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DECADAL SURVEY OF CIVIL AERONAUTICS
Foundation for the Future

The U.S. air transportation system is a key contributor to the economic vitality, public well-being, and national security of the United States. This Decadal Survey of Civil Aeronautics presents a decadal strategy for the federal government's involvement in civil aeronautics, with a particular emphasis on the NASA's research portfolio. A modified quality function deployment (QFD) process was used to identify and rank Research and Technology (R&T) Challenges in relation to their potential to improve the air transportation system by achieving four high-priority strategic objectives:

- Increase capacity.
- Improve safety and reliability.
- Increase efficiency and performance.
- Reduce energy consumption and environmental impact.

The prioritization process also considered two lower-priority strategic objectives:

- Take advantage of synergies with national and homeland security.
- Support the space program.

That process produced a list of 51 high-priority challenges that must be overcome to further the state of the art (see Table 1).

In order to achieve the above objectives, the committee makes the following eight recommendations:

1. NASA should use the 51 Challenges listed in Table 1 as the foundation for the future of NASA's civil aeronautics research program during the next decade.

2. The U.S. government should place a high priority on establishing a *stable* aeronautics R&T plan, with the expectation that the plan will receive sustained funding for a decade or more, as necessary, for activities that are demonstrating satisfactory progress.

3. NASA should use five Common Themes to make the most efficient use of civil aeronautics R&T resources:

- Physics-based analysis tools to enable analytical capabilities that go far beyond existing modeling and simulation capabilities and reduce the use of empirical approaches.
- Multidisciplinary design tools to integrate high-fidelity analyses with efficient design methods and to accommodate uncertainty, multiple objectives, and large-scale systems.
- Advanced configurations to go beyond the ability of conventional technologies and aircraft to achieve the strategic objectives.
- Intelligent and adaptive systems to significantly improve the performance and robustness of aircraft and the air transportation system as a whole.
- Complex interactive systems to better understand the nature of and options for improving the performance of the air transportation system, which is itself a complex interactive system.

4. NASA should support fundamental research to create the foundations for practical certification standards for new technologies.

5. The U.S. government should align organizational responsibilities as well as develop and implement techniques to improve change management for federal agencies and to assure a safe and cost-effective transition to the air transportation system of the future.

6. NASA should ensure that its civil aeronautics R&T plan features the substantive involvement of universities and industry, including a more balanced allocation of funding between in-house and external organizations than currently exists.

7. NASA should consult with non-NASA researchers to identify the most effective facilities and tools applicable to key aeronautics R&T projects and should facilitate collaborative research to ensure that each project has access to the most appropriate research capabilities, including test facilities; computational models and facilities; and intellectual capital, available from NASA, the Federal Aviation Administration, the Department of Defense, and other interested research organizations in government, industry, and academia.

8. The U.S. government should conduct a high-level review of organizational options for ensuring U.S. leadership in civil aeronautics.

TABLE 1 Fifty-one Highest Priority Research and Technology Challenges for NASA Aeronautics, Prioritized by R&T Area*

A Aerodynamics and Aeroacoustics	B Propulsion and Power	C Materials and Structures	D Dynamics, Navigation, and Control, and Avionics	E Intelligent and Autonomous Systems, Operations and Decision Making, Human Integrated Systems, Networking and Communications
A1. Integrated system performance through novel propulsion-airframe integration	B1a. Quiet propulsion systems	C1. Integrated vehicle health management	D1. Advanced guidance systems	E1. Methodologies, tools, and simulation and modeling capabilities to design and evaluate complex interactive systems
A2. Aerodynamic performance improvement through transition, boundary layer, and separation control	B1b. Ultraclean gas turbine combustors to reduce gaseous and particulate emissions in all flight segments	C2. Adaptive materials and morphing structures	D2. Distributed decision making, decision making under uncertainty, and flight path planning and prediction	E2. New concepts and methods of separating, spacing, and sequencing aircraft
A3. Novel aerodynamic configurations that enable high performance and/or flexible multi-mission aircraft	B3. Intelligent engines and mechanical power systems capable of self-diagnosis and reconfiguration between shop visits	C3. Multidisciplinary analysis, design, and optimization	D3. Aerodynamics and vehicle dynamics via closed-loop flow control	E3. Appropriate roles of humans and automated systems for separation assurance, including the feasibility and merits of highly automated separation assurance systems
A4a. Aerodynamic designs and flow control schemes to reduce aircraft and rotor noise	B4. Improved propulsion system fuel economy	C4. Next-generation polymers and composites	D4. Intelligent and adaptive flight control techniques	E4. Affordable new sensors, system technologies, and procedures to improve the prediction and measurement of wake turbulence
A4b. Accuracy of prediction of aerodynamic performance of complex 3D configurations, including improved boundary layer transition and turbulence models and associated design tools	B5. Propulsion systems for short takeoff and vertical lift	C5. Noise prediction and suppression	D5. Fault tolerant and integrated vehicle health management systems	E5. Interfaces that ensure effective information sharing and coordination among ground-based and airborne human and machine agents
A6. Aerodynamics robust to atmospheric disturbances and adverse weather conditions, including icing	B6a. Variable-cycle engines to expand the operating envelope	C6a. Innovative high-temperature metals and environmental coatings	D6. Improved onboard weather systems and tools	E6. Vulnerability analysis as an integral element in the architecture design and simulations of the air transportation system
A7a. Aerodynamic configurations to leverage advantages of formation flying	B6b. Integrated power and thermal management systems	C6b. Innovative load suppression, and vibration and aeromechanical stability control	D7. Advanced communication, navigation, and surveillance technology	E7. Adaptive ATM techniques to minimize the impact of weather by taking better advantage of improved probabilistic forecasts
A7b. Accuracy of wake vortex prediction, and vortex detection and mitigation techniques	B8. Propulsion systems for supersonic flight	C8. Structural innovations for high-speed rotorcraft	D8. Human-machine integration	E8a. Transparent and collaborative decision support systems
A9. Aerodynamic performance for V/STOL and ESTOL, including adequate control power	B9. High-reliability, high-performance, and high-power-density aircraft electric power systems	C9. High-temperature ceramics and coatings	D9. Synthetic and enhanced vision systems	E8b. Using operational and maintenance data to assess leading indicators of safety
A10. Techniques for reducing/mitigating sonic boom through novel aircraft shaping	B10. Combined-cycle hypersonic propulsion systems with mode transition	C10. Multifunctional materials	D10. Safe operation of unmanned air vehicles in the national airspace	E8c. Interfaces and procedures that support human operators in effective task and attention management
A11. Robust and efficient multidisciplinary design tools				

*Each challenge is designated by the letter of the area to which is belongs and by its NASA priority ranking in that area. Thus, the R&T Challenge with the highest NASA priority in the Aerodynamics and Aeroacoustics R&T Area is designated A1. Note that two Challenges in that Area tie for fourth place. They are listed alphabetically and are designated A4a and A4b. The next highest priority challenge is designated A6; there is no A5.