**SCIENCE, AERONAUTICS AND TECHNOLOGY**

**FISCAL YEAR 2002 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF AEROSPACE TECHNOLOGY** **AEROSPACE RESEARCH AND TECHNOLOGY PROGRAMS**

**SUMMARY OF RESOURCES REQUIREMENTS**

| | FY 2000 OPLAN REVISED | FY 2001 OPLAN REVISED | FY 2002 PRES BUDGET | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Aerospace Research and Technology | 985,395 | 1,241,658 | 1,357,600 | SAT 4.1-1 |
| Aerospace Institutional Support | [708,953]* | [810,359]* | 871,239* | SAT 4.1-89 |
| Commercial Programs | 140,005 | 162,442 | 146,900 | SAT 4.2-1 |
| Total | 1,125,400<br>[1,834,353]* | 1,404,100<br>[2,214,459]* | 2,375,739* | |

* Funding includes direct-program Institutional Support to Aerospace Technology Enterprise (from FY 2001 President's Budget, Mission Support section)

**PROGRAM GOALS**

NASA is responsible for addressing aeronautics and space priorities as outlined in national aeronautics and space policies. The responsibility of industry and operational government agencies is to meet their near-term customer requirements through evolutionary advancements to their products. The Aerospace Technology Enterprise's responsibility is to provide revolutionary advancements in science and technology that sustain global U.S. leadership in civil aeronautics and space, reduce the impact of aerospace operations on the public. Also to provide the public with a safe, reliable and efficient air and space transportation systems and reduce the costs associated with space travel. This includes the development of revolutionary concepts, physics-based analytical tools and modeling, revolutionary manufacturing environments and processes, and breakthrough technologies that will enable the Nation's air and space transportation systems to routinely demonstrate capabilities tomorrow that are not envisioned today.

As we approach the centennial of flight, the technological changes that have occurred in the past century are astounding. What is even more impressive is the impact of these changes on the Nation. Aerospace technologies are essential for the National Defense and provide unprecedented mobility for the general public. Aerospace spin-off technologies have revolutionized the way we live,

greatly improved the quality of life of the general public, and have become a driving force in keeping our economy strong. Aviation is vital to the Nation, but it is at a crossroads. With the National Airspace System approaching gridlock, the impediments to continued growth and prosperity have never been greater. Industry, the FAA, and NASA must work together to ensure that long-term, high-payoff research that could alleviate these conditions makes its way into the next-generation systems. The military is also becoming more reliant on commercial developments. The answer to ensuring the continued viability of aerospace technology is not through evolutionary or near-term approaches alone, but through the development of revolutionary, long-term approaches. The vision of aerospace for the 21st Century is based on promising advances in emerging technology such as nanotechnology, biotechnology, and information technology. The Office of Aerospace Technology is moving to develop the technological foundation, through investments in revolutionary, high-risk, and breakthrough technologies, to make the vision a reality.

During the past year, the Enterprise Strategic Plan has been updated, to reflect a new emphasis on innovation, as well as to reflect the technical progress and programmatic insights gained in recent years. The main goals of the Enterprise have been reformulated: Goal One is titled "Revolutionize Aviation," Goals Two is "Advance Space Transportation" Goal Three is "Pioneer Technology Innovation," and a fourth goal, added in this plan, is "Commercialize Technology," to formally recognize this important and ongoing Enterprise role.

**Goal One: Revolutionize Aviation - enable the safe, environmentally friendly expansion of aviation.**

Expanding the aviation system of the future to meet the demands for growth will mean providing a more distributed flexible and adaptable network of airways. This growth must take place within the physical and environmental constraints of today's system, while meeting the evolving needs of air travel. Advanced vehicles will operate in this new infrastructure, with better performance and new capabilities such as "morphing" wings that optimize their shape for take-off, flight, and landing. The aircraft of the future will be safer, cleaner, quieter, and faster. Advanced information and sensor technologies will make air travel safer and more efficient. Air transportation will be easily accessible from urban, suburban, and rural communities and affordable for all citizens.

Civil aviation provides the backbone for global transportation, the very basis of global economic and cultural exchange and integration. It is a large and growing market that the U.S. has traditionally led. Projected growth approaches a tripling of air traffic over the next twenty years. NASA coordinates its aviation technology development activities with the FAA and DoD through the *National Research and Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility*. Examination of various alternative futures suggests that there is also the potential for greater dispersion of operations, for a very high value for flexible, ultra-reliable operations, and for increasing utilization of aircraft with unique operational characteristics.

A need exists to address the fundamental, systemic issues for the aviation system to ensure the continued growth and development appropriate to the needs of the national and global economies. These systemic issues—safety, capacity, environmental compatibility, and mobility cut across markets including large subsonic civil transports, air cargo, commuter and general aviation. To ensure these systemic issues do not become constraints, dramatic improvements should be aggressively pursued. Therefore, the Enterprise has worked with its partners to identify five enabling technology objectives to sustain the United States aeronautics leadership by providing high-risk technology that cuts across all markets in Civil Aviation:

- Make an already safe air transportation system even safer by reducing the aircraft fatal accident rate by a factor of five by 2007 and by a factor of 10 by 2022 as compared with the baseline period of 1990 to 1996.

- Protect local air quality and our global climate by reducing Oxides of Nitrogen (NOx) emissions of future aircraft by 70 percent by 2007, and by 80 percent by 2022 (using the 1996 ICAO Standard for NOx as the baseline). Reduce carbon dioxide ($CO_2$) emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).

- Improve the quality of life for airport neighbors and travelers and reduce airport operations constraints by reducing the perceived noise levels of future aircraft by a factor of two (10 decibels) by 2007 and by a factor of four (20 decibels) by 2022, using 1997 subsonic aircraft technology as the baseline. The long-term 20-decibel objective for noise reduction will, in most cases, contain objectionable aircraft noise within the airport boundaries (55 Day/Night Level contour), freeing the system of most noise restraints.

- Enable the movement of more air passengers with fewer delays by doubling the aviation system throughput, in all weather conditions, by 2007 and triple it by 2022.

- Enable people to travel faster and farther, anywhere, anytime by reducing inter-city door-to-door transportation time by half by 2007 and by two-thirds by2022, and reduce long-haul transcontinental travel time by half by 2022.

**Goal Two: Advance Space transportation - create a safe, affordable highway through the air and into space**

The objectives of this goal are described in terms of the desired system attributes – Mission Safety, Mission Affordability, and Mission Reach (faster travel times) respectively. Technology for the next generation of space transportation is focusing on an order-of-magnitude increase in safety and reliability and an order-of-magnitude decrease in cost. NASA will focus on advances in systems, materials, structures, propulsion, and aerodynamics to increase operating margins while incorporating advanced, intelligent health management for reliability.

Revolutionizing our space transportation system to significantly reduce costs and increase reliability and safety will open the space frontier to new levels of exploration and commercial endeavor. With the creation of the Integrated Space Transportation Plan (ISTP), the Agency defined a single, integrated investment strategy for all its diverse space transportation efforts. By investing in a sustained progression of research and technology development initiatives, NASA will realize its vision for generations of reusable launch vehicles that will surmount the Earth-to-orbit challenge.

- Radically improve the safety and reliability of space launch systems by reducing the incidence of crew loss for a second generation Reusable Launch Vehicle (RLV) to 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1,000,000 missions (an additional factor of 100) for a third Generation RLV by 2025.

- Create an affordable highway to space, by reducing the cost of delivering a payload to Low Earth Orbit (LEO) to $1000 per pound (a factor of 10) by 2010, and to $100 per pound (an additional factor of 10) by 2025.

**Goal Three: Pioneer Technology Innovation - enable a revolution in aerospace systems.**

This goal addresses the need for a revolution in engineering tools and processes, and a culture change in our organizations if we are to ensure success in Goals One and Two. To create the air and space transportation systems of the future, as well as other highly complex civil and military systems, we need to develop a new approach to engineering that puts safety, reliability and mission assurance first. Critical to unlocking this capability are high-fidelity, collaborative tools and environments with intuitive human interfaces that allow us to simulate, in virtual space, complete product life-cycle evaluations before cutting the first piece of hardware. New system or vehicle characteristics such as intelligence, rapid self-repair, and adaptability will come about through innovation and integration of leading-edge technology, most notably nanotechnology, biologically-inspired technology and intelligent systems. By focusing on how these technologies can address design issues faced by NASA missions and other customers, NASA will accelerate the introduction of new, revolutionary capabilities.

Pursuing technology fields that are in their infancy today, developing the knowledge bases necessary to design radically new aerospace systems, and performing efficient, high-confidence design and development of revolutionary vehicles are challenges that face us in innovation. These challenges are intensified by the demand for safety in our highly complex aerospace systems. The goal to Pioneer Technology Innovation is unique in that it focuses on broad, crosscutting innovations critical to a number of NASA missions and to the aerospace industry in general.

- Enable rapid, high-confidence, and cost-efficient design of revolutionary systems by demonstrating advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications by 2007 and demonstrating an integrated, high-confidence engineering environment that fully simulates advanced aerospace systems, their environments, and their missions by 2022.

- Enable fundamentally new aerospace system capabilities and missions by integrating revolutionary technologies to explore fundamentally new aerospace system capabilities and missions by 2007; and demonstrating new aerospace capabilities and new mission concepts in flight by 2022.

**Goal Four: Commercialize Technology - extend the commercial application of NASA technology for economic benefit and improved quality of life**

This goal is not a new requirement but by its inclusion as a goal brings greater awareness to NASA's responsibility to transfer and commercialize technology resulting from NASA's research and development.

Commercialization is an outward; external process that provides benefit to the public fully supported by a network of NASA-affiliated organizations across the U.S. NASA technology benefits the aerospace industry directly. The creative application of NASA's advanced technology to disparate design and development challenges has also made numerous contributions to other areas such as the environment, surface transportation, and medicine. NASA achieves this by partnering with both aerospace and non-aerospace industry as well as academia. These partnerships involve the full range of NASA's assets: technological expertise, new technologies, and research facilities. The NASA Commercial Technology Network (NCTN) is a key mechanism for enabling technology transfer and commercialization. This network provides unique expertise and services to U.S. enterprises, facilitating the transfer, development, and commercialization of NASA-sponsored technology.

An effective external transfer effort augments our economy, benefits the public, and fosters technology leveraging across NASA programs. NASA will continue to improve its technology commercialization and outreach programs to ensure the widest application of NASA-developed technology to benefit the Nation.

**STRATEGY FOR ACHIEVING GOALS**

When the Enterprise identified the four goals and their enabling objectives, it was recognized that they are highly ambitious and will stretch the boundaries of the U.S. knowledge and capabilities. These goals and objectives provide the framework for the development of a portfolio of Aerospace Research and Technology (R&T) activities in both basic and focused research and technology development. Both the Aerospace R&T Base and Aerospace Focused programs contribute to the accomplishment of the Enterprise Goals which in turn support National objectives in terms of aerospace safety, capacity, reliability, efficiency, cost, and leadership. In order to achieve these National objectives, NASA carries out its aerospace technology mission in close partnership with U.S. industry, academia and other Federal agencies, such as the Federal Aviation Administration (FAA) and Department of Defense (DoD). During FY 1998, the Enterprise developed detailed roadmaps to define the path that it would need to follow in order to allow this partnership to achieve these objectives. Although the Enterprise Goals were revised in FY 2000, the technical objectives have remained unchanged with the exception of the newly developed mobility objective. Roadmaps for the mobility will be generated during FY 2001.

The Aerospace R&T program consists of five base-research programs and seven focused programs. The base programs are responsible for the development of advanced concepts, physics-based understanding of aerospace phenomena, validated models design tools and environments, design and manufacturing aids and processes, and suites of aerospace discipline and multi-discipline technologies that are not directly orientated to a specific user, vehicle, or application. The focused programs build upon the technological foundation provided by the R&T Base and further develop and adapt basic research products, in order to satisfy specific user requirements or system applications, to the point at which they could be transferred to a user for further development and implementation.

The Enterprise Technology impact is evaluated by both its Advisory Committee and an independent Inter-Center Systems Analysis Team (ISAT). The ISAT not only assesses the synergistic effect of all the Enterprise R&T activities toward meeting the goals but also provides an assessment of the individual contributions of each R&T activity toward each goal. Based on the information provided by

the ISAT team, the current R&T program was adjusted to better meet Enterprise long-term goals in a financially constrained environment.

These changes are described below:

- Restructured the Base R&T program by combining like activities in a synergistic manner that reduces management overhead, eliminates redundant and overlapping research activities, and concentrates our core expertise in critical technologies.

  - Created a new base research program entitled Computing, Information, and Communications by including the existing Aerospace Base programs in Information Technology and Aerospace Operations Systems (AOS); the existing Space Base programs in Space Communications, Thinking Systems, Autonomy and Search and Rescue; and the new activities in Aerospace Autonomous Operations, Design for Safety, and Bio-Nanocomputing and Electronics. Early infusion will be necessary for NASA to achieve the challenging goals for its many future missions of planetary and deep space exploration, science data acquisition, near-Earth orbit space operations, aeronautical systems, the National Airspace system and space transportation systems. To ensure the highest quality research and strong ties to NASA's missions, these investments will be guided by technology development agreements signed by customers in other NASA Enterprises and will be subject to external, independent reviews. A significant portion of these investments will be externally competed. To ensure the high quality research, the program will be subject to external independent reviews and a significant potion of the research will be externally competed. To endure strong ties to technology customers, a team of potential internal and external users will assess the relevance of the research to future NASA and commercial/government applications and provide recommendations for ongoing and future activities. The maturation of technologies to higher technology readiness levels will be guided by technology development agreements signed by the potential users of the technology and the program.

  - Moved the Aircraft Icing Project from the AOS program to the Glenn Research Center-led Propulsion and Power Base R&T Program

  - Integrated the remainder of the research activities of the Space Base (formerly the Cross-Enterprise Technology Development program) into the existing Aerospace Base R&T Programs

    - Highly distributed systems, sensors, nano-spacecraft, nanostructured materials, resilient materials and Advanced Concepts were merged with the Aerospace Vehicle Systems Technology Base Program

    - The Space On-Board Power and Electric Propulsion and Advanced Energy Projects were merged with the Aerospace Propulsion and Power Base R&T Program

- Terminated programs that were evolutionary in nature, had a narrow focus, had not performed well, or did not provide a significant contribution to the Enterprise Goals. Terminated programs included the Rotorcraft and Intelligent Synthesis Environment (ISE) Programs, as well as the Computational Aerospace Sciences (CAS) and NASA Research and Education

Network (NREN) projects in the High Performance Computing and Communications Program. The Power and Communications Commercial Space Centers, the Polymer Energy Rechargeable System (PERS) activity, the Ultra-Low Power Electronics activity, and the Glennon Initiative from the Space Base Program were also discontinued.

- Initiated a new effort, called Design for Safety, within the Computing, Information and Communications Technology area. This research will provide a paradigm shift in how systems engineering and operations will be performed, and aims to place risk estimation and risk countermeasures for overall mission and human safety on a more rigorous, explicit, and quantifiable basis. This new paradigm would allow design trades to be evaluated based on a risk factor, with the same fidelity and confidence used for other mission or system properties such as cost, schedule, and performance.

- Initiated a new effort, Virtual Airspace Modeling under the Aviation System Capacity Program, to model the airspace environment. In order to meet the demands for the airspace system of the future, a revolutionary change in the fundamental approach to airspace operations will be required. This modeling effort will provide the technical basis to guide policy by exploring revolutionary concepts and technologies, identifying those offering the greatest potential benefit, as well as their limits.

- Initiated a new effort, in the Vehicle Systems Base R&T Program, to develop the technologies needed for a 21st Century Aerospace Vehicle. This research will develop and verify critical technologies that provide leapfrog capabilities to today's state of the art vehicles. These new vehicles might be able to change their shape in flight –"like birds"-- to optimize performance or perform complex maneuvers in complete safety. They might be capable of self-repair when damaged, and has limited impact on the environment. These types of vehicles will require significant advances in technology such as biotechnology and nanotechnology sensors, materials, and computational sciences.

- Implemented five University-based Research, Education, and Training Institutes (RETIs). The RETIs will strengthen NASA's ties to the academic community through long-term sustained investment in areas of technology critical to NASA's future. At the same time the RETIs will enhance and broaden the capabilities of the nation's universities to meet the needs of NASA's technology programs. The role of the RETIs is intended to be research and exploitation of innovative, cutting-edge, emerging opportunities for science and technology that can have a revolutionary impact on the missions that NASA pursues in the future. At the same time the RETIs should expand the nation's talent base for research and development. To ensure the highest quality research and training and infusion of new ideas, these RETIs will be subject independent, external reviews and recompetition at regular intervals, including mandatory sunsets after ten years. To ensure the high quality research, the program will be subject to external independent reviews and a significant potion of the research will be externally competed. To endure strong ties to technology customers, a team of potential internal and external users will assess the relevance of the research to future NASA and commercial/government applications and provide recommendations for ongoing and future activities. The maturation of technologies to higher technology readiness levels will be guided by technology development agreements signed by the potential users of the technology and the program.

- Initiated a new effort in Aerospace Autonomous Operations. This research will enable better, faster, cheaper, more reliable aerospace missions by extending the scope of decisions and actions that can be done under computer control. The research

enables unmanned missions to accomplish more by making better autonomous decisions, including a health monitoring system with real time fault detection, isolation and recovery, a robust situational awareness with the ability for real time mission replanning and rescheduling. It will enable manned missions to be cheaper and safer by providing more sophisticated interactions between astronaut and machines. Finally, it will enable ground operations to be cheaper and faster, by allowing a reduced ground operations team to send more-complex, higher level instructions. To ensure the highest quality research and strong ties to NASA's missions, Aerospace Autonomous Operations investments will be guided by technology development agreements signed by customers in other NASA Enterprises and will be subject to external, independent reviews. A significant portion of these investments will be externally competed.

- Initiated new efforts in biotechnology and nanotechnology -- the true revolutionary technologies of the 21st Century. Systems using these technologies have no counterpart today. Nanotechnology-based aerospace materials, are lighter and have the potential to be 100 times stronger than steel at one-sixth the weight. Combined with biology-inspired processes, they could be made to self-assemble to a pre-designed shape, self-repair when damaged, and continuously, optimally modify their internal structure in response their operating environment. Bionanotechnology computing and electronics can provide capabilities orders of magnitude better than the best of today's electronics. For comparison, in terms of computing power of the human brain is about 10,000 times more capable than the best "silicon" computer and much more power efficient. It can perform up to 1000 trillion operations per second and consumes only about 10 watts of power. These technologies may also enable sensors and detectors, that could be sensitive to a single photon or electron; and they could enable spacecraft systems to be much smaller, with higher performance, and lower power consumption than is possible with today's technology. To ensure the highest quality research and strong ties to NASA's missions, these investments will be guided by technology development agreements signed by customers in other NASA Enterprises and will be subject to external, independent reviews. A significant portion of these investments will be externally competed.