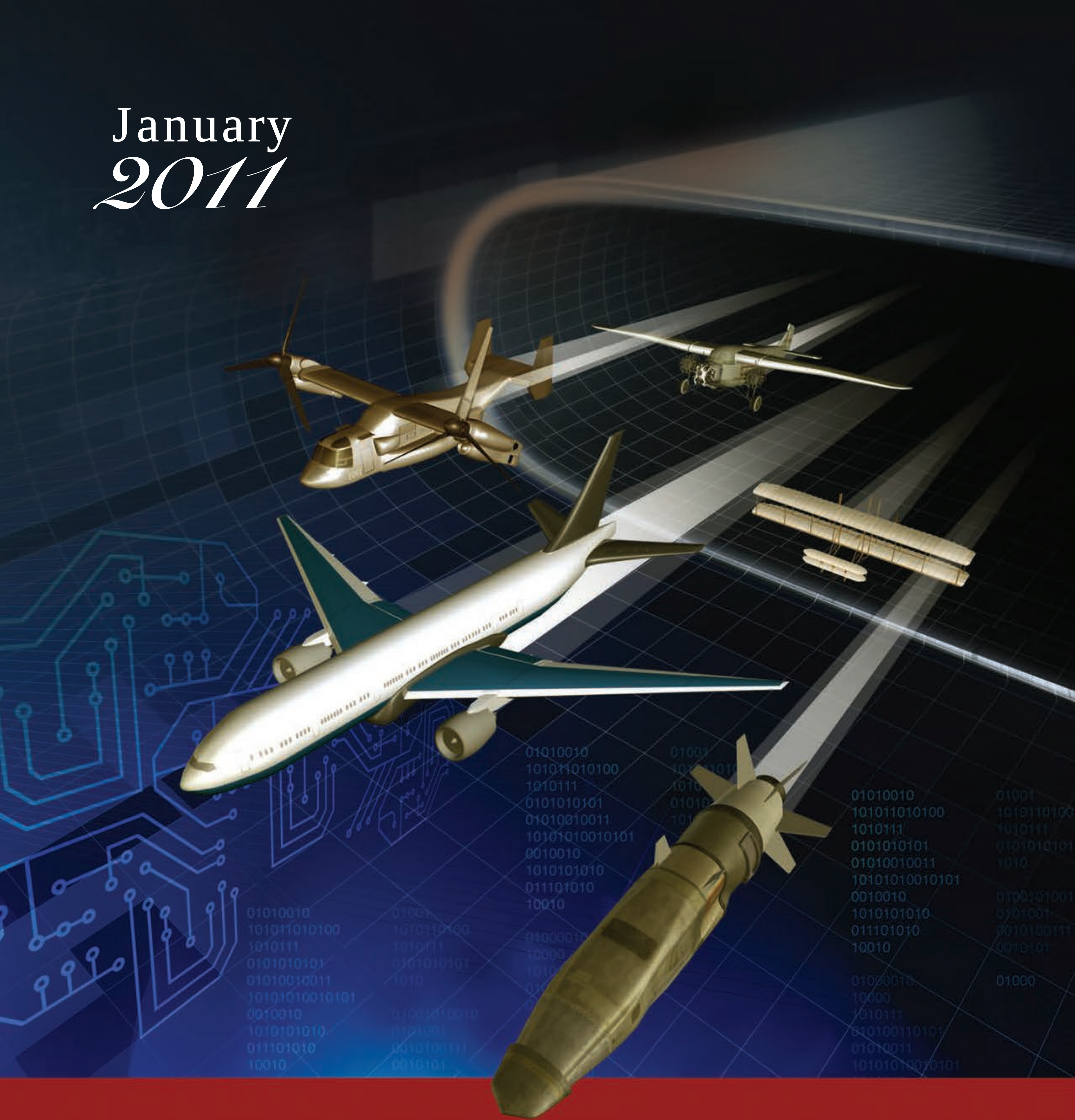
January
2011



National Aeronautics Research, Development, Test and Evaluation (RDT&E) Infrastructure Plan

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JAN 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**
4. TITLE AND SUBTITLE **National Aeronautics Research, Development, Test and Evaluation (RDT&E) Infrastructure Plan**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **National Science and Technology Council,Committee on Technology,Aeronautics Science and Technology Subcommittee,Washington,DC,20502**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**48**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

About the National Science and Technology Council

The National Science and Technology Council (NSTC) was established by Executive Order 12881 on November 23, 1993. This Cabinet-level Council is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the federal research and development enterprise. Chaired by the President, the NSTC is made up of the Vice President, the Director of the Office of Science and Technology Policy, Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other White House officials. For more information visit www.whitehouse.gov/ostp/nstc.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on all questions in which science and technology are important elements and articulating the President's science and technology policies and programs. For more information visit www.whitehouse.gov/ostp.

Front Cover: The image depicts a variety of aircraft—from the Wright Flyer to the latest hypersonic vehicles—where aeronautics research, development, test, and evaluation infrastructure (e.g., ground test facilities such as wind tunnels; flight test facilities such as test ranges; and simulation, computational, and network infrastructure) has helped to advance aeronautics and the mastery of flight.

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

January 4, 2011

Dear Colleague:

The 2010 National Aeronautics Research and Development Plan (R&D Plan) represents the Federal consensus regarding national aeronautics R&D challenges, goals, and supporting objectives. Key to the success of the R&D Plan is a need for improved interagency collaboration to best manage and use the Nation's aeronautics research, development, test, and evaluation (RDT&E) infrastructure. Recognizing this, the National Aeronautics Research and Development Policy that guides Federal aeronautics research and development (R&D) through 2020, directs relevant Federal departments and agencies to develop a plan for managing the infrastructure necessary to achieve the goals and objectives in the R&D Plan.

This *National Aeronautics Research, Development, Test and Evaluation (RDT&E) Infrastructure Plan* (Infrastructure Plan) is a companion to the R&D Plan that will help determine the availability and adequacy of the RDT&E infrastructure necessary to achieve the goals and objectives in the R&D Plan. The Infrastructure Plan includes:

- An analysis of critical shortfalls between the infrastructure that is foreseen to be available in the United States and that necessary to achieve the goals and objectives outlined in the R&D Plan.
- An examination of issues related to the interagency management of aeronautics R&D infrastructure, including recommendations on addressing some of those issues.
- Paths forward for evaluating network infrastructure needs related to national aeronautics R&D priorities and for analyzing issues related to the international usage of aeronautics RDT&E infrastructure.

This Infrastructure Plan is part of the Administration's sustained emphasis on interagency planning to define and achieve high-priority national aeronautics R&D goals and objectives. It highlights areas in which stronger interagency coordination will enable improved productivity from important national investments in aeronautics RDT&E infrastructure. Innovative interagency management processes and policies will assist the Federal departments and agencies in achieving the goals and objectives in the R&D Plan, thus contributing to the economic growth and security of the Nation, while assuring its continued technological leadership in aeronautics.

Sincerely,

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

National Aeronautics Research, Development, Test and Evaluation (RDT&E) Infrastructure Plan

January 2011

Aeronautics Science and Technology Subcommittee
Committee on Technology
National Science and Technology Council

Table of Contents

OVERVIEW

A capable aeronautics research, development, test and evaluation (RDT&E) infrastructure is essential to meeting the challenges, goals, and objectives of the nation's aeronautics research and development (R&D) community. Recognizing this, on December 20, 2006, Executive Order 13419, "National Aeronautics Research and Development," expressed the importance of aeronautics RDT&E infrastructure. As part of the Executive Order, the Director of the Office of Science and Technology Policy is charged with recommending to the President, the Director of the Office of Management and Budget, and to the heads of executive departments and agencies appropriate actions to "maintain and advance United States aeronautics research, development, test and evaluation infrastructure to provide effective experimental and computational capabilities in support of aeronautics R&D."

Innovation in aeronautics has served a prominent role in U.S. industry and defense for over 100 years. After World War I, aeronautics research labs, such as the National Advisory Committee on Aeronautics (NACA) Langley Memorial Aeronautical Laboratory, were conducting experiments and tests that led to the discovery of cantilevered wings. These wings could be attached directly to the fuselage without any external, stress-bearing structures. This newfound knowledge allowed for the development of metal-skinned airplanes with more powerful engines, a drastic change from the Wright brothers' *Flyer I* wood and cloth airplane. This technological advancement allowed for the Douglas DC-3 airplane, with powerful engines and an enclosed cabin, to simultaneously cut the time of flying across the United States and the cost of flying in half, making commercial airlines a profitable business.[1]

At the end of World War II, the U.S. Army Air Forces (known today as the U.S. Air Force) and NACA began the first of a series of experimental aircraft projects, many of which were designed to develop technology for high-speed flight. One of these experiments was the X-1. On October 14, 1947, the X-1, piloted by Captain Charles Yeager, proved that an aircraft could be controlled at speeds faster than the speed of sound. This demonstration led to several aerodynamic advances that were quickly incorporated into U.S. fighter aircraft designs.[2]

These aviation advancements laid the foundation for space travel. The Space Transportation System (STS), the official name for the Space Shuttle Program developed by the National Aeronautics and Space Administration (NASA), was designed to replace the expendable launch vehicles that NASA was using to deliver commercial, scientific, and applications spacecraft into Earth's orbit. Its unique design would also enable its use as

1 Dwayne A. Day, "The Monoplane," US Centennial of Flight Commission: Centennial of Flight 1903-2003. Accessed on October 12, 2010. Available at: http://www.centennialofflight.gov/essay/Evolution_of_Technology/Monoplane/Tech13.htm.

2 Dwayne A. Day, "Early X-Planes," US Centennial of Flight Commission: Centennial of Flight 1903-2003. Accessed on October 12, 2010. Available at: http://www.centennialofflight.gov/essay/Evolution_of_Technology/early_X_planes/Tech27.htm.

a platform for scientific laboratories, an orbiting service center for other satellites, and a return carrier for previously orbited spacecraft.[3] In April of 1981, the STS-1 became the first flown aerodynamic winged vehicle to reenter from space, employing technologies developed over 30 years.

These technological advancements would not have been possible if not for the infrastructure that supported them. Wind tunnels helped to advance aviation by enabling the use of models for testing, a less expensive method than building the full-size vehicle. Testing and experimentation were quickly advanced with the introduction of high-powered computers. For example, researchers have used computational fluid dynamics (CFD) to simulate various aspects of aircraft and aircraft flight, providing aircraft designers with a new tool to support the development and testing of new aircraft designs and avionics components.[4]

Aeronautics RDT&E infrastructure plays an important role in enabling rapid and cost-effective improvements in modern aircraft for both civilian and military applications. As a result, the maintenance, upgrading, and management of the RDT&E infrastructure are critical to the success of aeronautics research and development. This National Aeronautics RDT&E Infrastructure Plan identifies critical shortfalls in current infrastructure capabilities related to achieving the goals and objectives laid out in the National Aeronautics R&D Plan,[5] and reviews issues and approaches related to interagency management and use of critical infrastructure.[6] It also describes a path forward for evaluating the network infrastructure needs related to national aeronautics R&D priorities and for assessing issues related to international sharing and use of aeronautics RDT&E infrastructure.

The actions and associated resources required to implement this plan will need to be prioritized in the context of other U.S. Government priorities. This document is neither intended as direction to invest in new infrastructure, nor as inherent justification to seek increased budgetary authority. Rather, it provides insight into the infrastructure required to achieve the goals and objectives in the National Aeronautics R&D Plan. It is expected that departments and agencies will consider this document in their internal prioritization and planning processes.

3 Judy Rumerman, "Space Shuttle," US Centennial of Flight Commission: Centennial of Flight 1903-2003. Accessed on October 12, 2010. Available at: http://www.centennialofflight.gov/essay/SPACEFLIGHT/Shuttle/SP25.htm.

4 Dwayne A. Day, "Advanced Wind Tunnels," US Centennial of Flight Commission: Centennial of Flight 1903-2003. Accessed on October 13, 2010. Available at: http://www.centennialofflight.gov/essay/Evolution_of_Technology/advanced_wind_tunnels/Tech36.htm.

5 Office of Science and Technology Policy, National Science and Technology Council, "National Aeronautics Research and Development Plan," February 2010.

6 A table relating the critical shortfalls identified by the specialized task forces to the aeronautics goals and objectives in the 2010 National Aeronautics R&D Plan can be found as Enclosure 1.

INTRODUCTION

On December 20, 2006, Executive Order 13419, "National Aeronautics Research and Development," implemented the nation's policy to guide Federal aeronautics R&D through 2020. The Executive Order was accompanied by a Policy[7] that provided further guidance for the development of the National Aeronautics R&D Plan. The Policy called for a plan "comprising national research priorities and objectives, roadmaps to achieve the identified objectives, and timelines," to be updated biennially.

In addition, the Policy called for a supporting infrastructure plan for managing Federal RDT&E assets that are critical for accomplishing the national R&D goals and objectives. The Policy stated that the infrastructure plan should "identify which assets are considered critical from a national perspective and define an approach for constructing, maintaining, modifying, or terminating these assets based on the needs of the broad user community." The full set of demands on the national aeronautics RDT&E infrastructure extends beyond the requirements of the National Aeronautics R&D Plan; this infrastructure plan does not assess the full range of uses of this infrastructure. Rather, it is intended to support the National Aeronautics R&D Plan, and will be updated periodically in response to changes to that document.

The Policy laid out seven key principles to guide the conduct of the nation's aeronautics R&D activities through 2020:

- Mobility through the air is vital to economic stability, growth, and security as a nation.
- Aviation is vital to national security and homeland defense.
- Aviation safety is paramount.
- Security of and within the aeronautics enterprise must be maintained.[8]
- The United States should continue to possess, rely on, and develop its world-class aeronautics workforce.[9]
- Assuring energy availability and efficiency is central to the growth of the aeronautics enterprise.
- The environment must be protected while sustaining growth in air transportation.[10]

These principles, with two exceptions as noted, served as the framework for the National Aeronautics R&D Plan, which was released in December 2007 and updated in February

7 Office of Science and Technology Policy, National Science and Technology Council, "National Aeronautics Research and Development Policy," December 2006.
8 Aviation security R&D efforts are coordinated through the National Strategy for Aviation Security and its supporting plans.
9 The Interagency Aerospace Revitalization Task Force—established by Public Law 109-420 and chaired by the Department of Labor—is developing strategies for the aerospace workforce.
10 Energy and Environment were separate principles in the Policy; however, they are sufficiently integrated that they are considered together in the National Aeronautics R&D Plan.

2010.[11] The current National Aeronautics R&D Plan contains a set of fundamental challenges and associated high-priority R&D goals that seek to address those challenges. It also provides supporting objectives for each goal, with these objectives phased over three time periods: near term (under 5 years), mid term (5–10 years), and far term (over 10 years).

The 2007 National Aeronautics R&D Plan outlined the path forward for developing an RDT&E infrastructure plan that focuses on the assets and capabilities necessary to support the goals and objectives set forth in the National Aeronautics R&D Plan.[12] The goals of the National Aeronautics RDT&E Infrastructure Plan are stated as follows:

- Determine the national RDT&E infrastructure that satisfies national aeronautics R&D goals and objectives (laid out in the National Aeronautics R&D Plan), and
- Establish a coordinated management approach that is based upon a national perspective and interagency cooperation.[13]

For purposes of this infrastructure plan, the term "Federal aeronautics RDT&E infrastructure" refers to the aeronautics RDT&E infrastructure that is owned and/or managed by departments and agencies of the Federal Government. The "national aeronautics RDT&E infrastructure" refers to the aeronautics RDT&E infrastructure that is located within the United States, regardless of which organizational entity (Federal or non-Federal) owns or manages that infrastructure. The "foreign aeronautics RDT&E infrastructure" refers to the aeronautics RDT&E infrastructure that is located outside the United States.

METHODOLOGY

The Aeronautics Science and Technology Subcommittee (ASTS) of the National Science and Technology Council's (NSTC) Committee on Technology chartered an Infrastructure Interagency Working Group (IIWG) to develop this infrastructure plan. The IIWG, in turn, established five specialized task forces:

- Ground Test Facilities
- Flight Test Facilities (including aircraft)
- Simulation Facilities
- High-End Computational Facilities
- Network Infrastructure

11 Office of Science and Technology Policy, National Science and Technology Council, "National Plan for Aeronautics Research and Development and Related Infrastructure," December 2007; Office of Science and Technology Policy, National Science and Technology Council, "National Aeronautics Research and Development Plan," February 2010.

12 The 2010 National Aeronautics R&D Plan did not update the infrastructure implementation plan; therefore, the infrastructure goals laid out in the 2007 National Aeronautics R&D Plan remain in effect.

13 Office of Science and Technology Policy, National Science and Technology Council, "National Plan for Aeronautics Research and Development and Related Infrastructure," December 2007, pp. 35–37.

The primary task of these specialized task forces was to evaluate the sufficiency of the current Federal aeronautics RDT&E infrastructure with respect to the aeronautics R&D goals and objectives in the 2010 National Aeronautics R&D Plan. Each task force comprised subject matter experts from the relevant Federal departments and agencies.

The task forces identified the infrastructure capabilities required to attain the aeronautics goals and objectives in the National Aeronautics R&D Plan. A comparison of these required capabilities with existing national infrastructure assets revealed 12 critical shortfalls discussed in this document.

The Cyber Infrastructure Task Force developed an approach to providing the network architecture expected to connect and integrate the other components of the national aeronautics RDT&E infrastructure. In accordance with the National Aeronautics R&D Plan, the requirements, processes, policies, methodologies, and protocols to operate the network infrastructure will be further developed on a separate schedule (See Network Infrastructure).[14]

Designation of Critical Infrastructure

The Policy states that the infrastructure plan should "identify which assets are considered critical from a national perspective…."[15] The 2007 National Aeronautics R&D Plan states that "the infrastructure plan must clearly identify the critical assets of the national RDT&E infrastructure to ensure that all necessary RDT&E capabilities are ultimately available to support the goals and objectives of the (National Aeronautics R&D) Plan."[16]

Within this document, critical infrastructure is defined as those aeronautics RDT&E infrastructure capabilities that must be technically sufficient with adequate capacity available. Without these capabilities, it would not be possible to achieve one or more of the aeronautics R&D goals or objectives contained in the National Aeronautics R&D Plan. However, this document is neither intended as direction to invest in new infrastructure, nor as inherent justification to seek increased budgetary authority. Criticality evolves over time as technologies advance and as R&D plans and priorities change. Therefore, this assessment needs to be periodically updated to ensure that it reflects the goals and objectives of the aeronautics R&D community.

LIMITING FACTORS AND ASSUMPTIONS

A number of factors were determined to be outside the scope of this infrastructure plan. Those factors, which are described in the following paragraphs, limited the analyses and

14 Ibid., p. 36.

15 Office of Science and Technology Policy, National Science and Technology Council, "National Aeronautics Research and Development Policy," December 2006, p. 15.

16 Office of Science and Technology Policy, National Science and Technology Council, "National Plan for Aeronautics Research and Development and Related Infrastructure," December 2007, p. 34.

constrained the conditions used in examining the infrastructure and identifying potential shortfalls and unnecessary redundancies.

Full Set of Demands on the Infrastructure

The full set of demands on the national aeronautics RDT&E infrastructure extends beyond the requirements of the National Aeronautics R&D Plan. Aeronautics infrastructure facilities across the Federal Government support a combination of activities, including support of ongoing systems, test and evaluation, and research and development. The non-R&D uses often consume the majority of resources at a facility. Further, it is essential to note that mission-specific priorities exist for the use of infrastructure by individual departments and agencies to meet their respective missions and that these priorities may not be reflected within the goals and objectives laid out in the National Aeronautics R&D Plan. Among these mission-specific priorities are the development and testing of aeronautical weapon systems for the Department of Defense (DoD), development and testing of NASA's space systems (including any space vehicles and launch vehicles that require successful performance within Earth's atmosphere and the atmosphere of any planet that is entered by the space vehicle), periodic development and testing of systems to improve flight safety and air traffic management for the Federal Aviation Administration (FAA), and support for the development of commercial aircraft and space enterprises that are dependent on the Federal infrastructure for major test capabilities. These critical aeronautics missions are agency-specific and therefore are not reflected as interagency priorities in the National Aeronautics R&D Plan. Finally, assets in the national aeronautics RDT&E infrastructure are sometimes used for applications that are not aeronautical in a strict sense. For example, wind tunnels may be used for testing wind turbines, automotive vehicles, or other products. Thus, aeronautics R&D is not the only activity that requires the use of Federal aeronautics RDT&E infrastructure. This infrastructure plan accounts only for the infrastructure needs related to the National Aeronautics R&D Plan and therefore does not assess the full set of demands on the national aeronautics RDT&E infrastructure.

Redundancies within the Infrastructure

This infrastructure plan was intended to identify both deficiencies and excesses that might exist in the aeronautic RDT&E infrastructure. However, deficiency and redundancy analyses are dissimilar problems: a redundancy analysis is significantly more convoluted and difficult than a deficiency analysis. It is relatively straightforward to determine if there are unmet needs; it is substantially more difficult to determine if a particular capability does not meet any needs. This difficulty is directly related to the full set of demands on the RDT&E infrastructure described above, which includes support of ongoing systems, testing and evaluation, and research and development related to a broad range of priorities outside the National Aeronautics R&D Plan. Given the extent of Federal and non-Federal RDT&E activities that are not addressed in the National Aeronautics R&D Plan, identifying unnecessary redundancy solely on the basis of infrastructure required to support the goals and objectives in the National Aeronautics R&D Plan would result in an inadequate analysis that could adversely affect significant RDT&E work in areas that are not addressed by the National Aeronautics R&D Plan. Therefore, this infrastructure plan does not contain a redundancy analysis.

Computational Tools and Instrumentation

Items such as software and instrumentation are generally excluded from the scope of this infrastructure plan. The rationale for excluding software is that it is developed and evolves as necessary to operate a system or a subsystem. That process can be expected to continue notwithstanding investments made in the construction of test facilities, the manufacture or conversion of test aircraft, and the development and assembly of high-end computers. Similarly, instrumentation can be expected to be added or upgraded as necessary to facilitate effective controls and capture test data in wind tunnels, at open-air ranges, aboard test aircraft, and so on.

Foreign and Non-Federal Domestic Capabilities

The 2007 National Aeronautics R&D Plan states that the "RDT&E infrastructure used by the nation's aeronautics community includes both domestic (i.e., national) and foreign assets." It points out that the national RDT&E infrastructure includes both Federal and non-Federal assets and adds that the nation may rely on selected foreign assets to satisfy the requirements in that national plan.[17] In identifying critical shortfalls, the task forces included national assets, but did not include foreign assets.

Assumptions Regarding Maintenance, Modernization, and Aging Facilities

Many facilities in the aeronautics RDT&E infrastructure were constructed over 50 years ago. Periodic upgrades to those facilities have been principally focused on electronic components, but facilities with large electromechanical elements are now susceptible to the failure of older components. Many suppliers of older components are either out of business or have converted to more modern technologies and no longer have the ability to build replacement parts or to repair large components. Upgrading these components could result in long periods of inactivity at the facilities.

Both the maintenance and modernization of current aeronautics RDT&E infrastructure assets must be an integral part of the implementation of this infrastructure plan so those assets can continue to support the achievement of the aeronautics goals and objectives in the National Aeronautics R&D Plan. The shortfalls analysis in this document assumes that aeronautics RDT&E assets will be (1) adequately maintained by their respective owning or

17 Office of Science and Technology Policy, National Science and Technology Council, "National Plan for Aeronautics Research and Development and Related Infrastructure," December 2007, p. 34.

managing organizations; (2) modernized as necessary to ensure that they continue to provide the necessary data to support the development of state-of-the-art aircraft and related systems; and (3) upgraded or terminated when appropriate to allow the nation to remain fully competitive relative to the international community with respect to both military and civil aeronautics, as well as aeronautical aspects of the U.S. space program.

ASSESSMENT OF THE CURRENT AERONAUTICS RDT&E INFRASTRUCTURE

This chapter discusses the gap between the RDT&E infrastructure capabilities required to achieve the aeronautics goals of the National Aeronautics R&D Plan and the existing infrastructure capabilities expected to be available to U.S. entities to reach those goals. This chapter highlights those infrastructure categories with potential shortfalls and attempts to quantify the extent of the shortfalls where it is feasible to do so. This shortfalls analysis is offered to the departments and agencies to inform and support their decision-making processes with respect to improvement and modernization of the aeronautics RDT&E infrastructure.

EXISTING NATIONAL AERONAUTICS RDT&E INFRASTRUCTURE

The current aeronautics RDT&E infrastructure provides a good foundation for meeting the requirements of the R&D community. It consists of a broad range of facilities that can be categorized into ground test, flight test, simulation, and high-end computing facilities. It also consists of an expanding network infrastructure that links facilities.

- **Ground Test Facilities—**Ground test facilities make up the portion of the aeronautics RDT&E infrastructure used primarily to obtain data regarding the characteristics of air vehicles and/or components, by subjecting those vehicles or components, or scale models of those vehicles and/or components, to conditions on the ground similar to those they would encounter during flight. Ground test facilities include wind tunnels, air-breathing engine test cells, material and structures laboratories, etc. that are accompanied by data acquisition and instrumentation systems that allow engineers and researchers to collect and record data about the manner in which the vehicle, components, and/or materials and structures respond to temperatures, pressures, air flows, and similar environmental factors that they would experience in flight.

- **Flight Test Facilities—**Flight test facilities are the portion of the aeronautics RDT&E infrastructure used to obtain data about flight characteristics of test air vehicles, components of test air vehicles, and/or test articles during the time these entities are actually in flight, and then analyze those data for purposes of evaluating the flight characteristics and performance of the test article and its design. Such facilities would typically include open air test ranges, flight vehicle test beds, and supporting aircraft, together with the equipment and instrumentation needed to track and/or control the flight of the test entity and to measure and record data regarding its performance.

- **Simulation Facilities—**Simulation facilities are the portion of the aeronautics RDT&E infrastructure used to obtain data without the cost and risk of real-world testing. For the purposes of this plan, aeronautics simulation facilities include large-scale airspace simulators, both human in the loop and fast-time; flight simulators; and computational simulators. Simulation data from these facilities are typically used for analysis and research involving human factors, safety, capacity, and procedures.

- **High-End Computational Facilities—**High-end computational facilities are the portion of the aeronautics RDT&E infrastructure used for calculation-intensive tasks such as computational fluid dynamics, structural dynamics, and chemistry associated with understanding the complex physics involved with aeronautical engineering, as well as weather forecasting and climate prediction, which are used for air traffic management. High-end computational facilities include high performance computing centers, high-end computing laboratories, and individual supercomputers, and are typically composed of high speed computer processors, high volume storage capabilities, and high speed networks.

- **Network Infrastructure—**Network infrastructure is the critical framework through which devices, facilities, and organizations collaborate with each other. As described in Chapter 4, network infrastructure will be analyzed in a future revision.

The aeronautics RDT&E infrastructure will continue to enable progress in aeronautics research, provided certain conditions are met. *First*, access to this infrastructure should be assured for aeronautics R&D, given that the aeronautics R&D community is not the only user of these capabilities and that the capabilities generally exist within various individual department and/or agency boundaries. *Second*, the necessary investment should be made to sustain and upgrade existing capabilities. *Finally*, certain critical shortfalls should be addressed.

CRITICAL SHORTFALLS IN THE CURRENT INFRASTRUCTURE

The IIWG's assessment of the Federal aeronautics RDT&E infrastructure found the infrastructure described above to be largely adequate for supporting the goals and objectives in the 2010 National Aeronautics R&D Plan; however, some critical shortfalls that could hinder future progress were identified. The order in which those shortfalls appear is not indicative of their relative priority.

Ground Test Facilities

- Subsonic Acoustic Measurement and Low Turbulence Flow Test Facilities
- Hypersonic Materials Test Facilities
- Hypersonic Engine (Scramjet) Development Propulsion Test Facilities

- Turbine Engine Icing Test Facilities
- Turbine Engine Combustion Facilities
- Full-Scale Rotorcraft Test Facilities

Flight Test Facilities

- Transport Category Flight Test Aircraft
- Hypersonic Test Ranges
- Airborne Icing Capability

Simulation Facilities

- Flight Simulators Representative of Aircraft in Service
- Four Dimensional Trajectory Simulation Capability

High-End Computational Facilities

- High-End Computing Capacity

It is understood that the actions and the associated resources to mitigate the infrastructure shortfalls identified in this plan will need to be prioritized in the context of other U.S. Government priorities. This document is neither intended as direction to invest in new infrastructure, nor as inherent justification to seek increased budgetary authority. It is expected that departments and agencies responsible for the Federal aeronautics RDT&E infrastructure will consider these shortfalls in their internal prioritization and planning processes to enable progress on the highest order goals in the R&D Plan. Some of the critical shortfalls identified may be addressed in whole or in part by ongoing or planned infrastructure projects. The ASTS will periodically modify the list of critical shortfalls as they are mitigated.

Ground Test Facilities

Subsonic Acoustic Measurement and Low Turbulence Flow Test Facilities

In the 2010 National Aeronautics R&D Plan, development of N+2 aircraft, N+3 aircraft,[18] and next-generation rotorcraft with reduced noise requires the capability to replicate turbulence and the acoustic environment. The gap in subsonic acoustics is the inability of the existing test facilities to provide a quiet environment that can distinguish between test facility and research hardware noise. Acoustic and turbulence levels in existing large-scale facilities are too high to achieve the aeronautics goals in the 2010 National Aeronautics R&D Plan. Unsteady turbulence and flow angularity levels are 3 to 10 times too great to provide accurate data for complex dynamic models. An improved large-scale, low-speed

18 "'N' refers to the current generation of tube-and-wing aircraft. 'N+1' represents the next generation of tube-and-wing aircraft. 'N+2' refers to advanced aircraft in the generation after N+1, which are likely to use revolutionary configurations (such as hybrid wing-body, small supersonic jets, cruise efficient short take-off and landing and advanced rotorcraft). 'N+3' refers to the generation of aircraft after N+2, which have dramatically improved performance and reduced noise and emissions." Office of Science and Technology Policy, National Science and Technology Council, "National Aeronautics Research and Development Plan," February 2010, p. 13.

capability (from the suite of existing subsonic wind tunnels), with enhanced anechoic treatments and with greatly improved wind tunnel flow quality, is needed to meet future acoustic test requirements. These facility modifications are critical to achieving goals for fuel efficiency,[19] noise reduction, and military rotorcraft mission capability. This shortfall exists in the near, mid, and far terms.

Hypersonic Materials Test Facilities

Demonstrating sustained, controlled hypersonic flight requires the testing of aerothermal materials throughout the entire flight envelope. The gap in materials testing is the inability to duplicate the flight envelope *between* current facilities that provide high-pressure and low-power simulation (for intercontinental ballistic missile testing) and those that provide low-pressure and high-power simulation (for shuttle-like and other planetary reentry vehicles). This limitation of current facilities contributes to the expense of highly conservative material designs for hypersonic vehicle airframe thermal protection systems and propulsion system inlet leading edges. Current facilities can be modified to expand their operating envelopes to simulate hypersonic vehicle cruise conditions. This modification will allow for more exact material definition for required vehicle operations because the modified facilities can simulate cruise conditions. This shortfall exists in the near, mid, and far terms.

Hypersonic Engine (Scramjet) Development Propulsion Test Facilities

Demonstration of sustained, controlled, air-breathing hypersonic flight above Mach 5 requires an infrastructure capable of testing scramjet propulsion systems. The current infrastructure fails to meet required capabilities because of three limitations. The first is the inability to test full-scale propulsion systems because of limited test cell size and limited mass flow capability. The second limitation is the inability to test scramjets at Mach numbers greater than 5 in clean air and greater than 7 in vitiated air because current high Mach number facilities are limited in mass flow, flow quality, and run time. The third limitation is the inability to vary the wind speed during a test (time-variant Mach number). While the test article is in the test section of a hypersonic propulsion facility, it is highly desirable to test the operation of the propulsion system over a variable Mach number range. These limitations exist in the near, mid, and far terms, and impact not only scramjet propulsion systems, but potential turbine-based combined cycle systems as well.

Turbine Engine Icing Test Facilities

A greater understanding of the impact that icing conditions have on turbine engine operations is needed to develop enhanced design and operations technologies that help prevent accidents. No facility is now available to conduct research by testing turbine engines at

19 Low turbulence wind tunnels allow for research into laminar flow wings, which would contribute to increased fuel efficiency.

altitude for icing conditions that include ice particles. Achieving the goals and objectives of the aeronautics R&D plan requires a ground test facility that provides the capability to develop technologies for iced engine state awareness and hazard assessment. Understanding the physics of ice particle threats is necessary to develop monitoring strategies for safe turbine engine operations. While there currently is a shortfall in the ability to conduct this testing on both large and small turbine engines, an existing facility at NASA's Glenn Research Center is being modified to provide the capability for small turbine engines. However, assessments of icing in large turbine engines will only be achievable on representative test rigs modeling the most important sections of the engine core without being able to accommodate the engine fan, which may limit the ease of using the facility to assess large turbo-fan engines. The implications for test fidelity by using test rigs representing large engines are not fully understood, but they are believed to be manageable. This shortfall exists in the near term.

Turbine Engine Combustion Facilities

In the 2010 National Aeronautics R&D Plan, the development of N+1, N+2, and N+3 aircraft requires the capability to replicate conditions allowing full annular combustor testing. Further investigation is required to identify the combination of pressure, temperature, and flow rate needed to simulate environmental conditions for a chosen engine's annular combustor. Current combustor component test facilities offer lower flow rate capability than required and thus limit component testing to individual fuel injector concepts and sectors of annular combustors. Full annular testing allows researchers to quantify the interaction between the individual fuel injectors as opposed to extrapolating the data from sector test rigs. A facility to test these conditions would be used to quantify efficiency improvements and environmental impacts for planned subsonic and supersonic aircraft. New high-temperature instrumentation and diagnostics would have to be developed in conjunction with this new facility for it to meet the research needs of the 2010 National Aeronautics R&D Plan. This new capability would support goals and objectives relating to enabling new aviation fuels, increasing turbine engine efficiency, and decreasing the environmental impact of nitrogen oxide, carbon dioxide, and soot emissions. This shortfall exists in the near, mid, and far terms.

Full-Scale Rotorcraft Test Facilities

A large static rig facility is needed for testing full-scale prototype rotorcraft systems. A national hover test capability is needed for rotors up to 40 feet in diameter. The 2010 National Aeronautics R&D Plan calls for rotorcraft research into improved lift, range, and mission capability; reduced accidents and incidents; increased energy efficiency; and reduced environmental impacts. This shortfall exists in the near, mid, and far terms.

Flight Test Facilities

Transport Category Flight Test Aircraft

There is a gap in the capability to flight test on-board avionics systems as part of the Next Generation Air Transportation System (NextGen) and the increased safety-of-flight goals. Specifically, there are no transport-category research aircraft dedicated to performing this testing. Reaching these goals will require development of complete systems both on the ground and in the air, as well as a flight test environment. New separation standards, operational profiles, flight deck equipment, and weather-related tools will need to be tested and validated before they will be allowed to fly in the National Air Space. To integrate and test these emerging technologies, flight test aircraft are required for all aircraft categories [general aviation, regional, transport, and unmanned aerial systems (UAS)], but a clear shortfall currently exists in the transport aircraft category. This category of aircraft is critical to best emulate the real world environment for many of the goals. This aircraft will test and validate new systems in upset recovery due to damage, degradation, and failures. This aircraft will be modified with the specific systems under test, as well as the associated instrumentation, flight deck displays, caution/warning systems, and risk mitigation systems to ensure safe flight testing. Specific ground and airspace assets will also be required to safely facilitate testing. The majority of work in this area is in support of the Mobility and Aviation Safety Goals to meet mid-term and far-term objectives.

Hypersonic Test Range Capabilities

There is a shortfall in the capability to flight test hypersonic vehicles overland and limitations on the ability to test over the ocean in response to our National Security and Homeland Defense goals. Overland testing will require developing new hypersonic test corridors that extend beyond current test ranges and test routes and the operational procedures to use them. The long distances and execution times will strain our abilities in tracking, telemetry, flight termination, and control systems over both land and ocean. Range support aircraft that have traditionally supported these capabilities will require improvements or new technologies to replace them. This shortfall exists in the near, mid, and far terms.

Airborne Icing Capability

The demonstration of improved controllability in the presence of icing conditions during flight tests would be greatly facilitated by use of an airborne icing capability (e.g., a KC-135 water spray tanker). A new water spray tanker capability is anticipated to be operational in 2011. A spray array nozzle capable of generating the droplet field width required to optimally support large commercial transport category aircraft icing testing does not exist. This shortfall exists in the near, mid, and far terms.

Simulation Facilities

Flight Simulators Representative of Aircraft in Service

The existing aeronautics RDT&E infrastructure does not have medium to high fidelity, Government-modifiable flight simulators for the following categories of civil aircraft:

- Large Commercial Aircraft that will be in service in the mid to far term[20] (e.g., Boeing 737/767/777/787, Airbus A320/A330/A340/A350), including simulators with a high-fidelity representation of an integrated avionics architecture.
- Regional Airliners (e.g., Bombardier Q400/CRJ900, Embraer 170).
- Civil Rotorcraft

Although medium to high fidelity flight simulators with these capabilities exist in the non-Federal sector, government research may require the ability to modify the certified flight dynamics and/or avionics models in such simulators. This may create recertification, availability, cost, and other issues for the commercial owners. Research in mobility, aviation safety, and energy and environment will need to use mid- to high-fidelity simulators of civil aircraft to validate solutions in a realistic environment. The lack of the above medium to high fidelity modifiable flight simulators impacts mid-term and far-term objectives.

Four Dimensional Trajectory Simulation Capability

Trajectory-based operations are fundamental to the implementation of NextGen and the support of many of its requirements. The current simulation infrastructure regarding four dimensional trajectory (4-DT)[21] operations is limited, with most of the capabilities concentrating on the position and prediction aspects of 4-DT. The limited capability to simulate 4-DT within both the aircraft's flight management system and the national airspace system creates the following two shortfalls that may hinder the development of NextGen:

- Flight Management System—a modifiable, full-featured simulation of a modern flight management system with 4-DT capability.
- National Airspace Simulation—full-featured simulation of a national airspace system with 4-DT enabled aircraft.

These simulation shortfalls impact near-term, mid-term, and far-term goals for mobility, aviation safety, and energy and environment.

20 The FAA's B737-800 simulator is medium-fidelity, but the Federal Government does not have rights to modify the avionics model.

21 The four dimensions are latitude, longitude, altitude, and time.

High-End Computational Facilities

High-End Computing (HEC) Capacity

There is a 78% long-term shortfall in the total HEC capacity available to reach all the aeronautics goals and objectives in the 2010 National Aeronautics R&D Plan. The 10-year (2020) projected HEC *capacity* allocated to the plan goals is approximately 40,000 million core hours (MCH). This projected capacity is based on three assumptions: (1) Federal departments and agencies make currently planned HEC modernization investments, (2) they continue to allocate the same fraction of their HEC resources to the goals, and (3) HEC performance per dollar continues to increase by ~10× every 5 years. The 2020 HEC *requirement* to reach the 2010 National Aeronautics R&D Plan goals and objectives is estimated to be 185,000 MCH. This requirement was determined as a minimum multiple of current computational practice in the disciplines related to each of the goals and objectives. These amounts were added together to arrive at a total HEC requirement. The 78% shortfall between requirement and capacity (approximately 145,000 MCH) will have a particularly significant impact on the goals and objectives that require the greatest amount of HEC capacity. This shortfall increases from mid term to far term.

ADDRESSING SHORTFALLS

This identification of the most critical shortfalls in the present Federal aeronautics RDT&E infrastructure is the first crucial step toward addressing infrastructure deficiencies that may hinder progress toward the goals and objectives of the National Aeronautics R&D Plan. As noted, several of these shortfalls have plans in place that will address the shortfall or reduce its impact. With respect to the shortfalls for which no Federal department or agency has initiated corrective action, these will be identified to concerned departments and agencies for appropriate action within their established planning processes. Progress from new and ongoing plans and activities to address these shortfalls will be incorporated into future updates to this infrastructure plan.

INTERAGENCY COOPERATIVE MANAGEMENT

The Federal aeronautics RDT&E infrastructure comprises capabilities that were developed by individual departments and agencies (D&As) primarily to meet their organizational needs and secondarily to support the nation's broader aeronautical RDT&E requirements. The Federal Government assigns ownership, operational responsibility, and funding of its aeronautical RDT&E facilities to various D&As based on organizations' needs for the facilities to support the organizations' assigned missions.

Historically, Federal departments and agencies that own or manage part of the aeronautics RDT&E infrastructure have independently planned, programmed, and budgeted for their own RDT&E facility resources and needs. Over time, the interdependence of the Federal agencies for specific types of infrastructure has increased as technology has advanced, as development has become more complex, and as research focuses for individual D&As have changed. For example, the National Full-Scale Aerodynamic Complex was operated by NASA for decades until 2003. Although operational responsibility was later assumed by the Air Force, NASA continues to use the facility for large-scale subsonic testing such as Mars parachutes and research involving advanced rotor concepts. Similarly, the DoD relies on NASA's Transonic Dynamics Tunnel for testing involving complex aeroelastic phenomena. In spite of this, methods for planning, coordinating, and prioritizing that infrastructure have not generally changed to reflect this growing interdependence. For example, facility cost accounting structures have independently evolved among the D&As. The Federal departments and agencies that own and manage the federal aeronautics RDT&E infrastructure tend to focus their efforts and resources on their own agency-specific priorities. Under these circumstances, decisions involving investment in the infrastructure, divestment of infrastructure assets, and scheduling of competing workload in those assets are normally based on individual department or agency priorities.

Comprehensive interagency management policies for aeronautics infrastructure do not yet exist. It is difficult to prioritize national RDT&E needs across D&A boundaries, particularly given the existence of different budget processes and agency goals that are often reviewed by separate Congressional committees. Challenges that may impede interagency cooperation include:

- Competing authorization and appropriations legislation among the various D&As, which may present legal and procedural barriers to the sharing of resources;
- Lack of imperative or incentive to prioritize and ensure the availability of facilities that are inconsistently or intermittently used but that remain critical in those instances when they are needed;[22]

22 For example, absent binding agreements, a department may reduce support for a facility that it rarely uses but that is relied upon by a second department to meet mission priorities.

- Lack of consistent cost accounting and usage policies driven by individual D&A budgeting and accounting practices that hinder sharing of agency resources and raise an access barrier for non-Federal users;
- High costs for infrastructure construction, maintenance, and upgrading, which may create institutional barriers when considering the allocation of infrastructure resources to priorities outside of the owning agency's mission.

Despite these barriers, productive partnerships that serve as excellent examples of interagency progress have been created. Although a variety of management restructuring alternatives are possible, expanding on and replicating established interagency organizational efforts in an evolutionary manner is likely to be the most effective path forward. One successful example of such a partnership is the long-standing cooperation between NASA and DoD, which collectively own and/or manage the majority of major Federal aeronautics RDT&E infrastructure.

Since the mid-1990s, NASA and DoD have worked to define improved methods for cooperating in the management and operation of the major elements of their aeronautical test infrastructure. During 1995 and 1996, the NASA-DoD Aeronautics and Astronautics Coordinating Board (AACB) sponsored an initiative to enhance coordination and collaboration between NASA and DoD. One result of this initiative was the formation of six alliances[23] to provide improved coordination of facility investments and upgrades, better assessments of facility capabilities and requirements, and more efficient and effective facility operations.

In May 2000, NASA and DoD signed an Interagency Agreement to form a more extensive relationship. Called the National Aeronautical Test Alliance (NATA), it addressed specific ground test facilities such as wind tunnels and air-breathing propulsion test facilities. The NATA was replaced in 2007 by the National Partnership for Aeronautical Testing (NPAT).[24] NPAT is more inclusive than NATA: each military department in DoD is represented individually in NPAT, rather than through a department-wide executive agent. The science and technology communities in both DoD and NASA are represented on the NPAT, and NASA's Shared Capabilities Assets Program is represented as well.

23 The alliances were the National Wind Tunnel Alliance, the Air Breathing Propulsion Test Facilities Alliance, the National Rocket Propulsion Test Alliance, the National Space Environmental Simulation Facilities Alliance, the National Arc Heated Test Facilities Alliance, and the National Hypervelocity Ballistic/Impact Range Testing Alliance.

24 The NPAT was chartered by a Memorandum of Understanding signed by the NASA Administrator and the Under Secretary of Defense (Acquisition, Technology and Logistics) in January 2007.

RECOMMENDED APPROACH

Interdependencies and overlapping research goals among research agencies in the Federal Government create a need for closer cooperation and coordination of processes and facilities planning. Some of the barriers to improved cooperation can be lowered by leadership from the Federal departments and agencies that own critical infrastructure, the NSTC and the Office of Management and Budget (OMB). There are a number of existing bilateral collaborations on planning and coordination of aeronautics RDT&E infrastructure, and these efforts should be continued and expanded. The IIWG will interact with the relevant Federal infrastructure coordinating groups to develop a comprehensive view of interagency coordination, identify improvements that may enhance interagency management capabilities, and advise the ASTS of significant issues that merit further review or consideration by the NSTC or OMB.

NETWORK INFRASTRUCTURE

The 2007 National Aeronautics R&D Plan stipulated that this infrastructure plan would address the need to develop a distributed network infrastructure for the conduct of research and testing in support of the aeronautics goals and objectives. It called for the initial scoping of requirements to take place within a year, with further refinement of those requirements, as well as the processes, policies, methodologies, and protocols to follow. This initial assessment determined that a supporting network infrastructure will be necessary to integrate the various components of the national aeronautics RDT&E infrastructure.[25]

Network infrastructure is the critical framework through which devices, facilities, and organizations collaborate with each other. It includes the comprehensive set of deployable hardware, software, and algorithmic tools that supports research and collaboration across and among the overall RDT&E infrastructure. It consists of computing systems, data storage systems, data repositories and advanced instruments, visualization environments, sensors, people, and the necessary intellectual capital, all linked and made interoperable and accessible by software and advanced networks. The RDT&E infrastructure of the future will routinely allow adaptive integration of physical and simulated components, dynamically creating geographically distributed real-time systems of systems.

A rational, coordinated assessment of network infrastructure as it relates to aeronautics research has never been attempted. This infrastructure plan lays out the process for completing such an assessment. By 2012, the ASTS will develop a report that will characterize the existing data infrastructure in the national aeronautics RDT&E community; identify existing interoperability initiatives or interoperability plans for either simulation or live RDT&E capabilities, both within and across affected Federal department and agencies; and include recommendations for the development of a "Roadmap for Linking and Integrating Aeronautics RDT&E Infrastructure" to improve results for the R&D goals and objectives or more efficiently achieve them.

The development of the assessment will involve a three-stage process. The first stage will involve a detailed review of the 2010 National Aeronautics R&D Plan to develop an understanding of the network infrastructure required to link physical infrastructure assets to reach the national goals and objectives. In the second phase, the Cyber Infrastructure Task Force will survey the existing data infrastructure in the national aeronautics RDT&E community to assess its adequacy, to find common elements in existing networks, and to evaluate proposed data exchange architectures, protocols, and services. In the final phase, the findings will be synthesized and reported, and recommendations will be made for the development of a "Roadmap for Linking and Integrating Aeronautics RDT&E Infrastructure."

25 Office of Science and Technology Policy, National Science and Technology Council, "National Plan for Aeronautics Research and Development and Related Infrastructure," December 2007, p. 36.

INTERNATIONAL ISSUES

In recent years, U.S. Federal and non-Federal entities have increased their use of foreign aeronautical RDT&E infrastructure. In addition, U.S. Federal RDT&E infrastructure is used by foreign entities. There are many explanations for this increased usage, such as lower cost, political agreements, or non-availability of local facilities. Federal use of foreign infrastructure currently occurs on an ad hoc, as-needed basis; similarly, there is no overarching policy for the use of Federal assets by foreign entities. Furthermore, there is no existing national strategy for coordinating the development of aeronautics RDT&E capabilities with allies and collaborators in foreign countries.

There are both benefits and disadvantages to using foreign RDT&E infrastructure and allowing the use of Federal RDT&E infrastructure by foreign entities. Use of foreign infrastructure eliminates the capital costs associated with building, maintaining, and updating a facility; on the other hand, it can lead to purposeful or inadvertent technology transfer and could leave the Federal Government vulnerable to high costs or loss of access due to changing political tides. Similarly, allowing foreign use of Federal assets can lead to sharing of knowledge and enables cost recovery on expensive facilities; however, it can also eliminate the competitive edge created by top-notch testing facilities.

Collaboration with foreign governments on the development of aeronautics RDT&E infrastructure could lead to system-wide efficiencies and more rapid deployment of new facilities; conversely, it is clear that not all international sharing of RDT&E assets is in the nation's interest. A first step toward developing a clear and consistent policy regarding the Federal use of foreign infrastructure and vice versa is an analysis of current usage levels and of the policies that govern that usage.

As a part of the biennial update to this infrastructure plan, the ASTS will include results of an assessment of international use of, and collaboration on, RDT&E infrastructure and the impacts of that use on Federal assets and capabilities. The assessment will identify the extent of the use of foreign aeronautical RDT&E infrastructure by U.S. entities and the extent to which foreign entities use U.S. Federal and national RDT&E infrastructure. It will also identify existing Federal department and agency policies, processes, and procedures that address (1) the use of foreign aeronautics RDT&E infrastructure or (2) the use of Federally owned RDT&E infrastructure by foreign entities, and it will ascertain whether they are aligned with the goals of the National Aeronautics R&D Policy. Finally, the assessment will provide recommendations for consistent Federal policies and procedures regarding (1) the use of foreign aeronautical RDT&E facilities by Federal departments and agencies or by entities in the private sector performing work under Government contracts and (2) the use of the Federal aeronautics RDT&E infrastructure by foreign entities.

ENCLOSURE 1. RELATIONSHIP BETWEEN SHORTFALLS AND GOALS AND OBJECTIVES

The following tables can be used to identify the national aeronautics R&D goals and objectives that are impacted by the shortfalls identified in this RDT&E infrastructure plan. The first table lists each of the shortfalls in the left column and then lists codes for the specific goals and objectives that are impacted by the shortfalls.

The goals are identified with the following codes: MOB for mobility, NSD for National Security and Homeland Defense, AVS for Aviation Safety, and ENE for Energy and Environment. The codes for each objective indicate the near-term with an "N," mid-term with an "M," and far-term with an "F."

The second table displays the entire list of the national aeronautics R&D goals and objectives, numbering each goal and objective, and associates them with the codes used in the first table.

Table of Relationships between Shortfalls and Goals and Objectives

Shortfall	Goals Impacted	Objectives Impacted
Subsonic Acoustic Measurement and Low Turbulence Flow Test Facilities	NSD-2	N-22, N-25, M-24, M-27, F-21
	ENE-2	N-51, M-53, F-42
	ENE-3	N-53, N-54, N-55, N-58, M-55, M-59, M-62, F-46, F-47, F-50
Hypersonic Materials Test Facilities	NSD-5	N-31, N-32, M-32, M-33, M-34, M-35, F-25, F-26
	AVS-1	N-36, N-38, M-38, M-40, F-29, F-31
Hypersonic Engine (Scramjet) Development Propulsion Test Facilities	NSD-5	N-31, N-32, M-32, M-33, M-34, M-35, F-25, F-26
Turbine Engine Icing Test Facilities	AVS-1	N-36, N-38, M-38, F-29, F-30
	AVS-2	N-43
Turbine Engine Combustion Facilities	NSD-3	N-26, N-27, M-28, M-29, F-22
	ENE-1	N-47, M-49, M-50, F-39
	ENE-2	N-51, M-53, F-42
	ENE-3	N-53, N-54, N-55, M-55, M-56, M-57, M-58, M-59, M-60, F-45, F-47, F-48
Full-Scale Rotorcraft Test Rig	NSD-2	N-22, N-25, M-24, M-25, N-23, N-24, M-26, M-27, F-19, F-20, F-21
	AVS-1	N-36, N-37, M-38, M-39, F-29, F-30
	ENE-3	N-58, M-62, F-50
Transport Category Flight Test Aircraft	MOB-1	N-3, N-4, M-3, F-1, F-2
	MOB-2	F-4
	MOB-3	M-8, F-9
	MOB-4	N-12, M-12, F-10
	AVS-1	N-37, M-38, M-39, F-29, F-30
	AVS-2	N-40, N-41, M-42, M-43, F-33, F-35
	ENE-3	N-53, M-55, F-44

Table of Relationships between Shortfalls and Goals and Objectives—continued

Shortfall	Goals Impacted	Objectives Impacted
Hypersonic Test Range Capabilities	NSD-5	N-31, M-34, F-25
	AVS-1	M-38
Airborne Icing Capability	AVS-1	N-37, M-39, F-30
Flight Simulators Representative of Aircraft in Service	MOB-1	M-1, M-2, M-3, M-4, F-1, F-2, F-3
	MOB-2	M-5, M-6, F-4, F-5, F-6
	MOB-4	M-12, M-14, M-15, F-10, F-11, F-12
	MOB-5	M-16, M-17, M-18, M-19, M-20, F-13, F-14, F-15, F-16
	AVS-1	M-38
	AVS-2	M-41, M-42, M-43, F-32, F-33
	ENE-2	M-52, F-41
	ENE-3	M-55, M-60, F-44, F-47, F-48
Four Dimensional Trajectory Simulation Capability	MOB-1	N-4, M-1, M-2, M-3, M-4, F-1, F-2, F-3
	MOB-2	N-7, M-6, F-4, F-5, F-6
	MOB-4	N-12, N-13, N-14, M-12, M-14, M-15, F-10, F-11, F-12
	MOB-5	N-15, N-16, N-17, N-18, M-16, M-17, M-18, M-19, M-20, F-13, F-14, F-15, F-16
	AVS-1	N-37, M-38, M-39, F-30
	AVS-2	N-39, N-40, N-41, M-41, M-42, M-43, F-32, F-33
	ENE-2	N-49, N-50, M-52, F-41
	ENE-3	N-53, N-55, M-55, M-60, F-48
High-End Computing Capacity	All goals	Nearly all objectives

Table of Goals and Objectives from National Aeronautics Research and Development Plan, February 2010

Goal	Near Term (<5 years)	Mid Term (5-10 years)	Far Term (>10 years)
Goal MOB-1 Develop reduced aircraft separation in trajectory- and performance-based operations	(N-1) Develop separation standards that vary according to aircraft performance and crew training (N-2) Develop nonradar 30-mile separation procedures for pair-wise maneuvers in oceanic airspace	(M-1) Develop 5-mile nonradar separation procedures for current nonradar airspace (M-2) Develop positioning, navigation and timing precision requirements for fixed- and variable-separation procedures	(F-1) Demonstrate self-separation in at least one airspace domain (F-2) Validate performance-based variable separation standards for multiple domains
	(N-3) Develop Automatic Dependent Surveillance-Broadcast 3- to 5-mile spacing (N-4) Develop positioning, navigation and timing (including backup) capabilities to support NextGen	(M-3) Develop merging and spacing tools for continuous descent approaches that balance capacity and environmental considerations (M-4) Establish the basis for separation standards to increase airspace density	(F-3) Implement human-machine and air-ground interaction methods in a highly automated air transportation system
Goal MOB-2 Develop increased NAS capacity by managing NAS resources and air traffic flow contingencies	(N-5) Develop advanced airspace design concepts to support scalability to 3× operations (N-6) Develop Special Use Airspace and general aviation access procedures to maximize capacity to match demand	(M-5) Develop dynamically adjustable advanced airspace structures—including flow corridors—scalable to accommodate an interim target of an environment supporting 2× operations (M-6) Develop methodologies for the dynamic allocation of NAS resources	(F-4) Demonstrate dynamic allocation of NAS resources (F-5) Develop automated flight and flow evaluation and resolution capabilities to support Air Navigation Service Provider negotiations
	(N-7) Develop trajectory management methods for collaborative preflight routing including prediction, synthesis, and negotiation (N-8) Develop comprehensive strategies to translate weather information into operational impacts and integrate those impacts into decision support tools	(M-7) Integrate weather information into flow management decision support tools	(F-6) Demonstrate gate-to-gate trajectory-based flight planning and flow management to increase NAS efficiency, capacity, and reduce weather delays and environmental impact
Goal MOB-3 Reduce the adverse impacts of weather on air traffic management decisions	(N-9) Develop resolution and accuracy requirements for weather observation and forecasting information (N-10) Develop requirements for probabilistic weather prediction systems and methods for communicating forecast uncertainty	(M-8) Develop technologies for sharing weather hazard information measured by on-board sensors with nearby aircraft and ground systems and vice-versa (M-9) Develop probabilistic weather forecast products that communicate uncertainty information	(F-7) Integrate weather observation and forecast information in real time into a single authoritative source of current weather information (F-8) Develop air traffic management decision strategies to reference a single authoritative weather source, including understanding impacts of disparate interpretations of the data
	(N-11) Develop initial capability for net-centric four-dimensional weather information system, including enabling fusion of multiple weather forecast and ground and airborne observation products and researching the roles of humans in applying operational expertise to augment automated, four-dimensional weather grids	(M-10) Develop severity indices for aviation weather hazards using observations and forecasted weather data for short-to-long range decision making (M-11) Develop capabilities to translate weather severity information into adverse weather information for operational use	(F-9) Demonstrate NextGen Network-Enabled Weather capabilities to reduce adverse impacts
Goal MOB-4 Maximize arrivals and departures at airports and in metroplex areas	(N-12) Develop traffic spacing/ management technologies to support high-throughput arrival and departure operations while minimizing environmental impact	(M-12) Develop technologies and procedures for operations of closely spaced parallel runways (M-13) Integrate weather information into terminal area decision support tools	For a system that is scalable to 3× operations: (F-10) Reduce lateral and longitudinal separations for arrival and departure operations (F-11) Demonstrate technologies and procedures to support surface operations (F-12) Develop time-based metering for flows transitioning into and out of high-density terminals and metroplex areas to enable significant airspace design flexibility and reduced environmental impact
	(N-13) Develop time-based metering of flows into high density metroplex areas	(M-14) Develop performance-based trajectory management procedures for transitional airspace	
	(N-14) Develop technology to display aircraft and ground vehicles in the cockpit to guide surface movement	(M-15) Develop operations and procedures to integrate surface and terminal operations, especially in low-visibility conditions	

Table of Goals and Objectives from National Aeronautics Research and Development Plan, February 2010—continued

Goal	Near Term (<5 years)	Mid Term (5-10 years)	Far Term (>10 years)
Goal MOB-5 Develop expanded manned and unmanned aircraft system capabilities to take advantage of increased air transportation system performance	(N-15) Develop validated multidisciplinary analysis and design capabilities with known uncertainty bounds for N+1 aircraft, and develop procedures for the interaction of a variety of vehicle classes with the airspace system (including N+1, very light jets, UAS, and other vehicle classes that may appear in the system)	(M-16) Develop validated system analysis and design capabilities with known uncertainty bounds for N+2 and N+3 advanced aircraft, including their interaction with the airspace system	(F-13) Develop suitable metrics to understand realizable trades between noise, emissions, and performance within the design space for N+2 and N+3 advanced aircraft
	(N-16) Develop dynamic, need-based "fast-track" Federal approval process for airframe and avionics changes (N-17) Develop aircraft capability priorities for NextGen through 2015 to support standards development and certification	(M-17) Develop N+2 aircraft fleet and associated capabilities to support the development of procedures, policies, and methodologies for reduced cycle times to introduce aircraft and aircraft subsystem innovations	(F-14) Continue development and refinement of procedures, policies, and methodologies supporting reduced cycle times for introduction of advanced (N+3 and beyond) aircraft and associated subsystem innovations
	(N-18) Enable commercial supersonic aircraft cruise efficiency 15% greater than that of the final NASA High Speed Research (HSR) program baseline	(M-18) Enable advanced technologies for N+2 aircraft with significantly improved performance and environmental impact (M-19) Enable commercial supersonic aircraft cruise efficiency 25% greater than that of the final NASA HSR program baseline (M-20) Enable the development of N+2 cruise-efficient short takeoff and landing aircraft, including advanced rotorcraft, with between 33% and 50% field length reduction compared with a B737 with CFM56 engines*	(F-15) Enable advanced technologies for N+2 and N+3 aircraft with significantly improved performance and environmental impact (F-16) Enable N+2 and N+3 commercial supersonic aircraft cruise efficiency 35% greater than that of the final NASA HSR program baseline (through reductions in structural and propulsion system weight, improved fuel efficiency, and improved aerodynamics and airframe/propulsion integration)

* The reference aircraft is a B737-800 with CFM56/7B engines, representative of 1998 entry into service technology.

National Security and Homeland Defense R&D Goals and Objectives

Goal	Near Term (<5 years)	Mid Term (5-10 years)	Far Term (>10 years)
Goal NSD-1 Demonstrate increased cruise lift-to-drag and innovative airframe structural concepts for highly efficient high-altitude flight and for mobility aircraft	(N-19) Develop design methods for efficient, flexible, adaptive, and lightweight aerostructures (N-20) Demonstrate conformal load-bearing antenna elements and shape sensing subsystems	(M-21) Demonstrate 20% delay in laminar to turbulent transition over a 30° swept laminar flow airfoil (M-22) Demonstrate key component technologies for novel configurations with a substantial improvement in lift-to-drag ratios for unmanned intelligence, surveillance, and reconnaissance applications	(F-17) Flight demonstrate novel aerodynamic configurations with a substantial improvement in lift-to-drag ratios for unmanned intelligence, surveillance, and reconnaissance applications
	(N-21) Develop novel configurations for mobility aircraft through advanced aerodynamics and structural concepts	(M-23) Demonstrate key component technologies for novel configurations with >25% improvement in lift-to-drag ratios for mobility aircraft	(F-18) Demonstrate novel configurations with >25% improvement in lift-to-drag ratios for mobility aircraft
Goal NSD-2 Develop improved lift, range, and mission capability for rotorcraft	(N-22) Increase power to weight (+40%) and reduce noise of main rotor gearbox (–15 dB)	(M-24) Increase power to weight (+70%) and reduce noise of main rotor gearbox (–20 dB)	
	(N-23) Reduce vibratory loads 20%; improve forward flight efficiency 2%	(M-25) Reduce vibratory loads 25%; improve forward flight efficiency 5%	(F-19) Reduce vibratory loads by 30% and improve forward flight efficiency by 10%
	(N-24) Increase hover efficiency by 4%	(M-26) Increase hover efficiency by 7%	(F-20) Increase hover efficiency by 10%
	(N-25) Develop analytical tools and component technologies for advanced low-noise concepts	(M-27) Flight test tactically significant acoustic signature reduction	(F-21) Demonstrate 50% reduction in acoustic perception range

National Security and Homeland Defense R&D Goals and Objectives—continued

Goal	Near Term (<5 years)	Mid Term (5-10 years)	Far Term (>10 years)
Goal NSD-3 Demonstrate reduced gas turbine specific fuel consumption	(N-26) Design and demonstrate high pressure compressor technologies for high overall pressure ratio propulsion systems through key component tests	(M-28) Demonstrate a high-overall pressure ratio propulsion system enabling a 25% or greater specific fuel consumption reduction	(F-22) Develop and demonstrate advanced propulsion concepts with variable cycle features and high overall pressure ratio enabling a greater than 30% specific fuel consumption reduction
	(N-27) Design and demonstrate variable cycle propulsion component technologies through key component tests	(M-29) Demonstrate a variable cycle propulsion system enabling a 25% or greater specific fuel consumption reduction	
Goal NSD-4 Demonstrate increased power generation and thermal management capacity for aircraft	(N-28) Demonstrate 2× operating temperatures for power electronics	(M-30) Demonstrate 5× increase in thermal transport and heat flux for power electronics	(F-23) Demonstrate 10× increase in thermal transport and heat flux for directed energy weapons
	(N-29) Demonstrate 4× increase in generator power density for directed energy weapons		(F-24) Demonstrate 50% weight and volume reduction for aircraft power and thermal management systems
	(N-30) Demonstrate >60 W/kg power density for UAS rechargeable energy storage	(M-31) Demonstrate 2× power density for UAS hybrid energy storage	
Goal NSD-5 Demonstrate sustained, controlled, hypersonic flight	(N-31) Demonstrate sustained, controlled flight at Mach 5–7 for a duration greater than 5 minutes using an expendable airframe and hydrocarbon fuel	(M-32) Ground test scramjet propulsion systems to 10× airflow of today's scramjet technology (M-33) Increase effective heat capacity of endothermically cracked hydrocarbon fuel to extend vehicle thermal balance point beyond Mach 8	(F-25) Demonstrate scramjets operable to Mach 10 on hydrocarbon fuel and to Mach 14 on hydrogen fuel
	(N-32) Ground test hypersonic vehicle component technologies, including high-temperature structures, thermal protection systems, adaptive guidance and control, and health management technologies	(M-34) Flight test air-breathing vehicle technologies beyond Mach 7 and durations greater than 10 minutes for application to space launch systems and possible reconnaissance/strike systems (M-35) Demonstrate a lightweight, durable airframe capable of global reach	(F-26) Validate an optimum air vehicle solution that demonstrates an efficient thermal management approach to accommodate the combined thermal loads of the aero-thermal environment, integrated engines and internal vehicle subsystems
Goal NSD-6 Develop capabilities for UAS NAS integration	(N-33) Develop a flight safety case modeling capability including data collection methods (N-34) Define the appropriate target level of safety and the process for evaluation	(M-36) Validate and verify flight safety assessment capability	(F-27) Demonstrate rapid, routine flight safety assessments
	(N-35) Demonstrate sense and avoid capability for large UAS in low traffic environments	(M-37) Demonstrate sense and avoid for full range of UAS sizes and multiple UAS in low density airspace and mixed fleet interactions	(F-28) Demonstrate sense and avoid for full range of UAS in all classes of airspace including high density terminals and metroplex areas

Aviation Safety R&D Goals and Objectives

Goal	Near Term (<5 years)	Mid Term (5-10 years)	Far Term (>10 years)
Goal AVS-1 Develop technologies to reduce accidents and incidents through enhanced vehicle design, structure, and subsystems	(N-36) Develop vehicle health-management systems to determine the state of degradation for aircraft subsystems	(M-38) Develop and demonstrate tools and techniques to predict, detect and mitigate in-flight damage, degradation, and failures	(F-29) Develop reconfigurable health-management systems for managing suspect regions in N+2 vehicles
	(N-37) Develop and test adaptive-control techniques in flight to enable safe flight by stabilizing and establishing maneuverability of an aircraft from an upset condition	(M-39) Develop, assess, and validate methods to avoid, detect and recover from upset conditions	(F-30) Develop formal methods to verify and validate the safety performance margins associated with innovative control strategies, decision-making under uncertainty, and flight path planning and prediction
	(N-38) Develop improved mitigation techniques that prevent, contain, or manage degradation associated with aging, and show that tools and methods can predict the performance improvement of these techniques	(M-40) Deliver validated tools and methods that will enable a designer or operator to extend the life of structures made of advanced materials	(F-31) Develop advanced life-extension concepts (designer materials and structural concepts) by using physics-based computational tools
Goal AVS-2 Develop technologies to reduce accidents and incidents through enhanced aerospace vehicle operations on the ground and in the air	(N-39) Validate and verify methods that enable improvements in pilot and controller workload, awareness, and error prevention and recovery, including during off-nominal scenarios, given the increased automation assumed in NextGen	(M-41) Develop human-machine interfaces that enable effective human performance during highly dynamic conditions and allow for flexible intervention to ensure safety	(F-32) Develop formal methods to verify and validate the safety of complex airspace operations
	(N-40) Develop flight deck displays and automation to convey up-to-date weather conditions and near-term forecasts (N-41) Investigate in-situ and remote observing systems, technologies, and architectures that will provide hazardous and other weather information	(M-42) Develop an integrated flight deck system that alerts flight crews of all on-board and environmental hazards and defines and coordinates an appropriate, safe flight path (M-43) Develop in-situ and remote observing technologies, systems, and architectures that will provide weather information to flight crews and air traffic controllers	(F-33) Develop high-confidence, flight deck decision-support tools that use single authoritative information source for shared decision-making between air traffic management and flight crew about weather and other concerns in planning a safe flight path
	(N-42) Develop advanced tools that translate numeric (continuous and discrete) system performance data into usable, meaningful information for prognostic identification of safety risks for system operators and designers (N-43) Understand the concepts of degradation and failure as well as other potential safety issues associated with critical system functions integrated across highly distributed ground, air, and space systems (including UAS)	(M-44) Develop advanced methods to automatically analyze textual safety reports and extract system performance information for prognostic identification of safety risks for system operators and designers (M-45) Develop techniques to enable a priori safety assurance and real-time monitoring and assessment of critical system functions across distributed air and ground systems (including UAS)	(F-34) Develop fundamentally new data-mining algorithms to support automated data analysis tools to integrate information from a diverse array of data resources (numeric and textual) to enable rapid prognostic identification of system-wide safety risks (F-35) Validate and verify the safety of complex flight-critical systems (including UAS) in a cost- and time-effective manner
Goal AVS-3 Demonstrate enhanced passenger and crew survivability in the event of an accident	(N-44) Develop occupant-restraint design tools that support occupant crash protection that is as strong as the fixed- and rotary-wing aircraft structure	(M-46) Validate integrated vehicle structure and occupant restraint tools	(F-36) Validate integrated vehicle structure and occupant restraint tools for advanced concept vehicles
	(N-45) Develop analytical methodologies to model dynamic events in aircraft crashes to enable the development of lightweight and crash-absorbing airframe technologies for the fixed- and rotary-wing legacy fleet	(M-47) Establish analytical methodologies to model dynamic events in aircraft crashes to enable the development of lightweight and crash-absorbing airframe technologies for advanced aircraft, including those made with advanced composite and metallic materials	(F-37) Validate and verify analytical methods that model dynamic events in aircraft crashes for airframe structures
	(N-46) Assess and reduce flammability and smoke toxicity of advanced materials to be used in aircraft platforms	(M-48) Determine fuel vapor characteristics of alternative aviation fuel spills for post-crash survivability	(F-38) Validate and verify methodologies to determine impact of alternative fuels on cabin material flammability and propulsion system fire safety and survivability

Energy and Environment R&D Goals and Objectives

Goal	Near Term (<5 years)	Mid Term (5-10 years)	Far Term (>10 years)
Goal ENE-1 Enable new aviation fuels derived from diverse and domestic resources to improve fuel supply security and price stability	(N-47) Evaluate performance of alternative versus conventional fuels in associated systems, including consideration of certification processes	(M-49) Enable affordable "drop in"[a] fuels that have large production potential, meet safety requirements, and are certifiable (M-50) Explore renewable aviation fuels that reduce carbon footprints	(F-39) Enable renewable aviation fuels that meet safety requirements, are certifiable, have a large production potential, and are sustainable for aircraft and support systems
	(N-48) Evaluate alternative fuel-production impacts on the environment	(M-51) Enable environmental best practices in alternative and conventional fuel production	(F-40) Enable technologies to ensure that new aircraft, fuel supply systems, and airport infrastructure are built to standards that allow the most environmentally beneficial alternative fuels
Goal ENE-2 Advance development of technologies and operations to enable significant increases in the energy efficiency of the aviation system	(N-49) Define achievable energy efficiency gains via operational procedure improvements (N-50) Research operational procedures to enhance fuel efficiency (N-51) Enable fuel efficient N+1 aircraft and engines (33% reduction in fuel burn compared to a B737/CFM56[g])	(M-52) Research and enable new energy efficient operational procedures optimized for energy intensity (3%–5% energy intensity improvement[b] for the energy efficient procedures over existing 2006 baseline procedures) (M-53) Enable fuel efficient N+2 aircraft and engines (at least 40% reduction in fuel burn compared to a B777/GE90)[h]	(F-41) Enable new energy efficient operational procedures optimized for energy intensity (6%–10% energy intensity improvement for the energy efficient procedures over existing 2006 baseline procedures) (F-42) Enable fuel efficient N+3 aircraft and engines to reduce fuel burn by up to 70% compared with a B737/CFM56[g] (70% is a 25-year stretch goal and assumes significant advances in novel configurations, engine performance, propulsion/airframe integration, and materials)
	(N-52) Enable metrics and first-order empirical analytical capabilities to evaluate fuel efficiency enhancement strategies	(M-54) Develop advanced empirical analytical capability to assess and enhance fuel efficiency enhancement strategies	(F-43) Enable physics-based simulation analytical capability to optimize fuel efficiency enhancement strategies
Goal ENE-3 Advance development of technologies and operational procedures to decrease the significant environmental impacts of the aviation system	(N-53) Research and develop ground, terminal, and en-route procedures to reduce noise and emissions and determine sources of significant impact	(M-55) Develop and demonstrate advanced ground, terminal, and en-route procedures to reduce significant noise and emissions impacts	(F-44) Develop new approaches and models for optimizing ground and air operational procedures
	(N-54) Develop improved tools and metrics to quantify and characterize aviation's environmental impact, uncertainties, and the trade-offs and interdependencies among various impacts (N-55) Enable quieter and cleaner N+1 aircraft and engines (32 dB cumulative below Stage 4);[c] LTO[d] NO_x emissions reduction (70% below CAEP[e] 2 standard) (N-56) Continue research to identify alternatives to lead as an octane-enhancing additive in aviation gasoline	(M-56) Reduce uncertainties in understanding aviation climate impacts to levels that enable limiting significant impacts (M-57) Characterize $PM_{2.5}$[f] and hazardous air pollutant emissions and establish long-term goals for reducing to appropriate levels (M-58) Research the technical challenges associated with achieving low NO_x and very low CO_2 and soot emissions (M-59) Enable N+2 aircraft and engines; (42 dB cum below Stage 4); LTO NO_x emissions reduction (80% below CAEP 2) (M-60) Enable a 70% reduction in high-altitude emissions for supersonic aircraft (reference HSR configuration)	(F-45) Continue to reduce uncertainties in understanding aviation climate change impacts to levels that enable reducing significant impacts (F-46) Enable physics-based analytical capabilities to characterize environmental impacts of aviation noise and emissions (F-47) Enable N+3 aircraft and engines to decrease the environmental impact of aircraft (62 dB cumulative below Stage 4 (a 25-year goal); LTO NO_x emissions reduction better than 80% below CAEP 2) (F-48) Enable an order-of-magnitude reduction in high-altitude emissions for supersonic aircraft (reference HSR configuration)
	(N-57) Determine significant water quality impacts of increased aircraft operations	(M-61) Enable anti-icing and deicing fluids and handling procedures to reduce water quality impacts determined to be significant	(F-49) Enable environmentally improved aircraft materials and handling of fuel and de-icing fluids
	(N-58) Develop predictive capabilities for rotorcraft noise	(M-62) Enable low-noise acoustic concepts for low-noise rotary-wing vehicles	(F-50) Enable low-noise operation and high-speed, fuel efficient rotorcraft
		(M-63) Enable ~15 EPNdB[j] of jet noise reduction relative to unsuppressed jet for supersonic aircraft	(F-51) Enable ~20 EPNdB of jet noise reduction relative to unsuppressed supersonic aircraft exhaust
	(N-59) Enable reducing loudness ~25 PLdB[i] relative to military aircraft sonic booms	(M-64) Enable reducing loudness ~30 PLdB relative to military aircraft sonic booms	(F-52) Enable reduction of loudness ~35 PLdB relative to military aircraft sonic booms

Notes for the Energy and Environment R&D Goals and Objectives Table

a A "drop in" fuel is a fuel that can be used in existing aircraft and supporting infrastructure; drop in fuel properties may vary from average properties of conventional fuels within existing specification limits.

b Energy intensity is the ratio of energy consumption to economic or physical output. Potential metrics for aviation could be fuel consumption per distance, per passenger distance, or per payload.

c Current noise standard for subsonic jet airplanes and subsonic transport category large airplanes, http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgFinalRule.nsf.

d LTO is the landing and takeoff cycle.

e CAEP is the International Civil Aviation Organization Committee on Aviation Environmental Protection.

f Particles less than 2.5 μm in diameter.

g The reference aircraft is a B737-800 with CFM56/7B engines, representative of 1998 entry into service technology.

h The reference aircraft is a B777-200 with GE90 engines, representative of 1977.

i PLdB = Perceived loudness in decibels

j EPNdB = Effective perceived noise (level) in decibels

ABBREVIATIONS AND ACRONYMS

4-DT	Four-dimensional trajectory
AACB	Aeronautics and Astronautics Coordinating Board
ASTS	Aeronautics Science and Technology Subcommittee
CAEP	International Civil Aviation Organization Committee on Aviation Environmental Protection
D&A	Department and Agency
DoD	Department of Defense
EPNdB	Effective perceived noise (level) in decibels
FAA	Federal Aviation Administration
HEC	High-End Computing
IIWG	Infrastructure Interagency Working Group
LTO	Landing-and-takeoff cycle
MCH	Millions core hours
N	Refers to the current generation of tube-and-wing aircraft
N+1	Refers to the next generation of tube-and-wing aircraft
N+2	Refers to advanced aircraft in the generation after N+1
N+3	Refers to the generation of aircraft after N+2
NACA	National Advisory Committee for Aeronautics
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATA	National Aeronautical Test Alliance
NextGen	Next Generation Air Transportation System
NPAT	National Partnership for Aeronautical Testing
NSTC	National Science and Technology Council
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PLdB	PLdB should read Perceived loudness in decibels vs. noise (level)
R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
UAS	Unmanned Aerial System

Plan prepared by

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL (NSTC)
COMMITTEE ON TECHNOLOGY (COT)
AERONAUTICS SCIENCE and TECHNOLOGY SUBCOMMITTEE (ASTS)

COT Co-Chairs:
The Honorable Aneesh Chopra, Office of Science and Technology Policy (OSTP)
The Honorable Vivek Kundra, Office of Management and Budget (OMB)
Philip J. Weiser, National Economic Council (NEC)

ASTS Co-Chairs
Dr. Wilson N. Felder (FAA)
Dr. Spiro G. Lekoudis (DoD)
Dr. Jaiwon Shin (NASA)

NSTC Representative
William S. Davis

White House, Executive Office of the President, Departments, and Agencies

Council of Economic Advisors
Dr. Aaron K. Chatterji

Department of Commerce
Jonathan Chesebro

Department of Defense
Dr. Michael B. Deitchman
Dr. James A. Kenyon
Mary C. Miller
Lt. Col. Ralph Sandfry Ph.D.
Jeffrey D. Singleton
Todd M. Turner
Sheila R. Wright

Department of Energy
Dr. Julie Carruthers

Department of Homeland Security
Michael B. Smith
Randel L. Zeller

Department of State
David A. Turner

Department of Transportation
Dr. Richard R. John

Environmental Protection Agency
Robert D. Brenner
Sabrina R. Johnson

Federal Aviation Administration
Dr. Catherine A. Bigelow
Dr. Lourdes Q. Maurice
Maureen A. Molz
Barry C. Scott

Joint Planning and Development Office
Peggy Gervasi
Robert A. Pearce
Dr. Edgar G. Waggoner
Dr. Karlin R. Toner

National Aeronautics and Space Administration
Dr. John A. Cavolowsky
Jay E. Dryer
Thomas B. Irvine
Susan L. Minor
Doug Rohn
Jean Wolfe

National Economic Council
David C. Kamin

National Science Foundation
Dr. Michael M. Reischman

National Security Staff
Brian P. Rohde

Office of Management and Budget
D. Brooke Owens
Ryan J. Schaefer

Office of Management and Budget
D. Brooke Owens
Ryan J. Schaefer

Office of Science and Technology Policy
Dr. Richard B. Leshner

Office of the U.S. Trade Representative
Fred Fischer
Willis S. Martyn III

U.S. International Trade Commission
Peder A. Andersen

Infrastructure Interagency Working Group Members Supporting the ASTS

Michael W. George
National Aeronautics and Space Administration (Co-Lead)

Sheila R. Wright
Department of Defense (Co-Lead)

Shelley J. Yak
Federal Aviation Administration (Co-Lead)

Scott A. Doucett
Federal Aviation Administration (Executive Secretary)

Larry Freudinger
National Aeronautics and Space Administration

James Harris
National Aeronautics and Space Administration

Jose Munoz
National Science Foundation

George Rumford
Department of Defense

Paul Conigliaro
Department of Defense

Tom Curtis
Department of Defense

Keith Darrow
Department of Defense

Daniel Dugan
National Aeronautics and Space Administration

Bruce Fisher
National Aeronautics and Space Administration

Tony Ginn
National Aeronautics and Space Administration

Barton Henwood
National Aeronautics and Space Administration

Howard Lewis
National Aeronautics and Space Administration

Alan Micklewright
National Aeronautics and Space Administration

Chuck Smith
National Aeronautics and Space Administration

Jeffrey Swan
National Aeronautics and Space Administration

Dan Vairo
National Aeronautics and Space Administration

Bryan Biegel
National Aeronautics and Space Administration

Jim Pittman
National Aeronautics and Space Administration

Bimal Aponso
National Aeronautics and Space Administration

Michael Madden
National Aeronautics and Space Administration

John Gurka
Department of Defense

Dan Roth
Department of Defense

Col. Chris Sullivan
Department of Defense

Tom Best
Department of Defense

Barry Lakinsmith
Department of Defense

Mike Pilkenton
Department of Defense

Larry Davis
Department of Defense

Cray Henry
Department of Defense

Leslie Perkins
Department of Defense

Bruce Bailey
Department of Defense

Terry Christian
Department of Defense

Nelson Miller
Federal Aviation Administration

Hilda DiMeo
Federal Aviation Administration

Albert Schwartz
Federal Aviation Administration

Yukiko Sekine
Department of Energy

Committee on Technology
Aeronautics Science and Technology Subcommittee
National Science and Technology Council