biofuels could adversely affect the production of food).
4. Some participants noted that in overspecifying problems (i.e., promising too much), the JPDO may end up with no implementation, due to the high cost associated with the final program.

Regarding the fourth concern, several participants noted that the large scope of research still needed at this point could be seen as an impediment to meeting the dates targeted for implementation of the NextGen program. They suggested doing something to reduce the scope of the program and advance the dates. For example, one participant suggested that the JPDO restructure NextGen, either through more demonstrations, by focusing on a regional approach, or by selecting targeted issues that might be used as illustrations of what the NextGen program could achieve in terms of increased throughput without a loss of safety. The execution of a demonstration or an individual targeted piece of the plan could produce evidence that the system can work. Many workshop participants felt that if the application is chosen wisely, it could incorporate the major tenets of the system in one package.

This approach could focus the overall plan and would clearly highlight how all of the proposed tasks will yield real benefits in the future. It was further felt by several participants that demonstrations of this sort would make it more difficult for a new administration to reject the continuation of the NextGen program. The motivation for continuing NextGen would also be more visible to the public, especially in the change to a new administration. Several participants agreed that a demonstration of improved air operations could therefore be useful to a new administration as something to cite as an early accomplishment.

For example, one participant noted that one suggested project would focus on increasing airport landing capacity using a "concrete solution," i.e., by building more runways or better utilizing current runways. One way of doing this might be to combine many of the tasks now listed, such as piloted simulations, flight tests, and prototype demonstrations, to achieve the goal of reducing the required separation between parallel runways for use under instrument meteorological conditions. A substantial reduction in the spacing had been shown by NASA to be technologically feasible about 10 years ago. Several participants agreed that implementation of closely spaced parallel runways might provide as much as a 30 percent improvement, with minimal environmental impact for local communities. Another participant added that to provide a capacity increase beyond, say, 30 percent, the number of available runways must be substantially increased. He went on to say that the technology that enables the use of closely spaced parallel runways and the widespread building of such runways has the potential to make the NextGen targets (a two- or threefold capacity increase) realistic.

Many of the participants recognized that this approach to increasing airport landing capacity might accomplish only a portion of the currently envisioned program, leaving some items on the table. However, it would represent a visible start to addressing the problem. Another alternative suggested was to develop opportunities within the existing plan for innovations, such as ideas with a big impact that might increase capacity by up to five times.

DEFINITION OF PROGRAM BOUNDARIES

During the workshop, several participants expressed concern with the narrow boundaries and inward focus (at the FAA and NASA) of the NextGen R&D program. Participants suggested that a number of connections needed to be made or strengthened with other constituents, such as airport authorities, controllers, local communities, industry, DOD, and international organizations. Several participants pointed out that the bulk of current NextGen R&D funding is coming from the FAA and NASA and wondered why DOD and industry, for example, were not providing funding for this initiative. To succeed, many participants felt that NextGen must pull all of these constituents together to, for example, develop common themes and leverage scarce resources.

In addition, some participants noted that JPDO needs to, at some level, address both air traffic management (gate to gate) and non-air-traffic management (curb to curb) pieces of the system. In this area, they felt that JPDO needs to include in its planning considerations the advantages and disadvantages of multimodal transportation initiatives. Many participants believe that NextGen needs to connect with these multimodal efforts, but the JPDO also needs to be concerned that this connectivity does not strip resources needed to focus on critical air-side issues. In addition, there is a concern that an interagency focus misses issues that exist solely within aviation, including issues of incentives for operators to use the system, lack of sharing across competitors, and private-sector privacy issues. In particular, how users respond to NextGen policies and systems, how incentives, including economic incentives, might be used to help control the system, and the relationship between user behavior and system performance represent research areas that seem to be given little emphasis.

Regarding the issue of global harmonization, many participants felt that the JPDO needs to be concerned that solutions work everywhere, that is, both domestically and overseas. These participants felt that the presentations were U.S.-centric, and they were not convinced that the mechanisms planned for the NextGen goal of global harmonization were sufficient. As an example, one participant asked whether the International Civil Aviation Organization was the correct mechanism for achieving global harmonization. Several participants were concerned that one set of capabilities needs to be defined for worldwide use. Issues of fleet mix and the ability of a carrier to appropriately equip its individual aircraft were the concern here. Concern was also expressed about how information sharing might be arranged across different international agencies.

INABILITY TO COMMUNICATE THROUGH THE INITIAL INTEGRATED WORKING PLAN

Many participants felt that the next version of the IWP should provide a vehicle for communicating the NextGen plans and that it should be widely understandable to a broad audience. Specifically, they felt that the IWP needs to be accessible to the public; public opinion leaders; operating agencies, which have to implement the plan; and Congress, which has to fund NextGen. As part of the communication regarding safety data, one of these participants felt it was important to recognize that the goal is not to blame those who report safety problems but to understand the contributors to safety issues (e.g., technology as well as people). He felt it was also important for the JPDO to communicate what it means to "manage" risk.

Although most participants agreed that the work that went into creation of the IWP was monumental, they also felt that the current draft is difficult to comprehend. Many participants found version 0.2 of the IWP to be an intractable document as currently structured, one that does not clearly articulate the goals and anticipated benefits of NextGen; further, it was viewed as not being well integrated or prioritized, as giving the appearance of separate stovepipes, and as demonstrating a lack of effective top-level systems engineering. Although a large number of operational improvements were noted in the IWP, it was not clear what would drive decisions about final system requirements. As just one example, although many of the workshop participants spoke about passing information on a shared information network, the types of data that need to be passed on this grid were not specified.

Most participants felt that there is a need for coherence and integration across the various working groups and in R&D plans. For example, if a driver is airport capacity, and additional runways are the proposed solution, then the environmental impacts of the solution need to be considered. One specific example was a plan to satisfy the capacity needs in the San Francisco/Oakland Bay area that might require extensive filling in of the Bay, which could lead to an environmental issue. Addressing these challenges was one of the recommendations of the report of the ad hoc Committee on Technology Pathways, *Assessing the Integrated Plan for a Next Generation Air Transportation System*.[1] Several workshop participants suggested that the challenge of maintaining coherence and integration across the various JPDO working groups could be addressed to some extent by having the JPDO management listen more carefully and formally to the working groups and by providing them with more direction. Some of the participants also suggested involving industry more prominently in the activities of the JPDO working groups.

Addressing these issues may be difficult, though, because, as most participants noted, many issues and operational improvements are worded imprecisely in the IWP. This imprecision makes it difficult to understand (1) the ownership of an item and (2) what is being done or proposed. For example, some participants noted that many terms present in the IWP (e.g., "4-D trajectory") are not well defined and lack a commonly agreed-upon definition. Imprecise definitions lead to difficulties in predicting or modeling the impact of the implementation of changes. Some participants suggested that, at some level, the imprecision may be intentional, leaving room for different interpretations and recognizing that terms might be used differently by different players. Many workshop participants ultimately felt, however, that it might be useful for the JPDO to be clearer about the definitions of the new terms in the IWP.

Participants also felt that the IWP was not well structured from the research perspective and stressed that the document should make research priorities clear. Moreover, participants felt that the current draft IWP contains too much unprioritized detail that is not properly structured to plan what research needs to be done. Further, other participants felt the IWP does not appear to be the most effective way to oversee or manage the research. Many participants felt that key questions with decision points needed to be articulated in the plan. Finally, some of the workshop participants noted a definitional problem in the IWP discussion of research. In the current document, work ranging from basic

[1] National Research Council, *Assessing the Integrated Plan for a Next Generation Air Transportation System*, The National Academies Press, Washington, D.C., 2005.

research (category 6.1 in DOD parlance) through applied research (6.2) to operational systems development (6.7) is all described generically as "research," making it difficult to identify how close to implementation different projects might be.

Coupled with the above was a concern among many workshop participants that certain types of research, such as research in human factors, which need to be considered early in the process, have not been addressed sufficiently. These participants noted that human factors is an area that needs to be intentionally articulated early and throughout the program, since problems that are not addressed early can be difficult to fix later.

IMPLEMENTATION ISSUES

Several participants expressed concern that even if the IWP were better focused and well articulated, problems remain in moving from application to implementation of the program. Three specific issues were raised in this regard: the development of a transition path, the resources needed, and the appropriate organization to guide the implementation.

Transition Path

The first issue raised by workshop participants was the difficulty in defining the transition path from basic research to implementation. Concern was expressed by several participants that the JPDO management has produced a timid plan where bold steps are needed. Specifically, they wondered (1) what are the big, iconic decisions to be made and (2) what is the next decision that needs to be made? These participants felt that the JPDO needed to work to define performance requirements and then bring partners on board to develop systems.

Several participants recognized that there is a trade-off between tactical and strategic planning and that it is hard to identify the sweet spots of that trade-off. They argued that strategic planning will have to be done first to demonstrate the value of individual concepts, but that the JPDO will then have to provide incentives for moving those concepts into implementation. In creating those incentives, some participants pointed out, it is critical to consider the right amount of stick in relation to carrot. These participants expressed several concerns over the ability of the JPDO to provide this transition path. First, one participant asked if the JPDO needs to be able to use research transition teams to look at research being done by other agencies (not just NASA) to deliver technology readiness level (TRL) 1[2] requirements to organizations. Second, another participant cited a human factor challenge concerning management work stations and expressed concern that NASA return to a higher TRL, enabling greater effectiveness in moving from concept to design. Third, another participant pointed out that there is a flow contingency management[3] challenge and also said that it is important that the gap between advanced operational capability and flight operations capability not end up being fixed and bolted on later.

[2] TRL 1—observation and reporting of basic principles—is the lowest level of technology maturation. Mid-level TRLs (5-6) deal with validation and demonstration in a relevant environment, and the highest levels (7-9) are concerned with system demonstration and testing in an operational environment.

[3] Flow contingency management ensures the efficient management of major flows of traffic while minimizing the impact on other operations. See NextGen Concept of Operations version 2 at http://www.jpdo.gov/library/NextGen_v2.0.pdf. Accessed June 3, 2008.

Resources

Concerns were raised by many workshop participants that there may not be sufficient resources to enable development of these transition paths. First, it was not clear how the NextGen R&D activity is being financed. That is, it was not clear to workshop participants who is ultimately responsible for paying for the R&D needed to get to implementation of the program. One participant wondered, for example, about the extent to which FAA and NASA programs support the JPDO 5-year goals. Others also wondered how the JPDO and other government agencies can win industry acceptance of the outcomes of this research. In this regard, several participants wondered whether the impacts of airline business models (e.g., hub and spoke) on the efficiency of the air system were being considered. Another participant wondered whether the overall affordability of the system was being either studied or addressed and whether bond underwriters and others from the financial sector had been involved in plans for financing airport construction, for example.

Implementation Organization

Although the JPDO has had 4 to 5 years of experience, most participants felt that it did not seem to have learned what works and what doesn't. Further, they felt that the JPDO does not provide a good organizational model for implementing NextGen because the JPDO is first and foremost a "planning" agency, not a "program" agency; the JPDO does not have implementation authority, and the issue of authority is currently what most limits the JPDO's ability to be effective in moving the NextGen program forward. Thus, the question was raised of what kind of mechanism should be created to follow the JPDO.

Suggestions were provided about a potential structure for this organization. It might be, for example, a single agency, with single budget and implementation authority. Some participants saw it as a special program office; others saw it as a new federal agency. Some participants expressed a feeling that regardless of the structure, the post-JPDO organization needs to report to the FAA administrator to ensure program success. Whatever the final structure of this organization, many participants felt that it needs to be able to address issues such as the following: (1) Who decides that the network is secure? (2) Who is accountable? (3) Who owns each component of the system? and (4) How can systems be designed when threats are always in flux and the nature of the threat constantly changes?

POLITICAL DIFFICULTIES

The last key issue brought up in workshop discussions centered on political difficulties. Foremost among the workshop participants was a concern about the challenge of making difficult (politically charged) decisions. Government agencies tend to be risk-averse, and some participants felt that the lack of decision making is holding up the JPDO's ability to move forward on NextGen's research needs. A number of specific issues were identified that are difficult, but that participants felt will have to be addressed. For example, some participants raised the question of how to deal with the issue that although manufacturers are willing to invest in changes desired for environmental improvements, airlines are not willing to pay the additional costs; that is, there is an issue of the trade-off between outcome and cost constraints. Another issue of concern expressed by some was community opposition to proposed changes, such as the use of small existing airports as reliever airports. Opposition of this sort could push incremental changes rather than significant changes in the air traffic structure.

Another issue is the process that is being followed in the development of NextGen. Many workshop participants expressed concern that not all voices (or, the wrong voices—those of retired rather than active controllers) are being heard.

Processes will have to be developed for requirements and certification that balance mandates against incentives and the impact of NextGen against economic factors and that incorporate systems-level

testing before policies are set. Specifically in regard to certification, some participants wondered where new methods of certification fit into the JPDO plans. They expressed concern that a lack of new methods may be a barrier to adoption. Many workshop participants argued that the current time and cost to certify new systems is a problem, exacerbated when requirements are not frozen and when there is no mechanism for certification along the way. Some of the participants strongly urged a research agenda that addresses improving the certification process.

Several participants argued that better design of new systems can make transitions easier; thus, the ability to address certification issues at the design stage needs to be addressed. Many participants wondered whether it would be possible under a new system to get "precedent" coverage, and they suggested that policy research might be needed to address issues such as this and to accomplish the goal of new certification processes. They also raised particular concerns about the difficulty of developing requirements for equipage and certification of complex software.

Finally, several workshop participants suggested that a new organization (or administrator) might have to be chartered to make these difficult calls. Most political organizations cannot make the difficult decisions that are needed. For example, some participants noted that decision making is particularly difficult for the FAA, which serves both aviation regulatory and promotional functions. However, fixing inhibiting policies will be critical to the success of NextGen. Thus, these participants felt that it might be necessary to do some research to determine what sort of agency would have to be created to make NextGen a reality.

The agency created would have to possess certain characteristics. For example, it would need to be insulated from the changing priorities of Congress, perhaps in the same way as the nonpartisan Defense Base Closure and Realignment Commission (BRAC), with multiyear funding. One possibility suggested was a government-owned, private corporation agency, like the Tennessee Valley Authority or the U.S. Postal Service. However, most of the workshop participants also recognized that any programs arising from such an agency would have to be coordinated with the FAA; thus, a formal relationship between the two agencies might be needed. Several participants suggested that a congressional study might look into how this relationship might work.

3

Specific Observations and Research Questions Raised

In addition to the general issues evident in discussion at the workshop, a number of specific research questions were raised and observations made by individual workshop participants. These reflect concerns that individual participants would like to see addressed as part of the NextGen program, although it should also be noted that some of the items listed below may, in fact, already be represented in the next version of the IWP. The specific questions are presented as they were raised at the workshop, and so are presented chronologically in the sections that follow.

AIRPORT OPERATIONS AND SUPPORT

- Does NextGen address all causes of airport disruption (e.g., irregular operations from things such as ramp closure due to lightning or inefficiencies in individual airlines running de-icing programs)?
- Has there been any work on, or discussion of, placing wayports (airports built away from urban centers in order to decrease congestion there) or deciding where to place new hub airports?
- Are mechanisms for expedited environmental reviews of airports being investigated?
  —Is there a way to address how best to communicate with local communities about environmental impacts?
  —Is research needed to determine how airport advocacy can be undertaken?
- Might further discussion identify topics for needed research that have not yet been raised? For example,
  —Does the introduction of new aircraft such as the Boeing 787 allow expansion of city pairs?
  —What might be the impact on how city pairs will work?
- Is JPDO modeling better ways to load passengers and baggage?
- Is there investigation of how existing ramp space is used?
  —How much efficiency could be gained by allowing airlines to use open gates belonging to other airlines when their own gates are full?
  —If airports could run all gates, counters, etc., would this lead to improvements in efficiency and effectiveness?
- How can best practices at individual airports be identified and shared among airports and the JPDO?
- What clever airport designs are possible that would be approvable?

AIR NAVIGATION OPERATIONS, AIR NAVIGATION SUPPORT, AND FLIGHT OPERATION SUPPORT

- How are new systems changing training requirements and training technology?
- Embedded in this program are assumptions about equipage costs. The hidden cost of crew training needs to be acknowledged. What makes economic sense?

- Are there collaborations being established to accomplish goals in Global Positioning System procurement?

ENVIRONMENTAL MANAGEMENT

- NextGen ideas run from totally automated execution to totally human (manual) execution.
  —Research is needed to identify human factors issues now.
  —It is particularly important to focus on who is in charge.
  —The environmental challenge is both an execution issue and a policy issue.
  —NextGen is a technology issue (i.e., what is possible?)
- Are there any radically different or revolutionary ideas about what constitutes an aircraft (e.g., modular airplanes or systems)?
- Does the plan take into account how new systems enter the aviation system?
  —Can planners be opportunistic in introducing new functionality?
  —How can the changes that systems must accommodate be limited to one rather than several?
- Is there concern with legacy aircraft and/or concern with continuing to hire for the current air traffic management system rather than for future aircraft and NextGen?
- Is it recognized that having only one concept for the future is a problem?
- What skills will be needed 10 years out?
- What human factors work is needed to understand what criteria are important to guide hiring?

POSITIONING, NAVIGATION, TIMING SERVICES, AND SURVEILLANCE

- Can the Department of Homeland Security (namely, the Coast Guard) help by providing a standard for the enhanced long-range navigation system (eLORAN)?
- What are the developmental issues for eLORAN?
- What is the performance of the systems? What are the limits on accuracy? How much can be invested? Do systems have backward compatibility?
- How will satellite constellations and their placement affect performance?

WEATHER INFORMATION SERVICES

- The current system is brittle. Failure can suddenly occur when perturbations occur in the system (e.g., bad weather). Can JPDO “spec out” a less brittle system?
- Is there any research that is investigating the extent to which a conflict between “official” and “airline” sources of weather information will lead to problems?
- What research will be done to explore necessary levels of spatial and temporal resolution?
- What happens when a pilot is routed through a weather cell?
  —What is the impact on other planes routed in that area?
  —What is the pilot’s responsibility for decision making on going through a cell?
  —Are clearances/trajectories advisory or compulsory?
- How does the industry develop insurance for mitigation of risk?
- Is there any research planned to investigate consumer reaction to changes in departure times for weather/other potential delays?
- Is sufficient research being planned and conducted in the areas of data handling and communications as applied to weather information?

—What research is needed on how to pass information in a universal language (e.g., how to define terms such as “moderate turbulence” or “heavy turbulence”)?
—NASA is looking at the integration of uncertainty and trajectories, but is that enough?
—Is there sufficient connectivity between the JPDO and the U.S. Air Force and the rest of DOD, and with FAA operations planning?

- Is enough known about the passing of critical information, not just for weather but in all areas?
- Is research being done on the policy issue of how much money should be invested, against predicted benefits? What is the cost trade-off, and who will decide what level of investment is acceptable for a given level of benefit?
- How will consistency across distributed databases be ensured?
  —How will databases be brought together?
  —How will the correct level of resolution be arrived at?
  —How will that information be used strategically?
- What plans are in place for dealing with the legal and privacy concerns related to data maintained in air traffic system databases and used in the investigation of accidents, for example?
- What needs to be done for airlines to be comfortable with the direct sharing of weather information or with having one source of weather information?

SAFETY MANAGEMENT

- What tools can be included in NextGen that will help end users (e.g., airlines, airports, pilots) to understand, use, and manage the safety-related data they collect? Users often do not have the tools or analytical sophistication to effectively use the safety-related data they collect.
- How can the real-time monitoring of safety data be decoupled from the later analysis of the data?
- What tools can be included or developed that will help end users to mine and analyze safety-related text data including, e.g., text data from mechanics together with that from crew members? Is the plan connected to current NASA work on text data decoding?
- What can be done to address the concern that flight data recorders do not capture pilot intent when an automated system is being worked with, thus making it difficult to analyze data? What studies can be done to identify better ways to understand the relationship between the discrete data elements from the flight data recorder and the wider picture of what pilots are trying to achieve while using automated systems?
- Is research planned to ensure that the positive features of existing air traffic control systems are being identified for incorporation into new systems? Is this approach a real part of the NextGen plan, rather than just a general principle to be followed?
- Is there sufficient research being done or planned toward developing methodologies for predictive risk assessment?
- What level of safety in risk assessment is optimal? Should safety risk assessments be conducted that consider relative rather than absolute safety? Is a mechanism being developed to specify and approve things that are relatively safer rather than absolutely safe?
- How can safety research be aimed at achieving specific improvements?
  —What are the different mechanisms for achieving closely spaced parallel runways, and for ensuring equivalent safety?
  —How can it be determined which proposed approaches allow for equivalent or improved safety performance?
- How will the difficult issue of relative versus absolute safety be addressed?
  —There is the trap of proving the current system is okay or safe.

—It is often difficult to find a justification for current standards.
—The standards often don't reflect policy (e.g., prevent wake encounters, but change spacing requirements as a function of type of aircraft).

NETWORK-CENTRIC INFRASTRUCTURE SERVICES AND OPERATIONS

- Are testing and evaluation incorporated into the plan for validation?
- Are there R&D plans for studying the performance scalability and interoperability of the solutions proposed?
- How will the lexicons be investigated to bridge communication gaps that exist due to terminology differences?
- What research is needed to identify win-win situations for outsiders sharing information—to identify benefits of information sharing—despite the difficulty of building a business model for sharing information?
- Is anyone studying the problem of conveying constraints that are imposed when a system designed for a specific purpose is then used for another purpose (e.g., sharing information taken from one domain in another domain with another interface)?
- How does one understand the value of information, which is separate from the ability to share information?
- Is research being done to ensure that when systems fail, they fail "soft"?
- What are the technical, economic, and organizational mechanisms that should to be put in place to support the new levels of government-industry communications that will be required under NextGen?

LAYERED, ADAPTIVE SECURITY

- How can security issues be integrated across different JPDO working groups when security is layered in some applications, and not in others?
- Has off-site luggage handling been modeled? How can it work and can it work in high-load airports with limited real estate? Is this work connected to that of other JPDO working groups?
- Are the security plans out of proportion to the risk?
- Would security funding be better spent addressing safety issues?

Appendixes

A

Statement of Task

An ad hoc committee under the auspices of the Aeronautics and Space Engineering Board (ASEB) will organize a public workshop to assess the research and development plan for the Next Generation Air Transportation System (NextGen) being prepared by the Federal Aviation Administration's interagency Joint Planning and Development Office (JDPO). The agenda for the workshop will be developed to highlight R&D areas that merit particular focus, including those that appear to be of high value and/or high risk with regard to accomplishing NextGen goals. The committee will review the JPDO concept of operations and other relevant, publicly available documentation about the context in which the R&D plan has been generated and will determine what presentations or introductory materials are required for the workshop.

B

Workshop Agenda

TUESDAY, APRIL 1, 2008

8:30 a.m.	Convene. Welcome, introductions, workshop agenda and objectives (Chair, John K. Lauber)
8:50	Overview of NextGen: The end state and a synopsis of a roadmap from today to the end state. Robert Pearce, deputy director, and Jay Merkle, chief architect, JPDO
10:20	Session 1. Airport Operations and Support Speaker: Paul Devoti, JPDO Moderator: William J. Dunlay, Jacobs Consultancy
11:10	Session 2. Environmental Management Speaker: Julie Draper, JPDO Moderator: Michael Hudson, independent consultant
Noon	Lunch
1:00 p.m.	Session 3. Air Navigation Operations, Air Navigation Support, and Flight Operation Support Speakers: Robert Beard, Elizabeth Ray, and Jeff Duven, JPDO Moderator: R. John Hansman, Jr., MIT
3:05	Session 4. Positioning, Navigation, and Timing Services and Surveillance Speaker: Doug Arbuckle, JPDO Moderator: J. David Powell, Stanford University
4:00	Session 5. Weather Information Services Speaker: Mark Andrews, JPDO Moderator: William S. Leber, Chief Dispatcher, Northwest Airlines
4:55	Overnight assignments and tomorrow's agenda (Chair, John K. Lauber)
5:00	Reception
6:00	Dinner for committee, moderators, and rapporteur

WEDNESDAY, APRIL 2, 2008

8:30 a.m.	Welcome, review day's agenda (Chair, John K. Lauber)
8:45	Session 6. Safety Management Speaker: Stephen Darr, JPDO Moderator: Beth Lyall, Research Integrations, Inc.
10:00	Session 7. Network-Centric Infrastructure Services and Operations Speaker: Gene C. Hayman, Jr., JPDO Moderator: Doohwan Kim, University of Arizona and RTSync Corp.
10:55	Session 8. Layered Adaptive Security Speakers: Jeff Bruenig and Paul Polski, JPDO Moderator: Edmond R. Soliday, organizing committee member
11:50	Identify main areas for afternoon discussion session and repeat the objectives and goals for the workshop (Chair, John K. Lauber)
Noon	Lunch
1:00 p.m.	Open Discussion (1 hour and 40 minutes)
3:00	Brief comments from all attendees
4:45	Closing remarks (Chair, John K. Lauber)
5:00	Adjourn

C

Workshop Participants

ORGANIZING COMMITTEE MEMBERS

John K. Lauber, *Chair,* Senior Vice President and Chief Product Safety Officer, Airbus (retired)
Donald Fraser (unable to attend), Director, DRS Technologies
R. John Hansman, Jr., Professor and Director, MIT International Center for Air Transportation, Massachusetts Institute of Technology
John Hayhurst, Senior Vice President, The Boeing Company (retired)
S. Michael Hudson, Independent Consultant, Rolls-Royce North America (retired)
Charles E. Keegan, Director, Future Air Navigation Systems, Raytheon Company
Beth Lyall, Founder, President, and CEO, Research Integrations, Inc.
Gen. Lester L. Lyles, U.S. Department of the Air Force (retired) and The Lyles Group
Nadine B. Sarter (unable to attend), Associate Professor, Department of Industrial and Operations Engineering, University of Michigan
Edmond R. Soliday, Vice President, Safety, Quality Assurance, and Security, United Airlines (retired)

ADDITIONAL SESSION MODERATORS

William J. Dunlay, Director, Jacobs Consultancy (formerly Leigh Fisher Associates)
Doohwan Kim, ACIMS, University of Arizona and RTSync Corporation
William S. Leber, Chief Dispatcher, Northwest Airlines, Inc.
J. David Powell, Department of Aeronautics and Astronautics, Department of Mechanical Engineering, Stanford University

RAPPORTEUR

Deborah A. Boehm-Davis, Professor of Psychology, Human Factors and Applied Cognitive Program, George Mason University

JPDO STAFF AND SPEAKERS

Robert Pearce, Deputy Director
Mark Andrews, Co-Chair, JPDO Weather Working Group
Doug Arbuckle, Team Lead, JPDO Agile Air Traffic System Integrated Product
Robert Beard, Co-Chair, JPDO Air Navigation Services Working Group
Jeff Bruenig, ICF Consulting
Stephen Darr, Dynamic Aerospace, Inc.
Julie Draper, Operations Research Analyst, Federal Aviation Administration

Jeff Duven, Co-Chair, JPDO Aircraft Working Group
Chris Francis, Computer Sciences Corporation
Yuri Gawdiak, JPDO Division Director, Systems Modeling and Analysis Division
Gene Hayman, Co-Chair, JPDO Net Centric Operations Working Group
Roberta Leffwich, Booz Allen Hamilton
Jay Merkle, Chief Architect, JPDO
Paul Polski, Department of Homeland Security
Elizabeth Ray, Co-Chair, JPDO Air Navigation Services Working Group

PARTICIPANTS

Michael O. Ball, Orkand Corporation Professor of Management Science, Robert H. Smith School of Business, University of California
Greg Carr, System Engineer, Sensis
Paul Devoti, Federal Aviation Administration
Frank Durso, Department of Psychology, Texas Tech University
Vanessa Fong, The MITRE Corporation
Joseph J. Hance, Senior Management and Program Analyst, Office of the Inspector General, Office of Aviation and Special Program Audits, U.S. Department of Transportation
Bruce J. Holmes, Chief Strategist, NextGen Systems, DayJet Corporation
Stephen Kalish, Deep Water Point LLC (former President, CSC's Federal Sector Civil Group)
Dennis Lamy, National Air Traffic Controllers Association
Susan J. Mertes, Director, Aviation Infrastructure, Aerospace Industries Association
Guy Norris, Senior Editor, Southern California Bureau, Aviation Week & Space Technology
John O'Meara, Director, Flight Operations Test and Chief Test Pilot, Gulfstream
Glenn Roberts, Chief Engineer, Center for Advanced Aviation System Development, The MITRE Corporation
Richard Scott, Physical Infrastructure Team, U.S. Government Accountability Office
Arthur Shantz, Technical Advisor for Aviation Research and Acquisitions, Office of the Inspector General, Department of Transportation Office, U.S. Department of Transportation
Chris Sutherland, National Air Traffic Controllers Association
Karlin Toner, National Aeronautics and Space Administration
Kelli Willshire, National Aeronautics and Space Administration

NATIONAL RESEARCH COUNCIL STAFF

Robert L. Riemer, Senior Program Officer, Aeronautics and Space Engineering Board
Sarah Capote, Program Associate, Aeronautics and Space Engineering Board

D

Biographies of Organizing Committee Members and Rapporteur

ORGANIZING COMMITTEE

John K. Lauber, *Chair,* was senior vice president and chief product safety officer for Airbus SAS in Toulouse, France. Prior to assuming this position in January 2005, Dr. Lauber was vice president for safety and technical affairs for Airbus North America in Washington, D.C. Dr. Lauber holds a Ph.D. in neuropsychology from Ohio State University. He was vice president for training and human factors for Airbus Service Company from 1997 to 2000, and prior to joining Airbus was vice president for corporate safety and compliance at Delta Air Lines. He is a commercial pilot, with both airplane and helicopter ratings, and is type rated in the B727 and the A320. Dr. Lauber has also served as chief of the Aeronautical Human Factors Research Office for NASA, where he was instrumental in the development of advanced flight crew training concepts that are now used by airlines around the world. He has received numerous awards, including NASA's Outstanding Leadership Award, the Flight Safety Foundation/Aviation Week and Space Technology Distinguished Service Award, and the Industry/Public Service Award from *Air Transport World*. He has also served on several NRC boards and committees.

Donald Fraser (NAE) is a director of DRS Technologies and has a broad reach of management experience. He was the founder and director of the Photonics Center at Boston University. He joined Massachusetts Institute of Technology's (MIT's) Instrumentation Laboratory (which became the Charles Stark Draper Laboratory in 1973) as a member of the technical staff and later served as the director of the Control and Flight Dynamics Division, vice president of technical operations, and executive vice president. Dr. Fraser received his B.S. and M.S. in aeronautics and astronautics and his Sc.D. in instrumentation from MIT. From 1990 to 1991, Dr. Fraser was deputy director of operational test and evaluation for command, control, communications, and intelligence at the U.S. Department of Defense. He was the appointed principal deputy under secretary of defense (acquisition) from 1991 to 1993. From 1994 until he retired in 2006, Dr. Fraser was the director of Boston University's Photonics Center and a professor of engineering and physics. His honors include the Defense Distinguished Service Medal. He is a former member of the Aeronautics and Space Engineering Board, a former chair of three NRC study groups, and a former member of six other NRC study groups.

R. John Hansman, Jr., is a professor of aeronautics and astronautics, head of the Humans and Automation Division, and director of the MIT International Center for Air Transportation. He received his Ph.D. from MIT in physics, meteorology, aeronautics and astronautics, and electrical engineering. In addition to teaching, Dr. Hansman conducts research in several areas related to air transportation, flight vehicle operations, and safety. His current research activities focus on information technology applied to air transportation systems, air traffic control, integrated human-automation systems, advanced vehicles, and advanced cockpit information systems. He is also an internationally recognized expert in aviation meteorological hazards such as icing and wind shear. Dr. Hansman is a member of the Aeronautics and Space Engineering Board as well as a member of the NRC Committee for the Assessment of NASA's Aeronautics Research Programs. He has served on the Committee to Identify Potential Breakthrough

Technologies and Assess Long-Term R&D Goals in Aeronautics and Space Transportation Technology and the Committee on the Effects of Aircraft-Pilot Coupling on Flight Safety.

John B. Hayhurst retired in 2004 as senior vice president of the Boeing Company and president of Boeing Air Traffic Management after 33 years at Boeing and 3½ 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). Mr. Hayhurst's other Boeing assignments included general manager of the BCAG production site in Renton, Washington; vice president and general manager of 737 programs; BCAG vice president of sales; and BCAG vice president of the Americas—with responsibility 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. He is a member of the NRC Committee for the Assessment of NASA's Aeronautics Research Program.

S. Michael Hudson is vice chair (retired) of Rolls-Royce North America. Mr. Hudson assumed that position in early 2000 and continued in that role through his retirement in the spring of 2002. He graduated from the University of Texas with a degree in mechanical engineering. Mr. Hudson has served as chief engineer for advanced technology engines, chief engineer for small production engines, supervisor of design for the Model 250 engines, and chief of preliminary design and chief project engineer in vehicular gas turbines during his tenure at Allison. From 1962 to 1968, he was employed by Pratt & Whitney Aircraft, working in aircraft engine design, installation and performance, engine development and demonstration, and industrial and marine engine application engineering. His honors include membership as a fellow of the Society of Automotive Engineers and the Royal Aeronautical Society, an honorary fellow of the American Helicopter Society, and an associate fellow of the American Institute of Aeronautics and Astronautics. Mr. Hudson has served as chair of the SAE's Aerospace Council. He has also been on its Aerospace Program Office Committee and its Finance Committee. He has served as chair of the ASEB Committee on Technology Pathways and testified to the Subcommittee on Space and Aeronautics of the House Committee on Science, March 29, 2006, on assessing the integrated plan for a next-generation air transportation system.

Charles E. Keegan is director of Future Air Navigation systems for Raytheon's Network Centric Systems Airspace Management and Homeland Security business. In this role, he leads the NextGen initiative, Navigation and Landing Systems product line, and mergers and acquisitions efforts. Mr. Keegan graduated from Daniel Webster College in 1981 with a B.S. degree in air traffic control and business management. Prior to joining Raytheon, he was vice president, Operations Planning, for the Federal Aviation Administration (FAA) as well as chair and director of the FAA's Joint Program Development Office. As head of the JPDO, Keegan was responsible for the development and delivery of the NGATS plan for 2020 and beyond. Mr. Keegan served as the Air Traffic Organization's vice president for en route and oceanic operations, which included carrying out new en route capabilities and oceanic airspace services delegated to the FAA by the International Civil Aviation Organization. In that role, he was responsible for the delivery of all en route air traffic services. He was also responsible for the financial management associated with providing these services. Mr. Keegan's experience includes

directing system requirements and managing quality assurance and training programs. His first position with the FAA was as an air traffic controller. He is also a licensed pilot.

Beth Lyall has served as a consultant and contractor to the FAA on human factors issues related to flight deck automation design, training, operations, and certification for over 15 years. Dr. Lyall gained her Ph.D. from Arizona State University. She founded Research Integrations, Inc., to be an independent voice to influence flight safety through conducting and applying relevant research. She has served as a member of the international harmonization working group to develop a new regulation addressing human factors in flight deck design for transport-category airplanes and is currently serving on the Flight Deck Automation Working Group that is identifying current and future safety and other operational issues with the design, training, operation, and certification of flight deck automated systems and their interaction in the current and future air space. Research Integrations also has developed and maintains the Web site www.flightdeckautomation.com, which includes a searchable database of flight deck automation issues and related research findings for each of those issues.

Gen. Lester L. Lyles retired from the Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio, as commander. Gen. Lyles received a BSME from Howard University and an M.S. in mechanical and nuclear engineering from New Mexico State University. He has served in various assignments, including program element monitor of the Short-Range Attack Missile at Headquarters U.S. Air Force, special assistant and aide-de-camp to the Commander of Air Force Systems Command, Avionics Division chief in the F-16 Systems Program Office, director of Tactical Aircraft Systems at AFSC headquarters, and director of the Medium-Launch Vehicles Program and Space-Launch Systems offices. Gen. Lyles became AFSC headquarters' assistant deputy chief of staff for requirements in 1989 and deputy chief of staff for requirements in 1990. In 1992, he became vice commander of Ogden Air Logistics Center, Hill AFB, Utah. He served as commander of the center until 1994, and then was assigned to command the Space and Missile Systems Center at Los Angeles AFB, California, until 1996. Gen. Lyles became the director of the Ballistic Missile Defense Organization in 1996. In May 1999, he was assigned as vice chief of staff at USAF/HQ. He has served as the vice chair on the NRC Committee on Systems Engineering: A Retrospective Review and Benefits for Future Air Force Systems Acquisition and was a member of the Committee on Systems Integration for Project Constellation.

Nadine B. Sarter is associate professor in the University of Michigan's Department of Industrial and Operations Engineering Center for Ergonomics. She is a private pilot, rated for airplane single-engine land, and completed Airbus A-320 airline pilot training in 1994. She received a Ph.D. in industrial and systems engineering from Ohio State University. She has an M.S. in applied and experimental psychology from the University of Hamburg, Germany. Dr. Sarter has been associate editor of the IEEE's *Transactions on Intelligent Transportation Systems* since 2002 and is on the editorial boards of *Human Factors*, *Journal of Experimental Psychology*, *Applied Journal of Cognitive Engineering and Decision Making*, *Applied Ergonomics*, *International Journal of Aviation Psychology*, and *Journal of Human Performance in Extreme Environments*. She has received numerous awards from NASA as well as the National Science Foundation's Directorate for Computer and Information Science and Engineering and the American Psychological Association's Division of Applied Experimental and Engineering Psychology. Dr. Sarter was an invited participant at numerous workshops, including the DARPA ISAT Workshop on Discovery and Innovation During Field Use of Information Technologies; the 2006 NSF Human-Centered Computing Workshop; and the Joint Program Development Office Workshop on Next Generation Air Transportation System Human-Automation Interaction Issues and Research Needs. She has also served on several NRC committees and workshops.

Edmond L. Soliday was employed by United Airlines for more than 35 years as a pilot, operations expert, human factors instructor, flight manager, and staff executive, serving the last 11 as vice president for safety, quality assurance, and security. He has served on numerous aviation safety-related advisory

boards and commissions, and has extensive experience in flight operations. Over the course of his career, Capt. Soliday has chaired the Commercial Aviation Safety Team, the Air Transport Association Safety Council, the Star Alliance Safety Committee, and the ATA Environmental Committee. He formerly served on the Executive Board of the Flight Safety Foundation. Capt. Soliday currently serves on the Massachusetts Institute of Technology Global Airline Industry Program Advisory Group and is an Indiana State Representative serving on the Transportation, Commerce, Energy and Technology committees. Among his awards are the Bendix Trophy, the Vanguard Trophy, and the Laura Tabor Barbour International Air Safety Award. Capt. Soliday has previously served on four NRC study groups.

RAPPORTEUR

Deborah A. Boehm-Davis is currently a professor of psychology in the Human Factors and Applied Cognition Program at George Mason University in Fairfax, Virginia. She holds an A.B. in psychology from Rutgers State University (Douglass College) and an M.A. and a Ph.D. in cognitive psychology from the University of California, Berkeley. She worked on applied cognitive research at General Electric, NASA Ames, and Bell Laboratories prior to joining George Mason University in 1984. She is interested in how human performance is helped or hindered by the design of tools that help accomplish everyday tasks. Her particular research interest is in how improved display of information can improve human performance.

Dr. Boehm-Davis is the president-elect of Division 21 (Applied Experimental and Engineering Psychology) of the American Psychological Association. In the past, she served as the president and the secretary-treasurer of the Human Factors and Ergonomics Society. She is on the editorial boards of *Human Factors*, the *International Journal of Human-Computer Studies*, the *International Journal of Human-Computer Interaction*, and *Theoretical Issues in Ergonomic Sciences*.

Awards she has received include the Franklin Taylor Award from the IEEE Systems, Man, and Cybernetics Society (1985); the Washington Academy of Sciences Award for Scientific Achievement in the Behavioral and Social Sciences (1994); selection as a member of the Douglass Society (2002); and the Franklin V. Taylor Award from Division 21 of the American Psychological Association (2003). She is a fellow of both the American Psychological Association and the Human Factors and Ergonomics Society.