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NATIONAL
INSTITUTE OF
AEROSPACE

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This will be the future of American aviation without dramatic action by the U.S. Congress...

April 2005

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The Time is Now.

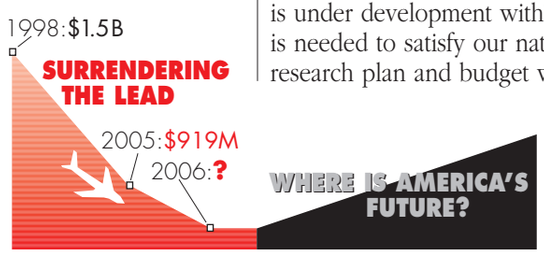
> "Due to a lack of significant and stable funding in long-term research, the centroid of aviation technical and market leadership is shifting outside the United States."

AMERICA SURRENDERS THE LEAD: Due to a lack of significant and stable funding in long-term research, the centroid of aviation technical and market leadership is shifting outside the United States. The consequences of this are that America is losing high paying jobs and intellectual capital to the detriment of our economy and national defense. We must reverse this trend.

Today, portions of our civil aviation manufacturing industry are #2 behind Europe. Europe's stated goal is to transform itself into "the most competitive and dynamic knowledge-based economy in the world." European presidents assembled for the rollout of the new Airbus A-380 aircraft. Because of Europe's committed investment in R&D they now boast that Airbus is #1 in civil aircraft sales and that the President of the United States will be flying in a helicopter built using Italian and British technology. Nations rather than companies are now competing in aviation.

CORPORATE WELFARE? America's response is exemplified by the X-43A. In December 2004, NASA aeronautics successfully flew the world's first air breathing hypersonic vehicle, the X-43A. This technology could someday allow aircraft to reach almost anywhere in the world in less than two hours, yet, budget cuts forced cancellation of the program! NASA's total FY 2006 budget request to Congress increased, yet aeronautics was cut by $200M. This will result in elimination of jobs for over 2000 highly-skilled aeronautics employees, the closure of key NASA national aeronautical facilities, and further reductions in external collaborative research. These cuts have been characterized as cutting corporate welfare. But, their result is cutting high paying American jobs in nearly every state and reducing the research available to our aviation industry, thus crippling its ability to compete around the world. The only way the U.S. can continue to create high wage, high value-added jobs and maintain leadership is to innovate faster than the rest of the world. As a nation we must have the foresight to create an environment in which America's aviation industry can be the world leader.

CONGRESS' CALL: Congress asked the National Institute of Aerospace (NIA) to lead the development of a five-year aeronautics research plan and budget for NASA. A National Strategy Team created seven sector teams composed of more than 250 of the nation's aviation experts from industry and academia. The participants have taken a national view and developed an integrated research plan and budget that contain the schedules, milestones, and funding of the aeronautics technology required to address America's needs.



AMERICA'S NEEDS: From building the strongest economy in the world to winning the war on terror in the skies over Afghanistan, Iraq, New York, and Washington, aviation and the aeronautics research that underpins it are key to our nation's success. We need aeronautics technology to create a civil aviation system that will bring affordable passenger service to every community, as well as provide same day cargo services. The development of new revolutionary vehicles will create new industries and transportation opportunities. Moving people and goods faster, safer, and more securely to anyplace in the world in a more environmentally-friendly way will stoke the fires of American business well beyond the aviation community. It will take research investment and a whole new generation of highly trained Americans to create the vehicles, airports, and air traffic management systems to make this possible.

Numerous national reports have called for increased aeronautics research investment and have described how aviation contributes to America's national needs. The following national needs are drawn from these reports:

- U.S. economic competitiveness
- Freedom of air travel
- Flight safety
- Secure and defend the nation
- Protect the environment
- Educate the future workforce

RESEARCH PLAN AND BUDGET TO SECURE AMERICAN LEADERSHIP: America's aviation experts recommend an average five-year annual increase of $885.5M in NASA's aeronautics budget over FY 2005 base levels. The proposed budget would return NASA's aeronautics budget to 1998 levels in constant dollars.

Why NASA? Aviation research requires unique national facilities, and world-class researchers that cannot be resident in any one company. The fruits of this research add to the nation's wealth, not to that of any individual company.

Because this research plan builds on NASA's FY 2005 plan, it is essential that the FY 2006 proposed budget cuts be restored. The budget increases we recommend are necessary to begin a revitalization effort for American aeronautics research. The five-year research plan, budget, and benefits are described on the following pages. The plan is based on in-depth knowledge of the NASA FY 2005 plan, what technology is under development within the aviation industry, and what is needed to satisfy our national needs. Implementing this research plan and budget would be a major step toward achieving America's long-term needs and begin a national debate on the fate of our nation's aviation leadership. The time to invest in NASA aeronautics research is now.

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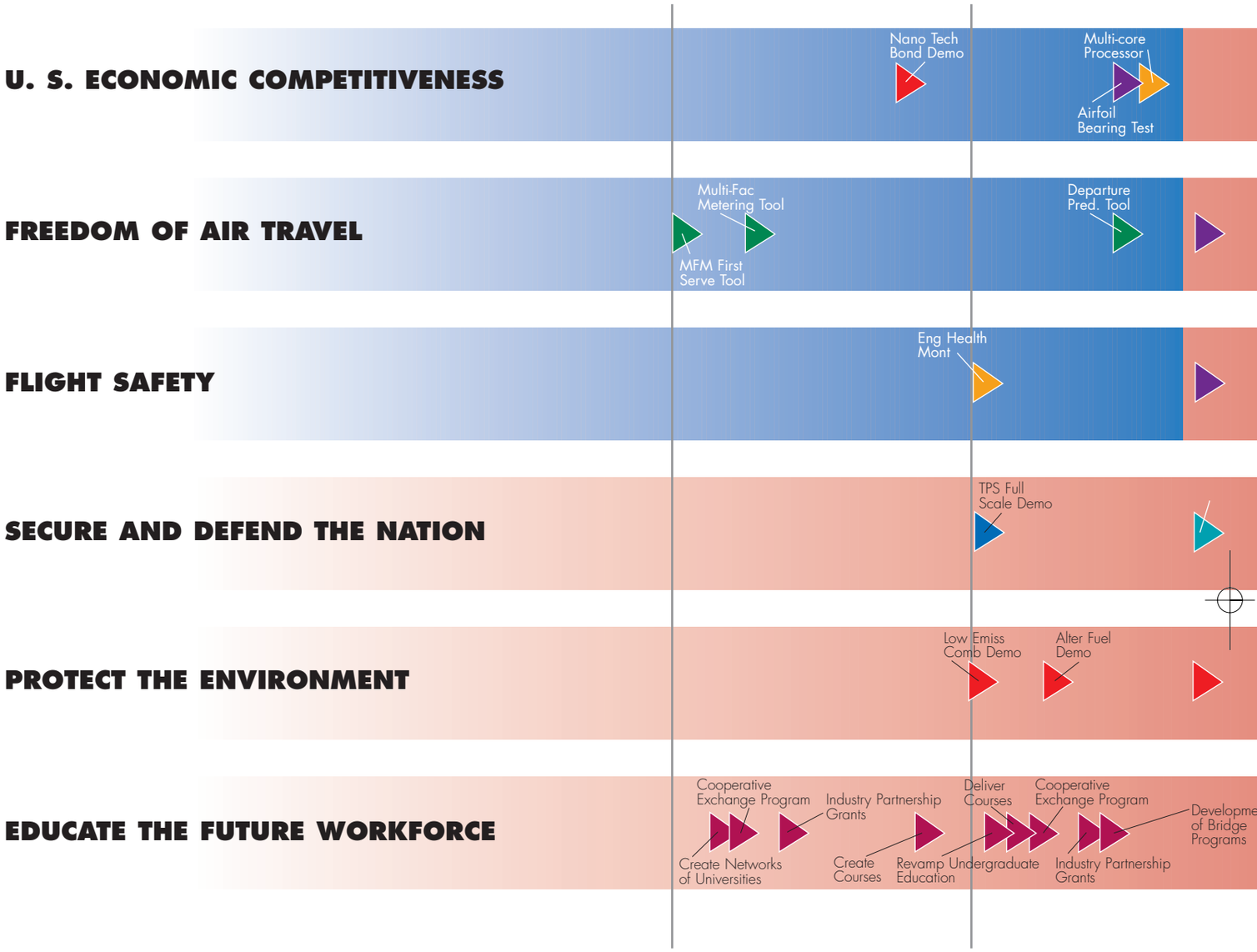
Fulfilling National Needs*



Industry and academia have come together under the leadership of the National Institute of Aerospace in an unprecedented non-partisan effort, teaming up across company lines and other divisions in order to generate a coherent rational plan that proposes crucial five-year aeronautical technology research investments. Participants were tasked to include augmentations to NASA's 2005 programs required to restore the U.S. to technological superiority in aviation and aeronautics, at a robust level commensurate with a global leadership position.

Technology goals achievable within the next five years were identified in each of the seven critical aviation sectors (see key). Each program element includes an estimated budget, milestones, and major deliverables. Using a traceable approach based on quantitative mapping of goals to the overarching national needs: technology portfolios were prioritized, duplication of efforts among the seven sectors was eliminated, and key cross-cutting technologies were identified. The annual budgets shown are the result of the decision-making process by

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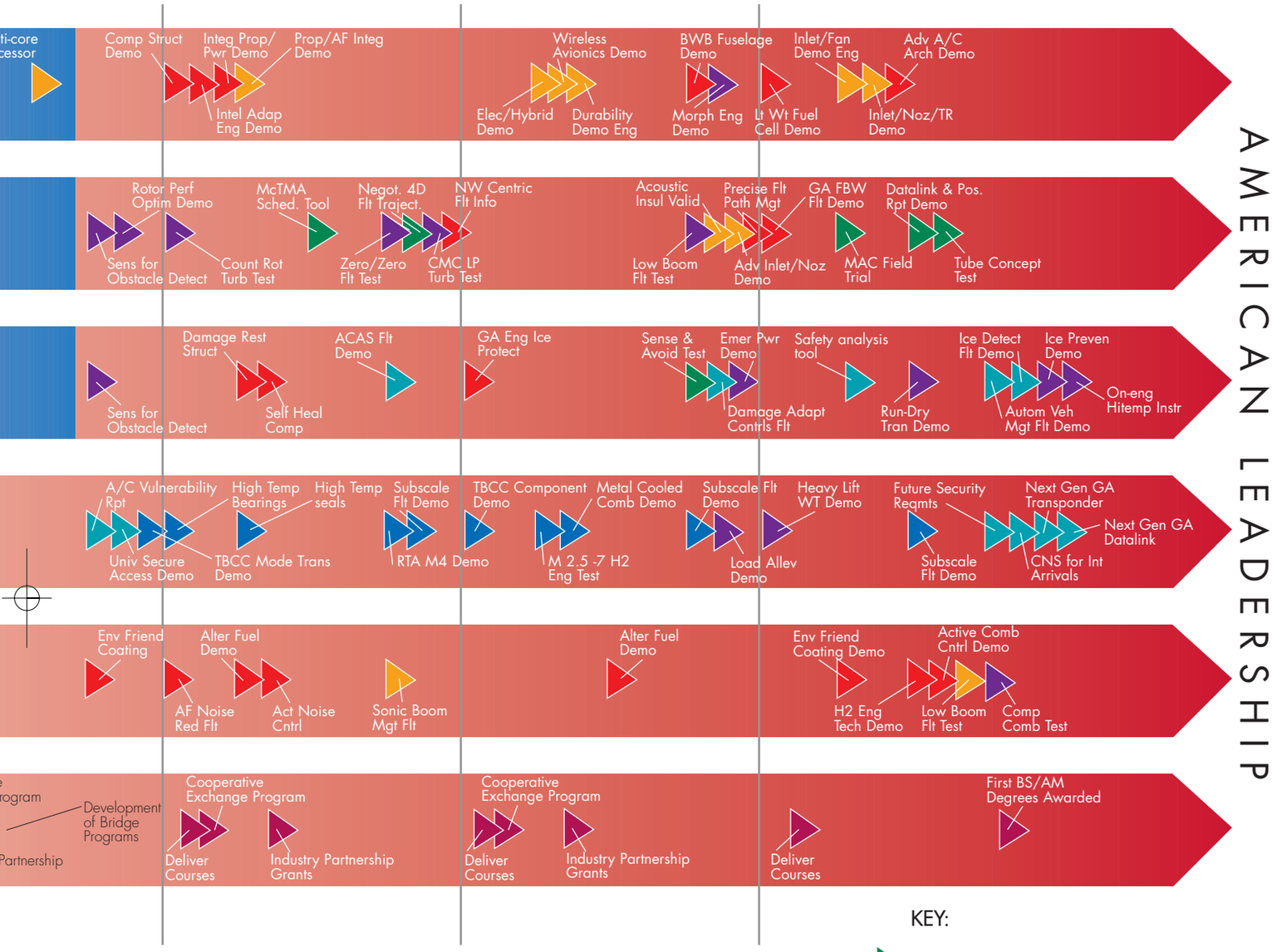

the National Strategy Team and constitute the budget augmentation recommended to Congress.

The technology roadmap above summarizes the results of this mapping process. It illustrates how major deliverables from each sector will provide crucial support in achieving our national needs and will contribute to American leadership.

*The national needs and their underlying technology requirements have been drawn from reports that are listed on the inside back cover.

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In aviation, timing is everything.

Freedom of air transportation and just-in-time commerce in America depend on the ability of aviation to provide economical, safe, reliable, and environmentally-friendly transportation. Our current aviation system, using radio, radar and human control of vehicle movements from gate to gate, will shortly reach its natural capacity limit. This method of handling air traffic is not scalable to meet anticipated demand, and unless today's air transportation system is transformed, air commerce and national economic growth will be significantly inhibited. Beyond the growth of demand for air transportation as currently configured, the utility of Uninhabited Vehicles, Personal Transportation Systems, and continued fractionalization of the commercial markets (both passenger and air freight), will contribute to an air vehicle demand that can easily be conceived to be many times that seen today. Demand will require major change in how that demand is safely handled. The current system of control will yield to a system that looks like and functions like today's internet. NASA aeronautics research is the technology driver to transform our air transportation system.

The industry and academic experts that prepared this plan see a need to shift toward a balanced portfolio of airspace system optimization and transformation. They call this "Flight Path to 3X" because it will result in three times current airspace capacity. This balance can be achieved by expanding the research portfolio to contain work directed toward leadership challenges and metrics described in the body of this report. These activities are challenging because they commit NASA to moving forward in areas that are technically challenging across the entire spectrum of air traffic management research, and create a significant opportunity for globalization. This effort will require a level of organizational leadership that give the "Flight Path to 3X" the same national imperative as NASA's Moon, Mars and Beyond initiative–bold, innovative, and necessary. This plan builds on the Next Generation Air Transportation Systems (NGATS) Integrated Plan delivered to Congress by the inter-departmental Joint Planning and Development Office, but it presents additional technologies to achieve the overarching national needs. The plan recommends a new vision for NASA. It is NASA's imperative to become the civil aviation research arm of the NGATS plan and act as the catalyst for aviation system transformation.

This report is focused on four subsectors, described here as new domains for research, development, and demonstration.

> "...widely available, high-quality information – in conjunction with powerful, fast-time analytical tools – can dramatically increase capacity and predictability of the aviation system by improving tactical, mid-range and long-range planning."

There is a considerable mix of research and development levels, but in the end, bold, new and high risk/reward portions of any research portfolio require demonstration.

STRATEGIC AIRSPACE USAGE: This area focuses on two precursors for the leadership challenges: creating economic models that make a solid business case for transformation; and investigating standards for an information architecture that looks at reducing uncertainties in information values and variability. It also addresses the need for global harmonization. In the near-term, system-wide traffic flow planning and departure information are needed to improve strategic management of traffic. The team recommends that these near-term tools be demonstrated, so that the value of the information can be used to further remove airspace system uncertainties and help build toward the future.

With the aviation internet, aircraft, airlines, air traffic control, airports and passengers will have information to make informed decisions.

AIRSPACE SYSTEM EFFICIENT FLIGHT PATH MANAGEMENT: This area addresses the significant challenges of changing how aircraft are controlled and the significant human factors issues of separation, sequencing, and spacing. The research in this subsector represents the bold leadership challenges of early discovery of issues through demonstration that can shape aviation transformation. The research and development starts with a new air traffic management paradigm that eliminates airspace boundaries as defined today in order to free up airspace and set the stage for optimizing performance from the aircraft. The air and ground functional allocations are shifted toward more autonomous aircraft operations. The essence of the flight path management research program is demonstration of trajectory-based aircraft operations. In these demonstrations

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RAYTHEON

NASA technology is transforming air traffic management today.

four dimensions of information–latitude, longitude, altitude, and intent over time (4D)–are known by air traffic control automation and the other aircraft flying in the airspace. The work starts modestly, by defining the performance of a single aircraft, then multiple comparably capable aircraft, and finally by introducing mixed equipage. The overall demonstration objective is to demonstrate the combined performance of aircraft and define the performance degradations as the fleet mix changes.

New concepts of 4D trajectory flights are supplemented with use of electronic means to attain the equivalent of good-weather capacity before proceeding to reductions in safe separation distances, enabled by technology and procedural changes.

Demonstrations in this subsector address the leadership challenges of changing the role of the controller, introducing more autonomous operations, and leveraging existing aircraft performance through full utilization of on-board avionics capabilities. With the addition of dynamically defined tubes in the airspace (HOV lanes in congested airspace), enroute capacity can be defined and safety improved.

AIRPORT AND SURFACE MANAGEMENT: This area begins to squeeze out additional capacity and improved airport throughput through better utilization of existing runways. It also introduces new concepts for how airports in metropolitan areas are provided air traffic services. Some concepts are designed to challenge the full potential of current airport design and use in meeting the needs of the traveling public. This work addresses the leadership challenges of increasing existing runway throughput and creating performance information that helps communities understand the need for airport improvements and new runways. The essence of this sub-sector is identifying all the possible ways to safely increase airport capacity.

Unless we transform our air transportation system, aviation and our economy will become gridlocked.

SYSTEM-WIDE INFORMATION MANAGEMENT: This focuses on network-enabled operations for both the ground and the air. Its emphasis and demonstrations are on moving information to get the right information to the right air transportation participants to make the right operational decisions. These decisions may be tactical–like separation–or strategic–like managing aircraft flows through congested airspace.

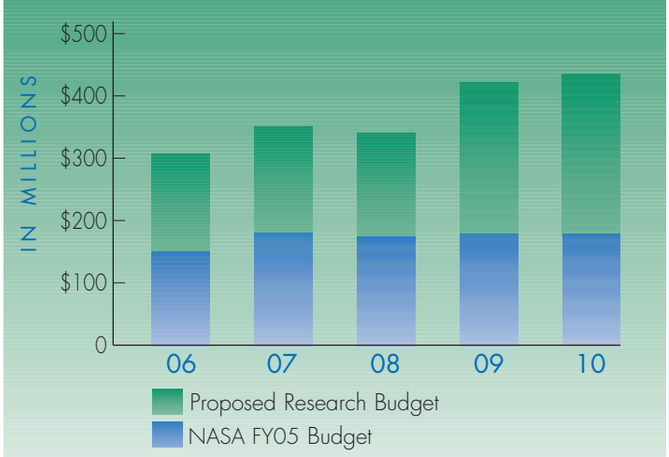
Demonstrations provide the evaluation of both network and communications performance needs, the quality of information needed for network-enabled air traffic management, and a new architecture for defining the transformed information network for 2025.

As a portfolio, each of these subsectors provide accelerated steps along the Flight Path to 3X, while delivering some near-term tools to deal with today's rising demand for air services in a time when costs, both to the Government and to the users must be reduced.

The common theme spanning all of these technologies is that widely available, high-quality information – in conjunction with powerful, fast-time analytical tools – can dramatically increase capacity and predictability of the aviation system by improving tactical, mid-range and long-range planning.

BUDGET AND OUTCOMES

- Triple aviation system capacity
- Create a network-enabled system
- Provide situational awareness for all users



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As aviation goes, so goes the economy.

The freedom of air transportation and America's ability to advance economically are lost if the aviation system is not safe and secure. An aircraft accident is front-page news and dramatically affects our air transportation system. When the nation's aviation system was grounded on September 11, 2001, the economy was grounded as well. For the nation to have a viable air transportation system, it must be safe and secure. Aviation safety and security research is currently spread across multiple federal agencies. In the future one agency needs to lead, integrate, and transfer the diverse research and technology development efforts to ensure that safety and security are not compromised. That agency should be NASA.

SAFETY: Aviation is an integrated system composed of aircraft, pilots, air traffic controllers, flight attendants, mechanics, ground personnel, security personnel, and others. The future air transportation system will be safer than today's if safety and safety monitoring are built into each part of the system. The impact of each part of the system must, therefore, be understood in order to maximize the safety impact per investment dollar.

LOCKHEED MARTIN

The Joint Planning and Development Office is creating a national plan to transform the air transportation system. Comprised of six government departments, it is working to integrate increased safety and security into the next generation system.

Increasing safety is achievable through integration and demonstration of existing technologies, along with development of new technologies where required. The recommended research plan and budget utilize a disciplined, data-driven approach to finding optimal, high payoff solutions to maximize aviation safety per investment dollar. The highest payoff research will address improvements in four technology areas.

1. FLIGHT SAFETY CRITICAL SOFTWARE: This area includes research and demonstrations of technologies that help avoid hazards on the ground, or in the air involving other aircraft, or adverse weather conditions. It also focuses on adaptive control and recovery technology, which will help save aircraft that are having trouble.

> "It is critical that the NASA research agenda recognize current and future system vulnerabilities based on changing air transportation concepts and designs."

2. HUMAN INTERFACE SYSTEMS: This research will help reduce human error. It involves synthetic vision systems that eliminate the safety problem of low visibility. It also includes flight data analysis capabilities to identify safety issues before they cause accidents.

3. HEALTH & RELIABILITY MANAGEMENT: This area involves developing sensor and analysis technology to monitor aircraft performance and alert crew and maintenance personnel prior to a failure. This technology not only improves safety but can reduce maintenance costs through "on-condition" maintenance programs.

4. PROPULSION: This area seeks to eliminate multiple engine shutdown, improve reliability, and contain engine blades in the event of engine failure.

SECURITY: The report contains technology elements and recommendations that broaden the focus of NASA aeronautics security research from a minor role regarding aircraft hardening to an integrated role leading security research. This broader role includes research that 1) builds on airspace and air traffic management capability to add conformance monitoring to track aircraft, 2) builds on communications, navigation, and surveillance capabilities to vastly improve detection of aircraft and vehicles in a given airspace, and 3) combines the critical activities in the aviation safety program with security activities, causing safety and security to be viewed as one activity. Further, the report recommends NASA's entry into the physical and cyber security realm of deterrence, protection, authentication, and access control for critical aviation infrastructure.

Applying security concepts to general aviation aircraft that are used for training, recreation, and travel from many small airports represents a unique challenge for aviation security. This is because 1) the variety, in both aircraft size and facility type, makes an airport-focused approach a challenging requirements definition problem, 2) the inability to use most general aviation aircraft as weapons emphasizes the need to clarify the general aviation security problem (risk, vulnerability, and criticality), and 3) the equipment under development for airliner operation will probably be too expensive for a large

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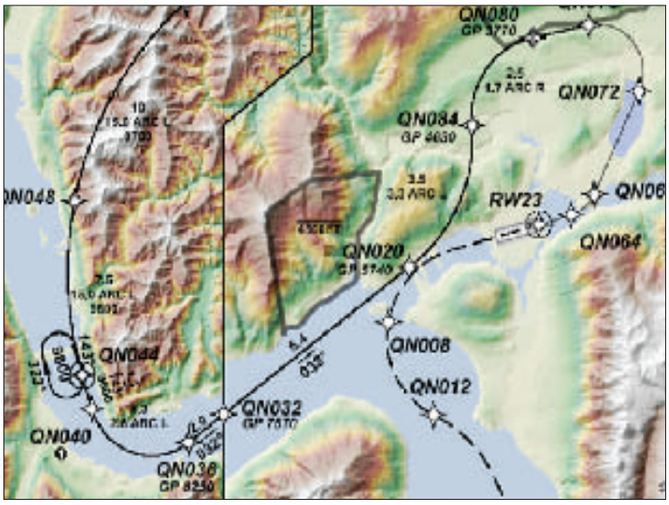


NAVERIS

Performance-based navigation can provide precision approaches at every airport. This results in greater access and safety is enhanced by eliminating accidents during low visibility and night operations.

fleet of small aircraft. The report, therefore, recommends striking a better balance between measures to protect commercial air carrier aircraft and the business and general aviation aircraft operations, including UAVs.

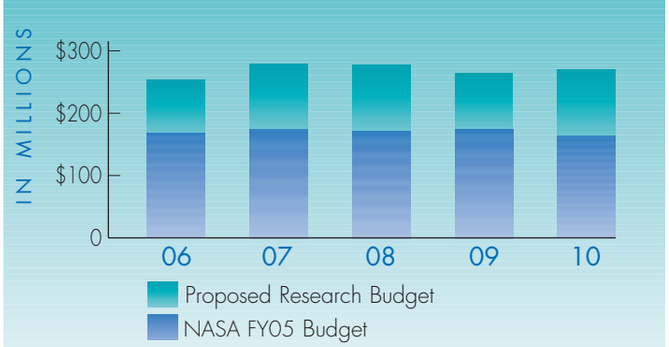
A NEW BALANCE: Today the nation's security focus is on near-term problems stemming from the events of September 11, 2001, and long-term implementation through new aircraft design. A new balance is recommended between changes to the aircraft and the security requirements of a transformed aviation system.

Specific recommendations were made to:

- Integrate security, safety, and capacity across the NASA aeronautics programs and projects;
- Balance the needs of commercial air transportation against the opportunities of emerging general aviation and UAV aircraft;

BUDGET AND OUTCOMES

- Reduce accident rate
- Embed safety and security in the future aviation system
- Eliminate visibility as accident cause
- Ensure security in expanding aviation system



- Deter attacks on aircraft through risk-driven continuous improvement and survivability;
- Deter attacks on aviation system infrastructure through innovative access controls;
- Detect potential intrusions through conformance monitoring of aircraft operations;
- Detect nonconforming behaviors through monitoring within network-enabled operations in a secure computing environment;
- Detect nonconformance through a highly integrated sensor capability for surveillance;
- Determine threats through verification of detected nonconformance with secure communications, authentication, and compliance monitoring;
- Determine access or operating permission of aircrews and passengers through biometric means;
- Defend the aviation infrastructure through innovative access control technologies that are transparent to the users;
- Defend against cyber attacks by investment in development of highly reliable and secure communications, networking, and automation that leverage best commercial practices, and are incorporated in capacity prototypes.

It is critical that NASA's research agenda recognize current and future system vulnerabilities, based on changing air transportation concepts and designs. While the air transportation network becomes an interoperable system of systems, research must focus on building a robust, resilient, and fault-tolerant system. This can be achieved by reducing complexity, isolating methods to meet functional requirements, and identifying and mitigating failure modes and effects–regardless of the concept, design, process, or technology researched or deployed. Only NASA aeronautics is in a position to accomplish these objectives.

NASA'S ROLE: Included in the report are technology elements designed to broaden NASA's portfolio through a combination of initiatives and modification of existing work, especially the integration of safety and security. The recommended security technology elements add approximately $50 million per year–less than 0.3% of the NASA budget. Many of the security measures defined and developed for aviation are equally applicable to the space program.

Finally, the report recommends that NASA be designated by Congress as the federal research arm of civil aviation. That role would require NASA to begin research in the area of highly secure computing and networking, which will be necessary to support network-enabled operations. This research should include automated separation, sequencing and spacing of aircraft, and information exchange between the aircraft and the ground. Safety and security can be embedded into the aviation system through 4D trajectory technology and by turning aircraft into nodes on the aviation system network.

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Aviation continues to shrink the globe.

Routine hypersonic flight is one of the last frontiers of aviation, and it is the most challenging because of the high energies involved and the extreme thermal environments encountered by hypersonic vehicles. Though significant progress has been made in more than four decades of hypersonic technology development, much work remains to be done before hypersonic flight can realize its potential. However, the remaining work is well worth the national investment.

"...will provide routine, responsive, safe, and affordable hypersonic global travel and access to space."

PLAN: The ultimate goal of hypersonic research is to develop vehicles that will provide routine, responsive, safe, and affordable hypersonic global travel and access to space. This cannot be achieved in the five year period of this research plan. Therefore, a near-term technology plan was designed to support a long-term view. The result is a so-called "bi-focal plan," which combines a long-term ultimate focus with a near-term focus on the first of three optional commercial vehicle flight demonstrators. In this "spiral development" approach, technology could be transferred for commercial development every five to seven years in a 15- to 20-year technology development program. The technology plan consists of 16 specific projects spread over four technology areas, including:

- Vehicle Design
- Hypersonic Propulsion
- Materials and Structures
- Ground and Flight Testing

NASA

State-of-the-art wind tunnels are critical to the development of hypersonic aircraft.

MEETS NATIONAL NEEDS: With the right investment, hypersonic vehicles will contribute to meeting national needs such as delivering high-value payloads to low earth orbit in support of NASA's space exploration initiative, conducting prompt global strike and operationally responsive space launch for the Department of Defense, creating space commerce for national economic growth and competitiveness (space tourism, manufacturing, power, science, and exploration, to name a few), and quickly delivering high-value commercial and military cargo around the globe.

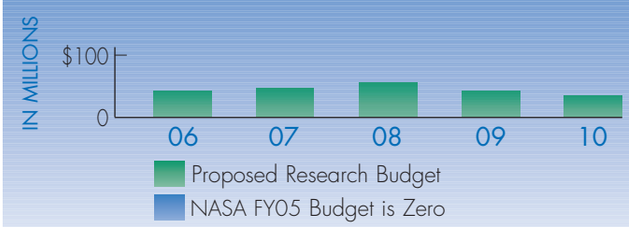
NASA

NASA Aeronautic's X-43A achieves world's first air-breathing, hypersonic flight. Budget cuts forced cancellation of this program.

In the wake of the recent successful Mach 7 and 10 X-43A flights, and given the current movement in Europe to wrest aerospace leadership from U.S. hands, it is imperative that America increase momentum in hypersonic technology and system development. We must not let budget cuts squander 40+ years of hypersonic technology R&D investment or let our nation become vulnerable to other nations who would build on our success.

BUDGET AND OUTCOMES

- Increase vehicle speed and safety
- Increase operational flexibility and reliability
- Reduce space launch cost and response time



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Rotor revolution lifts America.

Rotorcraft are contributing daily to a wide range of national needs including defending the nation around the globe, securing the homeland, and providing emergency relief, firefighting and medical services. In addition, rotorcraft support many commercial services, such as off-shore transportation for the petroleum industry, logging, sight-seeing, and construction. Today's rotorcraft configurations include many varieties of helicopters and tilt rotors, both manned and unmanned. While rotorcraft represent only a small fraction of the normal aeronautical activities, they often represent 100% in disaster situations, such as the Kobe earthquake and the recent tsunami.

As mission requirements and cost pressures continue to become more stringent, advanced rotorcraft technologies are required for the country to remain economically competitive within the global industry.

The principal members of the Rotorcraft Industry Technology Association (RITA), Inc. in cooperation with leading universities engaged in rotorcraft research, have created a plan and budget, for research in the rotorcraft sector that will reverse the decline and regain global leadership. The proposed research plan was coordinated with NASA to avoid duplication of their rotorcraft plan, and available information on foreign rotorcraft research has been taken into consideration.

> "As mission requirements and cost pressures continue to become more stringent, advanced rotorcraft technologies are required for the country to remain economically competitive and safe...

AIRFRAME: This plan consists of a total of 29 separate technology projects in addition to a comprehensive flight demonstration program. The projects are grouped into seven research thrust areas: exterior noise, interior noise, vibration reduction, weight reduction, aerodynamic efficiency, safety improvements, and zero-zero flight operations. These projects represent a robust suite of technologies that make a significant impact with respect to meeting national needs.

The majority of these projects culminate in practical demonstrations in the laboratory, the wind tunnel, or on a test aircraft. Two dedicated helicopters plus crews, instrumentation, and lab facilities support the flight test activity. The intent is to provide integrated demonstrations in a relevant environment of all key technologies funded under this plan.

One project is focused on longer-term possibilities in rotor development. It is an unconstrained study of the "ultimate" rotor, where it is assumed that a number of geometric adaptations at 1/rev or higher will eventually become practical. The intent is to define a boundary for future maximum helicopter capability, which will help to define future research thrusts.

SIKORSKY AIRCRAFT CORP.

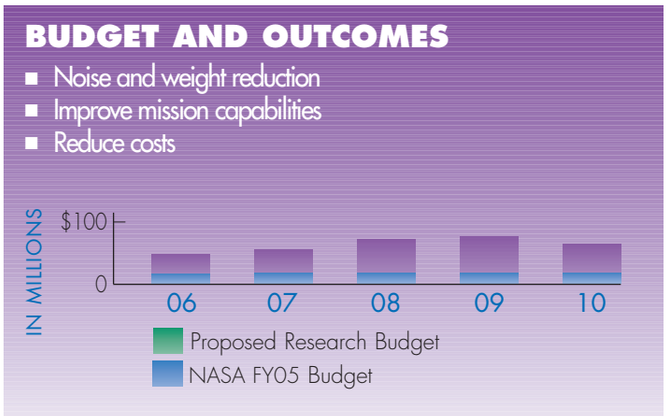
Cutting edge rotorcraft technology brings all-weather operations to emergency transport and commerce.

PROPULSION: Advancements in propulsion historically have been major drivers for capability increases in rotorcraft and other aircraft that use shaft-driven propulsion.

Affordability, reliability, and efficiency drive proposed investments in advanced propulsion technologies. These technologies improve the design of compressors, turbines, combustors, and smart control systems through the use of advanced aerodynamics, materials, algorithms, manufacturing processes, testing, and structural concepts–eventually resulting in superior, integrated end-products. Investments in these technologies will result in lower development and manufacturing, initial and operating costs, thus enabling the U.S. products to remain competitive worldwide.

The Propulsion Team has developed a budget plan consisting of a suite of eight technologies focused specifically on small turboshaft engines. These technologies will result in more efficient, lighter, more reliable, and more maintainable modular propulsion systems. They will improve specific fuel consumption 15-20%, increase power-to-weight ratios, and protect the environment.

While most of these technologies are equally applicable to general aviation propulsion, most would not be part of subsonic or supersonic propulsion programs.



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Nothing changes faster than aviation.

Aviation requirements in the 21st century will be driven by the desire to travel farther, get there faster, be safer, and access new frontiers at an affordable price. The Commission on the Future of the U.S. Aerospace Industry presented an air transportation vision that would move anyone and anything, anywhere at any time. NASA's subsonic vehicle research program is the centerpiece of achieving that vision. While many people see subsonic commercial aviation as a mature industry, it is, in fact, now redefining itself.

Airplanes are complex systems that require advanced tools and technologies to provide the comfort, performance, economy and reduced emissions expected by the traveling public. These advanced tools and technologies in turn require research into airframes, aircraft systems, and propulsion systems for large and small vehicle operations. They can only be provided by research organizations, such as NASA, that have the necessary background, test facilities, and skills in aerospace research. Industry teams are then able to build upon this research to mitigate the development risk associated with these technologies and tools that would otherwise be unacceptable for any one company.

THE BOEING COMPANY

The future of air travel is point-to-point. Cost and flexibility are primary drivers. Both require breakthrough technologies.

By 2010, the U.S. civil aviation industry (general, corporate and commercial) will be locked in a major global competition for business. This is largely due to European aeronautical investments totaling billions of Euros over the past decade. As our U.S. aviation industry prepares for the next generation of competitive offerings, it will need these tools and technologies to be competitive in the global market. This program provides those options.

AIRFRAME: Subsonic airframe technology needs research and development in four key areas: 1) community and cabin noise, 2) aerodynamics, 3) structures, and 4) materials. NASA's 2005 Vehicle Systems Program provides an excellent starting point for defining the goals and their required supporting technology development. Proposed budget cuts must be restored. The team estimates that additional airframe research will require an incremental investment of $82.6M per year on average for the next five years. This recommendation does not include the funds required to maintain or supplement existing NASA laboratory facilities.

> "While many people see subsonic commercial aviation as a mature industry, it is, in fact, redefining itself."

ACOUSTICS: Government noise standards around the world fall into two categories: community noise and passenger/crew noise. Either could be a barrier for sales if American technology falls behind Europe's. In the area of community noise, the goal is to have no emissions-related operational restrictions or constraints. One way to ensure no operational restrictions is to keep all intrusive aircraft noise within the boundaries of the airport. To meet this goal, over the next 20 years, airplane noise levels will need to be reduced 20 dB relative to a 777 airplane. Additionally, low noise flight procedures will be required to reduce the noise contour levels below 65 dB outside airport boundaries. By reducing actual aircraft noise and altering flight procedures, it will be possible to keep intrusive community noise within the airport boundaries and eliminate operational restrictions related to aircraft noise.

In the area of passenger/crew noise, new workplace rules and higher customer expectations are creating pressure to reduce interior noise levels in airplane cabins and flight decks. In the area of passenger and crew comfort, the goal is to reduce the noise inside an aircraft to the point where noise is no longer an issue for passengers trying to sleep, communicate or concentrate. In order to accomplish this goal, interior aircraft noise must be reduced to a level below 65 dB.

AERODYNAMICS: The Aerodynamic Team recommends strengthening NASA's current Vehicle Systems Program aerodynamics research plan by developing the following research tools:

- Rapid and accurate computational fluid dynamics tools
- Tools & test techniques for accurate prediction of scale effects
- Validated computational tools for general configurations & for full flight envelope analysis

Development of these tools is critical for the development of aircraft with novel configurations and control conditions. Added fidelity is also required for wind tunnel testing. Testing at flight Reynolds numbers with high fidelity tunnel models will become increasingly more important as configurations become more highly optimized and design margins are reduced. These technologies are key to transferring wind tunnel tests to final aircraft designs.

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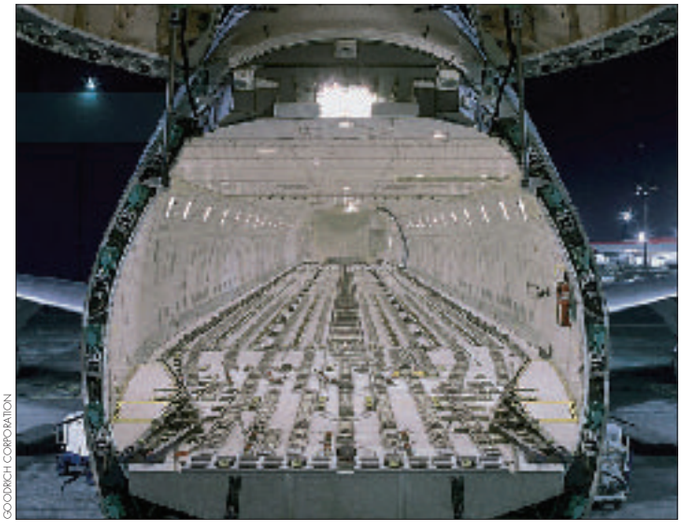


GOODRICH CORPORATION

Advancements in structures result in reduced weight, improved cost, and provide passenger comfort and increased cargo capacity.

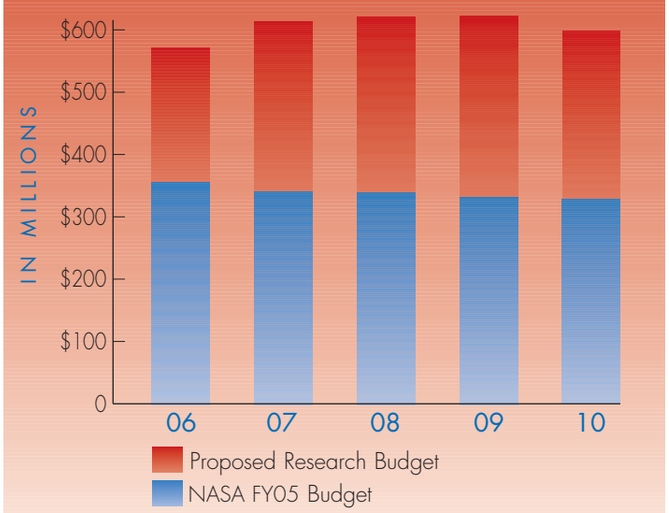
STRUCTURES: Advancement in structural technologies results in improved operator performance in the areas of reduced weight, cost of utilization, and/or improved maintenance. These improvements link directly to improved benefits for the flying public. Examples include: integral structures, composite structures, hybrids, aging fleet, probabilistic design, design and analysis tools, design data development, validation, structural health management, and hybrid repairs.

The goals and objectives of the structures technology budget plan are to place the U.S. commercial transport aviation industry in a commanding lead within the global marketplace. This will be partially enabled by achieving a 20% reduction in structure weight and a 30% reduction in recurring cost. The technology plan aims to develop strategic technologies using a building block approach, with a majority of the technologies being demonstrated within a 5 year time frame.

Many of the structures technologies will be proven at the sub-element level and then demonstrated at the system level with large scale fuselage and wing testing.

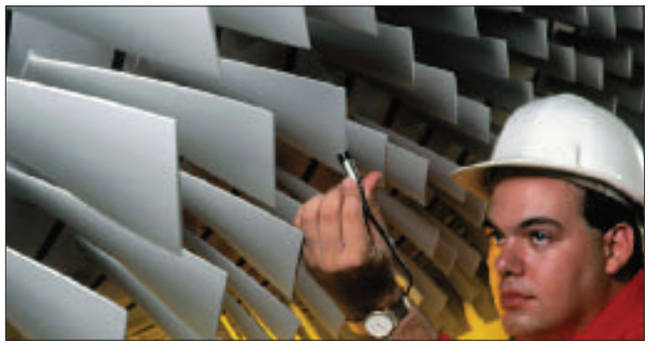
BUDGET AND OUTCOMES

- Reduce noise and emissions so that aircraft make good neighbors
- Transformational tools and facilities
- Invent the next generation power and propulsion systems
- Transforming mobility through new vehicles



MATERIALS: Breakthroughs are required in advanced materials and processes in support of the development of low cost, lighter, stronger, environmentally-friendly subsonic transport designs. By utilizing new structural design tools and advanced structural designs, the development and use of new advanced materials and processes will enable the United States' aviation industry to effectively compete.

The report identifies three major areas of materials technology requiring additional investment: 1) Composites: Affordable and advanced composite structures will only be possible by addressing cost-effective composite manufacturing technologies, timely implementation of new composite material systems, advanced structural tool development and automated/cost effective inspection techniques. 2) Coatings and Finishes: In support of protecting the environment, it is imperative that environmentally-friendly materials and processes be included in the focus on future technology and advanced materials development. Reduction of hazardous materials such as cadmium and chromium is a must in order to protect personal health, the safety of workers, and the surrounding environment. 3) Metals: Metallic materials such as aluminum, steel, and titanium alloys have been advanced over the last 100 years to the point where only incremental improvements appear possible by conventional means. Areas holding the most potential payoff are: 1) replacement of high-strength, low-alloy steels with more corrosion-resistant materials, 2) development of an aluminum-compatible fiber-reinforced epoxy system, and 3) fiber-reinforced metallic materials.



TELEFLEX AEROSPACE

Materials research is the building block on which many aeronautical breakthroughs depend.

Additional benefits in subsonic aircraft weight and performance can be achieved with new coatings and finishes. Specialty coatings can do everything from protecting a composite aircraft from lightning damage to assisting in the health monitoring of the structure. Both will improve passenger safety.

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SYSTEMS: The plan identifies five major areas where significant technology gaps exist.

DISTRIBUTED POWER SYSTEMS: Research in this area is important because it builds on the More Electric Airplane architecture. This is a technology enabler for new technologies in electrical energy storage, generation, and energy harvesting. It also enables technologies such as fuel cells, that not only provide power, but are environmentally friendly.

Computers provide better visibility and simplify a pilot's decision making.

MULTIFUNCTION STRUCTURES: Multifunction Structures are important because they represent the next level of integration in airplanes. The need for this level of integration is critical in aircraft advancement because it contributes to reduced vehicle weight, reduced parts count, simplified system architectures, reduced vehicle downtime, and lower costs. All of these are crucial to the advancement of airplane technology and performance.

INTEGRATED VEHICLE HEALTH MANAGEMENT: Integrated Vehicle Health Management takes integration to another dimension, connecting the vehicle, various onboard systems, and ground maintenance. It provides advancement in technologies that address operating cost, increased maintainability, and a higher level of knowledge and predictability concerning the state of the airplane.

FLIGHT DECK AND FLIGHT CREWS: Development of advanced Flight Deck and Flight Crew technologies is crucial because of the increasing importance of safety resulting from the rapid growth in air traffic. The flight crew must have the ability to rapidly and accurately assimilate information from both the ground and other airplanes, including real-time weather, wind, and wake turbulence data. Computer technology can provide enhanced vision and see-and-avoid capabilities, bringing a new level of perception and visibility to the pilot, along with expert tools to simplify decision-making.

> "...a higher level of knowledge and predictability about the state of the airplane makes air transportation more reliable, affordable, comfortable, and safe."

INTEGRATED WIRELESS AIRPLANE SYSTEMS: Integrated Wireless Airplane Systems include the technology passengers will come to expect in order to do their jobs and enjoy their onboard free time. It also involves using wireless technology as an enabler for a network-centric approach to airplane systems by eliminating miles of complex wiring and connectors. This will reduce airplane cost and improve weight, reliability, efficiency, and performance.

GENERAL & CORPORATE AVIATION: The General Aviation and corporate aircraft sector must have affordable access to the equipment required for operating in the aviation system of the future. However, these sectors will not drive technology development. Instead, they rely on NASA technology developed for the subsonic sector to provide affordable application to GA and corporate aircraft. The air transportation system cannot be transformed until all aircraft are capable of operating within the system. Creating affordable avionics and other aircraft systems is key to this transformation. The budget plan contains a detailed description of the technologies that must be adapted for general and corporate aviation use.

GULFSTREAM

Advanced corporate aircraft will provide American business people global reach.

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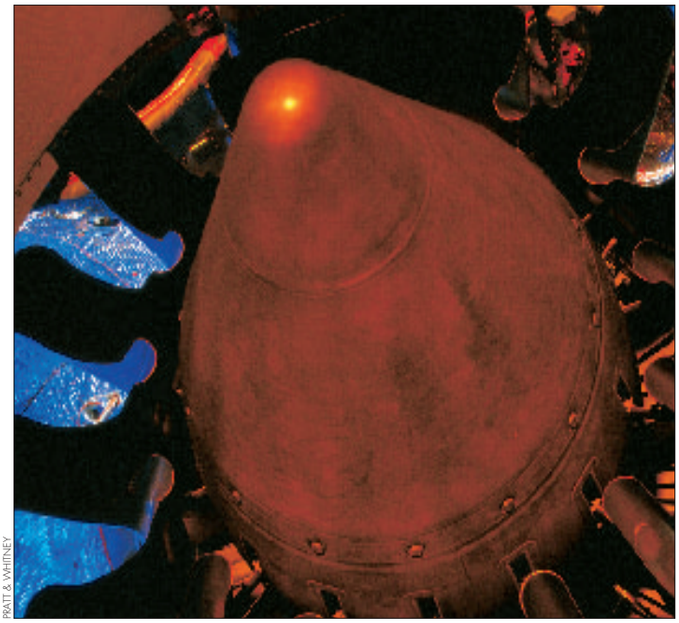

PRATT & WHITNEY

Propulsion is the key to all great advances in aircraft development. Today propulsion technology focuses not only on improved performance, but on environmental impact and cost considerations.

PROPULSION: At the subsonic propulsion system level, continuous improvements are needed to make vehicle propulsion systems more environmentally friendly, economical to operate, more reliable, and safer. For larger turbine engines, this will require significantly more aggressive investment in materials that are lighter, have longer life cycles, and can increase thermodynamic capability without sacrificing cost or safety. Related technologies required for both commercial and military applications include: intelligent adaptive systems, aerodynamics, fuel systems, electrical power generation, advanced materials, innovative components and structures, safety enhancements, and design tools and processes.

The propulsion team defined subsonic propulsion system goals, then identified the required key technology elements and priorities for this sector. These technologies represent breakthroughs in lightweight engine architecture, emissions, noise, performance, airfoil loading, cooling, materials, and reduced cost of ownership.

For smaller corporate and general aviation aircraft, improved performance and operability are critical in meeting stricter mission requirements and fuel burn targets. Specific sector goals include improved specific fuel consumption, increased power-to-weight ratios, and improved operability. Propulsion system costs represent 75% of direct aircraft operating cost, offering a significant challenge throughout the industry for continued progress. Research into reducing these costs is responsible for the development of today's micro-jets. The budget plan for this research is contained in this report.

In addition to the development plans, there is also a need for demonstrator engine tests to provide critical technology validation and maturation. In the near-term (5 year) plan, these demonstrators could utilize existing engine assets, inserting key technologies to be evaluated in a proven engine system. Multiple demonstrator tests are envisioned for this time frame, though common engine assets may be utilized for several tests, if appropriate.

REVOLUTIONARY CONCEPTS: Revolutionary Aeronautical Concepts (RevCon) covers a range of unique subsonic, fixed wing vehicles and is intended to push technology barriers beyond the comfort zone of current subsonic technology. These concepts include, but are not limited to: Low and High Altitude Airships, Blended Wing Body Aircraft, Ground or Surface Effect Transports, Piloted Vertical Take-Off and Landing Vehicles, Unmanned Aero Vehicles, and Extreme Short Take-Off and Landing Vehicles (ESTOL). This class of vehicles covers a spectrum of subsonic applications including low and high altitude operation, short and extended time-on-station endurance, unmanned and passenger aircraft. These vehicles can enhance national security and are directly applicable to surveillance, reconnaissance, personnel/equipment transport, interdiction, and law enforcement.

LOCKHEED MARTIN

Revolutionary new aircraft are the basis of American aviation leadership. These advances are critical contributors to our balance of trade in the world marketplace.

An example of a promising RevCon research program is an aircraft that is capable of extremely short take off and landing distances. ESTOL aircraft could provide additional capacity at hub airports, currently limited by runway availability. ESTOL also could divert traffic from congested hubs to more convenient, local airports.

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The goal is quicker and quieter.

Sustained supersonic cruise capability moves civil aviation to a new level of economic contribution; there is no current civil aircraft with sustained supersonic cruise capability. Whoever produces an environmentally and economically viable platform will establish itself as the leader in high technology supersonic flight. Such a supersonic platform would provide rapid, long-range transport of people and time-critical cargo, such as transplant organs, and would be able to leverage the military investment to support quick response movement of key personnel and supplies. The high visibility and importance of sustained supersonic flight demands that the U.S. establish itself as the technology leader in order to maintain its current commercial and military leadership position and provide future economic growth in this emerging world market.

Investment in NASA aeronautics could make supersonic business jets a reality.

LOCKHEED MARTIN

The development of efficient, long-range supersonic transports has been a long-standing dream in the aviation industry. The barriers to building such vehicles are substantial, not only from a technical point of view, but also from an economic and regulatory standpoint. Although several programs have tried and failed to create a viable supersonic transport, the barriers are gradually becoming more surmountable as aviation technology continues to evolve. In recent years, design techniques have been developed to help suppress the sonic boom; so, if current regulatory rules are relaxed, supersonic flights over the United States and other countries may be possible.

RESEARCH CHALLENGE: The suite of technologies proposed for funding in the supersonic sector plan are focused on maturing critical technologies needed to enable practical supersonic systems. Many of these technologies are also applicable to subsonic systems and therefore can potentially have a wider benefit than is assumed in this plan.

Military system requirements have continued to push technology for supersonic propulsion, mostly in the direction of higher thrust (higher cycle temperatures and pressures) and lower weight. Commercial applications would add the burdens of exhaust emissions, stringent airport takeoff and landing noise requirements, and durability at high sustained power before a viable system can be fielded. Meeting the environmental and engine life issues will require a combination of technologies including aerodynamics, cycle architecture, innovative exhaust system designs, and propulsion-airframe integration.

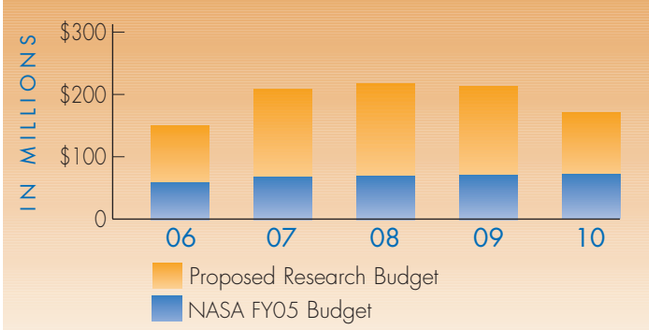
> "Whoever produces an environmentally and economically viable platform will establish itself as the leader in high technology supersonic flight."

COMPLEX INTEGRATION: Efficient, economical, supersonic flight demands adaptable, high pressure-ratio engine cycles. They must be capable of meeting low supersonic cruise fuel burn needs while providing critical take-off and transonic thrust needs. The acoustic requirements severely restrict the engine design space and push design parameters, such as fan pressure and bypass ratios, in opposite directions from the requirements for high transonic thrust and low supersonic drag. Thus the design of quiet, efficient supersonic cruise propulsion requires innovative approaches and careful integration of the propulsion/airframe system, i.e. engine placement, inlet and exhaust system design, and integrated thermal management.

Brief descriptions of the required development plans and budget to bring each of these technologies to a maturity level acceptable for commitment to commercial product application are provided in the body of the report.

BUDGET AND OUTCOMES

- Acceptable sonic boom
- Economic viability
- Acceptable level of emissions



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Universities and industry build our future.

The only way the United States can continue to create high-wage, high value-added jobs is to innovate faster than the rest of the world. Only a well-educated workforce composed of people who have learned to work productively and creatively with individuals from a multitude of races and backgrounds can maintain America's leadership and competitiveness in the increasingly diverse and interconnected world economy.

But, the federal government has been cutting basic research in aeronautics at NASA and Department of Defense, including university funding for education and research. Although students continue to show strong interest in aeronautics careers, the downward slide of the global technological leadership of the U.S. aviation industry has reduced opportunities for students to develop into world-class engineers who can lead in innovation. If we are to lead in aviation, we must have the best educated aviation workforce. To attract and prepare America's aviation workforce of the future, the Workforce Planning Team proposes innovative programs in four main thrust areas.

AERONAUTICS COALITIONS FOR EDUCATION: The planning team is suggesting the creation of coalitions to revamp

THE BOEING COMPANY

CESSNA AIRCRAFT COMPANY

BALL AEROSPACE & TECHNOLOGIES

The future depends on attracting, educating, and retaining the best of the next generation workforce.

the way in which we prepare our students for careers in industry. They propose that aeronautical engineering programs be transformed to meet industry needs and fund regional/state-based coalitions that will attract and educate engineers. The proposal includes an annual budget of $60 million to create five regional coalitions for education. The coalitions would consist of four-year universities offering degrees in aerospace, industrial partners, vocational schools, trade schools, community colleges, and K-12 feeder schools within a particular region of the country. A new degree option would be created at schools that choose to participate – the BS/AM (bachelor of science/applied masters) degree in aeronautics. Part of the curriculum would be an experience-broadening summer program to include hands-on work at community colleges, trade schools, and in industry. The major advantages of these coalitions will be a more exciting, job-oriented educational program for students, and better communication and interaction between industry and academia.

LONG TERM RESEARCH SUPPORT: Recent budget announcements within the federal government are drawing into question the commitment of the U.S. government to long-term, aviation research. NASA and Department of Defense budgets have been cut, and industry investment has been declining. Taken together, these two reductions in funding mean that universities may well become the only repositories of domestic aeronautics research. Therefore, it is imperative that U.S. research universities have the resources necessary to train U.S.

> "...universities may well become the only repository of domestic aeronautic research."

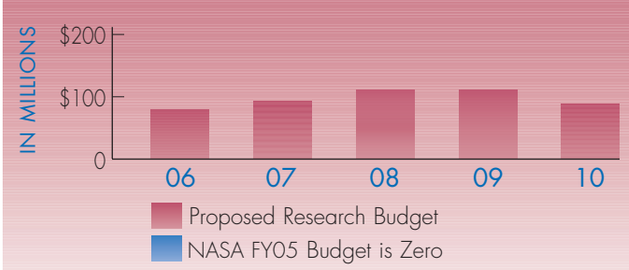
citizens so that they are able to make fundamental discoveries that will define the future course of aeronautics. Training of graduate researchers and conducting basic aeronautics research will require substantial funding of advanced degree seekers. The Workforce Team proposes that enough fellowship support be provided to support 400 graduate students per year.

AMBASSADORS PROGRAM: The Planning Team also proposes that now is the time to involve university and industrial personnel in K-12 systems. The team proposes funding of $10M for an Ambassadors Program in which business people and faculty members spend significant amounts of time with K-12 students. Ambassadors could work one-on-one with teachers and students and offer real-world examples of how solid math and science education can lead to one of the most exciting and rewarding careers that exists–aviation.

BRIDGE PROGRAMS: Far too few women and minorities enter aviation as a career. Currently, enrollments in aeronautical programs comprise only about 15% women and 15% minorities. The same is true for other engineering disciplines that are part of the aerospace workforce. The Workforce Team proposes $10M to fund universities and colleges to create bridge programs that would provide just-in-time assistance to women and minorities at critical stages in their studies.

BUDGET AND OUTCOMES

- Educate through industry/academia coalitions
- Increase university research
- Increase the aviation workforce diversity



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Good investments produce good results.

The U.S. aeronautics sector is encountering more and more serious competition from abroad, where ambitious national and supranational efforts are being directed at surpassing the U.S. in aviation technology. The only way the U.S. can continue to maintain aviation leadership is to innovate faster than the rest of the world. Now, in response to a direct congressional mandate, industry and academia have come together under the leadership of the National Institute of Aerospace in an unprecedented non-partisan effort, teaming up across company lines and other divisions in order to generate a coherent, rational, strategic plan that proposes crucial near-term aeronautics technology research investments.

This research plan was crafted for the sole purpose of outlining the initial steps the nation must take to regain its position as the world leader in civil aviation. Projects and technologies were considered based strictly on the merits of their potential impact on six national needs. Detailed subsector plans were created that contain descriptions of each research project, its milestones and budget. The subsector plans were integrated by a team at Georgia Institute of Technology. A National Strategy Team composed of 12 senior aviation leaders down selected to a final plan. The National Strategy Team's plan and supporting subsector plans are provided on the CD located on the inside the front cover of this Executive Summary. The result is an aggressive five-year research plan and budget focused on maturing high-risk, potentially high-payoff technologies that build on FY05 NASA aeronautics investments. Therefore, as a first step in implementing this research plan and budget, it is critical that the proposed FY 2006 budget cuts be restored.

The following research plan and budget is an apolitical prioritization of research effort to respond to our national needs and thus contribute to the quality of life of all Americans.

> "...an apolitical prioritization of research effort to respond to our national needs and thus contribute to the quality of life of all Americans."

The proposed budget would return NASA's budget to 1998 levels, in constant dollars.

Why invest in NASA? Aviation research requires unique national facilities, and world-class researchers that are not resident in any one company. The fruits of this research add to the nation's wealth, not just to that of any individual company. Implementing this research plan and budget would be a major step toward addressing America's long-term needs.

Augmentation to NASA Aeronautics FY 2005 Out -Year Budgets

Sector Budgets (in $k)	FY06	FY07	FY 08	FY09	FY10	Sector Total
Airspace Systems	154,000	174,000	172,000	245,000	255,000	1,000,000
Aviation Safety & Security	88,566	98,000	99,008	89,040	106,314	480,927
Aviation Safety	40,566	44,000	55,008	43,040	48,314	
Aviation Security	48,000	54,000	44,000	46,000	58,000	
Hypersonic Aircraft	44,695	46,380	54,945	40,075	36,575	227,670
Rotorcraft	33,828	42,499	61,368	72,095	51,200	260,990
Rotorcraft Airframes	25,995	32,865	52,535	62,595	44,700	
Rotorcraft Propulsion	7,833	9,634	8,833	9,500	6,500	
Subsonic Aircraft	220,958	269,665	283,635	289,390	274,710	1,337,905
Transport Airframes	76,075	92,675	93,400	77,695	73,190	
Transport Cockpit & Flight Systems	36,250	38,600	45,900	49,350	48,800	
Transport Propulsion	75,900	96,100	87,300	95,400	93,400	
GA/Corporate Airframes & Flight Systems	11,900	11,600	18,450	16,300	13,200	
GA/Corporate Propulsion	7,380	7,580	9,130	9,680	10,230	
Revolutionary Concepts Airframes & Flight Systems	8,100	15,110	17,610	26,300	23,400	
Revolutionary Concepts Propulsion	4,900	8,000	11,845	14,665	12,490	
Supersonic Aircraft	91,590	140,910	148,830	141,650	100,080	623,060
Supersonic Airframes	25,590	48,820	43,180	41,550	26,300	
Supersonic Cockpit & Flight Systems	18,880	28,270	26,750	18,450	17,080	
Supersonic Propulsion	47,120	63,820	78,900	81,650	56,700	
Workforce, Education, Centers of Excellence	79,300	99,250	113,800	113,300	92,800	498,450
Annual Total	712,484	870,704	933,586	995,550	916,679	4,429,002

The Time to Invest is Now.

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Background for this report and indentification of national needs are drawn from the following:

Final Report of the Commission on the Future of the U.S. Aerospace Industry, Aerospace Commission, 2002.

Securing the Future of U.S. Air Transportation: A System in Peril, National Research Council, 2003.

Persistent and Critical Issues in the Nation's Aviation and Aeronautics Enterprise, American Society of Mechanical Engineers, 2003.

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The NASA Aeronautics Blueprint. A Technology Vision for Aviation, National Aeronautics and Space Administration, 2001.
FY 2005, NASA Aeronautics Budget Plan.

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