CIVIL AERONAUTICS RESEARCH AND TECHNOLOGY

An AIAA Position Paper

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and approved by the

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EXECUTIVE SUMMARY

In December 2006, the President of the United States signed an Executive Order establishing the National Aeronautics Research and Development Policy. This policy defines the principles upon which Federal government aeronautics R&D will be based and the policy goal, objectives, and general guidelines that will drive Federal government aeronautics R&D activities through 2020. The U.S. Congress and the Administration must now decide how to move forward and implement the strategy put forth. Due in part to past government research, U.S. civil aeronautics is a major contributor to the national economy and the balance of trade. However, competition from abroad is increasing. The European Union has a clearly stated vision for aeronautics superiority and it is making the necessary investments to secure that vision. The United States has only recently released an aeronautics vision and defined research strategy. NASA's Aeronautics Research Mission Directorate has taken significant cuts to its budget, and other Federal organizations that have historically supported and conducted aeronautics research, such as the DoD and FAA, have also been forced to reduce their technology development activities. As a result, critical programs have been significantly scaled back or eliminated altogether, and the United States is rapidly losing its role as a global leader in aeronautics research.

It is the position of AIAA that stable, robust, long-term Federal civil aeronautics research and technology initiatives—funded at a level that will assure U.S. leadership in aeronautics—are critical to sustain a strong national economy, maintain a skilled workforce, and effectively support national security.

Specifically, AIAA recommends:

- The Federal government must now implement the National Aeronautics Research and Development Policy through an aeronautics research agenda consistent with recommendations contained in two recent independent studies. These recommendations include:
    - The "Decadal Survey of Civil Aeronautics: Foundation for the Future" (2006), developed under the auspices of the Aeronautics and Space Engineering Board of the National Research Council (2006), should be used to identify and prioritize research and technology projects.
    - "Responding to the Call: Aviation Plan for American Leadership" (2005), developed under the auspices of the National Institute of Aerospace (NIA) study, should be used to develop roadmaps, milestones, and metrics.
- AIAA specifically endorses the following three recommendations from the 2006 Decadal Survey of Civil Aeronautics:
    - A balanced split should be created in the allocation of aeronautics research and technology between in-house and external research.
    - The government should support research on new technologies to a level of understanding consistent with industry's ability to adopt and further mature these technologies for application to future products.
    - NASA should invest in research on improved ground and flight test facilities and diagnostics in coordination with the DoD, academia, and industry.
- NASA must continue to seek input from outside the agency (as with the NASA-funded Decadal Survey of Civil Aeronautics) to develop, review, and recommend

NASA aeronautics research and technology plans, programs, and strategies. Moreover, NASA must embrace and integrate these inputs.

- In performing a robust civil aeronautics research program, NASA must maintain the competence of its workforce.

- Federal funding for university research must be provided to produce graduates with advanced degrees to support the follow-on work that will be undertaken by industry.

A clear voice of leadership must emerge from Congress and the White House that recognizes the challenges facing this nation's aeronautics sector and enunciates a viable aeronautics research and technology vision with an unequivocal endorsement of the strategy to implement this vision.

INTRODUCTION

The U.S. Congress and the Administration must now make a decision on the relevance of a robust Federal aeronautics research and development program. In a time when the President's Vision for Space Exploration has resulted in unprecedented focus of dollars and resources within the space mission of NASA, there is no such focus, and funding for aeronautics is limited. As a result, NASA's Aeronautics Research Mission Directorate has taken significant cuts to its budget, critical programs have been significantly scaled back or eliminated altogether, and the United States is rapidly losing its role as a global leader in aeronautics research.

It is the position of AIAA that stable, robust, long-term Federal civil aeronautics research and technology initiatives—funded at a level that will assure U.S. leadership in aeronautics—are critical to sustain a strong national economy, maintain a skilled workforce, and effectively support national security.

To accomplish this goal, the Federal government must formulate a vigorous research agenda, maintain the required national research facilities, and provide adequate funding. In formulating the research agenda, the Federal government should rely heavily on two recent independent studies:

1) "Decadal Survey of Civil Aeronautics: Foundation for the Future," developed in 2006 under the auspices of the Aeronautics and Space Engineering Board of the National Research Council.

2) "Responding to the Call: Aviation Plan for American Leadership," developed in 2005 under the auspices of the NIA at the request of the U.S. Congress.

In December 2006, President Bush signed an Executive Order establishing the nation's first Aeronautics Research and Development Policy. This policy defines the principles upon which Federal government aeronautics R&D will be based and the policy goal, objectives, and general guidelines that will drive Federal government aeronautics R&D activities through 2020. This is an excellent first step, but now an implementation plan must be formulated that provides priorities, objectives, roadmaps, and funding necessary to achieve the vision set forth in the new policy.

PROBLEM STATEMENT

Federal budgets for civil aeronautics research and technology have declined to the point that a viable program is in question. NASA's aeronautics budget was just over $1 billion in FY 2004. The FY 2006 budget declined to $884 million, and the President's 2007 budget submittal decreased funding for aeronautics still further to $724 million, representing a funding reduction of 32 percent over three years (in then-year dollars). At these levels, it is not possible for NASA to maintain a stable, robust, long-term Federal civil aeronautics research and technology initiative. Further, declining support for aeronautics research is creating a manpower drain as aeronautics engineers are forced to find other work; likewise, universities and students are adversely impacted. This trend jeopardizes NASA's competency in this critical field and damages America's long-term leadership in all aspects of aviation, including safety, the effectiveness of our ATM system, and the sale of aircraft, engines, aircraft systems, components, and support equipment.

The FAA has a limited research agenda and budget. It relies predominantly on NASA for the majority of research relative to the ATM system and environmental issues. A large body of research will be required to achieve and implement the Next Generation Air Transportation System (NGATS). The Vision 100—Century of Aviation Reauthorization Act in 2003 mandated the creation of the Joint Planning and Development Office (JPDO), sponsored by seven Federal agencies and departments (DOC, DoD, DHS, DOT, OSTP, FAA, and NASA) with responsibility to establish goals, develop concepts for NGATS, and define research to achieve these goals and objectives. There is concern that the JPDO does not possess sufficient leverage to command the necessary resources and priority from its partner agencies, as well as a concern over partner agencies' commitment to the mission of the JPDO.

BACKGROUND

Thanks in part to past government research, U.S. civil aeronautics is a major contributor to the national economy. Historically, the aerospace industry has made a large contribution to a positive trade balance. In 2005, the aerospace industry had a $37 billion positive balance of trade, of which $29 billion was for civil aeronautics.[1] The United States is a leader in manufacturing aircraft, engines, and air traffic management (ATM) systems, and U.S. carriers move more passengers and freight than those from any other country in the world. The United States boasts more general aviation and business aircraft than the rest of the world combined. In addition, aviation indirectly enables the overall economy to accommodate increasing globalization and the rise of e-commerce.

The general public can safely and affordably fly anywhere, anytime, and packages and freight are able to reach worldwide destinations overnight. An affordable and efficient air transportation system makes the short transit times of aviation readily available to business and leisure travelers, improving the quality of life for all who choose to travel by air or who benefit from quick delivery of freight. Future requirements in terms of system saturation and environmental issues will make new air system and aircraft developments mandatory.

Advances in civil aeronautics assist the United States in controlling the airspace over battlefields around the world. Historically, advances in military aeronautics were the source of many of the advances in civil aeronautics. Recent declines in Federal funding for

[1] Napier, D., "2005 Year-End Review and 2006 Forecast—An Analysis," Aerospace Industries Association (AIA), Arlington, VA, 2005.

military research and technology, however, led instead to advances in civil aeronautics being transferred to the military. Therefore, the future of military aviation will be impacted by the results of the civil aeronautics research agenda. A robust ATM system will also impact airspace utilization for DoD and homeland security, as well as civil aviation.

The national aerospace workforce is aging, and skilled engineers will be needed to protect U.S. competency in aeronautics research and technology. NASA's personnel reductions since 1993 have impacted both its younger and older science and technology (S&T) staffs. Currently, the number of S&T personnel under the age of 30 is one-third the number of those over 60. In 1993, the reverse was true, i.e., the number of S&T personnel under age 30 was more than double the number of those over 60[2]. A particularly worrisome feature of this NASA personnel profile is the loss of personnel with skills critical to a robust aeronautics R&D enterprise and rapidly increasing number of NASA S&T personnel eligible for retirement. NASA core competencies in aeronautics are being lost at a disturbing rate.

The leading aerospace undergraduate and graduate academic programs have all reported slightly increasing annual enrollments since 2000. These increases are attributed to a continuing student interest in astronautics by a 2:1 margin over aeronautics and to the broad applicability of the aerospace degree at the undergraduate and graduate levels. None of the leading university aerospace programs is reporting an increase in aeronautics enrollments or NASA funding. Although the nation's university aerospace departments are not at risk, the future for creative and sustainable aeronautics initiatives on the nation's campuses is already facing a crisis. Also, our industry stakeholders have informed us of possible losses of personnel with skills critical to aeronautics R&D.

America's leadership in aviation correlates with the conception, design, manufacture, assembly, operations, and maintenance of aeronautics products. A supply of creative, assertive, and well-educated S&T personnel from U.S. universities is continuously required to sustain America's leadership in aviation. The Federal government has not developed a long-range plan to develop and nurture a source of aeronautics S&T personnel. It is recommended that NASA develop a workforce strategy with input and participation from industry, other government agencies, and universities to maintain a continuous supply of technically robust aeronautics S&T personnel.

For over 100 years, research and technology has been the driving force behind revolutionary advancements in civil aeronautics. The civil aeronautics industry has historically looked to the Federal government (originally NACA and subsequently NASA) to provide funding and expertise for high-risk, long-term research. However, application of major technological breakthroughs will come only after significant industry and government investment over many years of technology maturation, as manifested by the following examples:

- Almost 50 years of government and industry research on composite materials was required before airframe companies were willing to design and introduce them into their products.

- Combustion research developed at NASA during the early 1980s and further matured by the propulsion industry over the next ten years resulted in lower emissions combustors that are just now making their way onto airplanes.

[2] National Research Council, "Evaluation of the National Aerospace Initiative," The National Academies Press, Washington, DC, 2004, pp. 87–94.

- The DoD has historically collaborated with NASA through the use of NASA's research and test facilities. In conjunction with DoD, NASA provided the tilt-rotor research base and test facilities that enabled launch of the V-22 Osprey development program.

There remain significant challenges that will require aeronautics research and technology. Aeronautics is still an innovative and changing field. Ongoing major scientific developments have not yet manifested themselves in military or civilian application. Only recently have computational and experimental methods been capable of exploring certain regimes that have potential for major improvements. Recent history has shown that advancements in engine and material technology that took years to develop are just now being used by the civilian aerospace sector to more successfully compete in the worldwide marketplace.

The continued worldwide increase in air travel creates significant environmental challenges for future aircraft systems. Investments in aeronautics research and technology development are needed to significantly reduce aircraft noise and environmental emissions (specifically NOx and CO_2).

The United States has a long history of funding civil and military aeronautics research and technology. A general policy framework has been developed in a number of prior studies, parts of which still may be relevant today. Over the last ten years, there also have been several studies that examined the civil aeronautics sector and that developed specific recommendations for improving its competitiveness in world markets and identifying how government and industry could productively work together.

Projects that benefit the "public good"—such as capacity, safety and reliability, efficiency and performance, and energy and the environment—should fall within the role of the Federal government. In the areas of noise, emissions, and fuel economy, there are interdependencies and potentially large payoffs, including reductions in aircraft weight and modifications to aircraft engines. The increasing use of automation in aircraft and air traffic control raises issues related to safety and certification standards. Technologies that are associated with aviation security (e.g., NASA's Aviation Safety and Security Program, or ASSP) and that address the advancement of aircraft operations in national airspace need to be developed. Standards-setting has been recognized as an important role for government; it is a very fertile area for research and technology in the civil air transportation sector. New vehicle types can provide increased value for specific market applications and address mobility for the traveling public. While all of these advances have value to the nation at large, they may not be accomplished if left to market forces alone.

Government-funded aeronautics technology is taken to a level short of full application (often referred to as a "pre-competitive" state). The concept is that the private sector would advance the technology to the next level when it is sufficiently matured to become a product. There remain many areas where beneficial innovation will not take place without some level of government-sponsored research and technology. When the expected outcome of research carries much uncertainty, the private sector's incentive to invest in technology is limited without the Federal government providing a measure of risk reduction. Because the FAA has an operational mission and no capability to perform product development, technology must be advanced even further before adoption into the ATM system.

There has been a significant shift in philosophy relative to NASA aeronautics research and technology. In partnership with industry, NASA historically engaged in research and technology projects aimed at advancing technology through concept validation

to the point where industry could develop them into products. It worked with academia, as well, to conduct foundational research and engage students early in their programs. Recently, NASA adopted a new philosophy composed of four research areas: 1) foundational physics and modeling, 2) discipline level capabilities, 3) multi-discipline capabilities, and 4) system design. Dr. Lisa Porter, NASA Associate Administrator for Aeronautics, says that, under the new partnership model, "NASA will take responsibility for the intellectual stewardship of the core competencies of aeronautics for the Nation."[3] In the new vision, universities will compete for funding, and students and faculty will be integrated into NASA-specified research projects. In addition, the partnership with industry will "shift from near-term, evolutionary procurements to long-term, intellectual partnerships."[3] As a result of this change in philosophy, the majority of NASA's aeronautics research and technology will be done in-house with very little input from the academic and end-user communities.

Although the United States remains the global leader in aviation, competition from abroad is increasing. The strongest competition comes from the European Union. In the EU report, "Aeronautics Vision 2020," a goal of global superiority in aviation is clearly stated. The EU and its member countries are investing heavily in aeronautics research, technology, and development. Aeronautics research budgets in Europe continue to increase, while those in the United States continue to decline.

At the same time, environmental concerns are driving increasingly stringent regulations on when and where airplanes can fly, especially in Europe. Noise and emission caps limit the total capacity of airports. Nighttime restrictions significantly impact the movement of freight. If U.S. carriers are to compete globally, they must have the technology that allows them to fly anywhere, anytime.

CONCLUSION

It is the position of AIAA that stable, robust, long-term Federal civil aeronautics research and technology initiatives—funded at a level that will assure U.S. leadership in aeronautics—are critical to sustain a strong national economy, maintain a skilled workforce, and support national security.

RECOMMENDATIONS

- **The Federal government must develop an aeronautics research agenda consistent with recommendations contained in recent independent studies.** The recently released National Aeronautics Research and Development Policy provides the vision that will guide Federal aeronautics R&D activities through 2020. The Federal government must now develop an implementation plan. Using many of this nation's academic and industry experts, two exhaustive studies were completed that define and prioritize research and technology challenges and lay the foundation for a strong aeronautics research and technology agenda.

    - **The Federal government should utilize the "Decadal Survey of Civil Aeronautics" (2006) to identify and prioritize research and technology projects.** Using the recognized Quality-Function-Deployment (QFD) prioritization procedure, the Decadal Survey of Civil Aeronautics identified and

[3] Porter, L., "Reshaping NASA's Aeronautics Program," presentation given at AIAA Aerospace Sciences Conference, Reno, NV, 12 Jan. 2006.

ranked research and technology challenges to address four high-priority strategic objectives: 1) increase capacity, 2) improve safety and reliability, 3) increase efficiency and performance, and 4) reduce energy consumption and environmental impact.

The QFD process produced a number of high-priority technology challenges, motivating advances that would have significant, long-term impacts on civil aeronautics. These challenges fall into five discipline areas: 1) aerodynamics and aeroacoustics, 2) propulsion and power, 3) materials and structures, 4) dynamics, navigation and control, and avionics, and 5) intelligent and autonomous systems, operations and decision-making, human integrated systems, and networking, and communications.

- **The Federal government should utilize the NIA study to develop roadmaps, milestones, and metrics for their prioritized research agenda.** At the request of Congress, the NIA developed a five-year aeronautics research plan and recommended budget for NASA ["Responding to the Call: Aviation Plan for American Leadership" (2005)]. A National Strategy Team created seven sector teams composed of more than 250 of the nation's aviation experts from industry and academia. The result is an extensive, integrated research plan and budget that contains the schedules, milestones, and funding of the aeronautics technology required to address America's needs. AIAA believes that this study can provide the "how" to address the decadal survey's "what" relative to a national aeronautics research and technology agenda for the future.

- **AIAA endorses the following three recommendations, paraphrased from the 2006 Decadal Survey:**

  - **A balanced split should be created in the allocation of aeronautics research and technology funding between NASA research (performed by engineers and technical specialists) and external research (by industry and academia).** NASA's current budget and research philosophy have created an imbalance. NASA needs the expertise and strategy that academia and industry can provide across the spectrum of aeronautics research.

  - **The government should support research on new technologies to a level of understanding consistent with industry's ability to adopt and further mature these technologies for application to future products.** The government is not in the product development business, and industry is not in the long-term, high-risk research business. However, attention to the transfer between the two is needed to assure future competitive aircraft development and the implementation of advances in the ATM system.

  - **NASA should invest in research on improved ground and flight test facilities and diagnostics, in coordination with the DoD, academia, and industry.** Many of NASA's aeronautics research and test facilities are national assets and must be updated and maintained to remain viable. If NASA facilities are not updated, available, and affordable, the nation's research will be adversely affected and industry will be forced to seek test facilities, if even available, in other countries.

- **Funding for university research should also be provided to produce graduates with advanced degrees to support the follow-on work that will be undertaken by industry.**

NASA must seek and embrace input from outside the agency (other agencies, industry, academia) to develop, review, and recommend NASA aeronautics research and technology plans, programs, and strategies. An initial biennial review of national aeronautics capabilities and priorities should be conducted. Examples of such reviews already existing within the Federal sector are the Decadal Survey and the DoD quadrennial review. Such reviews enable the Federal government to better track progress and increase flexibility to react to changing research requirements and to avoid gapping or duplication of effort.

- **In performing a robust civil aeronautics research program, NASA must maintain the competence of its workforce.** A healthy NASA workforce, armed with appropriate skills and secure in its future, will provide better oversight for technical system procurement and program management. This competence will result in better performing systems, better ability to meet schedule, more productive interactions with other stakeholders in the aerospace enterprise, and more efficient use of taxpayer dollars. Although NASA must accommodate changing priorities and budgets, it must also ensure that it does not lose the important skills and knowledge currently possessed by its workers. NASA also must continue to ensure that the NASA workforce gains the new competencies needed in the aerospace industry of the future.

A clear voice of leadership must emerge from Congress and the White House that recognizes the challenges facing this nation's aeronautics sector and enunciates a viable aeronautics research and technology vision with an unequivocal endorsement of the strategy to implement this vision.