National Aeronautics and
Space Administration

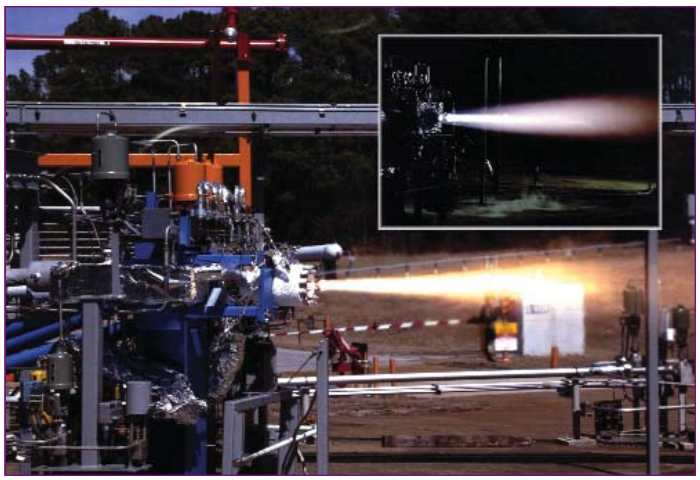
Aerospace Technology Enterprise Strategy

The Aerospace Technology Enterprise mission is to pioneer and validate high-value technologies that enable new exploration and discovery and improve quality of life through practical applications.

Langley Research Center

Researchers preparing X-43A for a high temperature wind tunnel test. Results will help engineers design future low-cost and reliable space launch vehicles.

Marshall Space Flight Center

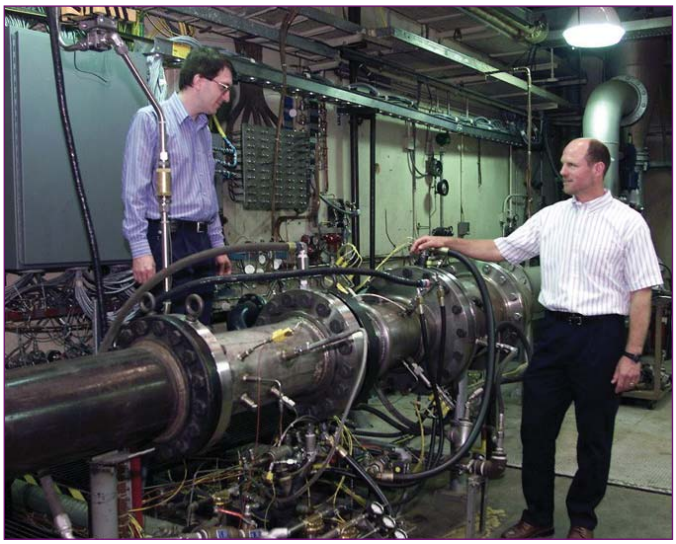


As part of the non-toxic auxiliary propulsion development effort in the Next Generation Launch Technology Program, a TRW liquid oxygen/liquid hydrogen reaction control thruster (shown above) undergoes testing. Non-toxic auxiliary propulsion systems have the potential to significantly reduce pre-launch processing time, launch-processing infrastructure, and cost. These systems will also provide environmental benefits by eliminating toxic fuels.

Dryden Flight Research Center

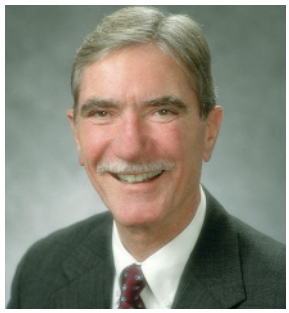
Unmanned aerial vehicles (UAV) have capabilities for long-duration, high-altitude missions such as homeland security or Earth science sensor platforms. Research into the ability of UAVs to detect and avoid other aircraft in the area is essential for wider use of the vehicles. The unique tandem-wing Proteus is a testbed for a series of UAV collision avoidance flight demonstrations.

Glenn Research Center



Advanced engine components, designed to improve aircraft engine efficiency and reduce emissions that cause global warming and smog, are tested in the Engine Components Research Laboratory.

A Message from the Associate Administrator for Aerospace Technology



As we commemorate the 100th anniversary of flight and look forward to the future of air and space travel, the United States continues to be the world leader in aeronautics and aerospace technology.

Over the past 45 years, NASA's aviation and space investments have transformed our society by contributing to safe and affordable air transportation, growth in critical national industries, enhanced national security, and scientific exploration and discovery that has revealed the cosmos and its wonders to the world.

The mission of the Aerospace Technology Enterprise is to pioneer and validate high-value technologies that enable new exploration and discovery and improve quality of life through practical applications. We work to ensure that promising new technologies are transferred to users within the government, including our own Agency, and to industry for development into valuable products and services for the marketplace. We measure success by the extent to which our results are used by others to achieve their objectives.

The NASA Strategic Plan presents many challenges and opportunities, and we know that innovative technologies are required to reach many of our objectives. Critical areas of our work include overcoming the physical and operational barriers to developing new transportation systems, gaining the ability to conduct science missions that are not feasible today, and understanding and safely operating today's complex vehicles and systems while pioneering vehicles and systems for the future.

The Columbia tragedy, and the prior loss of the Challenger and Apollo I missions, underscores the importance of the capabilities we strive to provide the Agency. This Enterprise is researching and developing a range of technologies that will directly address the recommendations of the Columbia Accident Investigation Board, such as organizational risk models, reconfigurable systems, and advanced materials and tools. We are committed, through our work, to honor the memories of the Columbia crew and others in the NASA family who have lost their lives pioneering air and space flight.

To fulfill the NASA Mission and achieve the Agency's goals and objectives—as presented in this Enterprise Strategy—we will continue using our resources wisely and achieve management excellence in accord with the President's Management Agenda. Our Strategy is a reflection of the needs, requirements, and priorities of our customers and stakeholders, along with the best interests of the public.

I am confident that our work under this Strategy will contribute to a new era of aviation and space exploration achievement—achievement that will improve our quality of life and greatly benefit our Nation and the world.

J. Victor Lebacqz, Ph.D.
Associate Administrator (Acting) for Aerospace Technology

Future aerospace vehicles can be enabled by NASA technology. Shown clockwise above: advanced general aviation aircraft, an advanced rotorcraft, a tiltrotor aircraft used for emergency medical transport, a 300-passenger supersonic transport, a 600-passenger subsonic transport with a blended wing-frame, and a reusable launch vehicle for transporting cargo to orbit. Technology will also fundamentally change the way pilots, ground controllers, and schedulers communicate, enabling safer and more efficient airspace and terminal operations.

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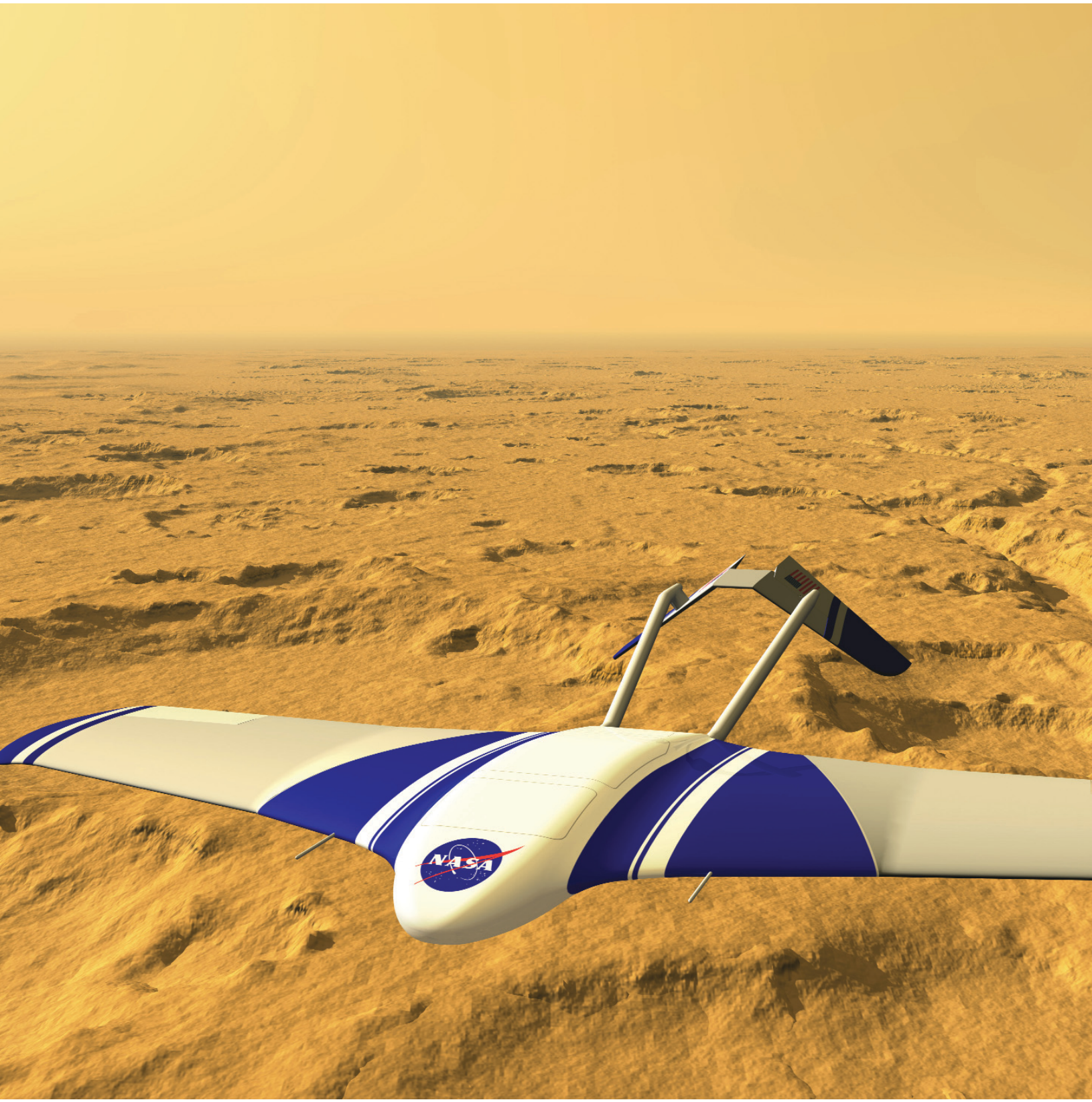
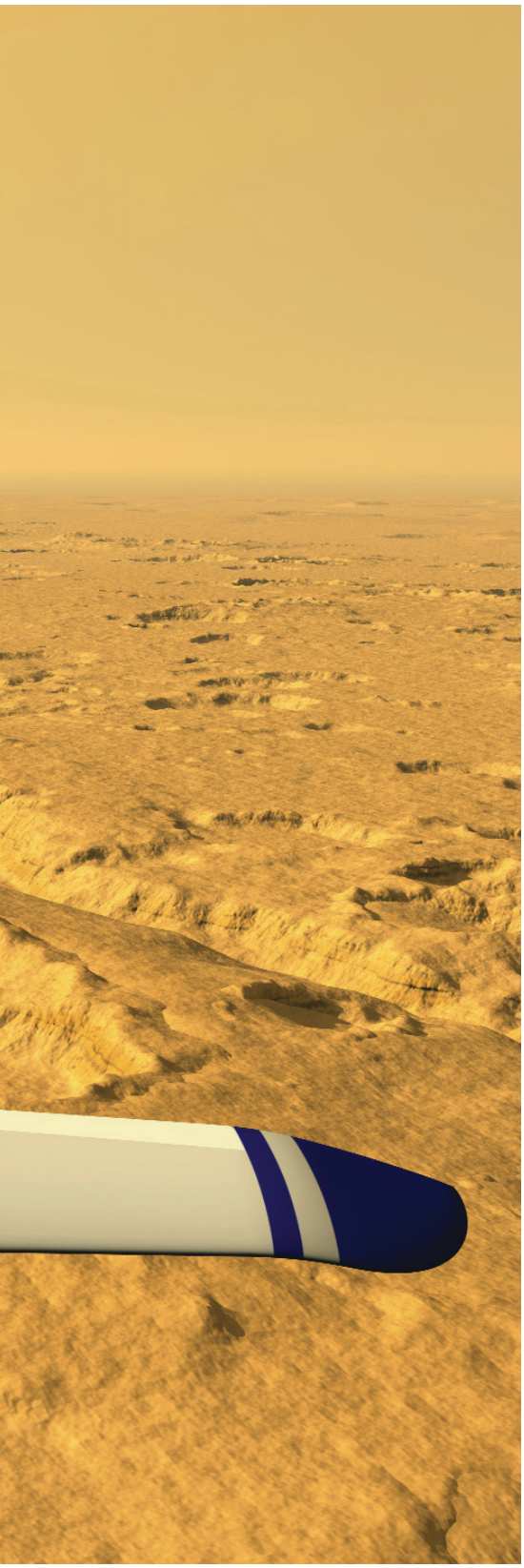
Using technology developed by the Aerospace Technology Enterprise, the Mars Reconnaissance Orbiter will use high-power microwaves to analyze the planet's surface for signs of water.

1 Aerospace Technology and NASA's Vision and Mission


NASA



1 Aerospace Technology and NASA's Vision and Mission

As a key technology provider for the Agency, the mission of the Aerospace Technology Enterprise is to pioneer and validate high-value technologies that enable new exploration and discovery and improve quality of life through practical applications. We measure success by the extent to which our results are used by others to achieve these outcomes for NASA and the Nation.

NASA's Enterprises each have unique responsibilities in working to fulfill the NASA Vision—

To improve life here,
To extend life to there,
To find life beyond

and the NASA Mission—

To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
. . . as only NASA can.

The role of the Aerospace Technology Enterprise is to be the advanced technology developer and provider for the long-term aerospace needs of NASA and the Nation.

The expansion of aviation and space transportation has had a tremendous impact on our economic, political, and social landscape, and NASA's contributions and achievements in aeronautics, space flight, and exploration have been

Exploration of other planets may involve winged flight vehicles, such as this Mars flyer concept, to bridge the critical measurement gap between orbital and surface perspectives. NASA is researching how to design vehicles that operate in different and unique atmospheres.

inspiring and in many cases revolutionary. These achievements were all made possible through advances in technology.

The development of aerospace technology has reached an important crossroads. Continued technology advancements that create improvements the American people expect and deserve will require a sustained national commitment and the direct interest and involvement of all transportation stakeholders.

For NASA's part, the Aerospace Technology Enterprise develops advanced technologies, engineering tools and processes, and system concepts for both NASA and its partners, with key capabilities provided by the NASA Centers. These facilities and their personnel—scientists and engineers with expertise in both traditional and emerging aerospace fields—allow the Enterprise to perform both basic and applied aerospace research and development at the frontiers of scientific discovery.

The centennial of powered flight provides an opportunity to reflect upon and celebrate our Nation's vast accomplishments in air and space, even as we set our sights toward an ever bolder future. This Enterprise Strategy outlines the next steps in our cutting-edge research and technology development and our continued commitment to NASA's Vision and Mission.

Research that expands the boundaries of our understanding and capabilities in flight is critical to making advances and maintaining U.S. leadership in aerospace. Shown above, pilots test experimental controllers that will allow aircraft to fly autonomously in close formation. This may one day have a radical impact on the efficiency of aircraft operations.

2 Role of the Aerospace Technology Enterprise

NASA
HYPER X

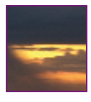
2 Role of the Aerospace Technology Enterprise

The role of the Aerospace Technology Enterprise is to develop enabling technologies for missions that presently exceed the scope, capacities, and risk limits of the other NASA Enterprises. The Enterprise also develops advanced system concepts and technologies that are outside the research and development scope of other government agencies and private industry. The Enterprise creates strategies to foster increased innovation in technology development, while working with external partners and the other NASA Enterprises to identify emerging, high-value technology opportunities.

The Enterprise takes a long-term approach to technology development, with the goal of realizing multi-generational, "orders of magnitude" technology improvements that will enable missions and concepts now deemed impossible. In the challenging process of creating high-performance aircraft, launch vehicles, and spacecraft systems for research and exploration, we set aggressive performance goals for power generation, efficiency, measurement resolution, speed, accuracy, size, and durability, while developing innovative solutions to the challenges of communications and data transmission, extreme temperature changes, and other risk factors.

As a key technology provider for the Agency, the mission of the Aerospace Technology Enterprise is to pioneer and validate high-value technologies that enable new exploration and discovery and improve quality of life through practical applications. We measure success by the extent to which our results are used by others to achieve these outcomes for NASA and the Nation.

Shown at left is an artist's concept of an experimental plane. The Hyper-X plane employs revolutionary aeronautical concepts and technologies to fly at Mach-7.



Technology change continues to accelerate in established fields—such as computational and information technology—and emerging fields such as nanotechnology and biologically inspired technologies. The Enterprise's expertise and research capabilities in these rapidly changing fields is complemented by our traditional research strengths in propulsion, materials, structures, aerothermodynamics, avionics, and flight research. The integration of our expertise with emerging research offers tremendous opportunities for innovation. Resulting new technologies and design capabilities will allow engineers to accelerate processes for the design, development, testing, and deployment of future aircraft and spacecraft.

The Commission on the Future of the United States Aerospace Industry developed nine recommendations to address the challenges to continued leadership in aerospace.

The Aerospace Technology Enterprise has had a critical role in pioneering and validating high-value technologies and revolutionary designs that have maintained U.S. leadership in the aerospace industry. The changing needs of our Nation in areas such as military readiness, aviation security, and global competition make continued technology development a necessity.

Advanced technologies and collaborative actions will be required to understand and successfully manage the complexity and scope of our air and space transportation systems in the years ahead. This "system of systems" must be transformed to meet many critical challenges, such as safety, security, environmental compatibility, and constraints to growth.

The ability to understand and manage risk in our complex systems is a key enabler for the future and an increasing focus of our efforts. The transformation of these systems through integrated technology solutions and advanced concepts will realize objectives that have been mutually exclusive in the past, such as aviation system efficiency and increased security. The effects of this transformation will be evident in our aircraft, airports, airspace, and the business model innovations by which air transportation services are delivered to the public.

An Integrated Management Approach: Delivering Results

The Aerospace Technology Enterprise Strategy provides an organizational framework to support the Enterprise mission of providing critical advanced technologies to the Agency and our external partners. The Enterprise has developed five strategies, discussed as follows in this section, to ensure a proper balance of research and technology development, sustain key investments, and guide technical, organizational, and process transformations.

"In particular, the Commission's views on maintaining our technology lead in the 21st century while ensuring safe, secure, and efficient air and space transportation systems are most welcome."

—Vice President Richard B. Cheney, letter to the Commission on the Future of the United States Aerospace Industry, November 20, 2002

Strategically Organize Our Programs

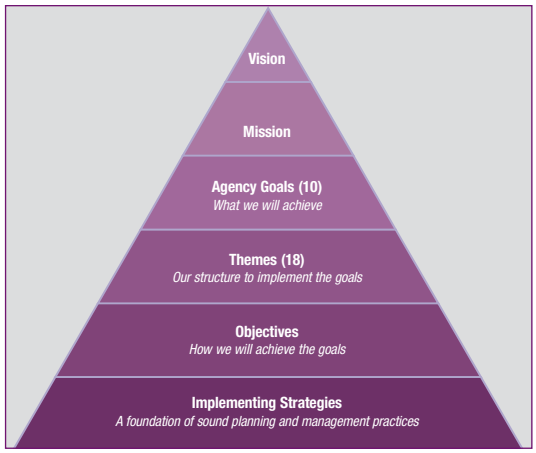
The Enterprise's programs are organized to achieve the Agency's goals and align with the distinct communities of technology users that constitute our customer base. Consistent with the Enterprise mission, we measure success by the extent to which our customers use Enterprise technology to achieve their own results and benefits. These results and benefits serve as the means for measuring our progress toward achieving the Agency's goals.

Four Enterprise themes—Aeronautics Technology, Space Launch Initiative, Mission and Science Measurement Technology, and Innovative Technology Transfer Partnerships—have been established to align the Enterprise's programs and customers with the goals of the Agency.

The theme designations provide a program management and accountability structure that is consistent for all of the Enterprises. In terms of program structure, the Enterprise's scientists, engineers, technicians, administrative personnel, managers, and other specialists are organized within the themes to apply their skills, expertise, and creativity to the challenge of achieving the Agency goals. The themes also develop educational and public outreach programs to foster interest in aerospace technology and encourage students to enter careers in aerospace engineering. Partnerships with academic institutions support the Enterprise workforce in maintaining competencies and developing skills to meet the future challenges of the Enterprise.

Maintain a Customer Focus

Within each theme, a primary community of technology users has been identified which represents either a general type of user, such as engine manufacturers, or a specific organization, such as another NASA Enterprise. Programs developed to meet theme objectives take into account the specialized needs of the technology user communities. This process is applied throughout the life cycle of technology programs, from program planning though technology transfer. Program planning is undertaken cooperatively to ensure that the correct scope of issues and needs has been identified and prioritized for each technology user community. Requirements for technology transfer are agreed upon in advance to ensure that program plans are properly scoped for implementation and mechanisms are identified to conduct the research and mature and transfer the technologies. This last step, transferring the technology, is the final measure of success in our customer relationships.



Enterprise programs are structured to meet Agency objectives. Section 3 describes each theme's program connections to this Agency framework.

Use Systems Analysis To Guide Our Technology Portfolio

The Enterprise uses systems analysis as a critical tool to make technology assessments and determine investment strategies to sustain our long-term focus on challenging technology requirements and desired capabilities.

Systems analysis, in all its forms, facilitates interactions with our customers to ensure that Enterprise programs are managed objectively within the scope of pursuing technology "as only NASA can." The Enterprise also supports the role of NASA's space architect, who provides a unified, long-term blueprint of the steps needed to achieve our Mission. Our systems analysis integrates the Agency's requirements, concepts, and program investment strategies to determine viable pathways to the future and define the strategic capabilities and critical technologies needed to fulfill our Vision.

In addition to supporting the functions above, the Enterprise uses systems analysis to:

- Assist managers and engineers in determining the progress of technology development programs

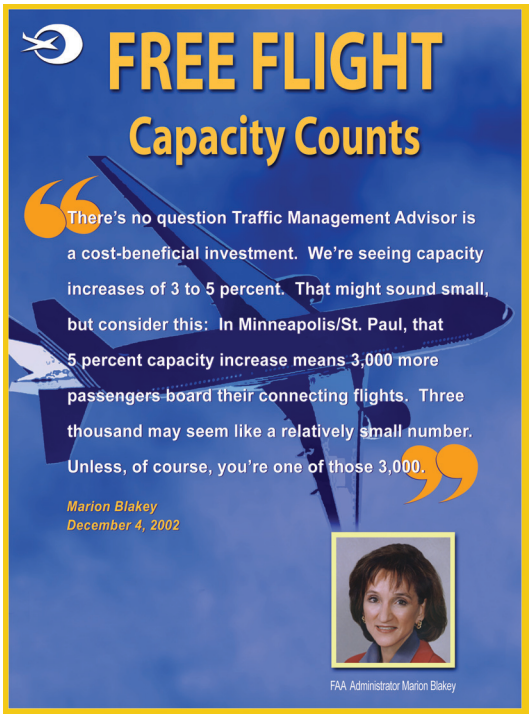
- Aid in the development of Enterprise mission concepts

- Perform analyses for ongoing missions

In this respect, the ability to couple systems analysis with engineering tools and modeling programs reduces the management risk of choosing one technology path over another. Systems analysis is an equally powerful tool when evaluating goals and objectives in conjunction with data from research results. This tool gives the Enterprise the ability to work with each technology user community to balance the overall Enterprise investment portfolio and identify the highest priority technology investments within a program.

Develop Strategic Partnerships

Strategic partnerships are essential for the effective transfer of technology, both from the Enterprise to external organizations and from external organizations to NASA (via the Innovative Technology Transfer Partnerships theme). These partnerships create synergy between the developers of enabling technologies and application users. Our criteria in establishing strategic partnerships is to enter into partnerships that align with our missions and goals, enhance communication, improve understanding of how technology can be transferred efficiently and effectively, and enhance our ability to leverage research efforts. For example, the Enterprise is creating strategic partnerships with the Federal Aviation Administration regarding National Airspace System transformation and with the Department of Defense regarding space access transformation.

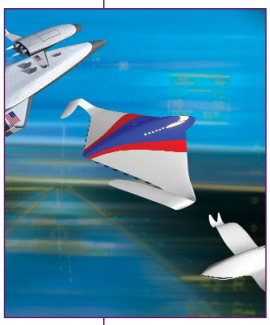


Through successful partnerships NASA develops and transfers tools and technologies that benefit the public. Traffic Management Advisor is an example of a NASA-developed tool being used today by the FAA.

The themes also form educational partnerships to develop materials and programs for students and educators, as well as public programs. This effort aligns with NASA's education and outreach goals to foster interest in aerospace technology and encourage students to enter careers in science, technology, engineering, and mathematics. Partnerships with academic institutions are intended to attract students into post-secondary study, as well as maintain and expand our workforce competencies to meet future challenges.

Create More Flexible and Effective Organizational Structures, Policies, and Processes

The Enterprise's Research Centers combine the resources of world-class facilities with the unique qualities of the NASA environment. The Enterprise is establishing organizational structures, policies, and processes that will allow the Centers to maintain flexible workplace and facilities management policies and quickly adapt to the changing needs of the Agency. This focus on change management will keep the Centers aligned with the latest trends in technology development and ensure the continued relevance of our work. Other priorities include maintaining a customer focus, encouraging innovation, expanding professional development, and enhancing our ability to produce and transfer high-quality technology products.



3 Achieving Aerospace Technology Objectives

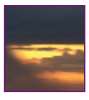
3 Achieving Aerospace Technology Objectives

To structure the allocation of resources for the accomplishment of its goals and objectives, the Agency has established a set of themes, which have been divided among the six NASA Enterprises. Each theme responds to a subset of the Agency's goals and objectives (see the NASA Strategic Plan for a full list of the Agency's goals and objectives).

The Aerospace Technology Enterprise administers four Agency themes—Aeronautics Technology, Space Launch Initiative, Mission and Science Measurement Technology, and Innovative Technology Transfer Partnerships—which are discussed in this section. The Enterprise's themes have established overarching programs, supporting projects, and strategic partnerships to plan and implement advanced research and technology development that will meet the needs of NASA and the Nation in the years ahead.

The key elements for success within each of the Enterprise themes are the scientific and engineering expertise and specialized research and technology facilities at the NASA Centers and the themes' partnerships with other NASA Enterprises, other government agencies, private industry, and academic institutions. This section will discuss each theme's objectives, partnerships, and projected outcomes.

Turning goals into reality—the Aerospace Technology Enterprise contributes technologies toward the realization of NASA's goals and the transformation of future flight. Shown left to right, concepts of "formation flyers" for large aperture space telescopes, future space transportation vehicles, blended-wing body aircraft, and "morphing-wing" aircraft.



3.1 Aeronautics Technology Theme

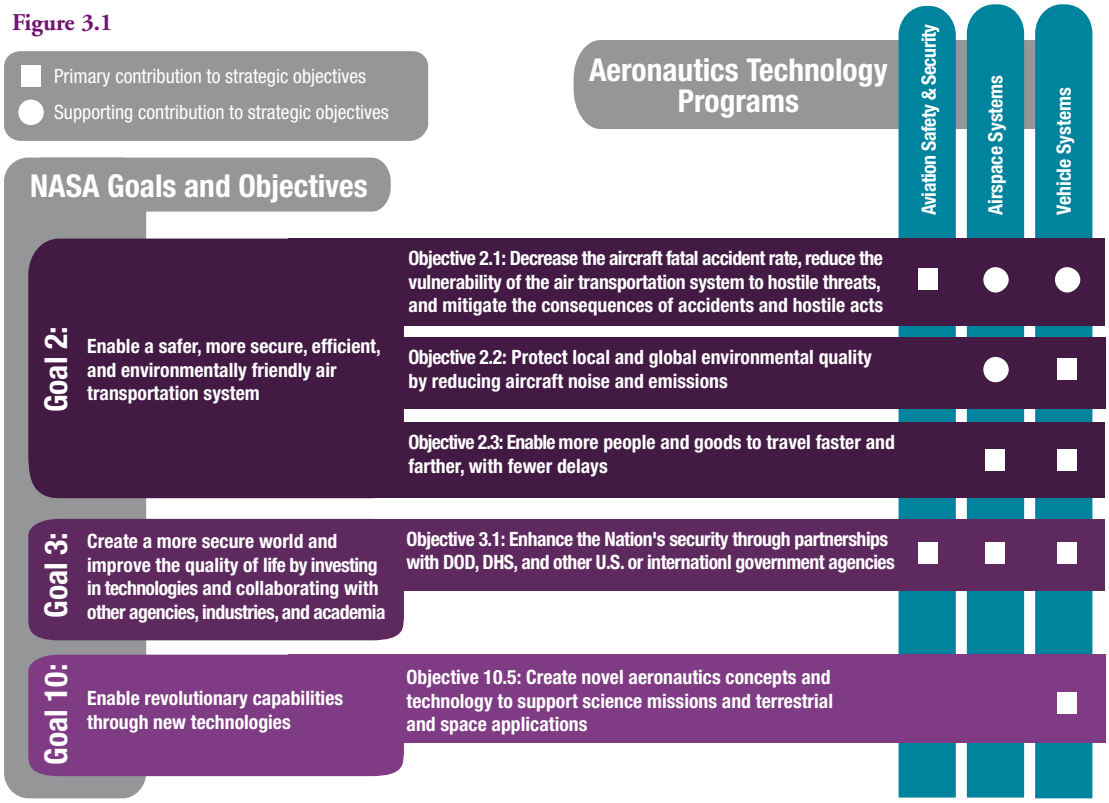
NASA's Aeronautics Technology theme develops advanced concepts and technologies that are critical to the future of aeronautics and beyond the risk level or capability of other organizations. Technology is a necessary, major force in addressing the physical and environmental challenges of air travel that have emerged for the Nation and the world. Transportation systems are integral to economic growth, national security, and enhanced quality of life, and barriers to air transportation growth will negatively affect all of these areas. The theme's research and technology development is organized into strategic technology focus areas, which are designed to achieve specific NASA objectives.

In pursuing its assigned goals and objectives, the theme works in close partnership with other government agencies, private industry, and academic institutions to ensure the relevance and effective transfer of new technologies. In 2001, in conjunction with our partners, the theme produced the *Aeronautics Blueprint* to look beyond the current horizon and investigate possibilities for long-term research efforts.

NASA is working with select Federal agencies in an unprecedented multi-agency strategic planning initiative to transform our Nation's air transportation system. Key members from each agency form the Joint Planning Office for the Transformation of the Air Transportation System, with a charter to create and coordinate the implementation of an integrated plan for transformation. Each agency will contribute their expertise and structure their programs to support this plan. The ultimate goals are to eliminate barriers to aviation growth and enable new opportunities for the safe and secure mobility of people and goods domestically and internationally.

The Aeronautics Technology theme supports 3 of NASA's 10 goals, as shown in figure 3.1.

Figure 3.1



Left: NASA's Aeronautics Technology theme develops and transfers technology for a safer, more secure, environmentally friendly, and efficient National Airspace System.

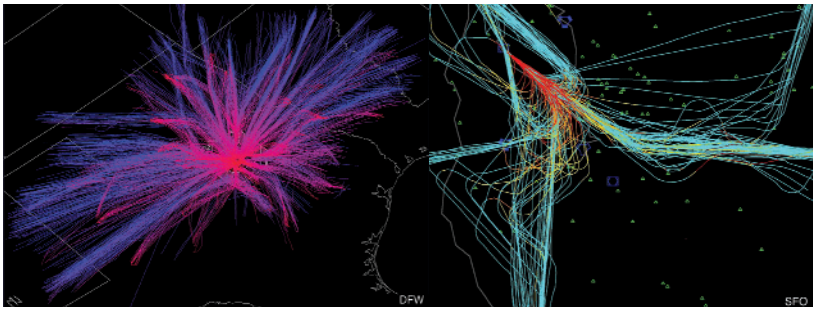
Protect Air Travelers and the Public

Goal 2, Objective 2.1: Decrease the aircraft fatal accident rate, reduce the vulnerability of the air transportation system to hostile threats, and mitigate the consequences of accidents and hostile acts.

The Aviation Safety and Security Program performs research to eliminate the most common causes of accidents, proactively identify emerging risks and vulnerabilities in the future air transportation system, examine security concepts, and develop technologies that could help stop or mitigate the effects of hostile acts. Through advances in modeling and technology, the program complements and extends improvements to operations, training, and technology made by the Federal Aviation Administration (FAA), Department of Homeland Security (DHS), Transportation Security Administration (TSA), and private industry. The program will create new models for aviation safety management, including real-time identification and mitigation of risk at all levels, while continuing work with other government agencies and industry to proactively address issues impeding the improvement of aviation safety.

NASA's Crew Vehicle System Research Facility is used to study pilot brain wave activity. Understanding the impact of fatigue, sleep loss, and circadian rhythm disruption during long-haul flights supports the development of countermeasures to human error.

NASA is investigating ways to improve a pilot's view of the terrain around airports. The Synthetic Vision System displays shown above provide "clear weather, day time" views in all weather conditions.



Aviation system monitoring and modeling is essential to aviation system safety. Shown above are 24 hours of flight data tracked at the Dallas Fort Worth (DFW, shown left) and San Francisco (SFO, shown right) airports to monitor air traffic control system hazards and safety risks. The flight paths are color-coded by altitude.

Partnerships

NASA is engaged in numerous aeronautics research and technology development partnerships, including the Commercial Aviation Safety Team (CAST) and the General Aviation Joint Steering Committee (GAJSC). CAST consists of senior government and industry commercial aviation leaders whose goal is to form a national safety agenda and a plan for making commercial aviation safer. GAJSC is a general aviation organization similar to CAST.

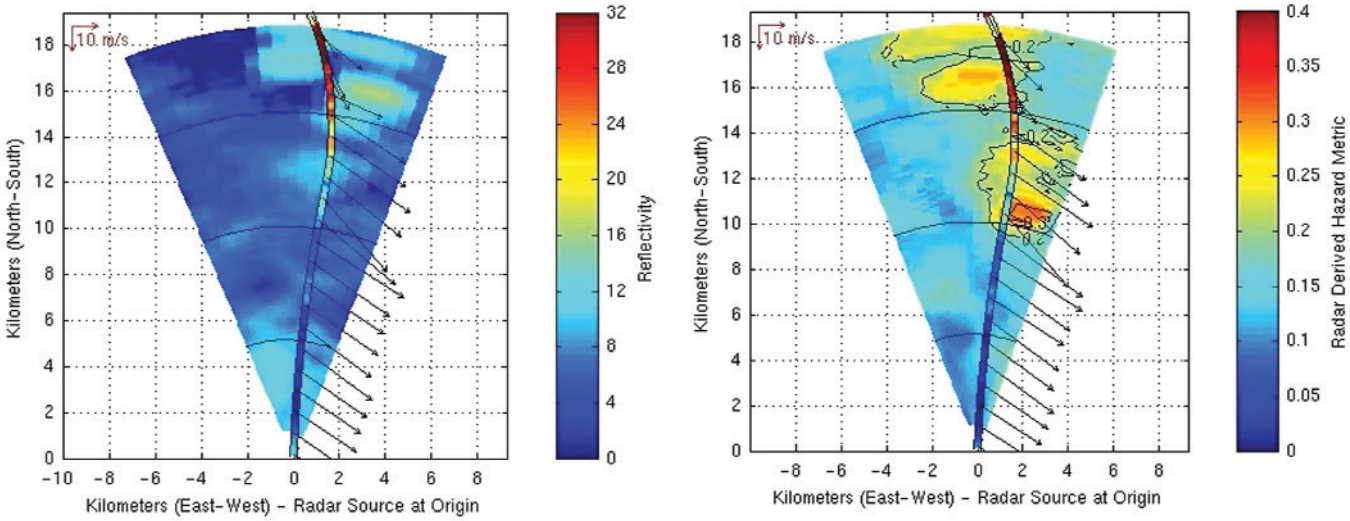
A NASA/FAA Joint Working Group (JWG) has been established to ensure that NASA and FAA safety research and development activities are appropriately coordinated. In addition, the JWG facilitates the transfer of technology into operational environments.

NASA is currently formalizing a partnership with the TSA. This partnership will provide the framework for NASA's technology investment in aviation security.

Outcomes

To improve aviation safety and security, the Aeronautics Technology theme will research, develop, and transfer technologies that

- By 2005, enable a reduction of the aviation fatal accident rate by 50 percent from the FY 1991–1996 average
- By 2009, enable a reduction in the vulnerability exposure of aircraft and other components in the air transportation system
- By 2012, facilitate the near real-time identification and resolution of risks and vulnerabilities in the air transportation system



Detecting turbulence on cloudless days is currently impractical for pilots during flight. NASA is demonstrating the feasibility of providing early warning of approaching turbulence by using a forward-looking X-Band radar. The image on the right clearly shows the pilot the regions of turbulence.

Table 3.1.—Aviation Safety and Security

Strategic Technology Focus	Purpose
Aircraft self-protection and preservation	Protect and prevent damage to aircraft due to abnormal operations and system failures through advances in airborne-based technologies
Hostile act intervention and protection	Increase resiliency of the air traffic system (ATS) against threats and hostile acts by providing technologies to identify and mitigate potential vulnerabilities
Human error avoidance and mitigation	Prevent unsafe flight situations due to breakdown between human and machine interface and promote optimal flight-crew performance, workload allocation, and situational awareness
Environmental hazards awareness and mitigation	Detect and/or mitigate the effects of natural hazards that could compromise safe air traffic system operation by reducing the role of atmospheric conditions in aviation fatal accidents, incidents, and injuries
System vulnerability discovery and management	Identify and inform users of potential ATS vulnerability by providing a system-wide safety risk assessment capability that is accessible to and actively utilized by key stakeholders in the ATS

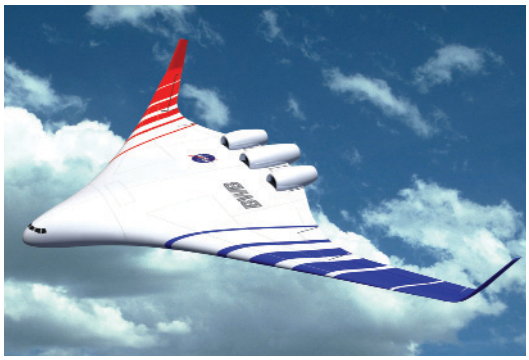
Protect the Environment

Goal 2, Objective 2.2: Protect local and global environmental quality by reducing aircraft noise and emissions.

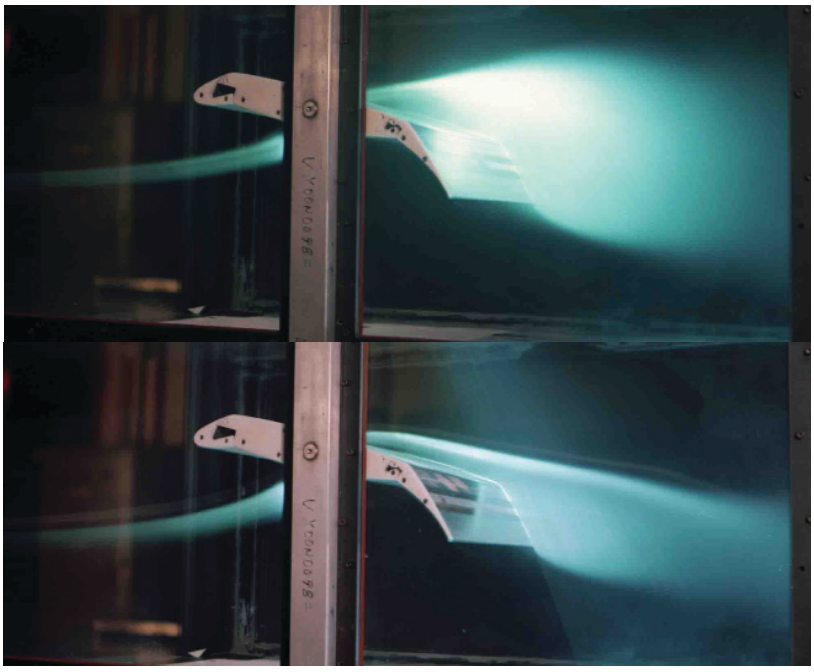
The Vehicle Systems Program develops technology to mitigate the environmental impact of aviation operations. In the future, the program will develop new airframe and propulsion configurations that can exceed what is possible in current configurations. The program will continue to develop new concepts, models, and approaches to controlling the complex physical and operational phenomena that impact the environment, focusing on noise abatement. In addition, the program works cooperatively with industry to transfer new knowledge, synthesize advanced concepts, and mature and validate new technologies.

Partnerships

The Aeronautics Technology theme has established partnerships with the aerospace industry and other government agencies to accelerate the transfer of noise and emission abatement technology to the marketplace and identify the key technologies needed for increased engine and airframe efficiency. Specific partnerships have been established with the FAA for all aspects of developing noise and emissions reduction technology, and with the Department of Defense (DOD), FAA, and Department of Energy (DOE) for research to improve turbine engine efficiency.



Blended-wing body concepts offer the potential of more fuel-efficient aircraft.



Reducing the complexity of wing flaps that provide high lift at slow landing speeds reduces fuel burn and harmful emissions. Oscillatory blowing devices (active in the bottom frame) have the potential to simplify flaps systems and increase flight efficiency.

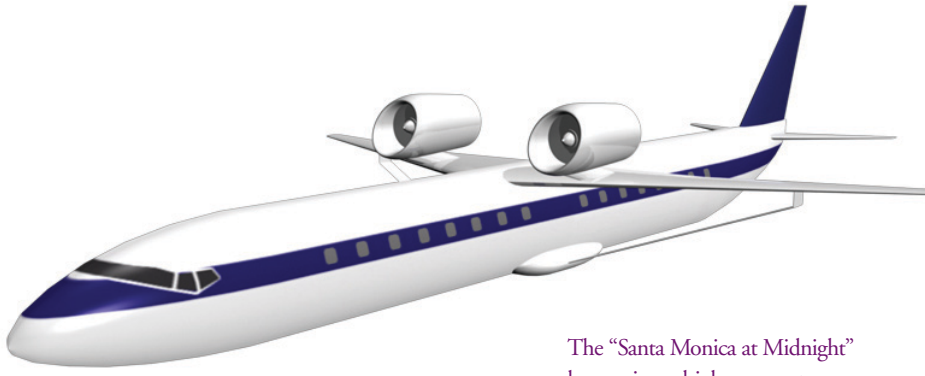
Outcomes

To reduce aircraft noise and emissions, the Aeronautics Technology theme will research, develop, and transfer technologies that

- By 2007, enable a reduction in community noise due to aircraft by half, based on the 1997 state of the art
- Beyond 2007, continue technology development to reduce community noise due to aircraft by a factor of four
- By 2007, enable a reduction of nitrogen oxides (NO_x) emissions by 70 percent from the 1996 International Civil Aviation Organization (ICAO) standard, to reduce smog and lower atmospheric ozone
- Beyond 2007, continue technology development to further reduce NO_x by one-third of the remainder
- By 2007, enable a reduction in carbon dioxide (CO_2) greenhouse gas emissions

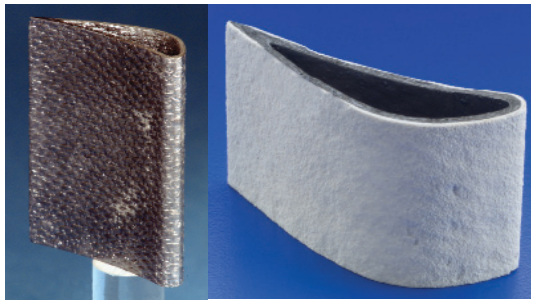
by 25 percent based on the 2000 state of the art for airframe and engine component technologies

- Beyond 2007, continue technology development to further reduce CO_2 by one-third of the remainder

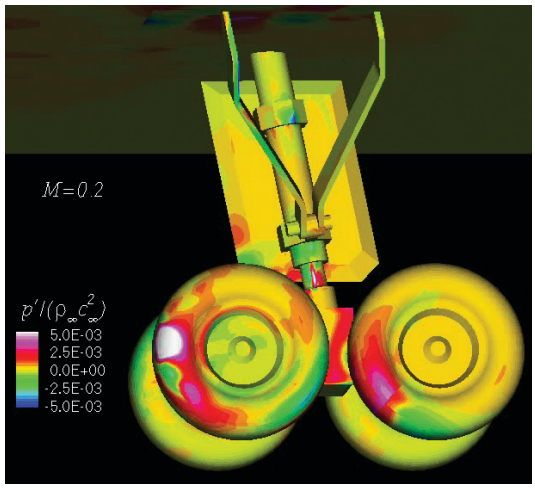


The "Santa Monica at Midnight" low-noise vehicle concept.

Still in the early stages of research, fuel cells that power aircraft could eliminate harmful emissions and reduce noise.



New temperature-resistant materials such as ceramic matrix composites enable more efficient and cleaner burning aircraft turbine engines.



Research is being performed to reduce noise generated as wing flaps extend and landing gear are lowered. One approach is to introduce air around landing gear in such a way that a "virtual" fairing, or shield, is generated to reduce noise.

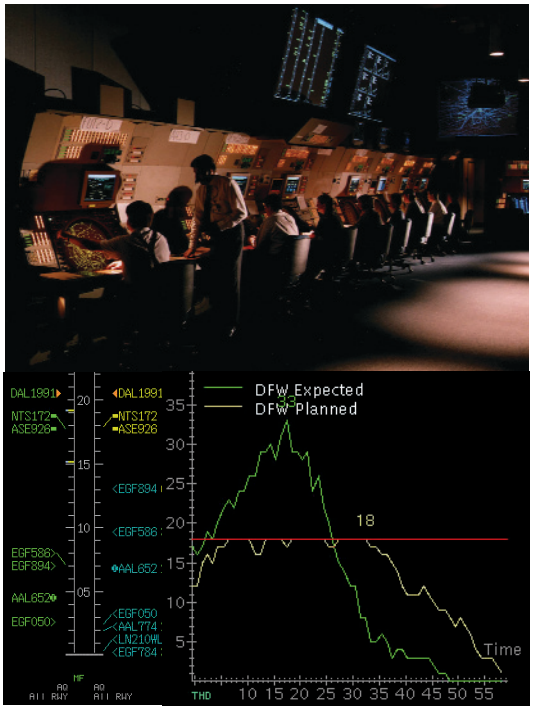
Table 3.2.—Aircraft Noise and Emissions Reduction

Strategic Technology Focus	Purpose
Environmentally friendly, clean-burning engines	Develop innovative technologies to enable intelligent turbine engines with significantly reduced harmful emissions, while maintaining high performance and increasing reliability
New aircraft energy sources and management	Investigate new energy sources and intelligent management techniques for zero emissions and enable new cleaner vehicle concepts for public mobility and new science missions
Quiet aircraft for community-friendly service	Develop airframe and engine noise reduction technology and operational concepts to bring objectionable noise within the airport boundary
Aerodynamic performance (for fuel efficiency)	Improve aerodynamic efficiency, structures and materials technology, and design tools and methodologies to reduce fuel burn and minimize environmental impact

Increase Capacity and Mobility

Goal 2, Objective 2.3: Enable more people and goods to travel faster and farther, with fewer delays.

The Airspace Systems Program develops advanced concepts and technologies for Communication, Navigation, Surveillance and Information (CNSi) and Air Traffic Management (ATM). The Vehicle Systems Program develops vehicle technologies to enable increased air transportation capacity, flexibility, and accessibility. NASA is examining the complexities of the "system of systems" that characterizes the air transportation system. The Agency is developing models and simulations to discover concepts and technologies to optimize and expand the system. The theme's performance goals include maximizing airport capacity in all meteorological conditions, expanding throughput at the Nation's small airports, effectively managing high density traffic flows, and designing new vehicle concepts, such as aircraft that can operate on short runways.



The Traffic Management Advisor (TMA), now in use at several U.S. airports, decreases aviation gridlock by balancing traffic flow with the manageable capacity of airports.

Understanding and modeling the human operator is essential to improving safety and performance throughout the complex air transportation system.

Partnerships

NASA works closely with the air transportation community to enable the development of complex CNSi, ATM, and vehicle concepts and technologies. The Agency is a key member of the Joint Planning Office for the Transformation of the Air Transportation System, whose other members include the Department of Transportation, FAA, DOD, DHS, and Department of Commerce.

The National Consortium for Aviation Mobility—a broad-based public/private consortium with more than 130 members—is a joint venture partnership working with NASA to develop and demonstrate air mobility technologies for transportation using small airports.

The theme is also working with the aerospace industry and other government agencies to accelerate the transfer of vehicle technology to industry.

Outcomes

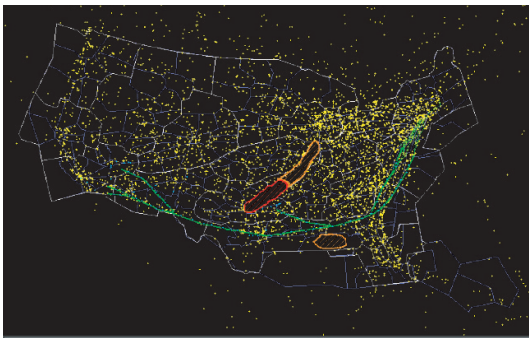
To increase airspace capacity and mobility, the Aeronautics Technology theme will research, develop, and transfer technologies that

- By 2004, enable a 35 percent increase in aviation system throughput in the terminal area and a 20 percent increase in aviation system throughput en route based on 1997 National Airspace System (NAS) capacities

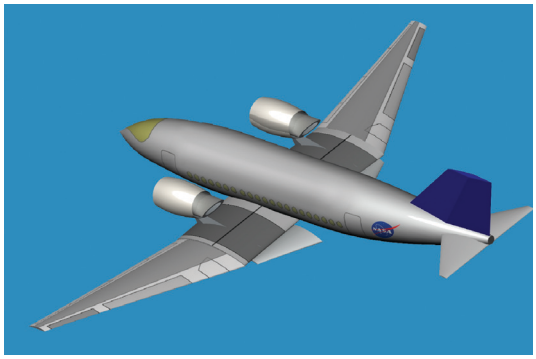
- By 2005, provide key enabling capabilities for a small aircraft transportation system

- By 2009, enable a further 5 percent increase in throughput in the terminal area and a further 10 percent increase in en route throughput based on 1997 NAS capacity

- Enable short-field take-off and landing while maintaining the capability for high-speed cruise



Over 4,500 commercial aircraft are routed each day by U.S. air traffic control. New methods for air traffic management (ATM) will be required to manage increasing volume. The Future ATM Concepts Evaluation Tool provides graphical simulations to test new ATM concepts of operation.



Higher cruise efficiency Short Take-Off and Landing (STOL) aircraft can operate on shorter runways.

New aircraft and ATM techniques can provide point-to-point service, which will reduce traffic delays at the major "hub" airports.

Table 3.3.—Airspace Capacity and Mobility

Strategic Technology Focus	Purpose
Efficient traffic flow	Operate individual aircraft within the NAS for efficiency through aircraft spacing and flight path management
System-wide operations technologies	Efficient operation of the NAS as an overall nationwide system with global interaction
Airspace human factors	Human interaction, performance, and reliability in the design of complex airspace systems
Aircraft weight reduction (for expanded access)	Develop ultralight smart materials and structures, aerodynamic concepts, and lightweight subsystems to enable advanced configurations for public mobility
Aerodynamic vehicle performance (for expanded access)	Improve aerodynamic efficiency, structures and materials technologies, and design tools and methodologies to increase aircraft efficiency for enhanced mobility
New aircraft energy sources and management	Discover new energy sources and intelligent management techniques to enable new vehicle concepts for public mobility

Partnerships for National Security

Goal 3, Objective 3.1: Enhance the Nation's security through partnerships with DOD, DHS, and other U.S. or international government agencies.

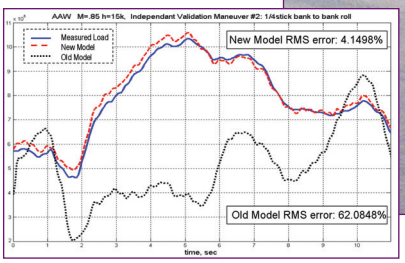
The Aeronautics Technology theme acts proactively to identify areas of common interest with the DOD and, more recently, the DHS. We maintain liaisons with these departments, establish joint agreements, review research and technology plans, and employ other mechanisms to develop common research objectives and leverage the results of each agency's research.

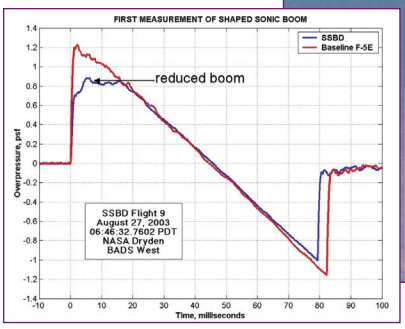
Partnerships

NASA has a long history of productive aeronautics partnerships with the DOD. Currently, the Vehicle Systems Program is the primary conduit for these partnerships. The Aviation Safety and Security Program is formalizing a partnership with the Transportation Security Administration. This partnership will provide the framework for NASA's technology investment in aviation security technology that will reduce the vulnerability of civilian aircraft to terrorist actions.

NASA has a number of ongoing cooperative engagements with the Army and Air Force. These

Wing flexibility to assist in controlling the aircraft—also known as wing warping—results in reduced weight and drag and better performing aircraft. Data taken during flight-testing of a highly instrumented F-18 was used to improve models (see inset) to design controls that will take advantage of a wing's flexibility.





The sonic boom has been one of the limiting factors for routine supersonic flight. The forebody of an F-5 was modified to change the shape of the sonic boom (blue line) compared to the unmodified F-5 (red line). This represents the first time that such a waveform, with the potential to reduce sonic boom annoyance, has been recorded. After completing the flight test, the test pilot remarked, "In 1947, Chuck Yeager broke the sound barrier. We just fixed it!"

include a cooperative agreement with the Army for aviation research and an Air Force-NASA aeronautics partnership to increase NASA's coordination with the Air Force Research Laboratory, which is the lead developer of aeronautics technology for the U.S. military.

The Joint Aeronautical Commanders Group—which includes FAA, NASA, Coast Guard, and military services logistics commanders—develops and improves joint processes to facilitate the design, development, and acquisition of common aviation systems that promote interoperability.

Outcomes

To strengthen national security, the Aeronautics Technology theme will expand, develop, and maintain partnerships with other Federal agencies to

- Transfer technology both to and from the Department of Defense
- Reduce the vulnerability of the air transportation system in partnership with the Department of Homeland Security and the Transportation Security Administration

An Intelligent Flight Control System, being demonstrated on an F-15, could have valuable civil applications. This system assists pilot control of aircraft even after significant system failures.

Cooperative development programs allow NASA to leverage advanced technologies into civil applications. The tailless Unmanned Combat Air Vehicle is an example of such a partnership. A tailless design applied to civil aircraft could reduce drag, resulting in fuel savings and less emissions.

Table 3.4.—National Security

Strategic Technology Focus	Purpose
Hostile act intervention and protection	Increase resiliency of the air traffic system (ATS) against threats and hostile acts by providing technologies to identify and mitigate potential vulnerabilities
Aircraft weight reduction	Develop ultralight smart materials and structures, aerodynamic concepts, and lightweight subsystems to increase vehicle efficiency
Smart aircraft and autonomous control	Enable aircraft to fly with reduced or no human intervention; optimize flight over multiple regimes; provide maintenance on demand toward the goal of a feeling, seeing, sensing, sentient air vehicle
Flight and system demonstrations	Mature and validate new aircraft capabilities in relevant flight environment in partnership with industry and other government agencies

Explore Revolutionary Aeronautics Concepts

Goal 10, Objective 10.5: Create novel aeronautics concepts and technology to support science missions and terrestrial and space applications.

NASA approaches this objective by understanding the needs of Earth and space science missions, and identifying and developing aeronautics technologies to meet the challenges posed by those missions. This approach has led to the development of highly advanced technologies for autonomous flight, particularly at very high altitudes and for very long durations. Another area that has been examined for future development is the application of aeronautical technologies in the atmospheres of other planets to enable highly robust and mobile exploration vehicles.

Partnerships

The FAA, DOD, and industry are all major partners. The high-altitude, long-endurance research effort is guided by a steering committee of representatives from NASA, FAA, DOD, and seven U.S.-based manufacturers of high-altitude, long-endurance, unmanned aerial vehicles. The FAA is supporting

Helios—a high-altitude, long-endurance aircraft using technologies pioneered by NASA—has demonstrated an economical approach to commercial aerial observation applications such as crop monitoring. Fuel cells may one day power these vehicles non-stop for weeks or months.

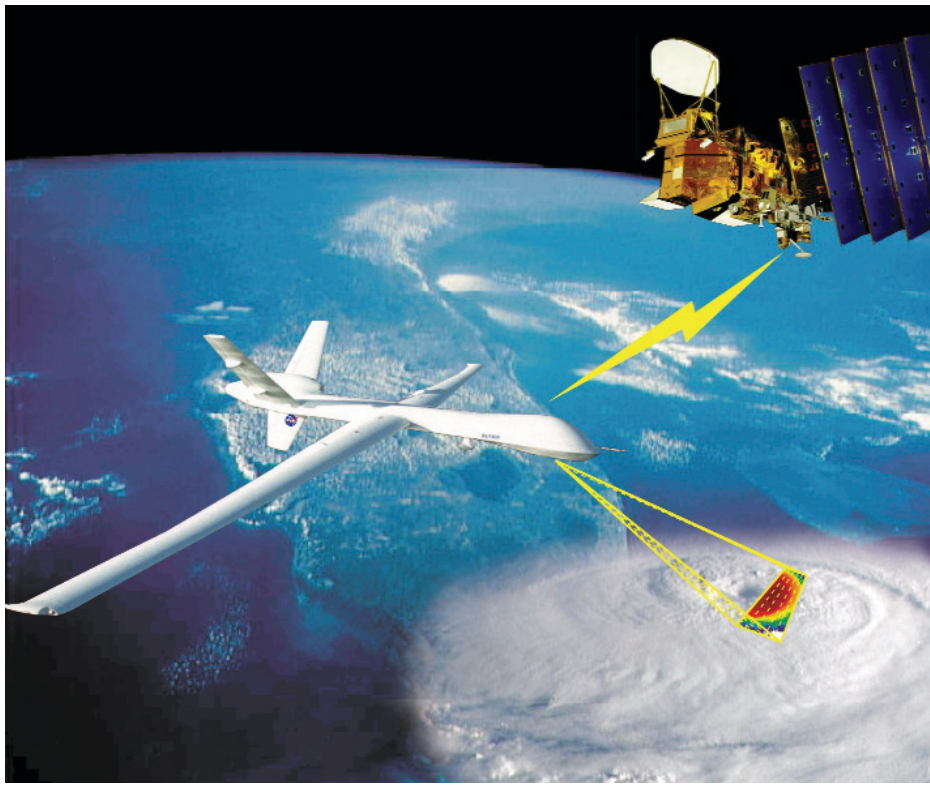
the effort through their Air Traffic Service and Regulation and Certification Service.

The Aeronautics Technology theme works with the Earth Science Enterprise to coordinate science mission requirements and guide Unmanned Aerial Vehicle (UAV) technology development. In addition, the theme supports the Earth Science Enterprise with their execution of UAV-based science programs developed through NASA research announcements. Specific areas of coordination include research vehicle availability, vehicle performance requirements, payload integration, and flight support.

Outcomes

To explore revolutionary aeronautics concepts, the Aerospace Technology theme will research, develop, and transfer technologies that

- By 2008, enable routine operations in the NAS above 18,000 feet for high-altitude, long-endurance UAVs
- Enable solar-powered vehicles to serve as suborbital satellites for science missions



Altair, a remotely operated aircraft, could perform missions that would be hazardous to a human pilot, such as tracking severe storms, hurricanes, and forest fires.

Table 3.5.—Mission-Enabling Aeronautics Concepts

Strategic Technology Focus	Purpose
Aircraft weight reduction	Develop ultralight smart materials and structures, aerodynamic concepts, and lightweight subsystems to increase vehicle efficiency, leading to high-altitude, long-endurance vehicles and planetary aircraft
New aircraft energy sources and management	Investigate new energy sources and intelligent management techniques for zero emissions and enable cleaner vehicle concepts for science missions
Smart aircraft and autonomous control	Enable aircraft to fly with reduced or no human intervention; optimize flight over multiple regimes; provide maintenance on demand toward the goal of a feeling, seeing, sensing, sentient air vehicle
Flight and system demonstrations	Mature and validate new aircraft capabilities in relevant flight environments in partnership with industry and other government agencies

3.2 Space Launch Initiative Theme

The Aerospace Technology Enterprise's Space Launch Initiative (SLI) theme is enabling the future of space launch beyond the Space Shuttle by developing systems and technologies for safe, affordable, and reliable access to space. With NASA as its principal customer, the SLI theme addresses the Agency's unique needs as defined by the NASA space architect and documented in the Integrated Space Transportation Plan, as shown in figure 3.2. The SLI theme collaborates with the DOD to leverage investments and contribute to solving common civil and military challenges in access to space, advanced space technologies, and hypersonics.

The SLI theme supports 2 of NASA's 10 goals, as shown in figure 3.3.

Figure 3.2

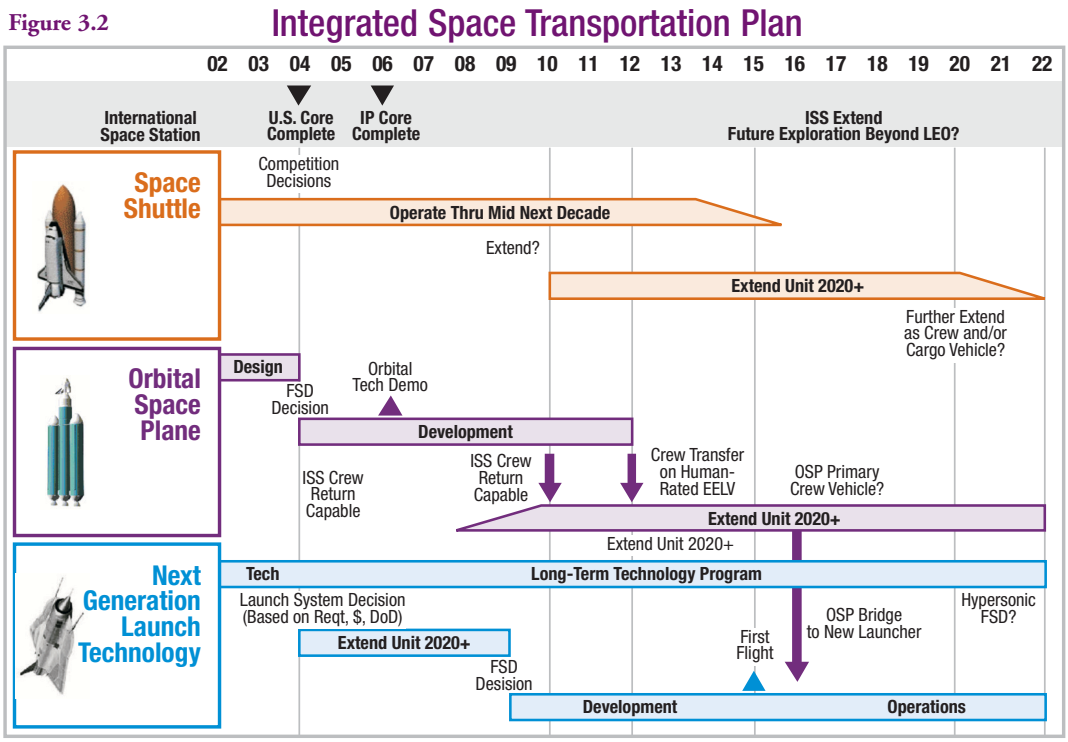
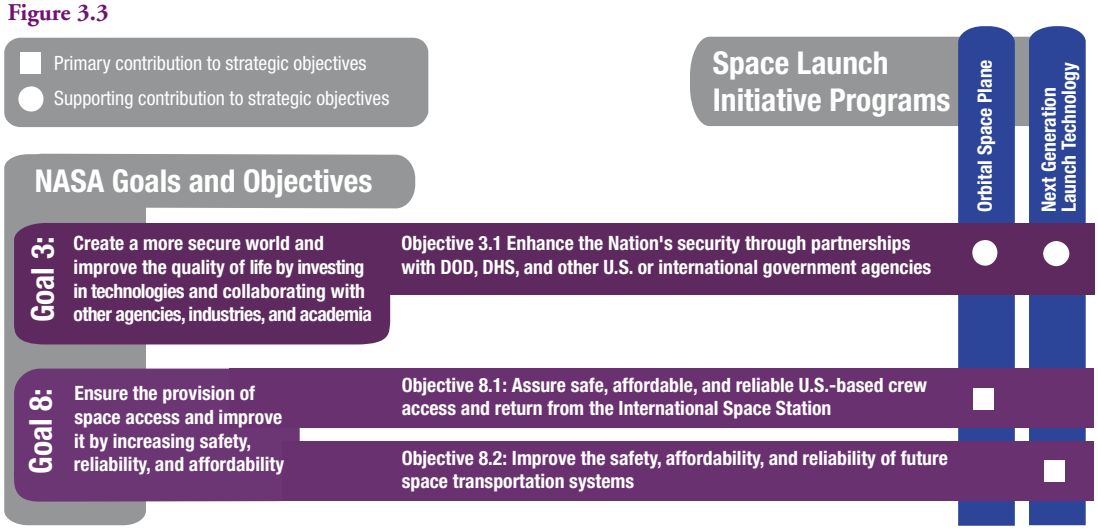


Figure 3.3



Opposite page: An artist's concept portrays future space launch technologies and space transportation systems that will enable more advanced missions for scientific discovery and exploration.

Partnerships for National Security

Goal 3, Objective 3.1: Enhance the Nation's security through partnerships with DOD, DHS, and other U.S. or international government agencies.

The SLI theme and the DOD have developed a roadmap of goals and plans to mature key technologies for hypersonics and access to space. The Next Generation Launch Technology (NGLT) Program supports this integrated roadmap with a balance of near- and far-term research efforts and ground and flight technology demonstrations. Most of the flight demonstrations are performed cooperatively with the DOD.

Partnerships

NGLT is partnering with academic institutions, private industry, the Office of the Secretary of Defense, the Air Force, and other NASA Centers to develop and demonstrate cutting-edge technologies for future launch systems. The program has developed a 25-year national technology plan to mature key technologies for NASA and DOD

The X-43C Project is a joint effort between NASA and the U.S. Air Force to flight demonstrate hydrocarbon-fueled, dual-mode scramjet technologies on an integrated hypersonic vehicle that will reach speeds of Mach 5–7. The Air Force Research Laboratory HyTech Program is providing key propulsion technologies. This image depicts the X-43C Flight Demonstrator Vehicle on a Pegasus Launch Vehicle prior to separation.

launch needs in three distinct technology areas or "pillars": high-speed hypersonics, space access, and space technology.

NASA is engaged in the U.S. Air Force (USAF) operationally responsive spacelift analysis-of-alternatives effort, which incorporates operations, requirements, a technology roadmap, and an acquisition plan for future USAF spacelift. NGLT is providing historical data, models for fleet size, cost assessment studies, launch vehicle models, data for spacelift options, and technology and acquisition planning.

Outcomes

To enhance national security, the Space Launch Initiative theme will

- In partnership with DOD, develop and demonstrate risk-reduction technologies by 2009 that will enable quick-response access to space

Tests to validate hypersonic propulsion and airframe technologies in actual flight environments will significantly advance NASA's readiness to move into prototype and operational phases of hypersonic flight. The X-43C demonstrations and resulting research data directly contribute to the NASA goal of safe, reliable, assured access to space. This image depicts the X-43C Demonstrator Vehicle in flight. The X-43C Project recently conducted tests of a lightweight, hydrocarbon-fueled, hydrocarbon-cooled scramjet ground demonstration engine (see inset).

Assured International Space Station Access

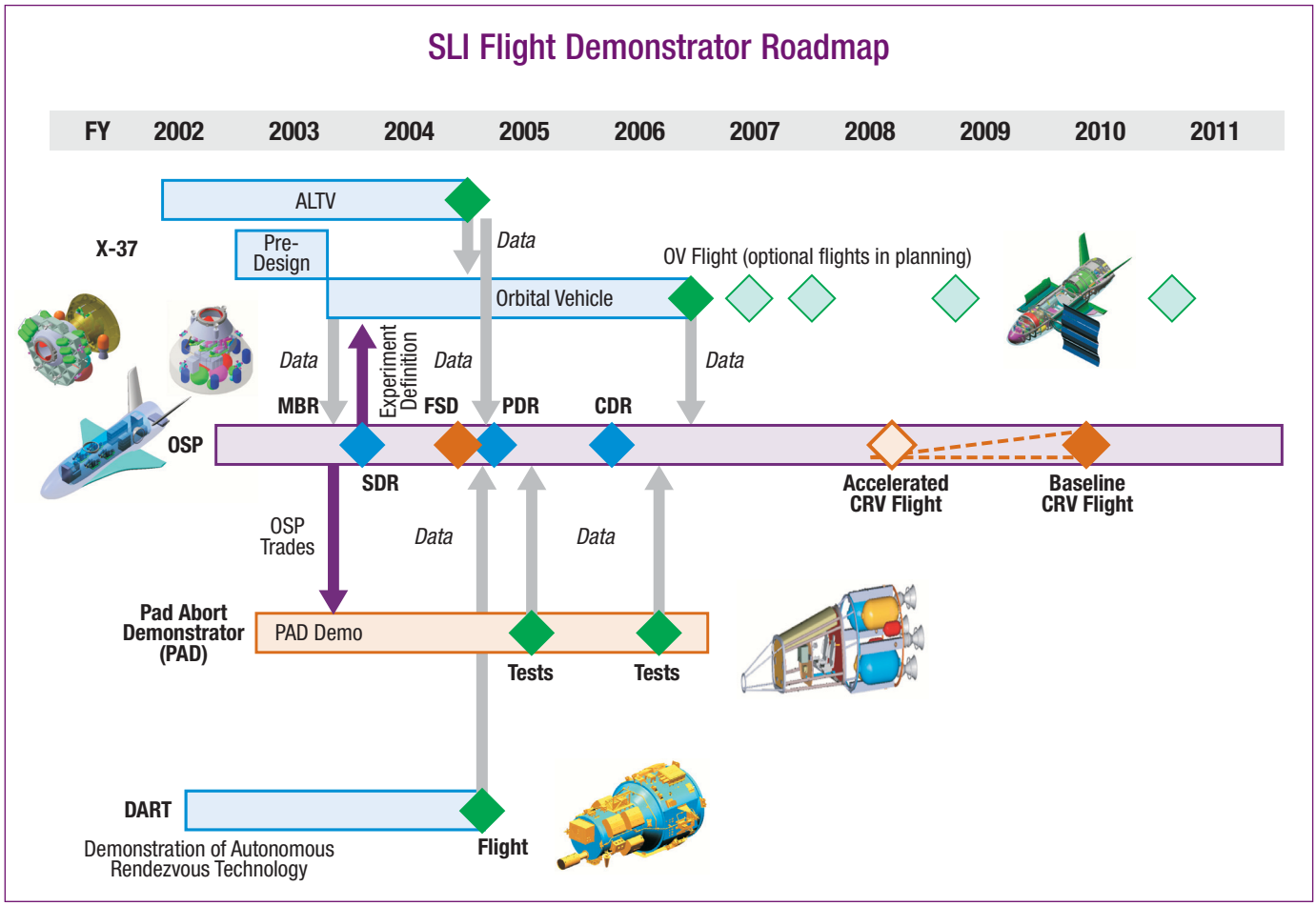
Goal 8, Objective 8.1: Assure safe, affordable, and reliable U.S.-based crew access and return from the International Space Station.

The principal approach to achieving this objective is the development of an Orbital Space Plane (OSP) as a simple and reliable alternative to the Space Shuttle for routine access for astronauts to and from the International Space Station (ISS). The OSP Program is developing and demonstrating technologies to reduce the development risk of an orbital space plane system, as well as managing the development of an OSP. The mission target is crew rescue from the ISS as soon as practical but no later than 2010 and crew and contingency cargo transport to and from the Space Station as soon as practical but no later than 2012. As part of the longer-term elements of the Integrated Space Transportation Plan (ISTP), the OSP also will enable a transition path to future transfer vehicles for transportation beyond Earth orbit, as shown in figure 3.4.

Partnerships

The OSP Program will develop an operational space transportation system to provide crew transportation capability to and from the ISS. The system will be implemented through partnerships with private industry and multiple NASA Centers.

Figure 3.4



Outcomes

The Space Launch Initiative theme will develop and deliver an Orbital Space Plane that provides safe, affordable, and reliable transportation capability for no fewer than four crew to and from the ISS as soon as practical, but no later than 2012.

The Orbital Space Plane Program is an essential element of NASA's Integrated Space Transportation Plan. Several different vehicle concepts may meet NASA requirements of providing safe, affordable crew rescue and transfer capability to and from the International Space Station.

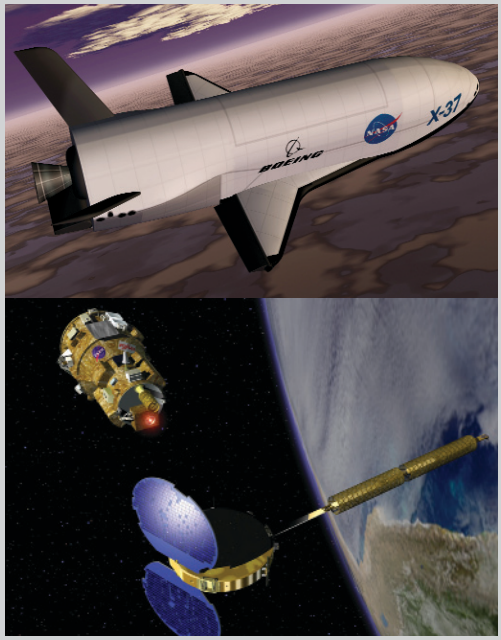
SLI Flight Demonstrators

The X-37 Approach and Landing Test Vehicle is designed to validate thermal effects during approach and landing (40,000 ft and below), and autonomous (no pilot) approach technology that incorporates advanced thermal protection systems and design and manufacturing techniques.

The Demonstration of Autonomous Rendezvous Technology (DART) will develop and demonstrate autonomous rendezvous and proximity operations between a chase vehicle (DART) and an on-orbit satellite.

The Pad Abort Demonstrator (PAD) will develop the fundamental capability to test crew escape technologies in a pad abort situation. This full-scale demonstrator is a reusable flexible testbed that provides a basis for understanding the environments of crew escape. This testbed will include fully instrumented mannequins to provide data on crew environments during demonstration of propulsion systems, parachute systems, orientation and landing techniques, and external aeroshell configurations. The PAD vehicle will be adaptable to test additional maturing crew escape technologies to meet the program goals for crew safety.

The X-37 Orbital Vehicle will provide a versatile technology demonstrator platform on which to mature, through demonstration, critical technologies required by future space transportation systems. It will validate ascent, on-orbit, and re-entry environments, incorporating a broad range of technologies including autonomous approach and landing, advanced guidance and navigation, advanced thermal protection systems, power distribution systems, and streamlined flight operations.



Top: Technology demonstrators will be used to reduce program development risk for the Orbital Space Plane. **Bottom:** This artist's concept shows the DART flight demonstrator (top left) rendezvousing with a target satellite (bottom).

Mission Safety and Reliability

Goal 8, Objective 8.2: Improve the safety, affordability, and reliability of future space transportation systems.

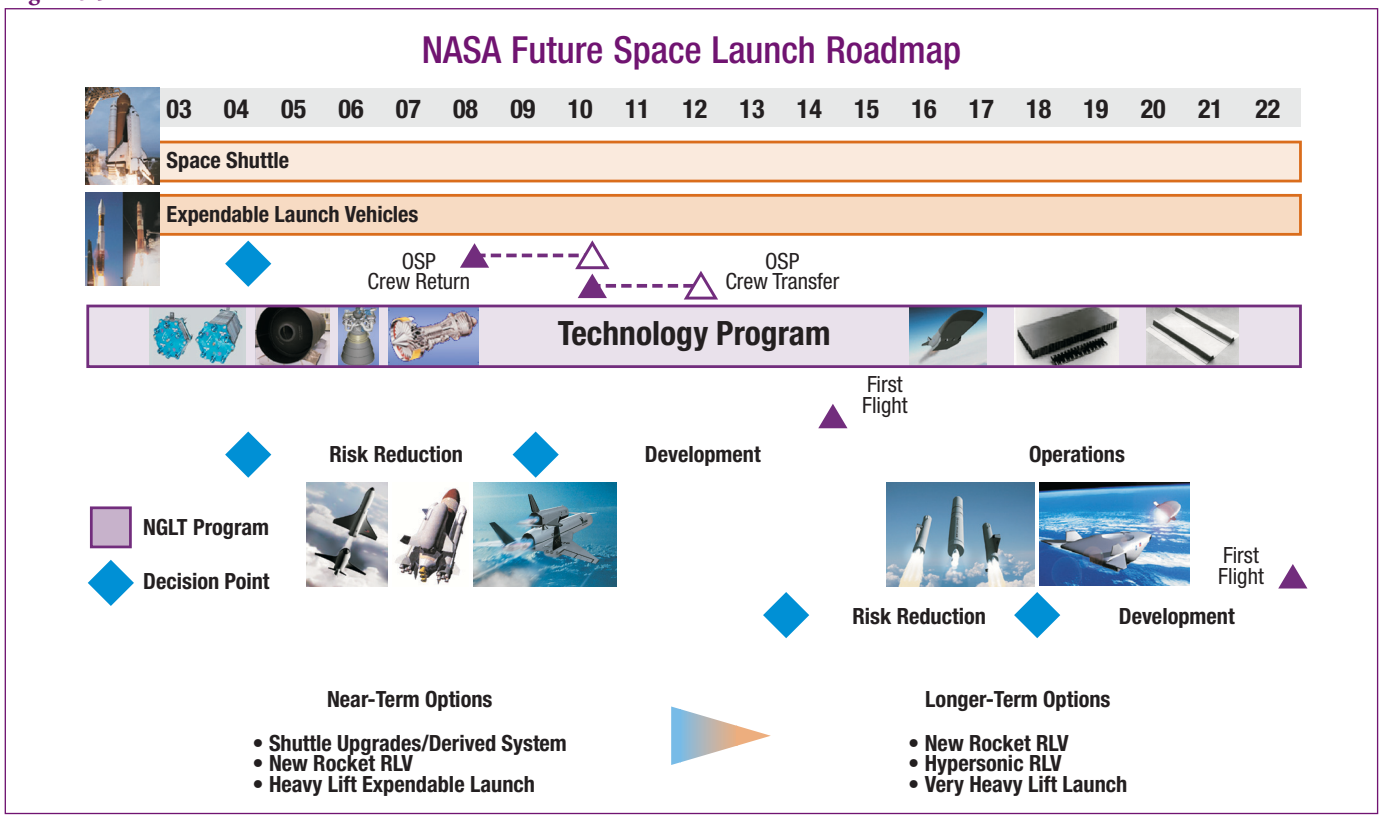
The Next Generation Launch Technology (NGLT) Program develops vehicle, propulsion, and operations technologies to improve the safety, affordability, and reliability of launch systems across a range of payload and performance requirements. Through NGLT, NASA develops new configuration concepts and models to control complex physical and operational phenomena. This new knowledge and related technical advances are then transferred to industry. The Agency synthesizes new concepts and works cooperatively with industry to mature and validate them. NGLT supports flight demonstration efforts to validate technologies in extreme conditions where ground facilities are inadequate. The program also provides NASA with the basis for decisionmaking for new launch system development, including the development of appropriate requirements.

NGLT also formulates concepts to support requirements developed by the space architect for human space exploration. These concepts are matured in the context of overall space exploration architectures, including human and robotic elements. The NGLT development path is shown in figure 3.5.

Partnerships

NGLT is partnering with academic institutions, private industry, the Office of the Secretary of Defense, the Air Force, and other NASA Centers to develop and demonstrate cutting-edge technologies for future launch systems.

Figure 3.5

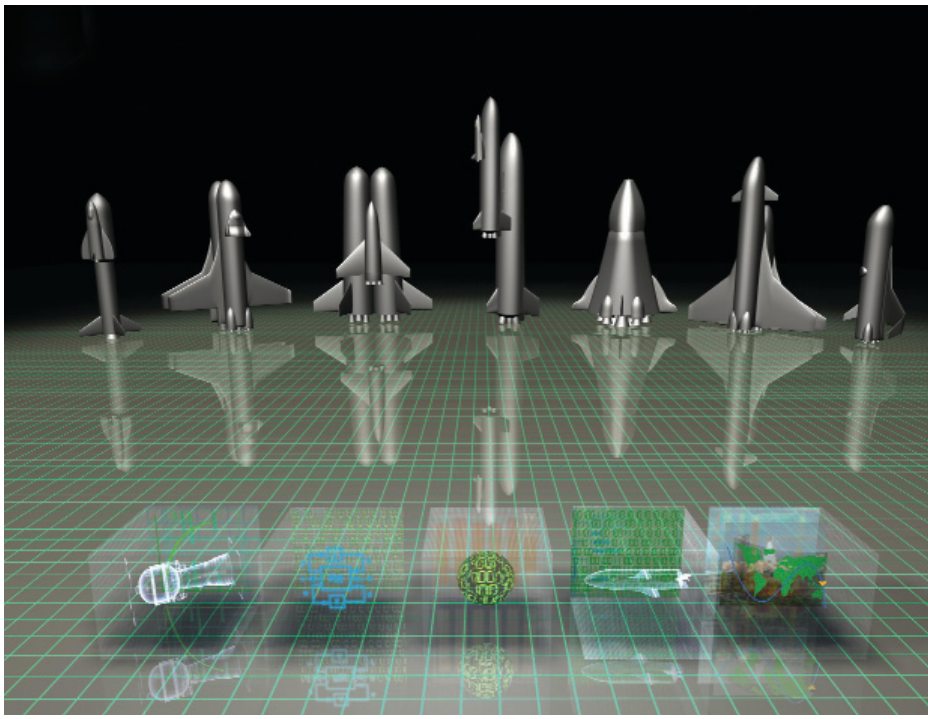


NGLT is exploring improvements for both existing (Space Shuttle, Expendable Launch Vehicles) and future NASA launch systems. Beyond the Orbital Space Plane, NASA needs technology investments for new reusable and expendable launch systems that support science and the International Space Station crew and cargo, operationally responsive spacelift for DOD, commercial spacelift, and heavy lift systems (100–135 metric tons) for exploration.

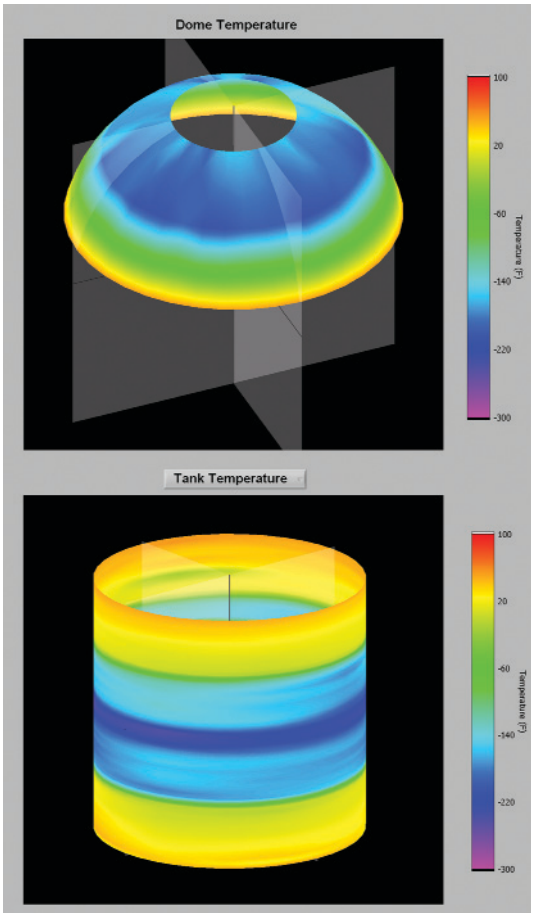
Outcomes

To improve mission safety and reliability, the Space Launch Initiative theme will

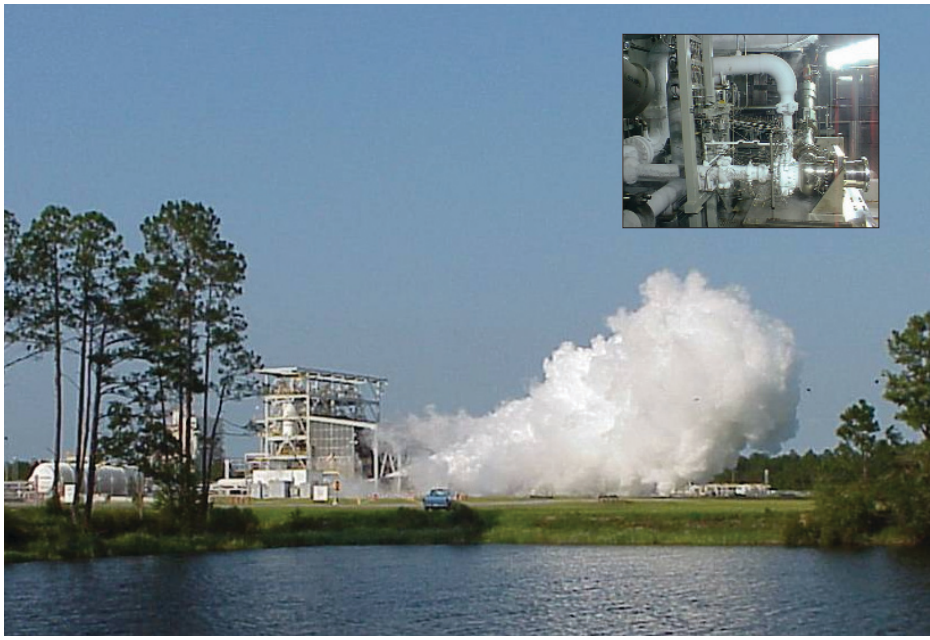
- Develop and demonstrate risk-reduction technologies by 2009 that will enable decisions for development of a lower-cost, higher-reliability space transportation system
- Provide a new modular launch system, the basis for the Nation's future medium-to-heavy launchers, by 2015



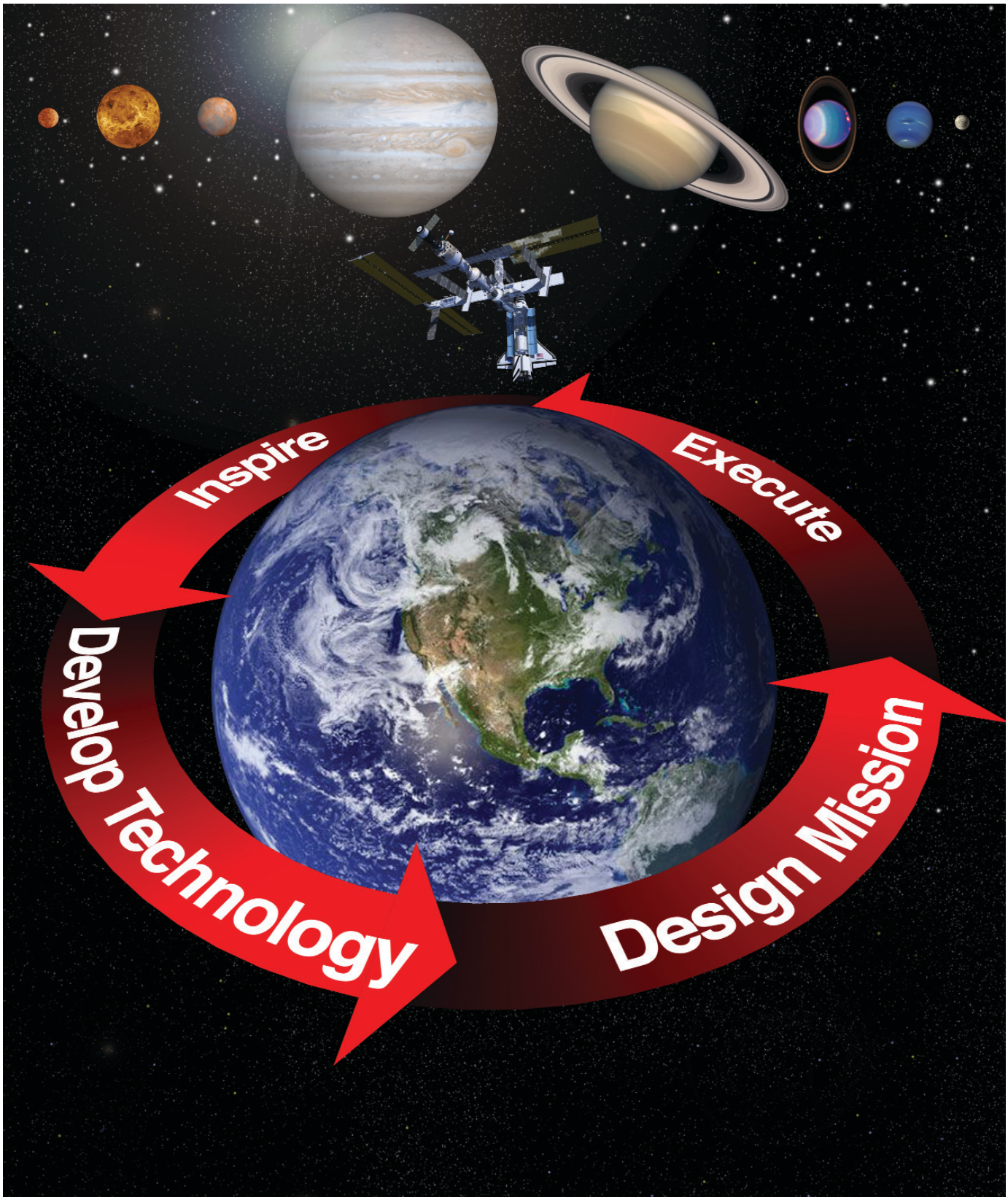
NGLT risk-reduction technologies support multiple future launch system concepts.



Initial analysis of recent liquid nitrogen tests of cryotank structures for future launch vehicle fuel storage show that the structures performed as anticipated.



View of the Integrated Powerhead Demonstrator (IPD) as it undergoes testing at the John C. Stennis Space Center. **Inset:** The IPD Liquid Oxygen Turbopump mounted in a teststand.

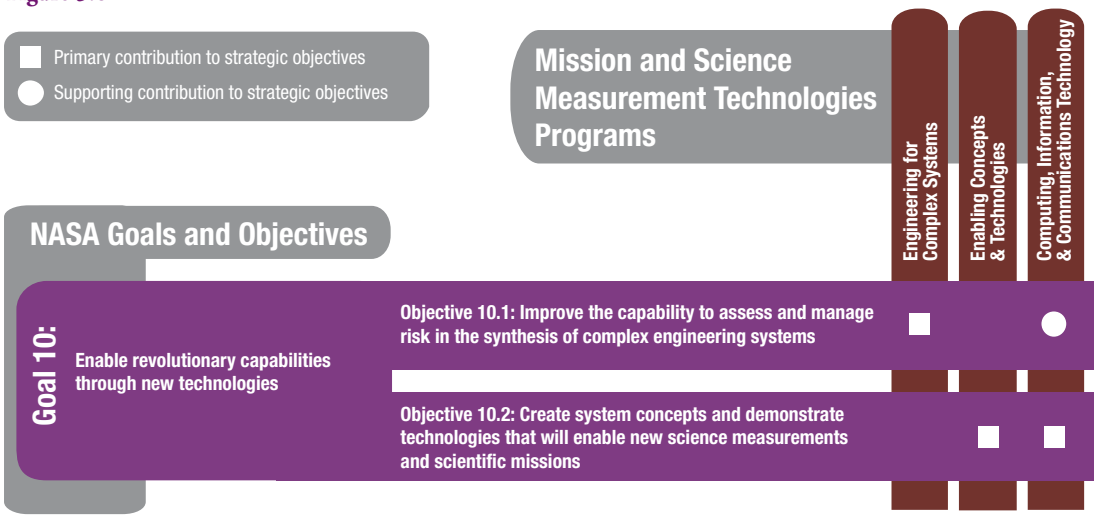

Inspire
Execute
Develop Technology
Design Mission

3.3 Mission and Science Measurement Technology Theme

NASA's Mission and Science Measurement (MSM) Technology theme opens the possibility of new space missions, making them feasible through radical improvements in technology. MSM also includes improvements to NASA's ability to manage risk and ensure the safety and success of complex missions and systems. In pursuing new frontiers, the theme identifies and develops high-value technology opportunities in collaboration with the other NASA Enterprises. The theme draws heavily on the expertise of NASA's Research Centers and university and industry partners. The theme has established significant partnerships with other government agencies that have space technology requirements. There is special focus on requirements that are unique to NASA and exceed those of other potential users.

The theme supports NASA goal 10, as shown in figure 3.6.

Figure 3.6



Above: The MSM Technology theme is focused on technologies and tools that enable advanced system concepts for the NASA Enterprises. Shown is an artist's concept of an exploration mission on Calisto, Jupiter's second largest moon, that could be made possible through MSM technologies.
Left: NASA's MSM Technology theme—revolutionary technologies and systems inspire bold new missions of scientific exploration and discovery and impact all phases of the mission life cycle.

Mission Risk Analysis

Goal 10, Objective 10.1: Improve the capability to assess and manage risk in the synthesis of complex engineering systems.

The Engineering for Complex Systems (ECS) Program develops tools and techniques to identify and eliminate risks; capture, integrate, and utilize knowledge; and provide an intelligent response to hazards. Based on analysis of previous mission failures, case studies, agency reports, and technology analysis, ECS is pursing several high-priority challenges. These challenges include: increasing the capability to perform analyses of systems and conduct trade-off studies between the options available within the system; understanding system, human, and organizational risk; instituting a robust knowledge capture and communication process; and increasing the ability to assess current status and implementing successful control strategies. Ultimately, the intent is to enable overall mission and human safety to be evaluated for risk with the

The Personal Satellite Assistant (PSA), developed jointly by the CICT and ECS programs, is an innovative, automated mobile assistant that can perform a variety of complex diagnostics and crew support tasks in space environments.

NASA's Engineering for Complex Systems program is augmenting the Agency's design and engineering capabilities to address current and future system and mission risks. The System Reasoning and Risk Management project is developing a suite of tools to support prototype collaborative design environments by addressing critical gaps in risk management, intelligent system design, and technology development assessments.

same fidelity and confidence as standard parameters such as cost, schedule, and performance. The ECS Program works cooperatively with other projects throughout the Agency to implement, test, evaluate, and transition tools and techniques.

Partnerships

The Technology Executive Board (TEB) is a key partnership composed of representatives from the NASA Enterprises. The TEB works to define needed capabilities and technology requirements for NASA missions developed by the Enterprises. The TEB negotiates agreements regarding priorities, the level of technology maturity at transfer, and the timeline for transfer to the receiving Enterprise.

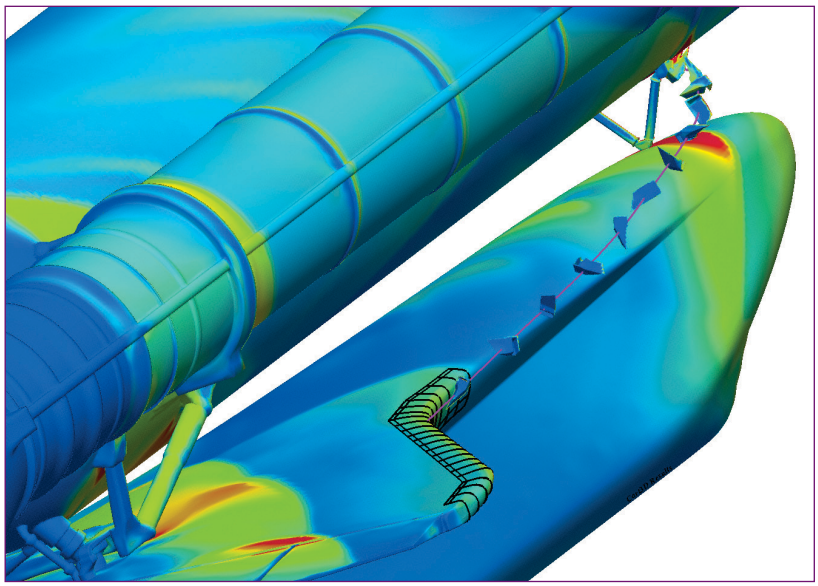
In addition to the TEB, the MSM theme works with the Space Shuttle Program Office to develop knowledge engineering and management technologies for large systems and wire integrity research methods and technologies. The Space Science Enterprise applies risk identification and management technologies. In addition, there are partnerships with other government agencies and institutions and numerous project relationships with the Agency's industry and university partners.

Outcomes

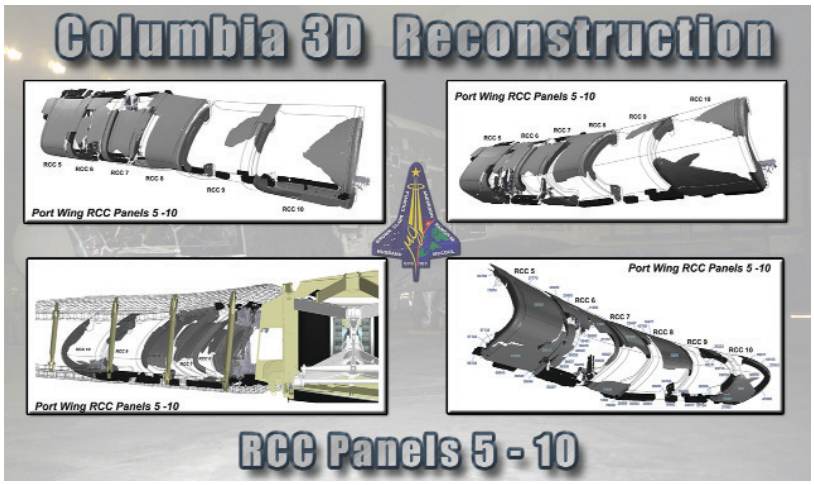
To improve mission risk analysis, the Mission and Science Measurement Technology theme will

- By 2005, demonstrate three prototype systems that prove the feasibility of resilient systems to mitigate risks in key NASA mission domains. Feasibility will be demonstrated by reconfigurability of avionics, sensors, and system performance parameters

- By 2006, provide five decision-support tools/methodologies to fill the current technology gaps in the following areas of risk management: organizational risk, engineering risk, and early life cycle design risks. These tools will provide verifiable completeness checks, relative risk exposure comparisons, and repeatable and distributable quantifications of system risk analysis



This image shows a "time lapse" of the debris event cited in the Columbia Shuttle tragedy. The computed trajectory is shown by the pink line. Computer modeling and simulation capabilities such as this can help to both investigate and analyze failures, as well as predict potential failure modes. Both actions help better understand system risks for improving the safety of current and future systems.



Tools developed through the ECS Knowledge Engineering for Safety and Success project assisted in reconstructing critical Shuttle wing debris to help the Columbia Accident Investigation Board in its work.

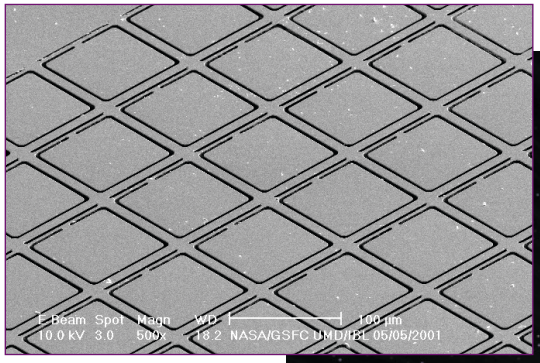
Science- and Engineering-Driven Architectures and Technologies

Goal 10, Objective 10.2: Create system concepts and demonstrate technologies that will enable new science measurements and scientific missions.

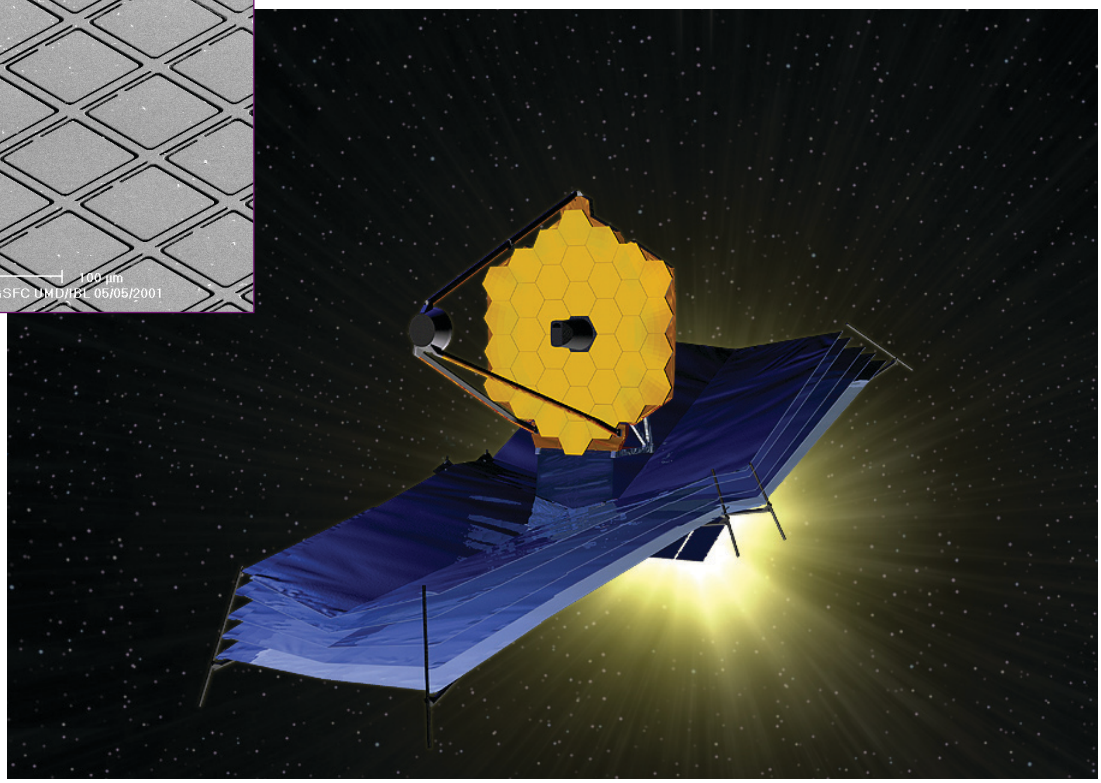
The Enabling Concepts and Technologies (ECT) Program invests in a broad portfolio of crosscutting technologies for sensing and spacecraft systems that have the potential to dramatically improve or enable science missions. The Computing, Information, and Communications Technology (CICT) Program develops technologies for system intelligence and autonomy and ground and space-based computing and communications technologies. The program explores communications and computing architectures based on NASA's unique mission needs and works with industry to prototype and test systems in actual applications. The portfolio is developed in cooperation with the other NASA Enterprises to focus on the highest priority mission requirements and to ensure a technology transition pathway. Systems analysis is used for a full and common understanding of concept benefits and the required technologies to enable the concepts.

Partnerships

The TEB performs the same advisory and planning role for the ECT and CICT Programs as it does for the ECS Program. The TEB identifies and prioritizes the crosscutting technology needs of the NASA Enterprises, and advises the MSM Technology theme on the relevance of technology development activities. The theme partners with other government agencies such as the National



Microshutter detail.



The ECT Program is developing a Micro-Shutter Array for the James Webb Space Telescope. The shutters are about 100 microns across, and they can be selectively opened using a magnet to direct light from multiple astronomical sources into the telescope's spectrometer. The array greatly improves performance over existing telescopes, and the selective capability will allow astronomers to study individual objects in the telescopes field of view, enhancing scientific returns. This artist's concept shows the James Webb Space Telescope deployed.

Cancer Institute, DOD, National Security Agency, Department of Energy, NSF, National Institutes of Health (NIH), National Oceanic and Atmospheric Administration (NOAA), United States Department of Agriculture (USDA), and Department of Interior. In addition, the theme maintains numerous partnerships with industry and academic institutions.

Outcomes

To create mission-enabling system concepts and technologies, the Mission and Science Measurement Technology theme will

- By 2007, perform 10 technology assessments to identify high-value mission-enabling technologies for guiding program investment decisions
- By 2007, develop advanced spacecraft propulsion technologies to reduce the trip time for planetary missions by 30 percent
- By 2007, develop six new science measurement capabilities
- By 2006, demonstrate six revolutionary spacecraft systems technologies to enable distributed science collection, exploration of extreme environments, and lower mission cost
- By 2006, increase capabilities to acquire and return scientific data by a factor of 3
- By 2005, demonstrate six automated reasoning, intelligent data understanding, or human-centered computing technologies for science exploration missions
- By 2005, demonstrate six distributed or collaborative applications to reduce the time required to design and operate future missions

The CICT Program develops advanced autonomy technologies that enable humans and robots to work together. These technologies have been demonstrated in field tests with prototype Mars rovers.

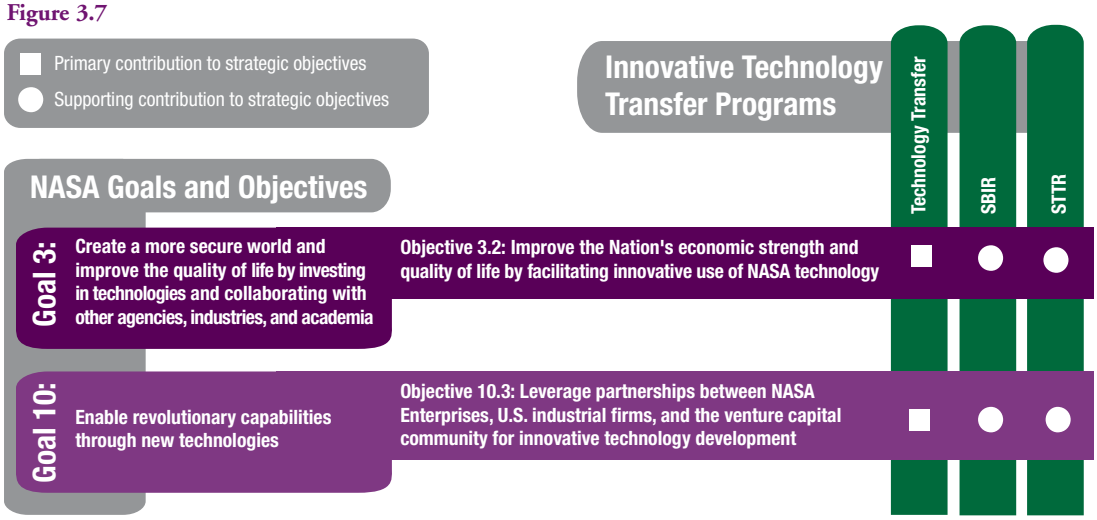
3.4 Innovative Technology Transfer Partnerships Theme

NASA's Innovative Technology Transfer Partnerships (ITTP) theme enables the creative use of intellectual assets both inside and outside of NASA to meet the Agency's technology needs and to benefit the Nation. ITTP serves to capture, manage, and support the full life cycle of NASA's intellectual property and technology assets in ways that foster innovative applications to generate benefits for NASA missions, U.S. industry, and the Nation. Primarily through developing innovative partnerships with non-aerospace companies, ITTP seeks new technologies and reduces technology development costs for the NASA Enterprises. To support the Agency and strengthen the U.S. economy, the ITTP theme uses many approaches, such as managing NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

The ITTP theme ensures that NASA-sponsored technologies are made available to private industry, academic institutions, and government agencies for use in creating new innovative products and competitive business opportunities. The theme is responsible for intellectual property management and protection, and also for increasing awareness of and enabling access to NASA technology for the purposes of transfer and collaborative technology development.

The theme supports 2 of NASA's 10 goals, as shown in figure 3.7.

Figure 3.7



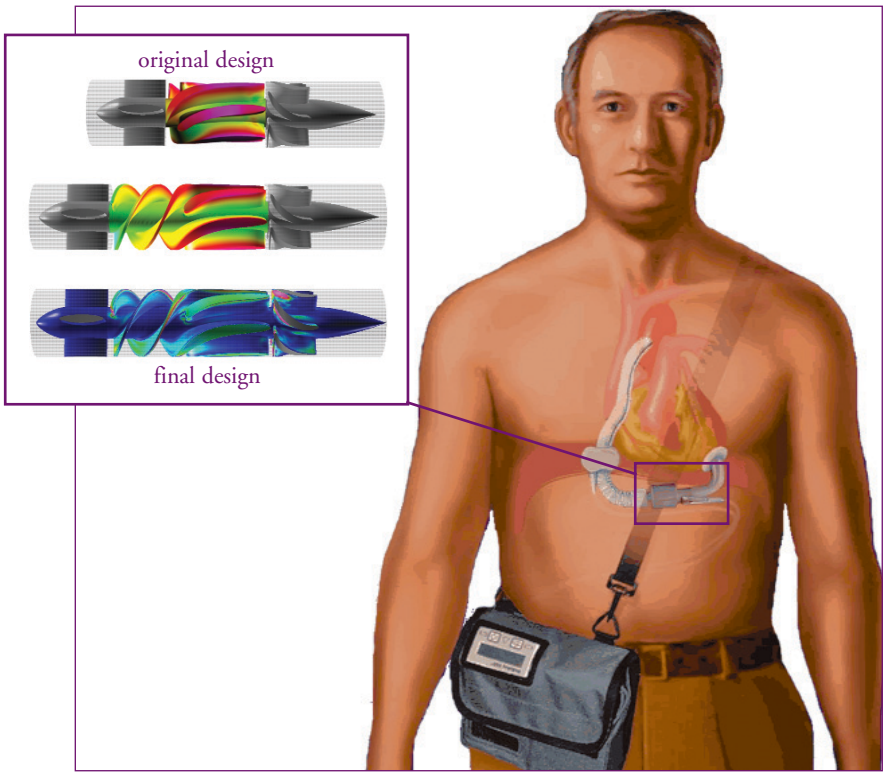
Left: The Innovative Technology Transfer Partnership theme seeks and establishes collaborations to meet the Agency's technology needs, as well as transfers NASA-sponsored technologies for commercial applications and improved quality of life.

Extending Benefits to Society

Goal 3, Objective 3.3: Improve the Nation's economic strength and quality of life by facilitating innovative use of NASA technology.

NASA-sponsored technologies are made available to the private sector for use in creating new innovative products and competitive business opportunities that help to strengthen the U.S. economy. NASA-developed technology also supports the critical technology needs of Federal and state agencies in supporting their objectives (e.g., Homeland Security). NASA's ITTP representatives work closely with U.S. business sectors, particularly non-aerospace industries, to facilitate the use of NASA technology. The achievement of this objective requires engagement on many fronts with other government agencies and private industry. Mechanisms for engagement include public access information systems such as a national network that includes regional technology transfer centers; the National Technology Transfer Center; and public outreach through seminars, conferences, the TechTracS database (*http://technology.ksc.nasa.gov/TechTracS/TechTracS.html*), and the NASA publications *Tech Briefs*, *Aerospace Technology Innovation*, and *Spinoff*.

Key components of this objective are rigorous intellectual property management to enable both the distribution of available technologies and the formation of technology development partner-



The MicroMed DeBakey Heart Pump benefits patients with congestive heart failure. NASA assisted in the development and refinement of the Ventricular Assist Device (VAD) incorporating tools used to simulate fluid flow through rocket engines. NASA researchers analyzed blood flow through the battery-powered heart pump using NASA supercomputers and fluid dynamic technology, and recommended improvement in the VAD design (see inset). This ultimately led to a VAD that minimized red blood cell damage, improved the blood flow pattern, and reduced the tendency for blood clots.

Video made with a handheld camcorder from police cars chasing criminals can result in shaky footage, making license plates unreadable (bottom). When NASA scientists at Marshall Space Flight Center enhanced the video with the VISAR software, they produced a clear, sharp image, (top) allowing the license plate to be read.

ships; the development of those partnerships; and the execution of the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs.

The SBIR Program, established by Congress in 1982, expands opportunities for small businesses to participate in research and development (R&D). The program's specific objectives are to stimulate U.S. technological innovation, use small businesses to meet NASA R&D needs, and increase private-sector use of innovations derived from Federal R&D, thereby increasing U.S. competitiveness.

The STTR Program (modeled after the SBIR Program) awards contracts to small business concerns for cooperative research and development with a research institution, such as a university. The goal of Congress in establishing the STTR Program is to facilitate the transfer of technology developed by a research institution through the entrepreneurship of a small business.

Partnerships

A new pilot program has been established to assist selected SBIR companies through advanced stages of technology development leading to commercialization. The key component of this pilot is to help position SBIR firms to achieve profitability by establishing viable joint venture partnerships with the introduction of private-risk capital to produce technologies needed by NASA. This pilot will create a self-sustaining operation for the successful entry of SBIR firms into the marketplace.

Outcomes

To extend the benefits of NASA technology to society, the Innovative Technology Transfer Partnerships theme will, on an annual basis, develop new technology transfer agreements with the Nation's industrial and entrepreneurial sectors.

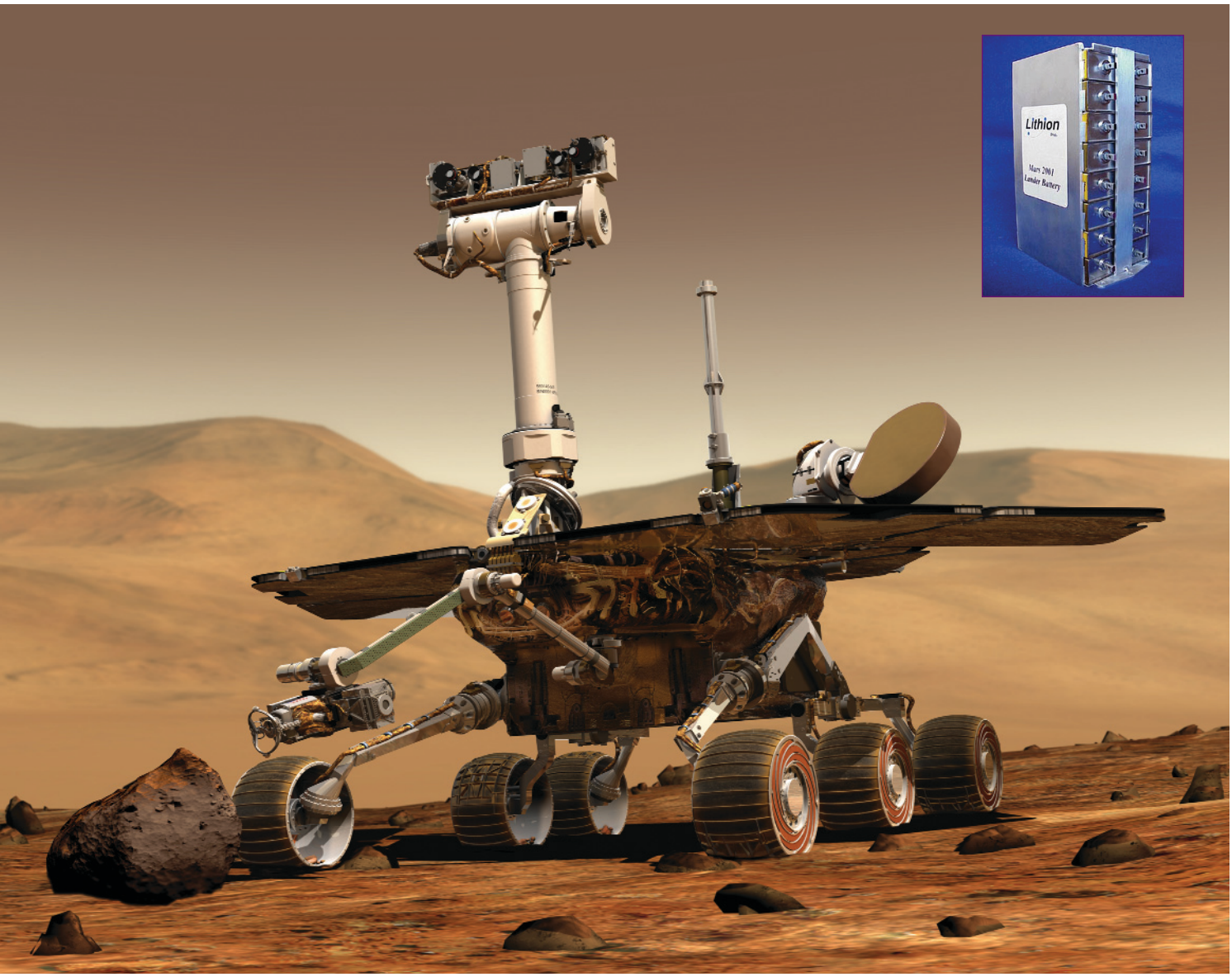
Parachutes are lifesavers in cases of engine failure, mid-air collisions, pilot disorientation or incapacitation, unrecovered spins, extreme icing, and fuel exhaustion. In October 2002, a pilot released his Cirrus SR-22 aircraft's parachute and landed safely in a Texas mesquite tree grove. The pilot was uninjured, and there was minimal damage to the plane. The safe landing made aviation history as the first emergency application of an airframe parachute on a certified aircraft.

New Sources of Technology for NASA

Goal 10, Objective 10.3: Leverage partnerships between NASA Enterprises, U.S. industrial firms, and the venture capital community for innovative technology development.

With the rapid pace of technology development on many fronts, opportunities exist for NASA to derive benefits from the technology innovations of individuals, small businesses, corporations, and academic institutions working in non-aerospace technology sectors. NASA is increasingly looking to enhance its mission capabilities with concepts and technology developed by the private sector.

The priority of the ITTP theme is to establish technology partnerships that support the NASA



The robotic explorers that NASA sends to Mars must be efficient and able to maintain reliable power in harsh conditions. NASA and the Air Force have contracted with Yardney Technical Products to develop space-qualified lithium ion batteries for future space applications. The Yardney batteries (see inset), powering the two rovers scheduled to land on Mars in 2004, are a quarter of the weight and half the volume of batteries used in past missions.

Enterprises and Centers. Using NASA's extensive technology transfer network, the ITTP theme identifies non-aerospace technology-solution providers that can contribute to NASA's research and missions, as well as innovative commercial entities and catalysts of technology innovation who can help meet the future needs of the Agency.

The theme also engages in dual-use technology development with U.S. technology developers and the venture capital community. An example of this type of engagement is the Enterprise Engine pilot program, which is designed to incorporate partnership-developed technologies into NASA's Enterprises, missions, and programs. The Agency will measure success by the degree to which the Enterprise Engine effectively contributes to NASA missions.

NASA will also continue to seek innovative technology developed through its SBIR/STTR programs by aligning its solicitations with mission technology priorities. ITTP personnel at the NASA Centers have a clear understanding of the Enterprises' mission technology needs and work with SBIR/STTR personnel and Enterprise project offices to manage the activities necessary for technology "spin-in" to NASA, such as technology evaluation, partnership facilitation, contract management, licensing, knowledge capture, intellectual property management, and information dissemination.

Partnerships

In FY 2004, the Enterprise Engine is being introduced to create dual-use partnerships between NASA, non-aerospace industrial firms, and the venture capital community. All of our partnerships are intended to attract new partners to NASA—innovators, investors, financiers, and non-aerospace companies that have not traditionally conducted business with the Agency. NASA's technology roadmaps are one means to identify the overlapping R&D interests of NASA, industry, academic institutions, and private risk capital. Areas of overlap identify potential partnerships to help NASA achieve specific technology objectives and to help industry achieve business goals. NASA resources will be matched or leveraged to the maximum extent possible.

Outcomes

To leverage partnerships that develop new sources of technology, the Innovative Technology Transfer Partnerships theme will

- Promote and develop innovative technology partnerships between NASA, venture capital firms, and U.S. industry for the benefit of the Enterprise's mission technical needs, initiating three partnerships per year

- Facilitate, on an annual basis, the award of venture capital funds or Phase III advanced program contracts to SBIR firms to further develop or produce their technology through industry or government agencies

A partnership that coupled JPL's spore-detection technology with an aerosol capture device by Universal Detection Technology of Beverly Hills is developing an anthrax "smoke" detector. This device would automatically and continuously monitor for the presence of bacterial spores and trigger an alarm when detected. For NASA, the use is for monitoring spores at spacecraft assembly facilities or monitoring aboard the Space Station. For Universal, the technology will be commercialized as a bioterrorism warning monitor.

Improve science, technology, engineering, and mathematics education...as only NASA can

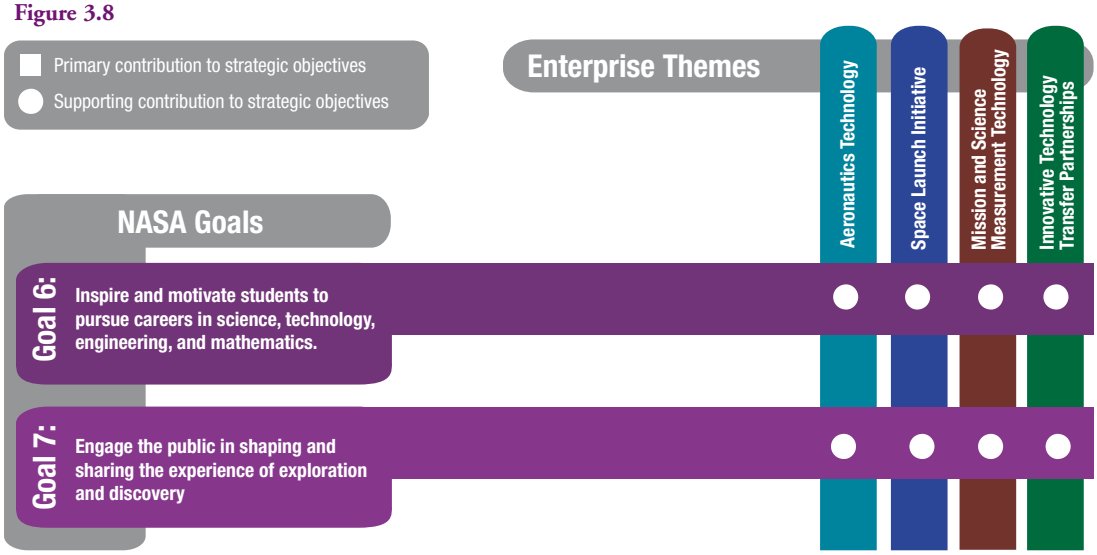
3.5 Enterprise Contributions to Agency Education and Outreach Goals

Supporting NASA Education Objectives

The Aerospace Technology Enterprise fully supports the NASA goal to "inspire and motivate students to pursue careers in science, technology, engineering, and mathematics." To that end, the Enterprise develops and implements a wide range of education programs, products, and services that augment the initiatives of the NASA Education Enterprise. The Aerospace Technology Enterprise's themes and programs each establish a plan to support the achievement of Goal 6 in NASA's Strategic Plan (shown in figure 3.8) and the following education objectives:

- Objective 6.1: Increase the number of elementary and secondary students and teachers who are involved in NASA-related education opportunities
- Objective 6.2: Support higher education research capability and opportunities that attract and prepare increasing numbers of students and faculty for NASA-related careers
- Objective 6.3: Increase the number and diversity of students, teachers, faculty, and researchers from underrepresented and underserved communities in NASA-related science, technology, engineering, and mathematics fields
- Objective 6.4: Increase student, teacher, and public access to NASA education resources via the establishment of e-Education as a principal learning support system

Figure 3.8



The Enterprise's education programs are a vital part of the overall NASA education effort. Our programs range in scope from products and services for elementary schools and informal education to university research. The Enterprise programs and projects create a host of exciting aerospace technology education materials shaped by the NASA objectives for education and targeted at science, technology, engineering, and mathematics (STEM) curricula. Materials include interactive multimedia CD-ROMs, educator guides, wall posters, lithographs, educational software, and informative brochures. To make the curriculum support materials more compelling, the Enterprise uses the latest research in aerospace technology to increase understanding of the connections between science, mathematics, and the real world.

At the post-secondary level, NASA's objective is to attract talented students and professionals to the aerospace industry and retain experienced

Preparing for Success

The Innovative Technology Transfer Partnerships theme provides opportunities and experience, via NASA internships, for students from underrepresented and underserved communities to help prepare them for successful careers in the field of technology management.

Distance Learning

Student cast on the set of The NASA Science Files™.

The Aerospace Technology Enterprise sponsors a series of Emmy® award-winning research and standards-based television programs which cover a broad range of education levels from 3rd grade to lifelong learners.

The NASA Science Files™ is a series of 60-minute instructional programs for grades 3–5, and NASA Connect™ is a series of 30-minute mathematics-focused instructional broadcasts for students in grades 6–8. Both programs have companion lesson guides and interactive Web-based applications. They air nationally on Cable Access, ITV, and PBS-member stations. Presently, more than 260,000 educators—representing over 8.9 million students in 50 states—have registered for NASA Connect™, and over 194,000 educators, representing 4.3 million students, have signed up for NASA Science Files.

Destination Tomorrow™, designed for educators, parents, and adult (lifelong) learners, focuses on NASA research, past, present, and future. Modeled after network television news magazines, the program illustrates the many ways NASA technology touches our lives. Nearly 600 cable access and satellite TV stations air the series to an international audience of approximately 230 million viewers.

professionals in the Agency. Enterprise relationships with colleges and universities help to address these needs. The Enterprise has established a number of university consortiums to engage in cutting-edge research and technology development activities supporting the aerospace technology mission. Joint research activities with universities serve to steer STEM students into aerospace careers. These joint research activities also benefit NASA professionals by providing life-long-learning, professional development, and exposure to new trends in technology. Establishing networks and creating environments that foster collaboration and innovation will be of great importance for the workforce of the future.

Partnerships

The Aerospace Technology Enterprise education program is guided by the Aerospace Education Coordinating Committee (AECC). The AECC is composed of the Enterprise's partnership manager for education at NASA Headquarters, education officers at the NASA Field Centers, and a representative from the Agency's Education Enterprise. The AECC works to maximize product development expertise, eliminate duplication, foster collaboration, and promote sharing of resources across the Enterprise and the Agency. This partnership ensures that all education products are grounded in sound educational principles and follow the guidelines established in the NASA Education Enterprise Strategy.

The Enterprise programs also provide direct support to the NASA education program by developing at least one program or product each year in coordination with their Center education offices. These education programs and products achieve high leverage and sustainability through intrinsic design, and the involvement of appropriate local, regional, or national partners in their design, development, and dissemination.

Outcomes

All education programs sponsored by the Aerospace Technology Enterprise include individualized evaluation elements in their program plans. Metrics for all Enterprise education programs are maintained on the NASA Education Evaluation Information System, a computer database service provided by the NASA Education Enterprise.

As part of the 2003 "Earth to Orbit: Engineering Design Challenge" program, students learned principles of aircraft propeller design.

Educational Web Sites

Robin Whirlybird: An online, interactive children's book to introduce history, concepts, and research in aeronautics and rotorcraft for K–4 students. (*http://rotored.arc.nasa.gov*)

Reliving the Wright Way: A central location of information on the Wright brothers and activities for educators and students related to the celebration of the 100th anniversary of powered flight. (*http://wright.nasa.gov*)

NASAexplores: Free lessons and other resources for educators in grades K–12. Each Thursday during the school term, NASAexplores provides teachers throughout the country a set of professionally designed STEM lesson plans and activities based on Aerospace Technology research. (*http://www.nasaexplores.com*)

Virtual Skies: A Web resource for educators and students that explores science, geography, and mathematics through air traffic management. Available to educators and students. (*http://virtualskies.arc.nasa.gov*)

The Aeronautics Kids Page: A wide range of information on aviation including entertaining, educational online games, which are tailored for young people. (*http://www.ueet.nasa.gov/StudentSite*)

For a complete list of Aerospace Technology Education Web sites, visit *http://aerospace.nasa.gov/edu*.

Supporting Public Outreach Objectives

Goal 7, Objective 7.1: Improve public understanding and appreciation of science and technology, including NASA aerospace technology, research, and exploration missions.

In addition to strong support of formal education activities, the Enterprise supports a number of initiatives for the general public. In our rapidly changing society, a basic technical literacy—understanding the use of technology and its impact—is an important element in future growth because all aspects of our lives are touched by technology. Health care, communications, energy, and national security are but a few fields that have tremendous consequences for our social, political, and economic well-being. Promoting a general understanding of scientific and technical topics helps citizens make more informed decisions on the policies that affect them. Added benefits are a positive public attitude toward understanding science and engineering, better appreciation for the men and women who contribute technology to society, and greater student interest in technology career fields due to consistent and positive exposure.

Partnerships

The Enterprise has partnerships with a variety of external organizations including museums, cultural organizations, and institutions to inform the public about the goals for NASA technology and NASA achievements. Each Enterprise theme contributes to this effort by providing technical articles, Web sites, conference and public exhibit participation, and personnel who volunteer for public speaking and other service activities.

Outcomes

The Aerospace Technology Enterprise will engage the public in NASA missions, discoveries, and technology through public programs, community outreach, mass media, and the Internet.

The Innovative Technology Partnerships theme has an extensive outreach program to facilitate technology transfer. ITTP publishes and distributes the magazines *Aerospace Technology Innovation*, *NASA Tech Briefs*, and *Spinoff* to promote technologies available for commercialization. ITTP also provides public and industry access to the TechTracS database, which features approximately 18,000 updated and evolving new technologies, as well as technical briefs, diagrams, and illustrations.

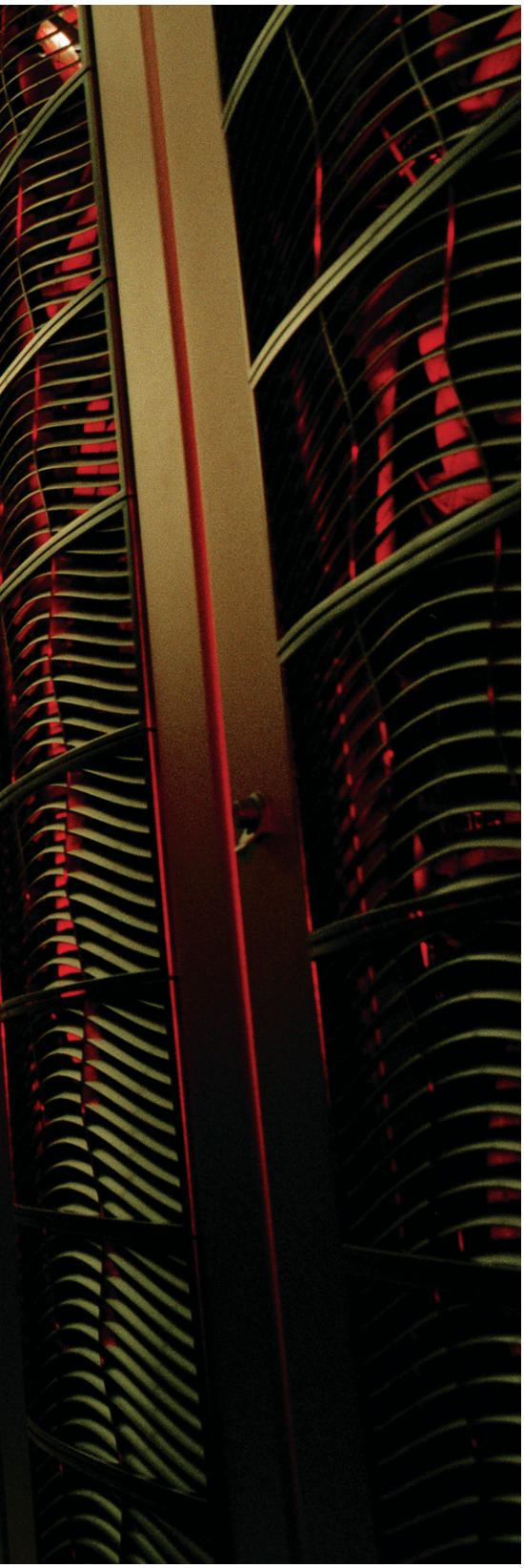
Aerospace Design: The Art of Engineering from NASA's Aeronautical Research

Orville and Wilbur Wright's historic achievement in flight development was supported by their ability to quickly modify experimental designs. Instead of wasting time rebuilding an entire plane for each test flight and hauling the craft to a suitable area, they simply built the particular components that needed to be tested. By 1900 they had built their own wind tunnel for such testing, and only three years later they launched the first powered, controlled flight.

To commemorate the 100th anniversary of the Wright brothers' landmark flight, the Aerospace Technology Enterprise partnered with the Art Institute of Chicago to present a history of aeronautically engineered forms—artifacts from NASA's collection dating from the 1930s. As the wind tunnel was the paramount advancement in the field, the exhibition examines some of the engineering and architectural aspects of wind tunnels as well as the work carried on within them. The exhibition features striking wind tunnel models, turbine blades, and engine components. NASA's current endeavors are illustrated with designs for future airplanes, including those with morphing wings and biologically inspired forms aimed at making commercial air travel accident-free, environmentally friendly, affordable, and accessible.

The Aerospace Design exhibit analyzes the aesthetic of industrial objects and reminds us that "form follows function," meaning that practical design can yield striking and aesthetic results. The Art Institute of Chicago notes that the objects also embody an aesthetic that has followed that of modern art. The 90 artifacts in the exhibit will tour through 2006 at 7 museums across the United States. In addition to the exhibit, related lectures and interactive programs for families will be planned with each host museum. The second host for this exhibit is the Octagon Museum in Washington, DC, during the spring and summer of 2004.

4 Strategy Implementation



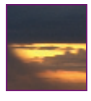
4 Strategy Implementation

4.1 Capital and Human Assets

NASA owns and operates unique and highly complex facilities, maintains core competencies in specialized and emerging technical disciplines, and performs inherently governmental functions related to the planning, management, and evaluation of mission-driven activities. The combination of world-class facilities and research personnel—not easily replicated elsewhere—enables the successful completion of Enterprise programs and the ultimate realization of the Agency's Vision and Mission.

Consistent with the overall NASA Strategic Plan, the Aerospace Technology Enterprise recognizes the importance of the effective and efficient management of these critical human capital and infrastructure resources. A key strategy from the NASA Strategic Plan, "Achieve management and institutional excellence comparable to NASA's technical excellence," is based on the five elements of the President's Management Agenda. The Agency also provides the strategic direction for many of the Enterprise's efforts in the human capital and infrastructure management arenas.

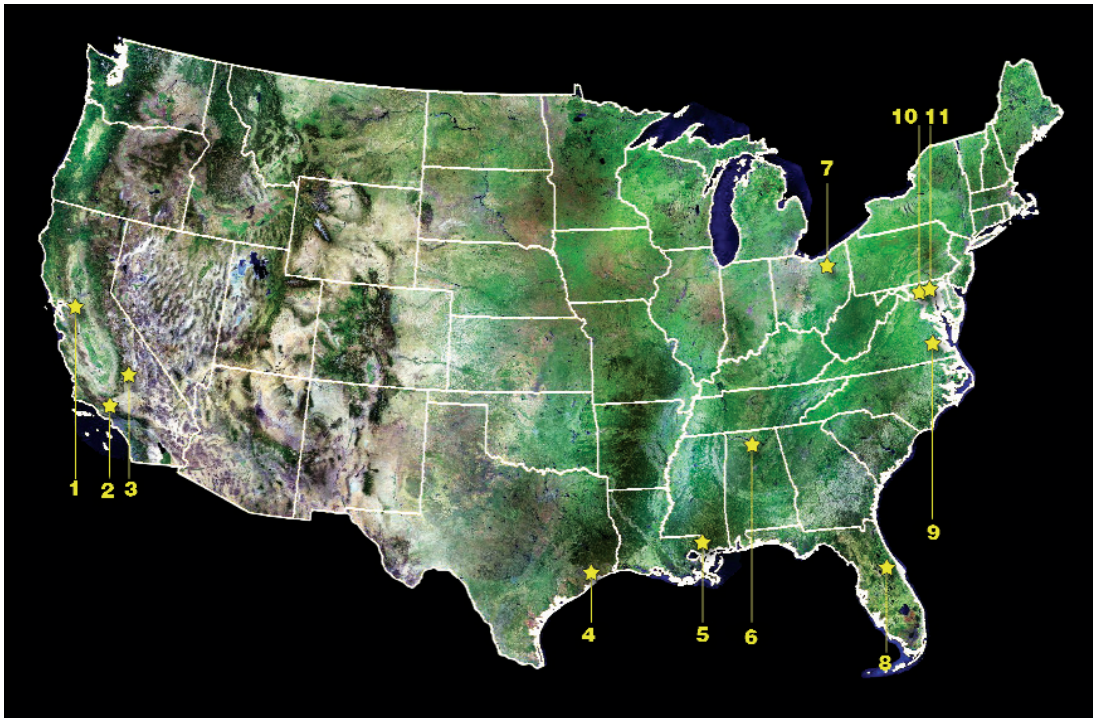
NASA's high-performance supercomputer, called "Chapman," is the first 1,024 processor computer with a single system image architecture in which all processors share a common memory. This arrangement, the largest in the world, enables all 1,024 processors to work simultaneously on a single problem with unprecedented efficiency. The Chapman represents a new approach to computing that enables a variety of science and engineering applications. Its advances have increased the Earth Science Enterprise's ability to model "climate days" in a single day from 900 to more than 2,900, which is a critical capability for climate research and weather forecasting.



Human Capital

NASA's renowned technical workforce—comprised of scientists, engineers, and technicians—is the foundation of the Agency's success, both near-term and long-term. These highly trained and experienced individuals help set the direction for the Agency's programs, oversee and evaluate contracted research and mission efforts, and perform, as only NASA can, significant portions of the Agency's programmatic activities. Perhaps less visible, but just as indispensable, is the professional and administrative workforce that supports the technical mission. These functional areas, including cost analysis, information technology, physical and cyber-security, and workforce management, are increasingly critical as the Agency continues to meet the managerial and technical challenges of the new century. The Aerospace Technology Enterprise actively engages in education and outreach to renew and maintain our critical technical workforce.

NASA has developed and issued a Strategic Human Capital Plan in recognition of the importance of the proactive management of the Agency's human resources, aligned with the Agency's Vision and Mission. The plan is based on five human capital pillars and their associated goals. These five pillars—strategic alignment, strategic competencies, life-long learning, performance culture, and leadership—serve as the foundation to strengthen the Agency and each individual Enterprise in areas where current activities do not exist or where significant improvement is needed.



NASA Center Locations

1. Ames Research Center*
2. Jet Propulsion Laboratory
3. Dryden Flight Research Center*
4. Johnson Space Center
5. Stennis Space Center
6. Marshall Space Flight Center
7. Glenn Research Center*
8. Kennedy Space Center
9. Langley Research Center*
10. NASA Headquarters
11. Goddard Space Flight Center

*NASA Centers managed by the Aerospace Technology Enterprise

From when it was established in 1917 as America's first civilian aviation and space research lab until today, NASA Langley Research Center's work has had a significant impact on the global economy. Located in Hampton, VA, Langley leads NASA's initiatives in aviation safety, quiet aircraft technology, small aircraft transportation, and aerospace vehicles system technology.

The Aerospace Technology Enterprise fully supports the NASA Strategic Human Capital Plan, and the Enterprise's four Research Centers are actively planning and implementing activities in support of the five human capital pillars outlined in this document. In addition, the Enterprise is actively addressing two overarching human capital issues of particular importance to the Agency:

- Maintaining core competencies in light of current demographics and evolving programmatic requirements

- Effectively leveraging a constrained resource (civil service workforce), focusing on appropriate in-house activities, and making full use of the skills and abilities of our industry, academic, and government partners

The Enterprise is pursuing a three-pronged strategy for addressing these workforce challenges. First, the Enterprise supports the Agency's efforts to develop and use a competency management system to shape future recruiting and retention strategies at each Center. This system allows the Enterprise to monitor the skills and capabilities of the current workforce, develop requirements associated with future programmatic activities, and understand the gaps between these future requirements and current skills. A retention strategy for current NASA professionals is critical and, to this end, we are establishing a comprehensive distance and continuing education program for the Enterprise workforce.

Second, the Enterprise proactively applies the full range of existing workforce tools to manage its human capital resources, as well as support

Located in California's Silicon Valley, Ames Research Center was established in 1940. The Center plays a critical role in supporting NASA's missions in aeronautics and space science, as well as Earth and biological sciences. Ames is an Agency leader in information technology and conducts vital research in fields of nanotechnology and biotechnology.

Agency plans to secure new workforce flexibilities. A major initiative in this area is the renewed emphasis on term and temporary employees that will enable the Enterprise to respond more quickly to fluctuations in program requirements. In addition, the Enterprise will continue to use a full suite of retirement incentives, including targeted buyout and early out, to help re-balance the skill sets at the Research Centers.

Third, the Enterprise develops management mechanisms to sustain competencies in a full-cost environment. Near-term, the Agency's workforce is largely determined by ongoing programs; however, there is a critical need to maintain and nurture competencies required for the future success of the Agency.

Effective, competency-based management of the in-house workforce will complement the other overarching issue—the need to use the best of the best—whether inside or external to the Agency, to plan and conduct the Enterprise's programs. This need is driven by mutually reinforcing goals, focusing the in-house workforce on those areas that are appropriate only for NASA personnel, and ensuring that the Enterprise takes advantage of the wide range of ideas and skills available from the public and private sectors.

Partnerships

The Enterprise, through its four Research Centers, will pursue innovative approaches and partnerships with industry, academic institutions, and other government agencies to leverage its in-house workforce and ensure access to outside expertise. The National Institute of Aeronautics (NIA) at the Langley Research Center is representative of such collaborative efforts. The NIA, a joint venture between Langley, the American Institute of Aeronautics and Astronautics (AIAA) Foundation, and six university partners, will draw upon the expertise of these external partners to conduct aerospace and atmospheric sciences research, foster graduate education in science and engineering, commercialize new intellectual property, and conduct outreach activities. The planned University-Affiliated Research Center (UARC) at the Ames Research Center is another example of future collaborative ventures.

Finally, the Enterprise fully supports the use of competitive sourcing as a tool for achieving the most appropriate balance between civil service

and non-NASA activities. Each of the four Research Centers currently has competitive sourcing plans in place and initial activities underway. The Enterprise will continue to support efforts to tailor competitive sourcing to best serve the needs of the Research Centers.

4.2 Management

Infrastructure Management

Effective management of the Enterprise's physical research infrastructure is critical to achieving mission success. Consistent with the NASA Strategic Plan, the Enterprise will work to ensure that its physical assets are properly aligned with the Enterprise mission, maintained in sound operating condition, and operated in a safe and environmentally sound manner. We also will use non-NASA assets wherever possible and pursue innovative approaches to the acquisition, utilization, and divestment of our physical infrastructure.

Particularly critical to the Enterprise at this juncture is the proper alignment between physical assets and programs. The Aerospace Technology Enterprise has undergone significant change in the past decade and its investment in supporting infrastructure has followed suit. For example, demand both inside and external to the Agency for large aerodynamic, aerothermodynamic, and aeropropulsion test facilities (e.g., wind tunnels and engine test stands) has declined as the number of new aircraft development programs (both commercial and military) has dropped. Correspondingly, NASA now operates about half the number of these facilities compared to 10 years ago. The Enterprise will continue to make decisions to maintain or divest such facilities according to program and mission demand. Future Center facilities and infrastructure requirements will be incorporated into the Center implementation plans consistent with Center master plans. Each Center's master plan provides the roadmap for the development of the Center's physical assets, including land, facilities, resources, and infrastructure in support of the goals of the combined Enterprise plans.

NASA is but one component, however, of a broader national test capability—the other major component is the DOD. Decisions regarding research and test facility investments must be made in full consultation with the DOD and the customers of each facility. NASA joined DOD in the National Aeronautical Test Alliance (NATA) to enable coordinated decisionmaking in this key area. Among other responsibilities, NATA serves as a forum for ensuring that facility investments made by NASA and the DOD are complementary, and not duplicative.

Over the past 50 years, work done at Dryden Flight Research Center, at Edwards Air Force Base, California, has led to major advances in aircraft designs and capabilities. The Center's history is the story of modern flight research in America. From the X-1 breaking the "sound barrier" to advances in space technology, the newest, the fastest, and the highest have all made their debuts in the clear desert skies over Dryden.

The Enterprise is pursuing initiatives in effective management of supporting infrastructure. For example, the Ames Research Center is embarking on a renovation by replacement strategy which—recognizing the full life-cycle cost of research laboratory buildings—will replace older high-maintenance facilities with energy- and space-efficient, environmentally friendly buildings. Recent congressional approval to establish working capital funds within the Agency contributes to this and other initiatives, including enhanced use leasing.

4.3 Enterprise Program Management

The Enterprise has responsibility for 4 of NASA's 18 themes. Within the Enterprise, the themes act

as managing entities with a theme director. The themes strategically direct the Enterprise's research and technology programs, as summarized in table 4.1 and discussed at length in section 3. The themes are aligned to specific budget lines to provide better insight into the performance of the Enterprise and linkage with the Agency's Strategic Plan.

To strengthen this alignment, the Enterprise has been reorganized to include an Enterprise-wide strategic planning and program integration and coordination entity (the Strategy, Communications, and Program Integration Division), as well as specific divisions that are aligned with each theme. Each theme is managed at NASA Headquarters through a director who reports to the Associate Administrator and is accountable for the theme's performance. The "Lead Center" concept has been replaced by the establishment of program managers who are accountable to the theme directors for program performance.

The research and technology development activities which comprise the Enterprise's programs are conducted at one or more of the NASA Centers. The Center directors are accountable for projects conducted at their Center and are responsible for providing the facilities and research staff required to achieve specific project objectives and program goals. Project managers report to their respective Center directors and communicate directly with program managers.

The Associate Administrator manages the Enterprise with the advice and counsel of an executive board, which includes the center directors of the four Research Centers (Ames, Dryden, Glenn, and Langley) and other Center directors who are responsible for major parts of the Enterprise programs.

Table 4.1

Theme	Program
Aeronautics Technology	• Airspace Systems • Aviation Safety and Security • Vehicle Systems
Innovative Technology Transfer Partnerships	• Technology Transfer Program • Small Business Innovative Research/Small Business Technology Transfer
Mission and Science Measurement Technology	• Computation, Information and Communications Technology • Enabling Concepts and Technology • Engineering for Complex Systems
Space Launch Initiative	• Orbital Space Plane • Next Generation Launch Technologies

Aerospace Technology Enterprise Programs by themes.

Investment Strategy

The Enterprise's research and technology investment strategy is based on national priorities, national and international trends, and U.S. policy regarding research and technology. The investment strategy is supported by sound systems analysis to assess the needs of the Enterprise's technology customers and partners, and the performance of ongoing programs in meeting those needs. The Program Assessment and Rating Tool (PART), a new performance tracking tool developed by the Office of Management and Budget (OMB), is used to inform budget decisions, support management, identify design problems, and promote performance measurement and accountability.

Implementation

Once investment strategy decisions are in place, the Enterprise formulates programs and projects to develop advanced technologies and technology products. Systems analysis continues during the formulation process to refine the schedule and resource requirements for the development of technical products and deliverables (outputs) that result in outcomes which meet customer needs and accomplish the goals articulated in the NASA Strategic Plan. At the conclusion of the formulation process, a baseline for implementation is established.

A successful R&T program delivers truly innovative concepts and revolutionary techniques that realize NASA's Vision and Mission. The revolutionary nature of the Enterprise's work makes the accomplishment of planned milestones a continual challenge. Leaps of knowledge in advanced R&T development typically occur in conjunction

with occasional unexpected results. In this dynamic environment, managing risk and controlling change are the key components for successful implementation. Specific risk-management approaches and control requirements are established for each Enterprise theme and program.

As employed by the Enterprise, risk management is a structured, continuous process to identify and track program risks, assess and analyze the risks based on their likelihood and consequence, and implement strategies to mitigate risks. The primary risk categories for an R&T program are technical—critical enabling technologies encountering unexpected developmental difficulties, physical risks to personnel and property—and programmatic—resources, schedule, and partnership challenges.

When risk mitigation is implemented, accommodating changes must be made to specific program plans which guide technology development. Systems analysis, a key component of program and project formulation, is also critical for change management. In this context, the Enterprise uses systems analysis in conjunction with regular program reviews to reallocate resources, modify work schedules, and ensure that elements critical to meeting program objectives are maintained. Configuration management systems are used to track changes and provide for the documentation, control, accounting, and verification of product requirements and configurations throughout a program's life cycle. Standard processes are used in accordance with relevant NASA and industry standards and publications.

Independent Reviews

Independent review of the themes and programs has three dimensions: performance, quality, and relevance. Performance reviews assess the ability of a program to manage its resources to achieve its objectives. Quality reviews ensure that research and technology conducted by the Enterprise are at the forefront of comparable work in the field. Relevance reviews examine the connection between the theme and the customer. The results of these reviews are factored into both future implementation and Enterprise investment strategy.

Typically, performance reviews are conducted by independent review teams that assess the technical, schedule, and resource planning related to the execution of a theme's programs, projects, and tasks. Performance review results are presented to the appropriate management councils. In addition to independent reviews, internal status reviews of theme, program, and project activities also are presented to senior management on a quarterly basis.

The men and women of the John H. Glenn Research Center at Lewis Field, Cleveland, OH, have, since 1941, been pioneers and innovators whose work has expanded horizons and opened frontiers for our explorers in air and space. The Center defines and develops propulsion, aerospace power, microgravity science, and communications technologies for NASA's aeronautics and space missions.

The National Research Council (NRC) conducts triennial quality reviews of each theme, which consists of an exhaustive review of the themes at the principal investigator level. The NRC findings are then put through an external peer-review process to ensure that conflicts of interest are minimized. In addition, the Aerospace Technology Advisory Committee conducts relevance reviews through subcommittees associated with each theme. The findings of these reviews are presented to the Aerospace Technology Enterprise Associate Administrator as well as the NASA Advisory Council.

Documentation

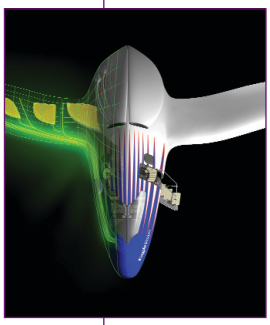
Once Enterprise programs are accepted for implementation, a series of standardized NASA documents establish the baseline to which they will be managed and by which subsequent technical

(as well as cost and schedule) progress will be measured. The Program Commitment Agreement, which serves as the overall controlling document, is a contract between the NASA Administrator and the Enterprise Associate Administrator. This document also represents the agreement between the theme director and the Associate Administrator. A second document, the Program Plan, represents the agreement between the theme director and the program manager. The agreement between the program manager and the participating Center director and Center project manager is represented by the Project Plan document.

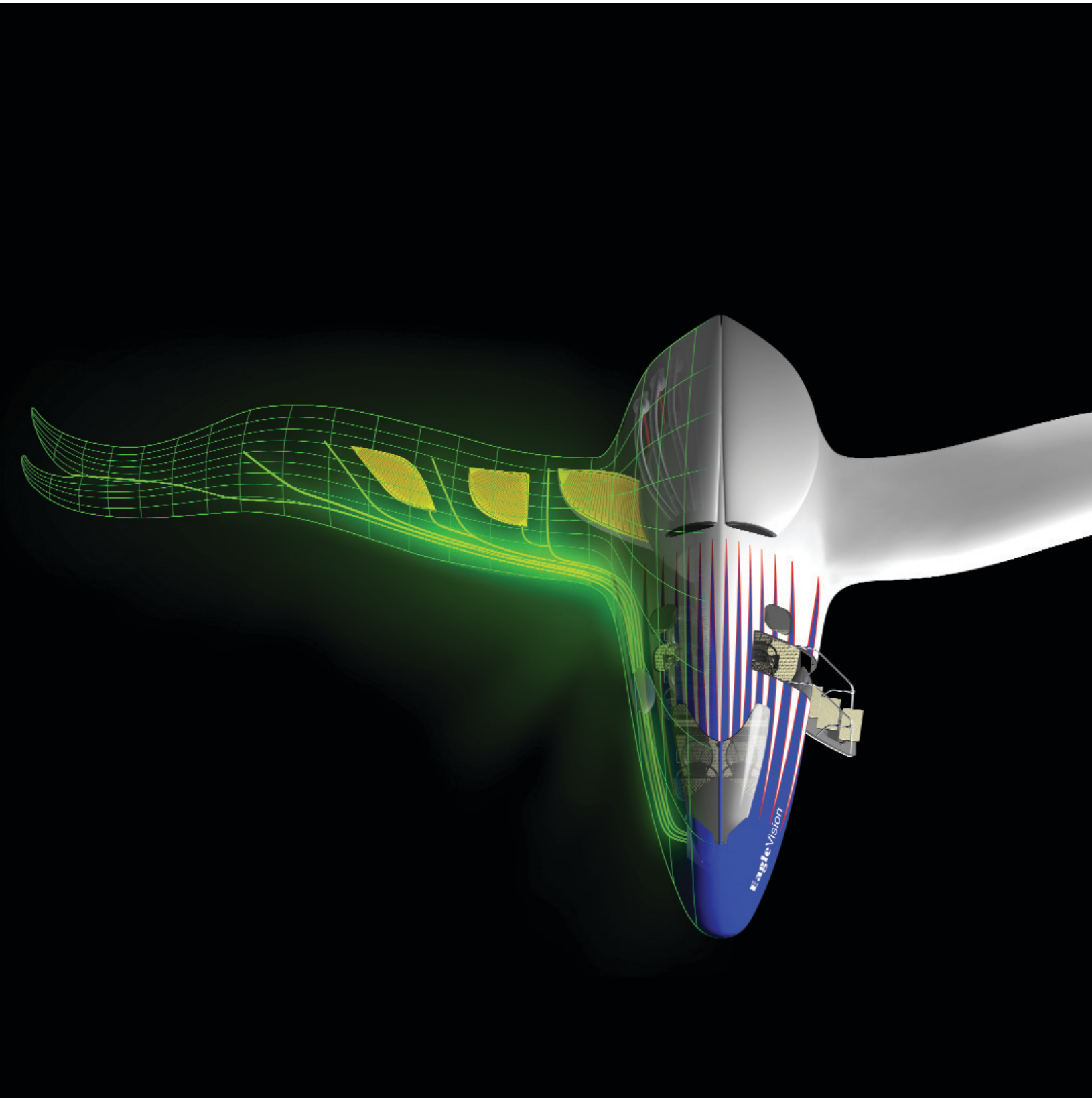
The Program Plan is a multi-year document that contains program management parameters such as cost, schedule, and formal agreements with implementation partners. This document also provides detailed descriptions of results-oriented performance goals and measures including minimum success criteria, identification of mitigation strategies for high-risk areas, and implementing strategies that articulate how goals and objectives will be achieved. In turn, Project Plans are also multi-year documents that capture the relationship of each individual research activity to the overall program objectives and milestones.

The Integrated Budget and Performance Document (IBPD) is prepared on an annual basis and is a key step in meeting the Budget and Performance Integration objective of the President's Management Agenda (PMA). This document takes the place of several separate documents including the annual budget request and the Agency Performance Plan. It directly links each theme's budget and programs to specific Agency missions, goals, and objectives as defined in the Strategic Plan. The IBPD contains both annual performance goals (APGs) and long-term outcome measures for each theme as well as technical and schedule commitments for each of the theme's programs. This provides the baseline against which the Agency and Enterprise measures incremental progress toward the achievement of the theme and Agency objectives and goals.

With a rich history spanning more than four decades, Marshall Space Flight Center, Huntsville, AL, is home to the Space Launch Initiative's Orbital Space Plane and Next Generation Launch Technology program offices and the International Space Station Payload Operations Center. Marshall is also a key leader in NASA's Earth science and space science research.



5 Beyond the Horizon


EagleVision

5 Beyond the Horizon

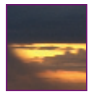
The many technology improvements made over the last 40 years have given the United States the most modern aviation fleet operating in the safest aviation system in the world. NASA has been a major contributor to these technology improvements. As we enter the 21st century, the emergence of biotechnology, nanotechnology, and information technology represents the dawning of a new era of development for aerospace vehicles and transportation systems. This new era has the potential to enable revolutionary changes in aircraft and space flight.

The aircraft of the future will not be built from multiple, mechanically connected parts. The aircraft will have smart materials with embedded sensors and actuators. Sensors—like the nerves of a bird—will measure the pressure over the entire surface of the wing and direct the response of the actuators—the muscles. These actuators will smoothly change the shape of the wing for optimal flying conditions.

With advanced materials, miniaturized sensors, and embedded actuators, aircraft could weigh half of what today's vehicles weigh. Lighter-weight vehicles and revolutionary technologies for engines and noise suppression will reduce fuel use and cut noise by over 50 percent relative to today's vehicles.

Intelligent systems comprised of smart sensors, microprocessors, and adaptive control systems

Emerging technology fields, such as nanotechnology and biologically inspired technology, coupled with continued advances in existing engineering and information technology fields, will one day enable the creation of a "morphing-wing" aircraft, capable of bird-like control of flight. Future concepts such as this, matched with operational advances, would dramatically elevate levels of flight safety and performance.

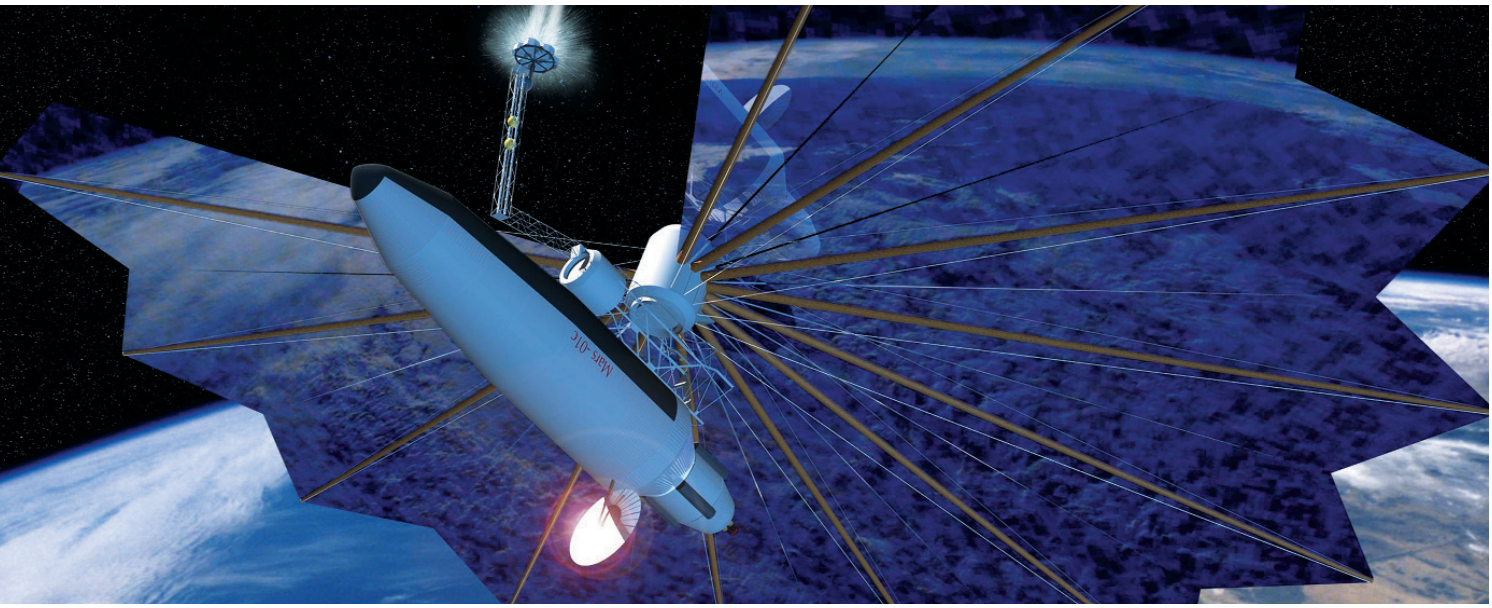


will enable aircraft and spacecraft alike to monitor their performance and environment and assist human operators in avoiding mishaps, incidents, and catastrophic failures. Distributed as a network throughout the vehicles, they will provide the means for imbedding a nervous system in the structure, stimulating it to create physical responses including being able to change shape. Intelligent systems will sense damage or impending failure long before they can lead to system failures. In some cases, vehicles could conduct self-repair, providing order of magnitude increases in safety and reliability while vastly lowering operating costs.

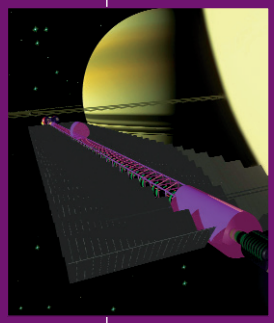
To achieve this, NASA will develop the tools and systems architecture to provide an intuitive, high-confidence, highly networked, engineering design environment. This interactive network will unleash the creative power of teams. Engineers and technologists, in collaboration with mission or product team members, will redefine the manner in which new vehicles or systems are developed. Designing from atoms into aerospace vehicles, engineering teams will have the ability to accurately understand all key aspects, including risk, of its systems, its operating environment, and its mission.

The possibilities are exciting and require a commitment to intensive research programs over the long-term. NASA's Aerospace Technology Enterprise has a history of successful technology programs that have revolutionized flight to what we know today. The actions that have led to this success are reflected in our strategies today. We know our customers and continue to partner with them for mutual and synergistic benefit. We have organized around our four themes to serve our customer base and achieve Agency goals. Our themes have clear strategies, identified partners, outcomes to measure success, insight into and support from NASA Field Centers, and solid accomplishments on which to base future success. We embrace education to maintain the vitality of our current workforce as well as attract students into careers that will ensure the vitality of our Nation's future technical workforce. Additionally, our management approach enables wise investment decisionmaking. Our infrastructure management focuses on maintaining and retaining core competencies and the facilities and programs to support this valuable human capital.

The challenge for continuing our tradition of successful programs in a rapidly changing technical, social, and political environment is to remain true to our Enterprise strategies. We have a critical role in achieving Agency goals, and this strategy provides the focus to succeed.



A number of advanced technologies will be needed to enable future space transportation systems. Shown is a system concept for payload transfers from low-Earth and high-Earth orbit. An inflatable structure with thin film solar cells (the kite-shaped panels), and 100 kilowatt-class Hall Effect Thrusters, helps position a Mars vehicle for the final leg of its journey.



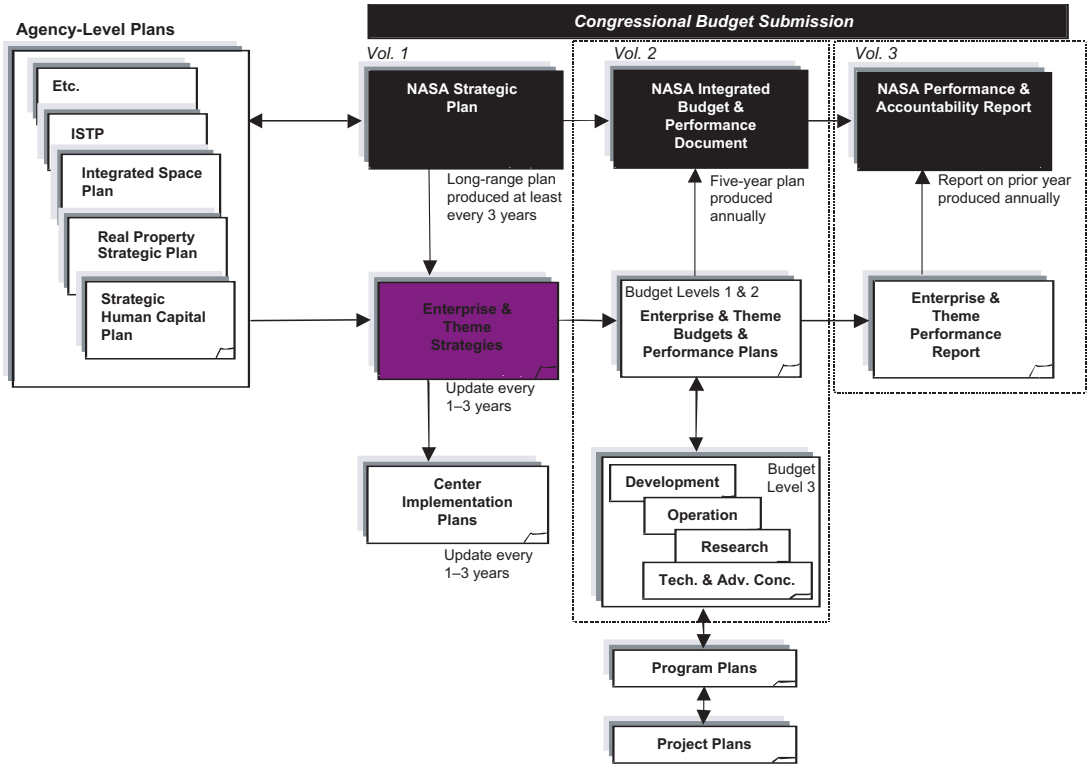
Appendices

Appendix 1

Relationship to Agency Planning

The Agency's planning process includes the development of a Strategic Plan, the annual budget, and a performance plan. The Strategic Plan is a 5-year plan, updated every 3 years, that defines the Agency's goals and objectives. The NASA Enterprises base their planning on the strategic emphasis, implementing strategies, goals, and objectives outlined in the Strategic Plan. In addition, Enterprise budget planning and performance reporting are directly traceable to the Agency-level documents.

The Enterprise Strategy communicates the results of the Agency and Enterprise planning processes to the NASA stakeholders and other audiences listed below.



Stakeholder/Audience	Enterprise Strategy Function
Executive and Legislative Branches	Communicate purpose and value of investments
NASA Employees	Achieve alignment within the Enterprise and Agency
Other NASA Enterprises	Strengthen inter-Enterprise collaboration
Science Community	Document consensus on objectives and priorities
Contractor Community	Communicate programmatic objectives and priorities
Interagency, International, and Commercial Partners	Establish basis for future collaborations
The Public	Inform and inspire

Appendix 2

Principal Enterprise Partnerships

Space Flight Enterprise

- Functional and operational requirements for new technologies
- Spaceport launch facilities
- Integrate payloads
- Conduct experiments on the Space Shuttle and on the ISS
- Service space telescopes
- Launch robotic spacecraft on expendable launch vehicles
- Rocket propulsion testing
- Communications and data services
- Education and public outreach programs

Aerospace Technology Enterprise

- Advanced technology development and transfer
- Aerospace Technology Enterprise assets
- Systems analysis capabilities
- Technology problem-solving expertise
- Commercial technology transfer to Enterprises
- Orbital Space Plane
- Airborne sciences
- Education and public outreach programs

Space Science Enterprise

- Functional and operational requirements for new technologies
- Functional and operational requirements for launch vehicles
- Manage Deep Space Network
- Manage optical communications development
- Manage Astrobiology Program
- Provide space weather data
- Education and public outreach programs

Biological and Physical Research Enterprise

- Functional and operational requirements for new technologies
- Functional and operational requirements for launch vehicles and ISS
- Biomedical research
- Operational protocols
- Physical science design and safety standards
- Data measurement for Mars related to sustainable human presence and safety
- Education and public outreach programs

Earth Science Enterprise

- Functional and operational requirements for new technologies
- Functional and operational requirements for launch vehicles
- Study of Sun-Earth connection
- Adapt Earth system models to other planets
- Assist in improving aviation safety
- Study effects of global change on human health
- Ground network services
- Education and public outreach programs

Education Enterprise

- Guidance and integration of other Enterprises' education programs
- Linkages of NASA education programs to other Enterprises' future competencies and skill requirements
- Public outreach programs

Key

- Supports Space Flight Enterprise
- Supports Aerospace Technology Enterprise
- Supports Space Science Enterprise
- Supports Biological and Physical Research Enterprise
- Supports Earth Science Enterprise
- Supports Education Enterprise

Appendix 3

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Appendix 4

NASA Center Contributions to the Aerospace Technology Enterprise

Aerospace Technology Enterprise Centers	Aeronautics Technology Theme				Innovative Technology Transfer Partnerships Theme			Mission and Science Measurement Theme				Space Launch Initiative Theme		
		Airspace Systems Program	Aviation Safety and Security Program	Vehicle Systems Program		Technology Transfer Partnerships Program	SBIR/STTR Program		Computation, Information, and Communications Technology Program	Engineering for Complex Systems Program	Enabling Concepts and Technologies Program		Orbital Space Plane Program	Next Generation Launch Technology Program
Ames Research Center		■	■	●		■	●		■	■			●	●
Dryden Flight Research Center		●	●	■		■	●						●	●
Glenn Research Center		■	■	■		■	●		■		■		●	■
Langley Research Center		■	■	■		■	●		●		■		●	■
Marshall Space Flight Center						■	●				●		■	■
Johnson Space Center						■	●				●		■	
Kennedy Space Center						■	●						■	●
Stennis Space Center						■	●						●	●
Goddard Space Flight Center						■	●		●	●	●		●	
Jet Propulsion Laboratory			■			■	●		■	■	■		●	●

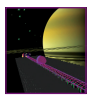
Center Contributions to the Aerospace Technology Enterprise

■ Primary Contributor ● Support

Appendix 5
Acronym List

AECC	Aerospace Education Coordinating Committee	**FAA**	Federal Aviation Administration
AIAA	American Institute of Aeronautics and Astronautics	**FSD**	Full Scale Demonstrator
ALTV	Approach and Landing Test Vehicle	**FY**	Fiscal Year
APG	annual performance goals	**GAJSC**	General Aviation Joint Steering Committee
ATM	Air Traffic Management	**IBPD**	Integrated Budget and Performance Document
ATS	air traffic system	**ICAO**	International Civil Aviation Organization
CAST	Commercial Aviation Safety Team	**IPD**	Integrated Powerhead Demonstrator
CDR	Critical Design Review	**ISS**	International Space Station
CICT	Computing, Information, and Communications Technology (Program)	**ISTP**	Integrated Space Transportation Plan
CNSi	Communication, Navigation, Surveillance, and Information	**ITTP**	Innovative Technology Transfer Partnerships (theme)
CO_2	carbon dioxide	**JWG**	Joint Working Group
CRV	Crew Return Vehicle	**LEO**	low-Earth orbit
DART	Demonstration of Autonomous Rendezvous Technology	**MBR**	Mission Baseline Review
DHS	Department of Homeland Security	**MSM**	Mission and Science Measurement Technology (theme)
DOD	Department of Defense	**NAS**	National Airspace System
ECS	Engineering for Complex Systems (Program)	**NASA**	National Aeronautics and Space Administration
ECT	Enabling Concepts and Technologies (Program)	**NATA**	National Aeronautical Test Alliance

NGLT	Next Generation Launch Technology (Program)
NIA	National Institute of Aeronautics
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NPG	NASA Procedures and Guidelines
NRC	National Research Council
NSF	National Science Foundation
OMB	Office of Management and Budget
OSP	Orbital Space Plane (Program)
PAD	Pad Abort Demonstrator
PART	Program Assessment and Rating Tool
PDR	Preliminary Design Review
PMA	President's Management Agenda
PSA	Personal Satellite Assistant
R&D	research and development
R&T	research and technology
RLV	Reusable Launch Vehicle
SBIR	Small Business Innovation Research (Program)
SDR	System Definition Review
SLI	Space Launch Initiative (theme)
STEM	science, technology, engineering, and mathematics
STOL	Short Take-Off and Landing
STTR	Small Business Technology Transfer (Program)
TEB	Technology Executive Board
TMA	Traffice Management Advisor
TSA	Transportation Security Administration
UARC	University-Affiliated Research Center
UAV	Unmanned Aerial Vehicles
USAF	United States Air Force
USDA	United States Department of Agriculture
VAD	Ventricular Assist Device



Appendix 6

Enterprise Acknowledgments

The NASA Aerospace Technology Enterprise would like to express appreciation for the work undertaken by the members of our community to help formulate the Aerospace Technology Enterprise Strategy.

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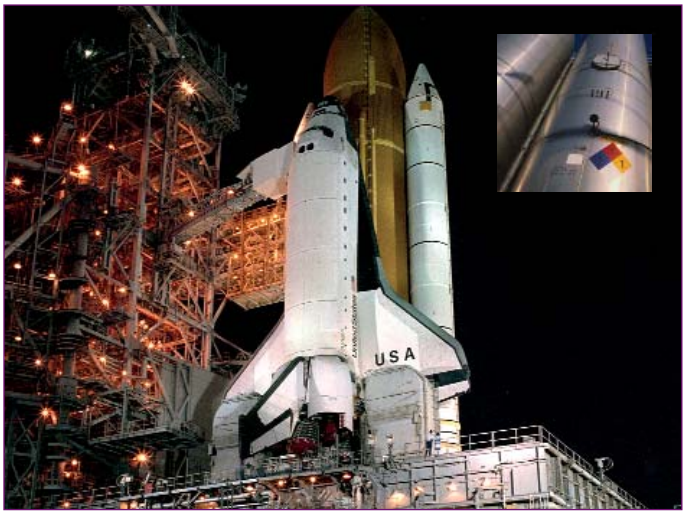
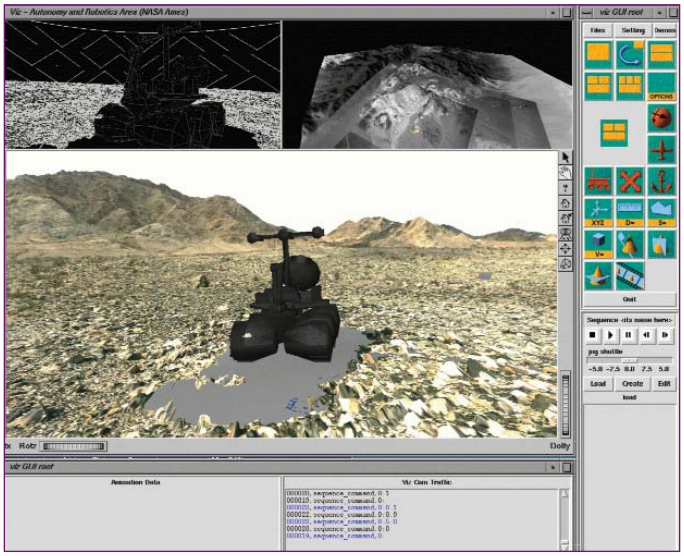
FutureFlight Central is an interactive air traffic control tower simulator and research facility with a mission to improve the safety, efficiency and cost-effectiveness of airport procedures, designs and technologies. Dallas-Ft. Worth airport tower controllers are shown using the facility during a successful evaluation for an airport taxiway concept.

The Aeronautics Technology theme formed a partnership that combined Honeywell's Weather Information Network, United Airlines aircraft, and NASA weather display technology. This partnership demonstrated the ability to choose the best route for passenger aircraft through storms. This technology system is now available for use by airlines. As a result, passengers will have fewer weather related delays and smoother flights.



NASA engineers enhanced a process known as Friction Stir Welding (FSW). This has contributed to reducing material distortion and contamination and producing greater strength in FSW applications in aerospace and other industries. The FSW innovation was commercialized through the Innovative Technology Transfer Partnerships theme, and used in an upgrade to the Space Shuttle External Tank to provide a high degree of reliability and an increased safety margin.



The Mission and Science Measurement Technology theme has developed a suite of advanced information technologies that will streamline mission operations for the Mars Exploration Rover. One of these technologies is a terrain visualization tool that maps hundreds of images acquired by the rover into a three-dimensional model of the Martian surface. This tool will help mission scientists select targets for the rover to investigate, and facilitate the planning of paths to traverse the surface.

We measure success by the extent to which our results are used by others to achieve these outcomes for NASA and the Nation.

National Aeronautics and
Space Administration

NASA Headquarters
Washington, DC 20546
NP-2003-01-298-HQ

http://www.nasa.gov