Aerospace Technology Enterprise

Strategic Plan

The Aerospace Technology Enterprise is an investment in America's future.

The future we see includes:

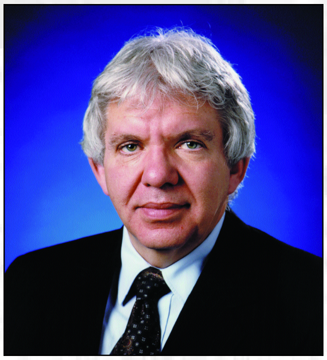
- A safer, cleaner world, in which the safety of air transportation is unquestioned and aircraft noise and emissions are dramatically reduced.

- A more open world, in which people everywhere can quickly, easily, and inexpensively travel wherever their lives lead them.

- An expanded world, in which space is fully opened for all human endeavor

- A world of opportunity, in which technologies developed through NASA's R&D investment are fully exploited for the benefit of our society.

Letter from the Associate Administrator



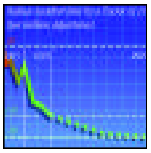
This strategic plan represents our blueprint for a new era in aerospace for the United States. The plan sustains the commitment of NASA's Aerospace Technology Enterprise to the Nation with technologies that contribute to the public good, quality of life, and national security. The challenges and opportunities facing the Nation in commercial transportation for both air and space, and for civil space and exploration, provide the imperative for our Goals and Objectives. A revitalized commitment to innovation in technology and engineering practices provides the vision and means to achieve these Goals and Objectives.

This is an exciting time for aerospace technology. New expertise and research directions in areas such as information technology, nano-technology, and biologically-inspired technologies are all creating new possibilities. Coupled with our traditional aerospace engineering competencies such as aerodynamics, guidance and controls, and materials and structures, these new competencies will enable levels of performance and functionality that were unimaginable only a decade ago. We can now envision a wing that "morphs" its shape, a structure that heals itself, and a control system that senses and controls its own operations down to the molecular level. This is truly one of those unique periods of discovery, during which we can match our traditional strengths with emerging capabilities to produce a new era in aerospace.

This plan and the supporting programs of the Enterprise are both exciting and important. We are continually looking for ways to increase our contributions to technological advancements in flight and our effectiveness in meeting the challenges that come our way. I invite you—our partners, customers, users, and stakeholders—to join with us in creating the future and turning goals into reality.

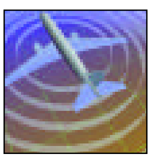
Samuel L. Venneri
April 2001

Goal One:
Revolutionize Aviation
Enable a safe, environmentally-friendly expansion of aviation
(Baseline: 1997)

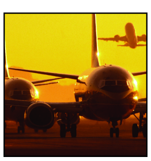


Increase Safety:
Make a safe air transportation system even safer
Objective 1: Reduce aviation's fatal accident rate by a factor of 5 within 10 years, and by a factor of 10 within 25 years.

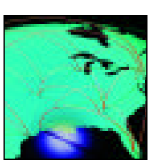
Reduce Emissions:
Protect local air quality and our global climate
Objective 2: Reduce NO_x emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NO_x as the baseline). Reduce CO_2 emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).



Reduce Noise:
Reduce aircraft noise to benefit airport neighbors, the aviation industry, and travelers
Objective 3: Reduce the perceived noise levels of future aircraft by a factor of 2 (10 decibels) within 10 years and by a factor of 4 (20 decibels) within 25 years, using 1997 subsonic aircraft technology as the baseline.



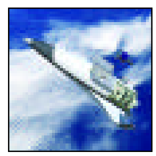
Increase Capacity:
Enable the movement of more air passengers with fewer delays
Objective 4: Double the capacity of the aviation system within 10 years and triple it within 25 years, based on 1997 levels.



Increase Mobility:
Enable people to travel faster and farther, anywhere, anytime.
Objective 5: Reduce inter-city door-to-door transportation time by half in 10 years and by two-thirds in 25 years, and reduce long-haul transcontinental travel time by half within 25 years.

Goal Two:
Advance Space Transportation
Create a safe, affordable highway through the air and into space.
(Baseline: 2000)

Mission Safety:
Radically improve the safety and reliability of space launch systems
Objective 6: Reduce the incidence of crew loss for a second generation Reusable Launch Vehicle (RLV) to 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1 million missions (an additional factor of 100) for a third generation RLV by 2025.

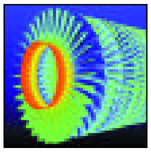


Mission Affordability:
Create an affordable highway to space
Objective 7: Reduce the cost of delivering a payload to Low-Earth Orbit (LEO) to $1000 per pound (a factor of 10) by 2010 and to $100 per pound (an additional factor of 10) by 2025. Reduce the cost of interorbital transfer by a factor of 10 within 15 years and by an additional factor of 10 by 2025.

Mission Reach:
Extend our reach in space with faster travel
Objective 8: Reduce the time for planetary missions by a factor of 2 by 2015 and by a factor of 10 by 2025.

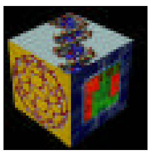
Goals and Objectives

Goal Three:
Pioneer Technology Innovation
Enable a revolution in aerospace Systems.



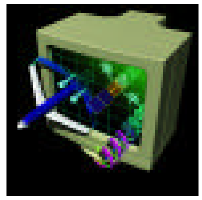
Engineering Innovation:
Develop advanced engineering tools, processes, and culture to enable rapid, high-confidence, and cost-efficient design of revolutionary systems

Objective 9: Within 10 years, demonstrate advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications; and within 25 years, demonstrate an integrated, high-confidence engineering environment that fully simulates advanced aerospace systems, their environments, and their missions.

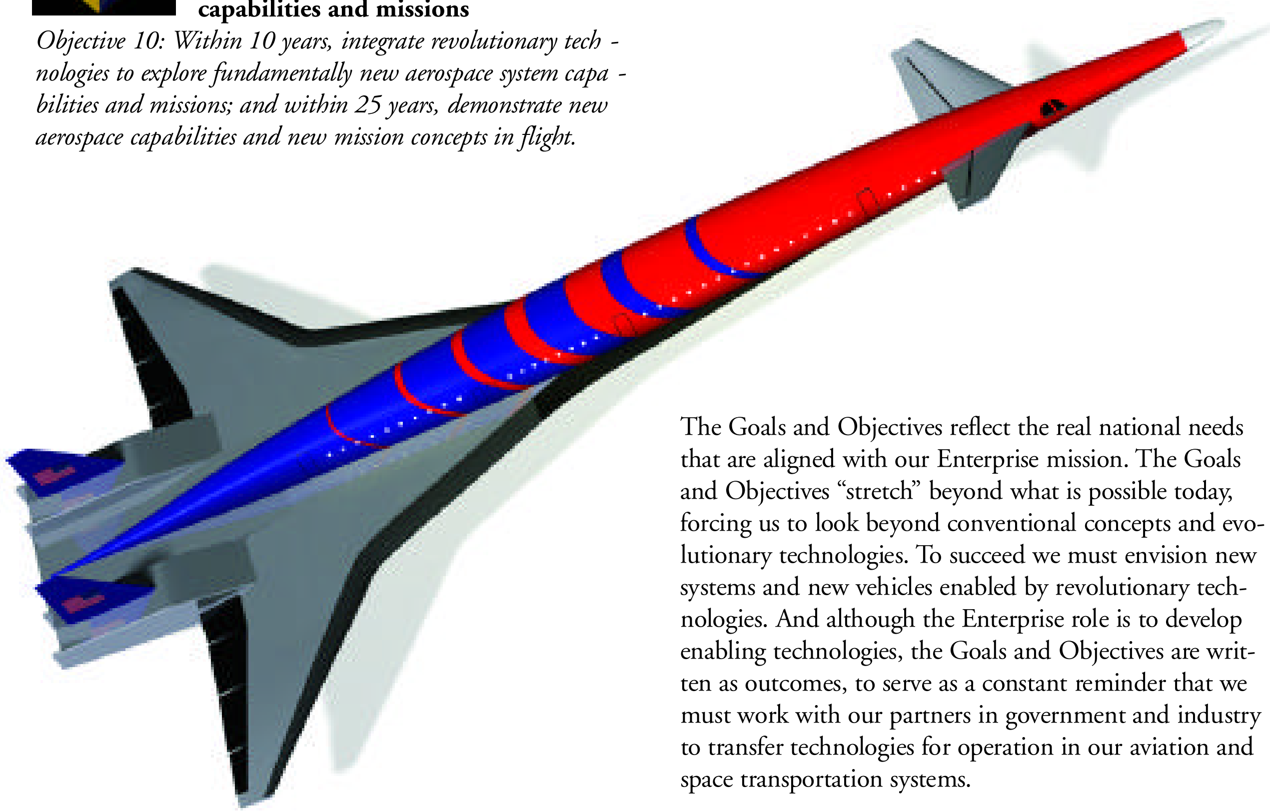


Technology Innovation:
Develop revolutionary technologies and technology solutions to enable fundamentally new aerospace system capabilities and missions

Objective 10: Within 10 years, integrate revolutionary technologies to explore fundamentally new aerospace system capabilities and missions; and within 25 years, demonstrate new aerospace capabilities and new mission concepts in flight.

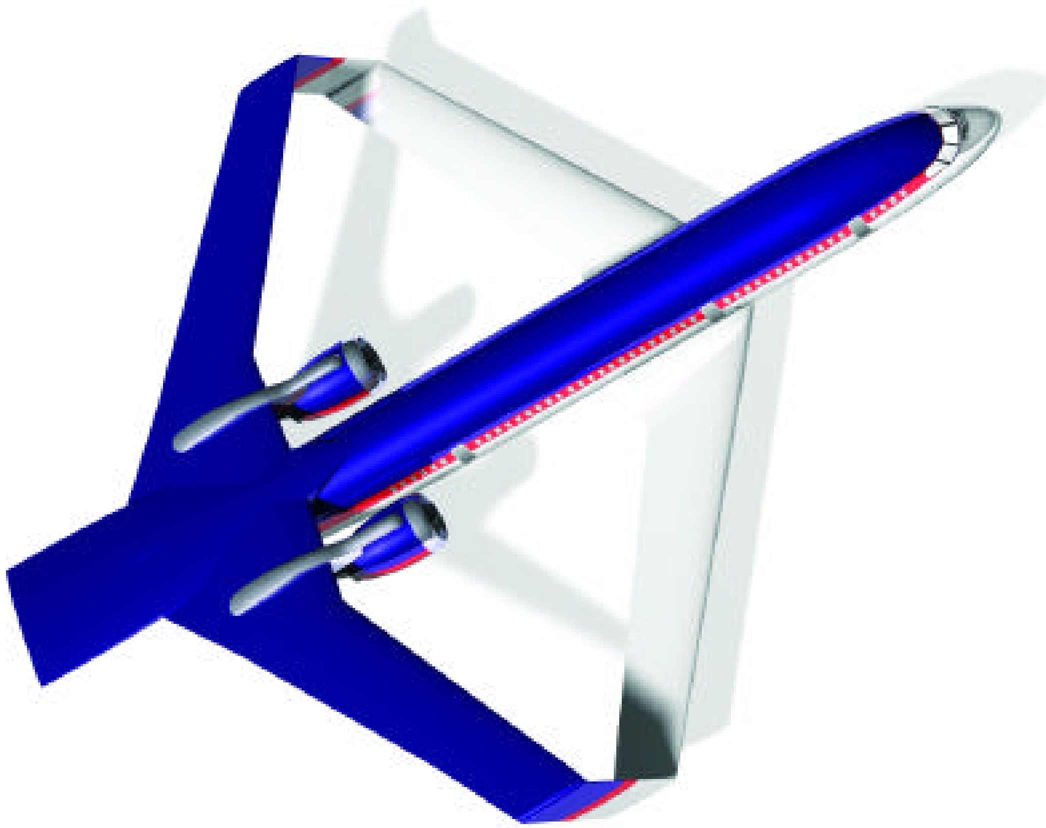


Goal Four:
Commercialize Technology
Extend the commercial application of NASA technology for economic benefit and improved quality of life.



The Goals and Objectives reflect the real national needs that are aligned with our Enterprise mission. The Goals and Objectives "stretch" beyond what is possible today, forcing us to look beyond conventional concepts and evolutionary technologies. To succeed we must envision new systems and new vehicles enabled by revolutionary technologies. And although the Enterprise role is to develop enabling technologies, the Goals and Objectives are written as outcomes, to serve as a constant reminder that we must work with our partners in government and industry to transfer technologies for operation in our aviation and space transportation systems.

NASA's charter is to pioneer advanced technologies that will meet the challenges facing air and space transportation, to maintain U.S. national security and preeminence in aerospace technology, and to extend the benefit of our innovations throughout our society.



Summary of Issues

- Both the economy and our quality of life depend on a safe, environmentally-friendly air transportation system that continues to meet the demand for rapid, reliable, and affordable movement of people and goods.
- To fully benefit from the revolution in communication and information technology, we also need a revolution in mobility.
- To open the space frontier to new levels of exploration and commercial endeavor, we must reduce cost and increase the reliability and safety of space transportation.

Strategic Basis

Strategic Basis for the Aerospace Technology Enterprise Goals and Objectives

A modern air and space transportation system is fundamental to our national economy, quality of life, and the security of the United States. For 75 years, a strong base for aerospace technology research and development has provided enormous contributions to this system; contributions that have fostered the economic growth of our Nation and provided unprecedented mobility for U.S. citizens. In the past 30 years we have reduced aircraft noise by a factor of 10, cut fuel consumption in half, and maintained a notably low accident rate despite a threefold increase in flight operations.

Although major technical advances have made our Nation's air and space transportation system the largest and best of its kind, the future holds critical challenges to its continued growth and performance. Meeting these challenges with effective solutions will require a sustained focus on long-term advances in science and technology.

Because the U.S. air and space transportation system serves both critical national security needs and the public good, ensuring the continued health and preeminence of that system is a key issue for the future of this Nation.

NASA is the Nation's leading government agency for providing technological leadership and advancements for the Nation's aerospace industry and the traveling public. To address the major needs for our future air and space transportation systems, NASA's Aerospace Technology Enterprise has formulated 10- and 25-year objectives in ten areas. Achieving these objectives would not only create a future system characterized by many new capabilities, but would also continue to contribute toward strengthening national security and improving the quality of life for all Americans. In addition to its role in advancing air and space transportation, the Enterprise has a role in developing basic technology for a broad range of space applications, such as aerospace communications, power and propulsion systems, microdevices and instruments, information technology, nano-technology, and biotechnology. These advances will allow space missions to expand our knowledge of Earth and the universe.

Importance of Air and Space Transportation to the U.S. Economy

Air travel is the preferred mode for long-distance travel, accounting for 50 percent of all personal travel farther than 1000 miles and 75 percent of travel farther than 2000 miles. For years, the amount of air cargo has been growing at a rate of 10 percent or more annually. Its growth is driven by increases in global commerce and a greater volume of high value, time sensitive cargo. In 1998, the total economic output attributable to aviation-related activity was $259 billion, or about 3 percent of the Nation's $8.67 trillion Gross Domestic Product (GDP). For aircraft alone, the projected market for the years 1999 to 2008 is in excess of $800 billion. Worldwide, the passenger and cargo air transportation markets together are growing at a faster rate than that of global GDP.

Historically, transportation and communication have always been integrally linked. Today, tourism, e-commerce, and other factors such as economic growth and changing demographics are fueling demand for access to high-speed, highly distributed transportation systems. The transportation system for this new interconnected world must feature greater mobility, measured in terms of increased flexibility, greater convenience, shorter door-to-door trip times, and lower real costs.

Growth in the space sector is fueled by rapid acceptance of satellite and broadband services, a result of worldwide demand for various mobile services and the critical nature of business and consumer data. The media, internet, entertainment, and telecommunications communities have embraced satellites and made them an integral part of their overall infrastructure.[1] Fueled by non-government applications, industry revenues worldwide reached $97.6 billion in 1998 and, although revenues fell to $87 billion in 1999[2], experts expect continued steady growth.

For the U.S. commercial space launch industry, however, 1998 and 1999 were disappointing years, due to a string of failures that restricted the launch rate and slowed the development of new vehicles.

Increasingly, “commercial space” companies are smaller start-up companies (versus established aerospace companies) and are faced with a fundamental need for faster and less expensive development and delivery of systems. A number of entrepreneurial ventures have announced plans for commercial launch vehicles in hopes of capturing some of the strong market for launch services of commercial satellites. Satellite systems, projected to account for approximately two thirds of the demand for launches, are beginning to demonstrate how well they fit into the global information infrastructure.

As we begin the 21st century, our government’s space program seeks to forge a “Highway to Space” that will enable its citizens to travel, work and live in space as a matter of routine. NASA research will make it possible for industry and the private sector to make space transportation economical. This in turn will create enormous opportunities for commercial endeavors, new services, scientific and medical research, and other uses not yet imagined.

Limits to Growth

“Aerospace has for a number of years been among the most dynamic and expansive of U.S. industries. In 1998, domestic and international sales by U.S. aerospace companies were about $140 billion, or about 3% of all U.S. industrial manufacturing activity. New orders for the year totaled about $124 billion, and the backlog of orders at year-end amounted to $204 billion. The industry currently employs approximately 860 thousand Americans. The industry’s export performance has been most remarkable, particularly when compared to that of other U.S. industries. In 1998, exports reached $64 billion, while imports of aerospace products amounted to about $23 billion. This means the U.S. trade surplus in aerospace products was roughly $41 billion, a continuation of a long-term trend of positive trade balances.”[3]

Because of this and other impacts on the U.S. economy, aerospace systems are under heavy pressure to keep pace with rising demands. Unfortunately, aviation’s infrastructure is unlikely to expand in the foreseeable future in response to those demands, because of the noise and air quality impact on communities near airports. Therefore, rising demands must be accommodated by the airports and facilities that already exist.

[1] Source: PR Newswire, June 19, 2000, "Worldwide Revenues Soar to $87 Billion in 1999 to Increase by More Than 90 Percent Over Next Five Years."

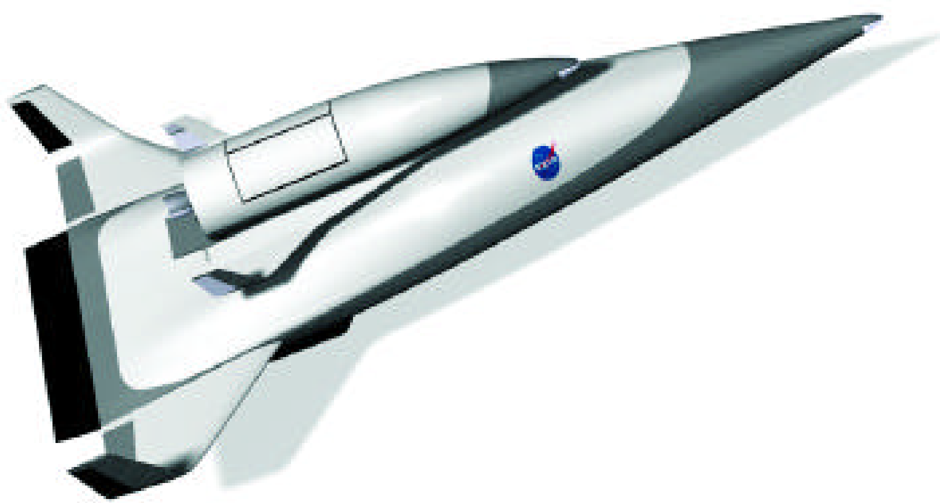
[2] Source: 1999 State of the Space Industry, 2000 State of the Space Industry, International Space Business Council.

[3] Source: Testimony by Joel L. Johnson, Vice President, International Aerospace Industries Association, to the House of Representatives Committee on Government Reform, June 29, 1999, Offsets Related to Military Sales.

The challenges for aviation are to improve safety and security, enable more flexible and efficient air traffic management, and eliminate the negative environmental impact of aircraft operations. Compounding these challenges is the reduced drive by the military for aerospace technology, due to the decline in military aerospace research and development (R&D) and procurement. In past decades, the motivation for advances in aerospace technologies was dominated by military needs: the partnership among NASA, Department of Defense (DoD), and industry rapidly advanced, matured, and integrated aerospace technologies; then these technologies were appropriated for commercial use, with great success.[4]

The main challenges for the space industry continue to be reliability and cost. Space launch is prohibitively expensive and risky for all but missions of national importance and the most lucrative commercial efforts, such as worldwide broadcasting satellites. Whether doing business in Earth orbit or exploring distant worlds, the first few hundred kilometers of the "Highway to Space" are the toughest part of the journey. Fully half the energy needed to go to the farthest planets in our solar system is devoted to escaping Earth's gravity and getting into low earth orbit. U.S. commercial launch vehicles are based largely on decades-old technology, and foreign companies now control the majority of the launch business once dominated by the United States.

The space industry is changing dramatically as it transitions from government-driven needs to market-driven growth. However, this industry is less mature than the aviation industry and the technologies are more complex. Increasing safety and reliability and reducing the cost of space transportation will expand its market and increase this industry's role in the economies of many nations.



[4] Examples of technology transfer from the military to the commercial sector: The turbine engine introduced on the B-707 was originally designed for military aircraft. The Pratt & Whitney J-57 and General Electric J-79 engines were also originally developed for military use. The B-707 airframe was developed jointly with a military tanker program. The DC-10, L-1011, and B-747 were developed based on research into wide-bodied aircraft, while competing for what became the C-5A military transport contract. Revolutionary fly-by-wire flight controls that were developed and first adopted for U.S. military aircraft are now incorporated into Boeing's newest commercial aircraft.

The Role of Technology

Technology has a significant role in meeting these challenges. Advanced physics-based modeling, simulation, new materials and structural concepts, and other technologies will enable quieter, more efficient aircraft and more robust and affordable spacecraft. A new information network for a modernized National Airspace System (NAS) will allow greater flight efficiency and capacity. As the space transportation system grows, it will be linked increasingly with the aviation system. In the future, a single aerospace system will serve both air and space transportation.

Aerospace has always been a leader in applying advanced technologies. New technology will drive the next wave of innovation, enabling missions to be performed in completely new ways and creating missions that were never before possible.

Technologies that enable simplified space transportation operations, robust design and operating margins, and near complete reuse of hardware have the potential to reduce costs dramatically. Equally important are new propulsion technologies that will enable new in-space operations, such as economical travel between low-earth orbit and geo-stationary orbits and faster travel to other planets and—ultimately—the stars. Safe, low-cost space transportation will make space commercially accessible for both passenger and cargo operations. It will also allow the continued expansion of human and robotic exploration throughout our solar system.

The Role of the Government

Problems with the environment and other elements of the aviation infrastructure, such as air system capacity and air traffic control, are not easily addressed by the private sector. The resulting delays and the noise and emissions pollution are not even priced in the market place. Economists term these problems "externalities" because, unlike other costs, no market participant pays for them directly. As a result, the private sector has inadequate incentives for addressing the very real problems that aviation imposes. Developing, maintaining, and regulating national transportation infrastructures, as well as other significant areas such as national security, are the responsibilities of the government.

Enterprise Field Centers

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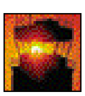
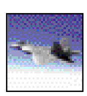
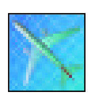
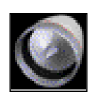
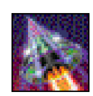
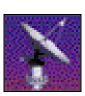
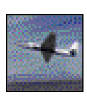
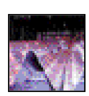
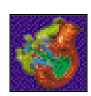
Mission	 *Aviation Operations Systems*	 *Flight Research*	 *Airframe Systems and Atmospheric Systems*	 *Aeropropulsion*	 *Transportation System Development*
Center of Excellence	 *Information Technology*	 *Atmospheric Flight Operations*	 *Structure and Materials*	 *Turbomachinery*	 *Space Propulsion*

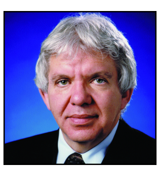
The government also has responsibility for maintaining a strong technology base for air and space transportation, to ensure the competitiveness of the U.S. economy. This is a multi-faceted issue that the government can affect as a direct or indirect result of policy. “Key factors that will influence future global [economic] growth are rates of productivity, technological innovation, international competition, improvements in aviation infrastructure, levels of defense spending, and support by governments for their aerospace industries.”[5]

The aerospace industry remains critically dependent on technology. Even as NASA’s priorities change to meet the changing needs of society, it still pursues long-term efforts in aerospace science and technology; efforts that would not be made otherwise, either by the private sector or by other government agencies.

NASA continues to play a unique role by connecting and leveraging the aerospace research infrastructure in both the private and public sectors. In this regard, partnerships remain a critical element in disseminating and applying NASA-developed technologies.

There is a strong relationship between leadership in aerospace technology and the economic, social, and political well-being of this Nation. Given this relationship, the Nation’s continued investment in aerospace technology research remains critical, and NASA’s role remains clear and vital.

Enterprise Executive Board



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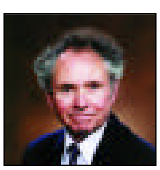

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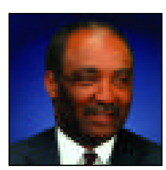

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[5] U.S. Industry & Trade Outlook 2000, International Trade Administration of the U.S. Department of Commerce, and The McGraw-Hill Companies, Inc., p. 21-1.

Future aerospace vehicles can be enabled by NASA technology. Pictured clockwise from the top: advanced general aviation aircraft, advanced rotorcraft, a tiltrotor aircraft used as an emergency medical transport, a 300-passenger supersonic transport, a 600-passenger subsonic transport (a Blended Wing Body concept), and a reusable launch vehicle for transporting cargo to orbit. Technology will also fundamentally change the way pilots, ground controllers, and schedulers communicate, to help enable highly-efficient and accident-free airspace and terminal operations.

Goal One: Revolutionize Aviation

NASA's goal is to enable the safe, environmentally friendly expansion of aviation.

Expanding the aviation system of the future to meet demands for growth will mean providing a more distributed, flexible, and adaptable network of airways. This growth must take place within the physical and environmental constraints of today's system, while meeting the evolving needs of air travel. The system of the future will continue to be international in scope, requiring close coordination across a global network. Advanced vehicles will operate in this new infrastructure, with better performance and new capabilities, such as "morphing" wings that optimize their shape for take-off, flight, and landing. Advanced information and sensor technologies will make air travel safer and more efficient. Air transportation will be easily accessible from urban, suburban, or rural communities and affordable for all citizens. Airplanes will be cleaner, quieter, and faster. NASA aims to revolutionize aviation by delivering the long-term, high-payoff aerospace technologies, materials, and operations research needed for enabling these new vehicle and system characteristics and capabilities.

Objective 1: Increase Safety
Make a safe air transportation system even safer.

Reduce the aviation fatal accident rate by a factor of 5 within 10 years and by a factor of 10 within 25 years.

Although the commercial aviation accident rate is very low, that rate has remained stubbornly constant for the past two decades. Even with the current low accident rate, the anticipated growth in commercial aviation would mean an accident frequency approaching a major accident every week. This could result in a perception that air travel has become unsafe, which could inhibit the full growth potential of the air travel market. This national objective is intended to reduce the accident rate such that, even with traffic growth and an aging aircraft fleet, the frequency of future accidents will be reduced as compared with the baseline period of 1990 to 1996.

NASA's strategy for achieving this objective is to pursue three major technology thrusts:

- System Monitoring and Modeling—Develop technologies for using the vast amounts of data available within the aviation system to identify, understand, and correct aviation system problems before they lead to accidents.
- Accident Prevention—Identify interventions and develop technologies to eliminate the types of accidents that can be categorized as "recurring."
- Accident Mitigation—Develop technologies to reduce the risk of injury in the unlikely event of an accident.

Metrics for quantifying progress in each of the thrust areas include accident rate, fatal accident rate, number of fatalities, and number of injuries.

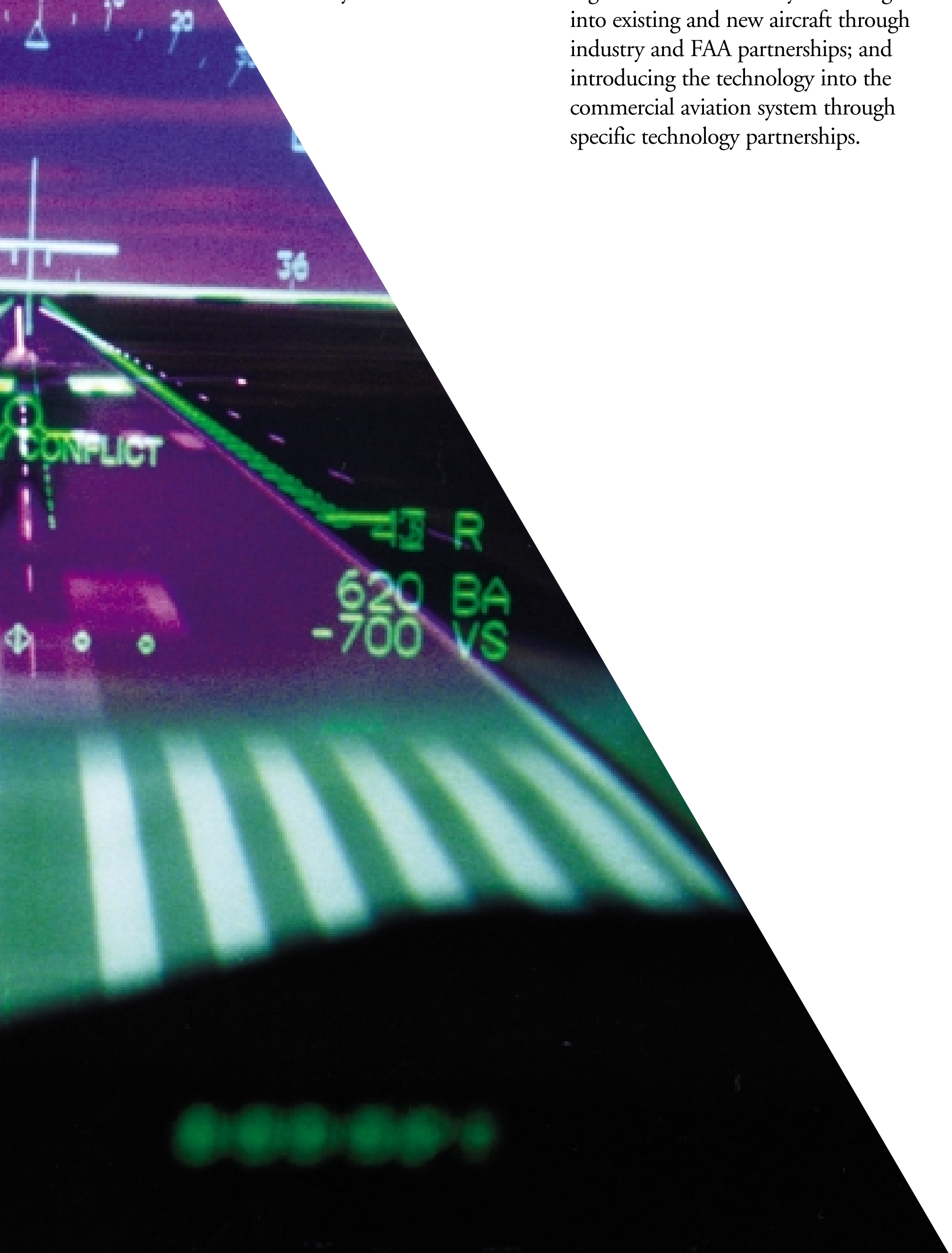
Outcomes
Successful research and development efforts that lead to improved vehicles and operational practices would result in:

- Elimination of major categories of recurring accidents.
- Early warning and prevention of hidden and potential safety issues.
- Reduced risk of injury to passengers and crew in the unlikely event of an accident.

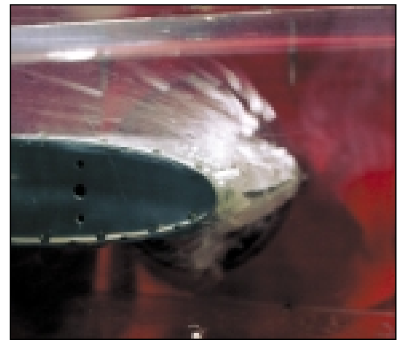
Synthetic vision systems being developed at Langley Research Center, combine accurate geo-positioning, digital terrain databases, and digital data links to portray an accurate representation of the terrain, air traffic, runway hazards, ground structures, and other equipment in low-visibility conditions. Such systems will help eliminate hazardous runway incursions and controlled-flight-into-terrain (CFIT) accidents, as well as improving all-weather operational efficiency.

Objective 1: Increase Safety

Key Strategy and Partnership Issues
Reducing the accident rate requires technologies and strategies that target recurring types of accidents and precursor events. Developing these technologies and strategies entails continually improving in our understanding of the root causes of accidents. To do so will require full, proactive access to and use of all the data available in the aviation system.



Success will require the formation of alliances with the Federal Aviation Administration (FAA) and others across the aviation community. We will also enhance our partnership with DoD to address common problems in aircraft safety, such as aging systems. Key aspects of these alliances include developing high confidence methods for determining the effectiveness of new tools and technologies; accelerating the insertion of safety technologies into existing and new aircraft through industry and FAA partnerships; and introducing the technology into the commercial aviation system through specific technology partnerships.



Officially known as the Electro-Expulsive Separation System, the "ice zapper" could greatly increase aircraft flight safety. It uses one-thousandth the power and is one-tenth the weight of typical electrothermal ice removal systems and can remove layers of ice as thin as frost or as thick as an inch of glaze. This high-speed photo captures ice as it is zapped from a wing surface.

Objective 2: Reduce Emissions

Protect local air quality and our global climate.

Reduce NO_x emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NO_x as the baseline). Reduce CO_2 emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).

The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection is addressing worldwide concerns about local air quality and climate change. The 1999 report "Aviation and the Global Atmosphere," issued by the Intergovernmental Panel on Climate Change (IPCC), projects that aviation's emission of carbon dioxide (CO_2) in the year 2050 will be up to 10 times greater than in 1992. Furthermore, in response to stringent ozone and particulate matter standards under the U.S Clean Air Act, local authorities and environmental groups are demanding action from Federal agencies and air carriers. They want to reduce emissions of nitrogen oxide (NO_x), which is suspected of contributing to toxic ozone production, as well as other pollutants. In the long run, technology is superior to other actions such as regulation, which could constrain aviation growth.

Lean-burning (low fuel-to-air ratio) combustors can greatly reduce engine emissions, but they have an increased susceptibility to thermo-acoustic instabilities. These high-pressure oscillations, much like sound waves, can fatigue combustor components and even the downstream turbine blades, decreasing their safe operating life. With active combustion control, being developed at Glenn Research Center, pressure oscillations can be put into the system by pulsing the fuel (shown above), canceling out the oscillations from the instabilities. Thus, the engine can have lower pollutant emissions and a longer life. Shown are the pulsating fuel modulations used to suppress combustion instabilities.

Objective 2: Reduce Emissions

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Airframe Weight and Drag Reduction**—Develop airframe technologies that reduce fuel consumption and therefore reduce CO_2 and NO_x emissions.
- **Propulsion Optimization**—Develop advanced engine system technologies to reduce emissions such as NO_x that have an impact on local air quality and those such as CO_2 that affect the global climate.
- **Operation Optimization**—Develop more efficient operations at and around airports, in order to reduce aviation fuel burn and therefore reduce emissions.
- **Alternative Vehicle Concepts**—Develop advanced concepts for propulsion systems, airframe structures, and fuels that dramatically reduce or completely eliminate emissions from civil aviation aircraft.

Metrics for these thrusts include the reductions in the percentage of Landing/Take-Off (LTO) NO_x (relative to those in the 1996 ICAO LTO NO_x standard), total NO_x (g NO_x/asm), and total fuel burn/CO_2 (kg CO_2/asm).

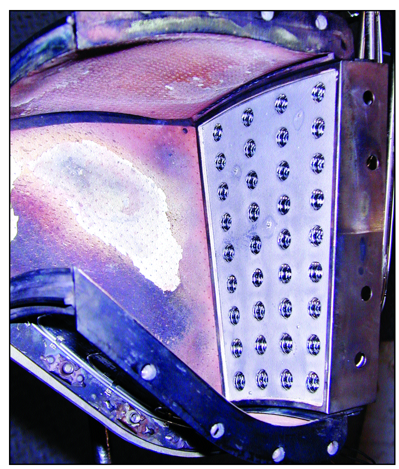
Outcomes

Successful research and development efforts that lead to improved vehicles and operational practices would result in:

- Significant or total elimination of aircraft emissions as a source of climate change.
- Minimized impact of emissions on local air quality.
- Elimination of unnecessary aviation emissions due to operational procedures.
- Non-traditional, environmentally compatible modes of propulsion for civil aviation.

Key Strategy and Partnership Issues

Aviation has continually adopted the best technologies with each succeeding generation of aircraft. As a result, the aviation industry is not able to apply "quick fixes" in response to demands for reduced emissions. In implementing emissions reduction technologies, a careful balance must be maintained to ensure success. The new technologies must be consistent and compatible with affordable air travel, airspace operations, and noise reduction technologies, and must not have a negative impact on safety. Likewise, improved aircraft operations to reduce emissions must be compatible with capacity improvements. NASA will work with DoD to leverage technologies that contribute to aircraft efficiency; and will also work with industry, the FAA, the Environmental Protection Agency (EPA), and international organizations to ensure that technology development and adoption are viable alternatives to regulation.



The next generation of revolutionary combustors will employ multipoint arrays of lean-burning combustion zones to enable reduction of NO_x emissions to extremely low levels. This multipoint array of lean direct injectors is shown integrated into a sector combustor rig.

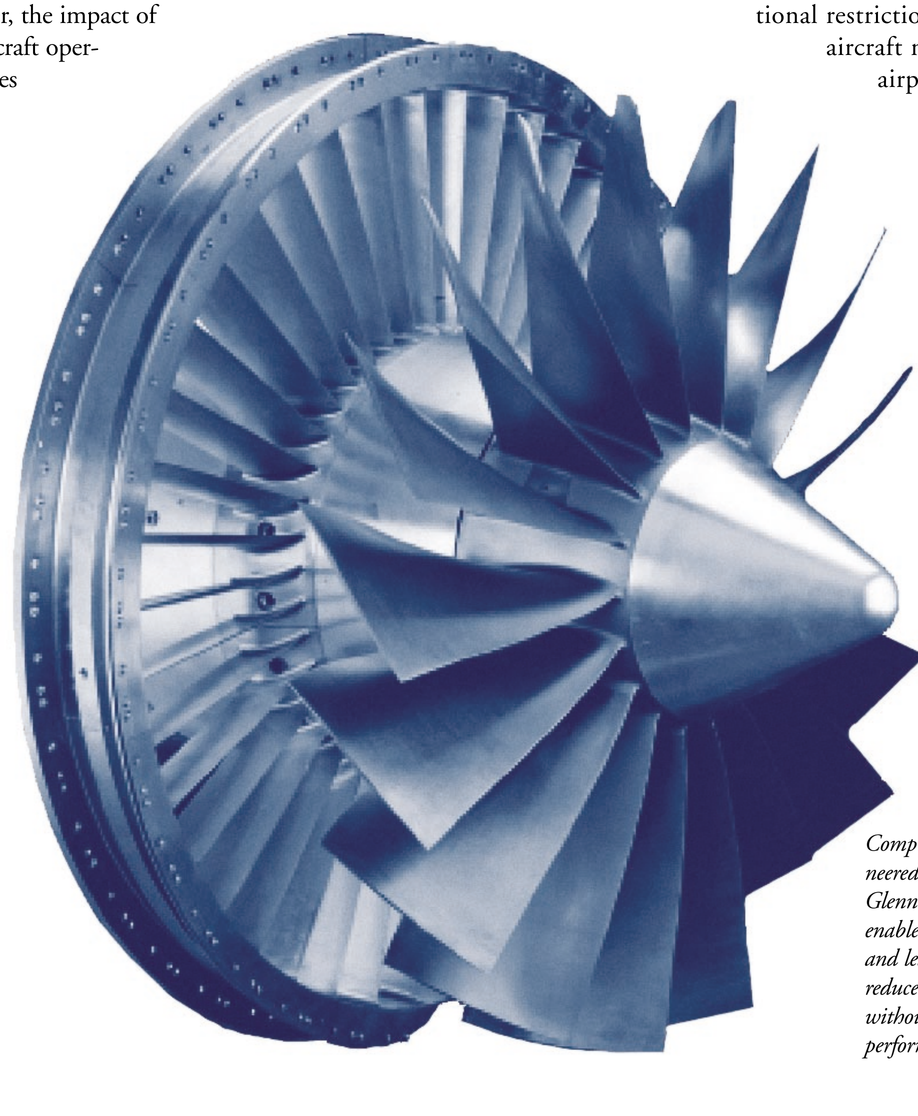
Objective 3: Reduce Noise

Reduce aircraft noise to benefit airport neighbors, the aviation industry, and travelers.

Reduce the perceived[6] noise levels of future aircraft by a factor of 2 (10 decibels) within 10 years and by a factor of 4 (20 decibels) within 25 years, using 1997 subsonic aircraft technology as the baseline.

Aircraft noise has diminished dramatically in the last 30 years, enabling a tremendous net reduction in the number of people affected by aircraft noise. However, the impact of noise from aircraft operations continues to constrain the air transportation system through curfews, noise budgets, and slot restrictions; and the number of airports affected by local noise restrictions has grown significantly worldwide. Public expectation is clearly for reduced noise impact and, in the absence of appropriate technology, that impact is handled through constraints, such as inhibiting expansion or construction of new facilities. Increasingly stringent standards governing aircraft noise have mandated a phase-out of Stage 2 airplanes by the year 2000. Stage 3 is already in effect and Stage 4 is looming on the horizon. The long-term 20-decibel objective for noise reduction will, in most cases, when implemented throughout the fleet, contain objectionable aircraft noise within the airport boundaries (55 Day Night Level contour), freeing the system of most noise restraints.

The noise reduction challenges are being addressed through three strategic thrusts. Pursuit of these thrusts may yield low-noise aircraft that reduce noise in areas near airports and eliminate operational restrictions by keeping aircraft noise within the airport boundaries.



Computational codes pioneered by Langley and Glenn Research Centers have enabled the design of swept and leaned fan stators that reduce fan noise by 3dB without sacrificing engine performance or efficiency.

Objective 3: Reduce Noise

- **Propulsion System Source Noise Reduction**—Develop technologies to reduce engine noise at the source.
- **Aircraft System Source Noise Reduction**—Develop technologies to diminish airframe-related noise.
- **Operational Noise Reduction**—Develop advanced aircraft operating procedures, including steeper glide-slopes and precision, wind-compensated flight paths.

The metric related to the noise reduction thrusts is Effective Perceived Noise (EPNdB).

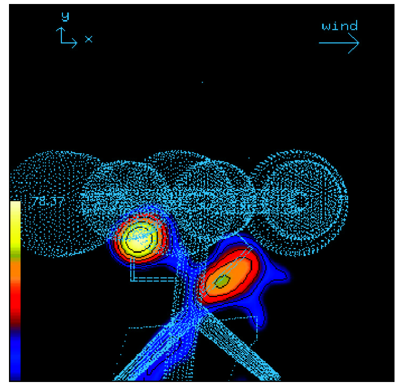
Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

- Quieter airframes and propulsion systems that confine noise impact to the airport boundaries.
- Air traffic management operations that minimize the impact of noise.

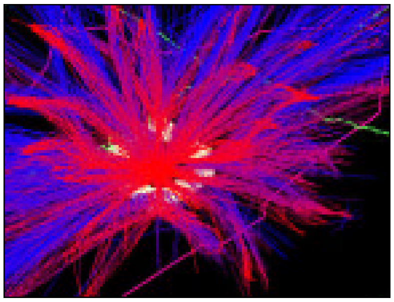
Key Strategy and Partnership Issues

The key issue in this objective is to shrink the noise "footprints" from around airports to within airport boundaries. Achieving this creates a "win-win" situation for local communities and aviation, by reducing the impact of airport noise on communities and at the same time eliminating operational restrictions based on noise. The ability to operate both night and day will create new travel choices for the public, greater capacity for delivery of freight, and economic benefits that can be passed on to the consumer in terms of lower prices for tickets and consumer goods. NASA will work with the FAA, EPA, and industry to accelerate development and adoption of technologies that create a viable alternative to regulation. The DoD also needs to be a good neighbor to communities near military airbases, and will partner with NASA on noise reduction technologies.



A computerized image of wind noise around a landing gear model displays the sounds that occur during takeoffs and landings. Pictures of the sounds are similar to the "false color" of infrared film images of heat. Such computer models will allow for the redesign of landing gear for minimum noise.

[6] *The word "perceived" is key to the intended interpretation of the Enterprise noise reduction goal. In subjective acoustics, noise that is reduced by 10db is perceived as being "half" as loud; therefore, the stated interpretation of the goal.*



Tools for air traffic management show, in this unique image, an entire 24-hour pattern for all incoming (red) and outgoing (blue) aircraft at Dallas-Fort Worth International Airport. This type of computer modeling and visualization capability is essential to understanding and solving airport capacity and delay problems.

Objective 4: Increase Capacity [7]

Enable the movement of more air passengers with fewer delays.

Double the capacity of the aviation system within 10 years and triple it within 25 years, based on 1997 levels.

NASA's focus is on the capacity to move significantly more aircraft through the aviation system safely with less delay.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Infrastructure and Operation Optimization**—Optimize use of the current infrastructure without adding new airports or new runways by developing Air Traffic Management (ATM) technologies that increase the efficiency and capacity of the NAS.
- **Alternative Vehicle Concepts**—Develop new civil aviation vehicle concepts that are designed to use segments of the NAS not suited for traditional commercial aircraft, such as short runways and vertical take-off and landing pads.
- **Alternative Infrastructure Concepts**—Develop entirely new concepts and systems, such as fully automated towers and airports, that would increase the use and capacity of the Nation's 5000 public-use airports.

[7] The factors for capacity are based on predicted demand growth in revenue passenger miles (RPMs). The capacity and delay baseline reflects the proportion of good and adverse weather conditions that typically occur on an annual basis.

Objective 4: Increase Capacity

Metrics for these thrusts include annual operations, revenue passenger miles (RPM), and average delay.

Outcomes

Successful research and development efforts to improve the NAS would result in:

- Better use of the existing NAS without compromising safety; for example, safe all-weather operation.
- Real-time, distributed, "intelligent," and automated monitoring of the entire aviation system, and safety and operational advisories.
- More productive use of all the Nation's airports, by including short-runway and runway-independent aircraft in the NAS.
- High productivity, weather-tolerant vehicle systems capable of intermodal operations.
- Increased capacity, significantly beyond gains made by optimizing the current system.

Key Strategy and Partnership Issues

Alternative vehicle concepts and infrastructure concepts must be developed interdependently to ensure that they can operate together successfully as well as increase the capacity of the NAS. The thrusts must be worked in close partnership with the FAA, U.S. air carriers, manufacturers, and operators. The FAA's Free Flight Program to transition to a modernized NAS over the next 5 to 10 years provides a major opportunity to integrate NASA technologies. Research on concepts and technologies to increase airspace system throughput will be a priority for the foreseeable future.

FutureFlight Central, an award-winning full-scale air traffic control tower simulator at Ames Research Center, provides realistic airport conditions and configurations. It will allow researchers to look at the feasibility, safety, reliability and cost benefits of technologies before they are incorporated into airports, and can assist in the design of new airport facilities or proposed changes for existing airports. Deployed on the seamless out-the-window field-of-view is San Francisco International Airport. Shown are research staff Bob McMahon, Jim McClenahen, Boris Rabin, and Cedric Walker.

FJX-2 engine technology, developed in partnership with NASA by Williams International and its industry team, is at the heart of the new Eclipse 500 six-passenger jet (first deliveries are expected in 2003). The EJ22 commercial engines on this aircraft are based on FJX-2 engines, which produce 700 pounds of thrust, yet weigh only 85 pounds, nearly twice the thrust-to-weight ratio previously available.

Objective 5: Increase Mobility
Enable people to travel faster and farther, anywhere, anytime.

Reduce inter-city door-to-door transportation time by half in 10 years and by two-thirds in 25 years, and reduce long-haul transcontinental travel time by half within 25 years.

Improving the mobility of U.S. citizens by reducing travel time for both short and long journeys requires a wide range of innovations and improvements. NASA is working on methods to integrate small aircraft and all public use landing facilities into the national air transportation system, to increase significantly the access to the air transportation network, reducing travel times into and out of every community. This will require improvements both to aircraft and to the network of small airports. For long journeys, affordable supersonic travel will be essential, but the technological challenges are significant. NASA is working to resolve specific technology problems such as sonic booms, engine noise, and emissions.

NASA will also assess new vehicle design concepts, develop advanced mobility concepts such as the tiltrotor, and fully integrate them within the total aviation system. All these will contribute to reductions in travel time.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

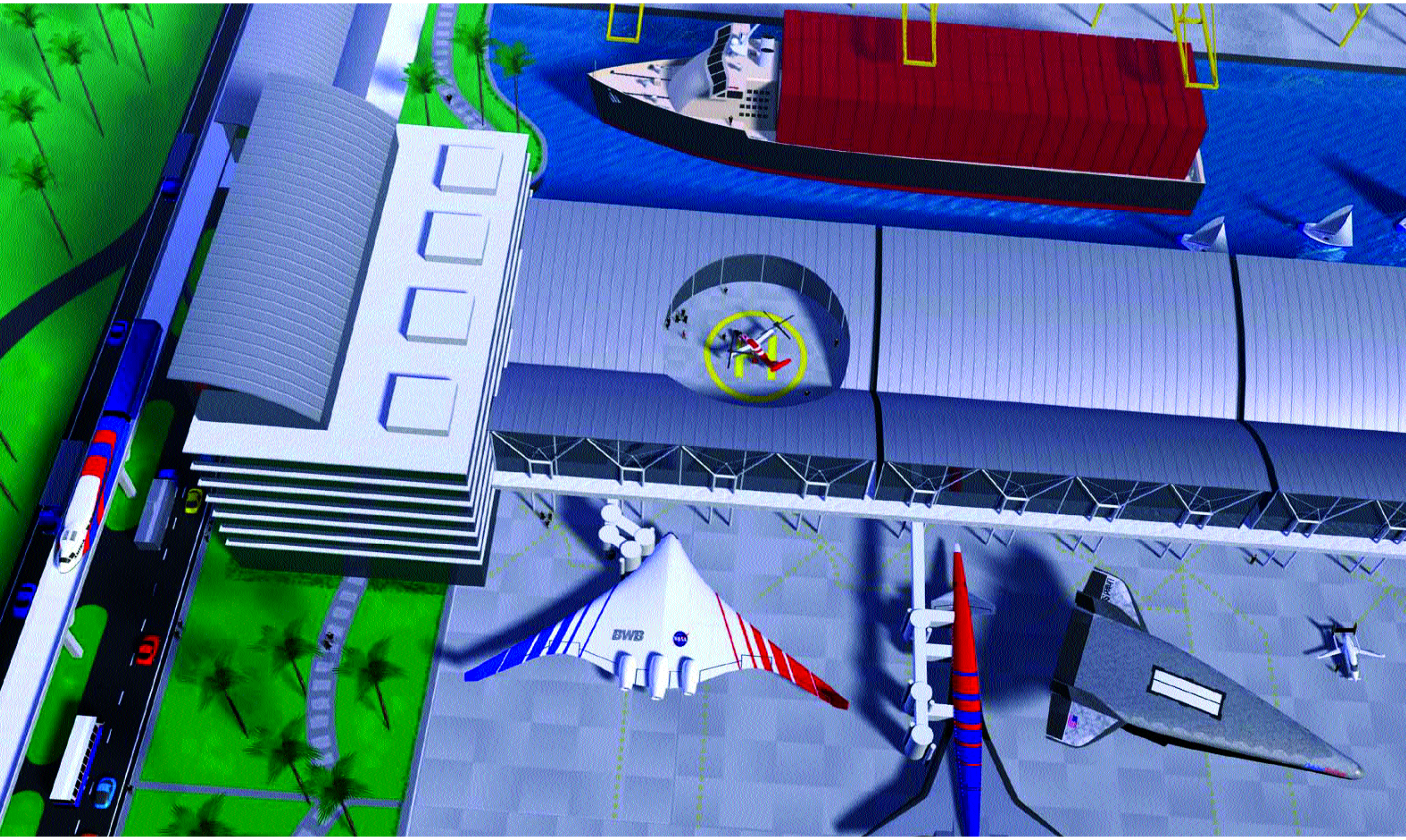
- **Small Aircraft Transportation**—This thrust will focus on developing vehicle, communication, and information technologies to allow small aircraft to operate easily and affordably at small airports in most weather conditions.
- **Supersonic Transportation**—Develop technologies critical to the economic viability of supersonic transport, such as propulsion concepts that meet stringent noise and emissions criteria.
- **Advanced Mobility Concepts and Technology**—Investigate non-traditional vehicles and operations concepts to take advantage of operational airspace that is currently underused.

Metrics associated with the mobility thrusts include inter-city access and trip efficiency, and long-haul trip times.

Outcomes
Successful research and development efforts to improve the NAS would result in:

- A Small Aircraft Transportation System (SATS) featuring affordable, all-weather use of the Nation's public-use landing facilities.
- An economically competitive supersonic transportation capability that is as safe and environmentally compatible as subsonic air travel.
- New aircraft configurations for more efficient use of the airspace system.

Objective 5: Increase Mobility

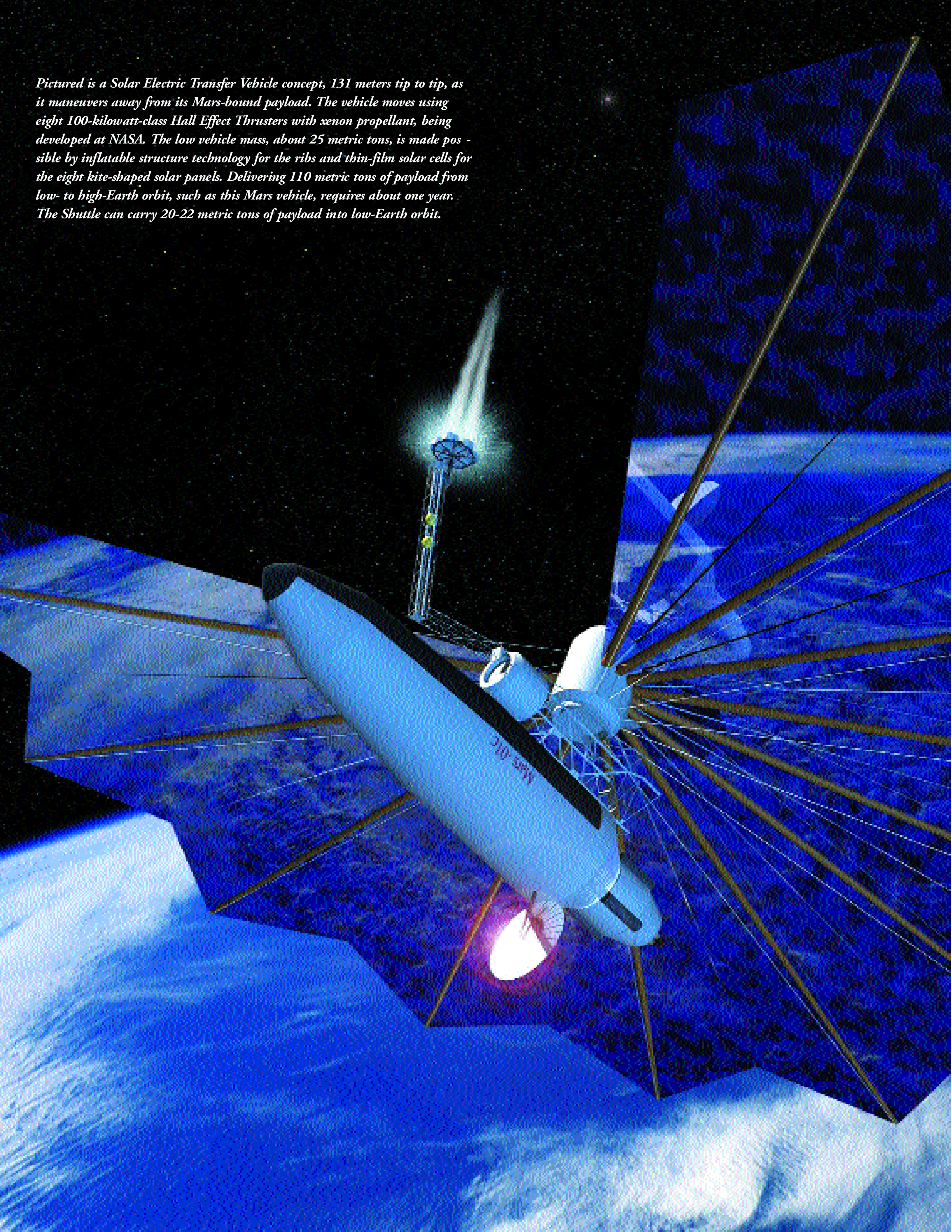


Information technology will help revolutionize future aerospace vehicles as well as the transportation system and its operation. With multiple interfaces shared information, and infrastructure elements, the transportation system will become more flexible and intermodal in nature. The foundation of communication and information will enable a future system that can economically move anyone and anything anywhere, anytime, on time. Shown is a concept where advanced vehicles for air, surface, rail, and waterway transportation are converging at a station designed for the efficient transfer of people and goods.

Key Strategy and Partnership Issues

Better small aircraft transportation will require systems innovations allowing small aircraft to become an integral part of the commercial air transportation system. The strategy is to expand the framework of the public-private sector partnership, which is being used in current efforts to advance general aviation. This partnership can accelerate the development, integration, and demonstration of technologies required to prove the concept that a small aircraft system can coexist and flourish with the commercial air transportation system, and can augment the system as well.

For supersonic transportation, NASA will focus its research on basic technologies to meet stringent design criteria. A significant effort will be made to explore a broad set of technology options. The program will also examine research in space transportation technologies for opportunities to leverage existing work. A key strategy will again include government-industry partnerships. Early partnerships to identify, develop, and implement advanced aircraft design and performance concepts will help the industry team later in developing a commercial aircraft.



Pictured is a Solar Electric Transfer Vehicle concept, 131 meters tip to tip, as it maneuvers away from its Mars-bound payload. The vehicle moves using eight 100-kilowatt-class Hall Effect Thrusters with xenon propellant, being developed at NASA. The low vehicle mass, about 25 metric tons, is made possible by inflatable structure technology for the ribs and thin-film solar cells for the eight kite-shaped solar panels. Delivering 110 metric tons of payload from low- to high-Earth orbit, such as this Mars vehicle, requires about one year. The Shuttle can carry 20-22 metric tons of payload into low-Earth orbit.

Goal Two: Advance Space Transportation

NASA's goal is to create a safe, affordable highway through the air and into space.

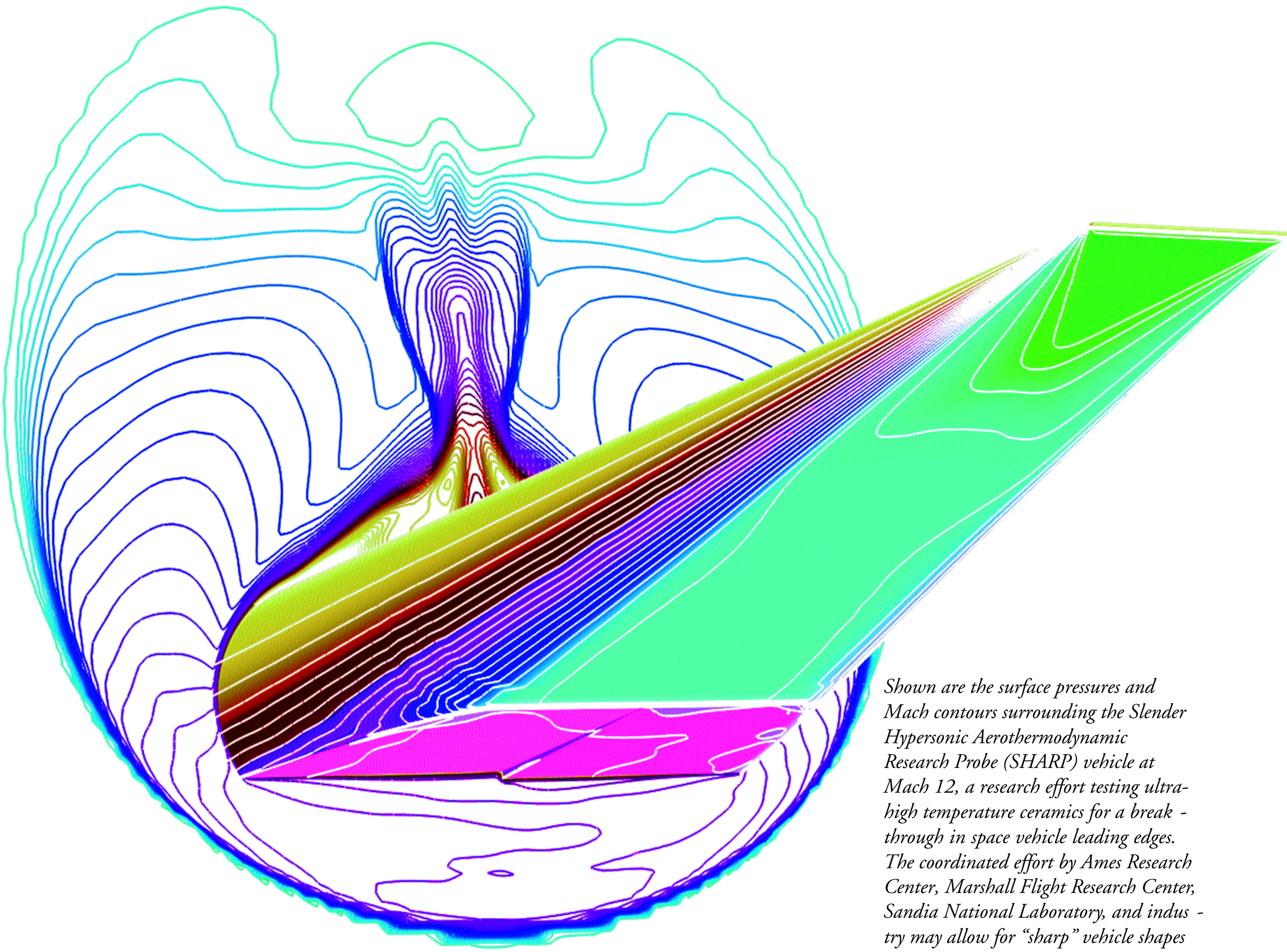
Revolutionizing our space transportation system to significantly reduce costs and increase reliability and safety will open the space frontier to new levels of exploration and commercial endeavor. With the creation of the Integrated Space Transportation Plan (ISTP), the Agency defined a single, integrated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

Objective 6: Mission Safety

Radically improve the safety and reliability of space launch systems.

Reduce the incidence of crew loss for a second generation Reusable Launch Vehicle (RLV) to 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1 million missions (an additional factor of 100) for a third generation RLV by 2025.

Achieving the long-term goal translates to an advanced space transportation system with an accident rate roughly equivalent to that of today's commercial aviation system. A significant increase in the performance margin of launch systems is fundamental to achieving this objective. NASA is working to reduce the risk of crew loss by designing for inherent vehicle safety and reliability, with fewer parts and more robust subsystems. Integrating intelligence into vehicle systems will result in improved vehicle health management and self repair. The development of tools that will enable end-to-end computer design and testing of an entire vehicle and its mission, including life cycle risk assessment, will dramatically



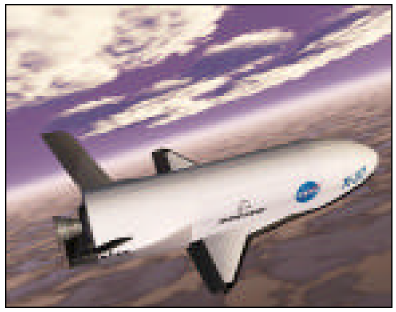
Shown are the surface pressures and Mach contours surrounding the Slender Hypersonic Aerothermodynamic Research Probe (SHARP) vehicle at Mach 12, a research effort testing ultra-high temperature ceramics for a breakthrough in space vehicle leading edges. The coordinated effort by Ames Research Center, Marshall Flight Research Center, Sandia National Laboratory, and industry may allow for "sharp" vehicle shapes that can withstand the high temperatures of atmospheric reentry. Not only good for efficiency, it would also allow more maneuverability and vehicle range, which greatly increases safety and reliability for crew return vehicles.

Objective 6: Mission Safety

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Reusable and Robust Propulsion Systems**—Develop technologies for inherent reliability, more robust subsystems, and an increased performance margin for propulsion and power systems.
- **Integrated Vehicle Health Management (IVHM)**—Develop advanced sensors and algorithms to integrate intelligence, such as real-time failure detection and isolation, into vehicle systems.
- **Crew Escape**—Develop systems to remove the crew safely from a vehicle in the event of catastrophic failure during the highest risk phases of a mission, including vehicle ascent and descent.

Metrics associated with these thrusts include crew survivability and reduced mission loss.



Marshall Space Flight Center and Boeing plan to build and fly the X-37 reusable vehicle to demonstrate a wide range of enabling technologies for reducing the cost of access to space while increasing safety and reliability. The X-37 will operate and provide data in both orbital and re-entry phases of flight. Current planning includes 31 embedded technologies and 8 NASA/Air Force experiments.

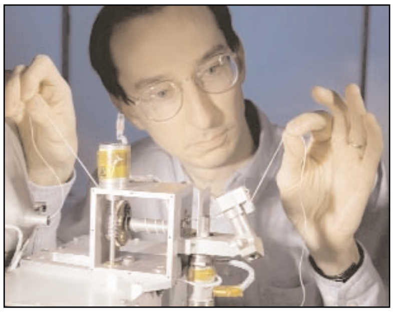
Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

- Intelligent, reliable systems and subsystems.
- Increased safety margins for all systems.
- Highly robust systems that can tolerate multiple failures and still complete the mission.
- Fast, efficient identification of abnormal conditions to increase the time available for corrective actions.
- Systems to protect human life in the event of unavoidable failure of a vehicle or launch system.

Key Strategy and Partnership Issues

The approach for second-generation reusable launch vehicle systems will be to develop and maintain system level requirements to meet safety, cost, and reliability goals. Assessing the impact of subsystem requirements on these integrated system level requirements is key to ensuring that the overall architecture remains commercially competitive and affordable. The integrity of the requirements will be maintained by using integrated systems engineering, prioritizing technology investments, and managing the convergence of commercial and civil space needs. Within this framework, investments for the purpose of risk reduction will be pursued to optimize factors for robust safety margins, reliability, redundancy, operational procedures, crew escape, and embedded intelligence. For third generation vehicle systems and beyond, a broad suite of the most promising technologies that enhance safety will be pursued. We will work closely with our industry, DoD, and academic partners to accelerate the development of enabling technologies and vehicle designs.



NASA's Propulsive Small Expendable Deployer System (ProSEDS) will be the first demonstration of a propellant-free space propulsion system. Les Johnson, of Marshall Space Flight Center, inspects the nonconducting part of a tether as it exits a deployer similar to the system in the ProSEDS flight experiment. This propulsion system, if applied to maintaining the International Space Station's operating orbit, could potentially save more than $1 billion over ten years.

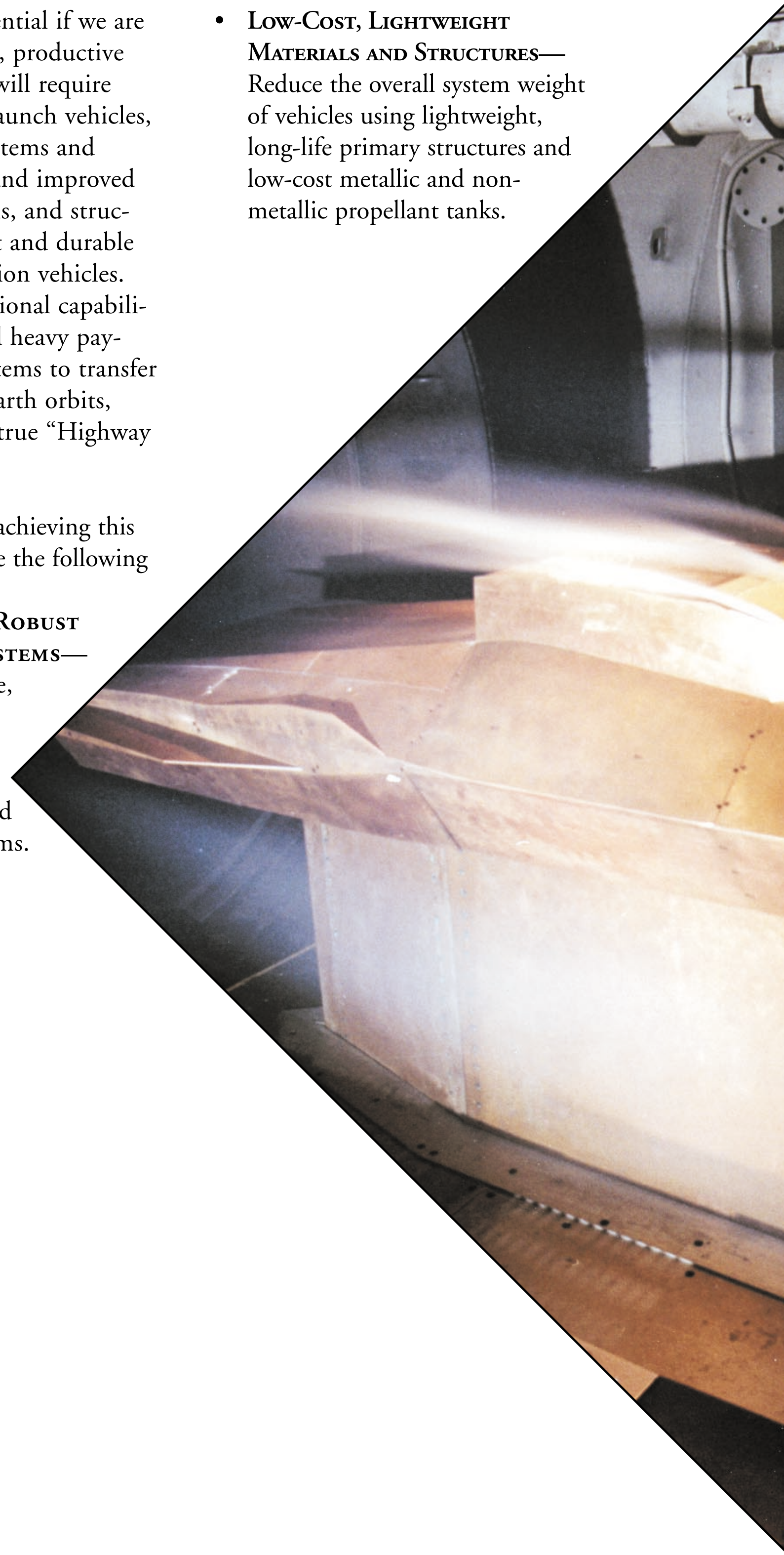
Objective 7: Mission Affordability
Create an affordable highway to space.

Reduce the cost of delivering a payload to Low-Earth Orbit (LEO) to $1000 per pound (a factor of 10) by 2010 and to $100 per pound (an additional factor of 10) by 2025. Reduce the cost of interorbital transfer by a factor of 10 within 15 years and by an additional factor of 10 by 2025.

Achieving this objective will enable payload delivery to LEO for $100 per pound, a dramatic reduction from the approximate $10,000 per pound that it costs today. We also seek to reduce the overall cost of delivering payloads to their final destination at a higher orbit. In both cases, the cost reduction must occur without compromising safety or reliability. Safety, reliability, and affordability are essential if we are to realize a dynamic, productive space market. This will require improved reusable launch vehicles, advanced launch systems and launch operations, and improved propulsion, materials, and structures for lightweight and durable in-space transportation vehicles. By developing additional capabilities for medium and heavy payloads, including systems to transfer payloads between Earth orbits, NASA will create a true "Highway to Space."

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Reusable and Robust Propulsion Systems**—Develop long-life, highly reusable engine systems and inherently reliable integrated propulsion systems.
- **Low-Cost, Lightweight Materials and Structures**—Reduce the overall system weight of vehicles using lightweight, long-life primary structures and low-cost metallic and non-metallic propellant tanks.



Objective 7: Mission Affordability

- **Operations Optimization**—Develop the capability for autonomous checkout and vehicle control, modular payload systems, and new launch site operations.
- **Risk Reduction**—Develop key technologies for full-scale development of a second-generation RLV system.

Metrics for measuring impact on mission affordability include customer cost per pound and cost to final destination.

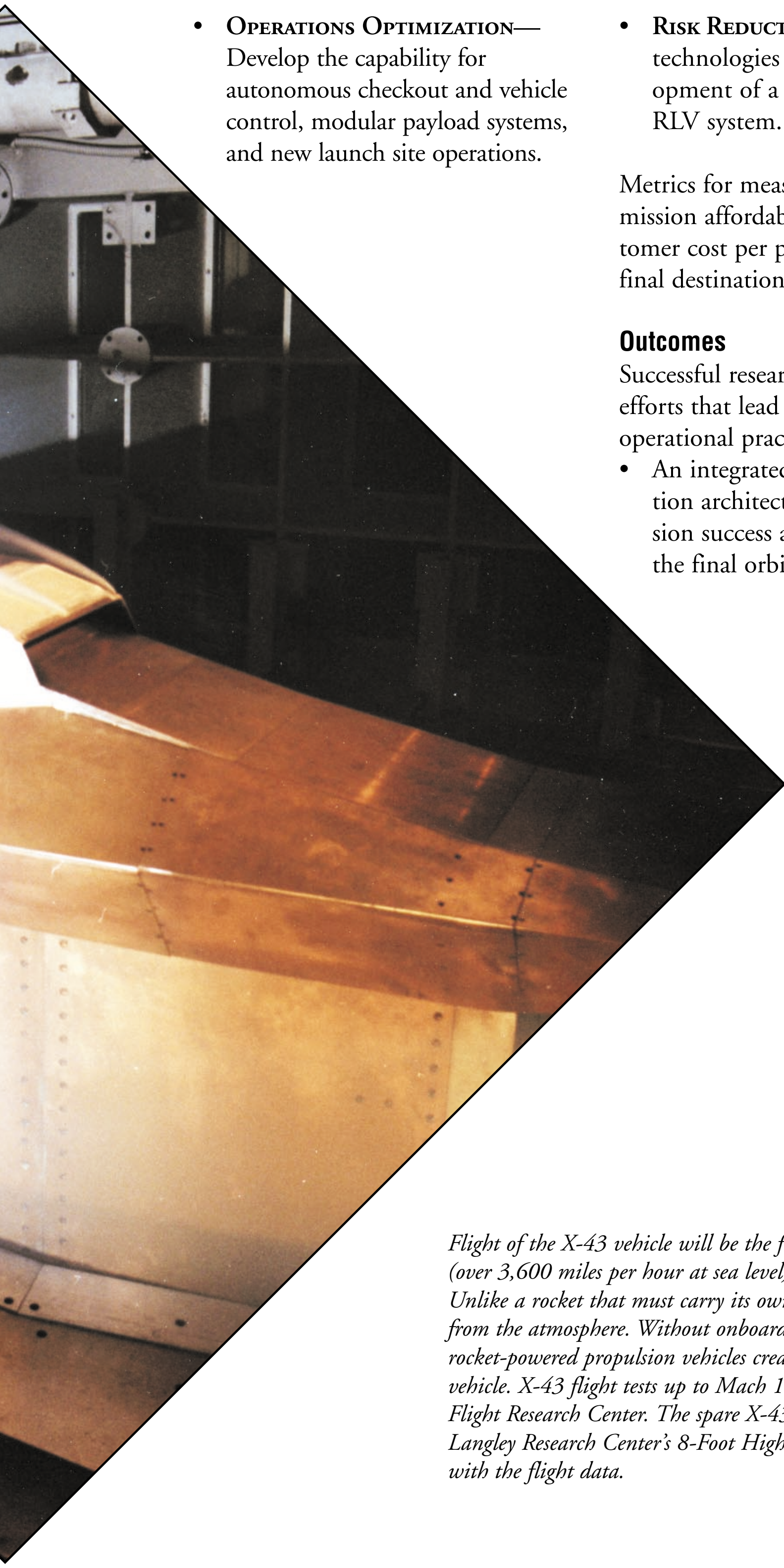
Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

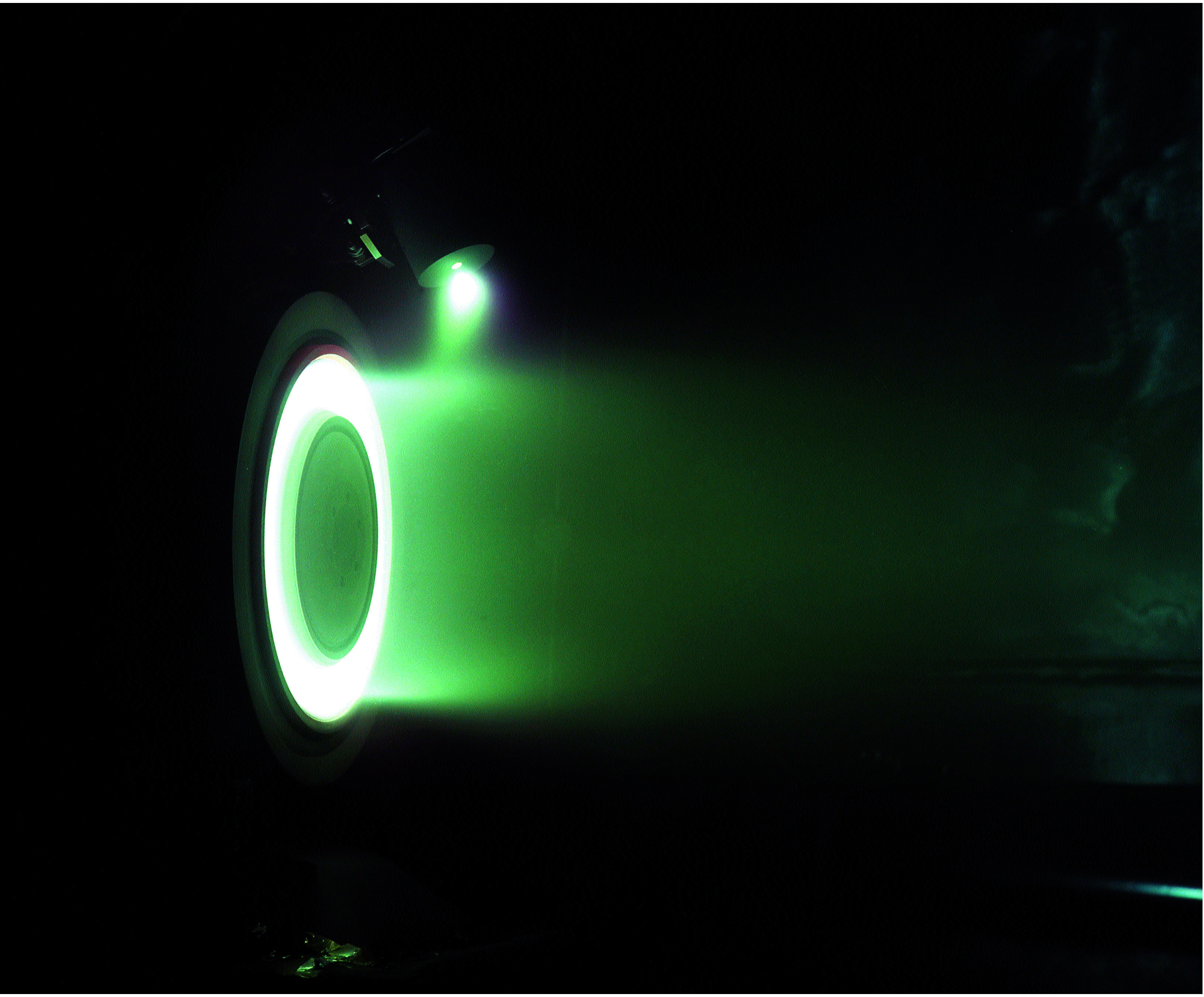
- An integrated space transportation architecture to optimize mission success and minimize cost to the final orbital destination.
- Advanced, reusable, and robust transportation systems.
- Reduced for vehicle turnaround time inspection and increased launch operation efficiency.
- The creation of new markets and new uses for space.

Key Strategy and Partnership Issues

The strategy is to accelerate the development of key technologies, to create lower-cost reusable launch vehicles, and to continue our investment in areas of long-term research to enable the development of third and fourth generation launch vehicle systems. The approach to lower-cost, second-generation reusable launch vehicle systems is parallel to safety efforts. Using systems engineering, NASA will manage requirements, prioritize technology investments, manage the convergence of commercial, civil, and military space needs, and maximize technology partnership opportunities. For third-generation vehicle systems and beyond, a broad suite of the most promising technologies for reducing overall space transportation costs will be pursued. We will work closely with industry, DoD and academic partners to accelerate the development of enabling technologies and vehicle designs.



Flight of the X-43 vehicle will be the first time a non-rocket engine has powered aircraft at hypersonic speeds (over 3,600 miles per hour at sea level), significantly expanding the boundaries of air-breathing aircraft. Unlike a rocket that must carry its own oxygen for combustion, the X-43's air-breathing engine scoops oxygen from the atmosphere. Without onboard oxygen, the vehicle is lighter and able to carry more cargo/payload than rocket-powered propulsion vehicles creating the potential for a more capable, affordable and versatile launch vehicle. X-43 flight tests up to Mach 10, or ten times the speed of sound, are being performed at the Dryden Flight Research Center. The spare X-43 flight engine is shown during a full test of its flight conditions in the Langley Research Center's 8-Foot High Temperature Tunnel, to measure engine performance for comparison with the flight data.



Between April and August of 2000, a 10-kilowatt Hall effect thruster, designated T-220, was subjected to a 1000-hour life test evaluation in Vacuum Facility #12 at Glenn Research Center. Hall effect thrusters are propulsion devices that electrostatically accelerate xenon ions to produce thrust. The T-220 performed well throughout the test (doubling the 500-hour goal), with discharge current oscillations and propellant use improving over time. The T-220 produces enough thrust to enable efficient orbital transfers, saving hundreds of kilograms in propellant over conventional chemical propulsion systems.

Objective 8: Mission Reach

Objective 8: Mission Reach

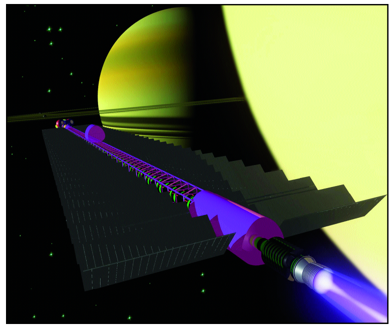
Extend our reach in space with faster travel.

Reduce the time for planetary missions by a factor of 2 by 2015 and by a factor of 10 by 2025.

This objective aims to develop light, rapid space propulsion systems that will reduce travel times. Technology focus areas include small systems for traveling to other planets and "breakthrough" propulsion technologies to allow missions to reach other stars within a human life span.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Advanced Propulsion Concepts**—Identify and develop breakthrough technology for advanced propulsion systems.
- **Materials and Structures**—Develop lightweight airframes, tanks, and micro-components using nano-technology and ultra-high temperature ceramics.



An artist's concept of a fusion-powered space vehicle approaching the Saturn moon Titan.

Metrics include days to final destination, propulsion system mass, and vehicle system mass.

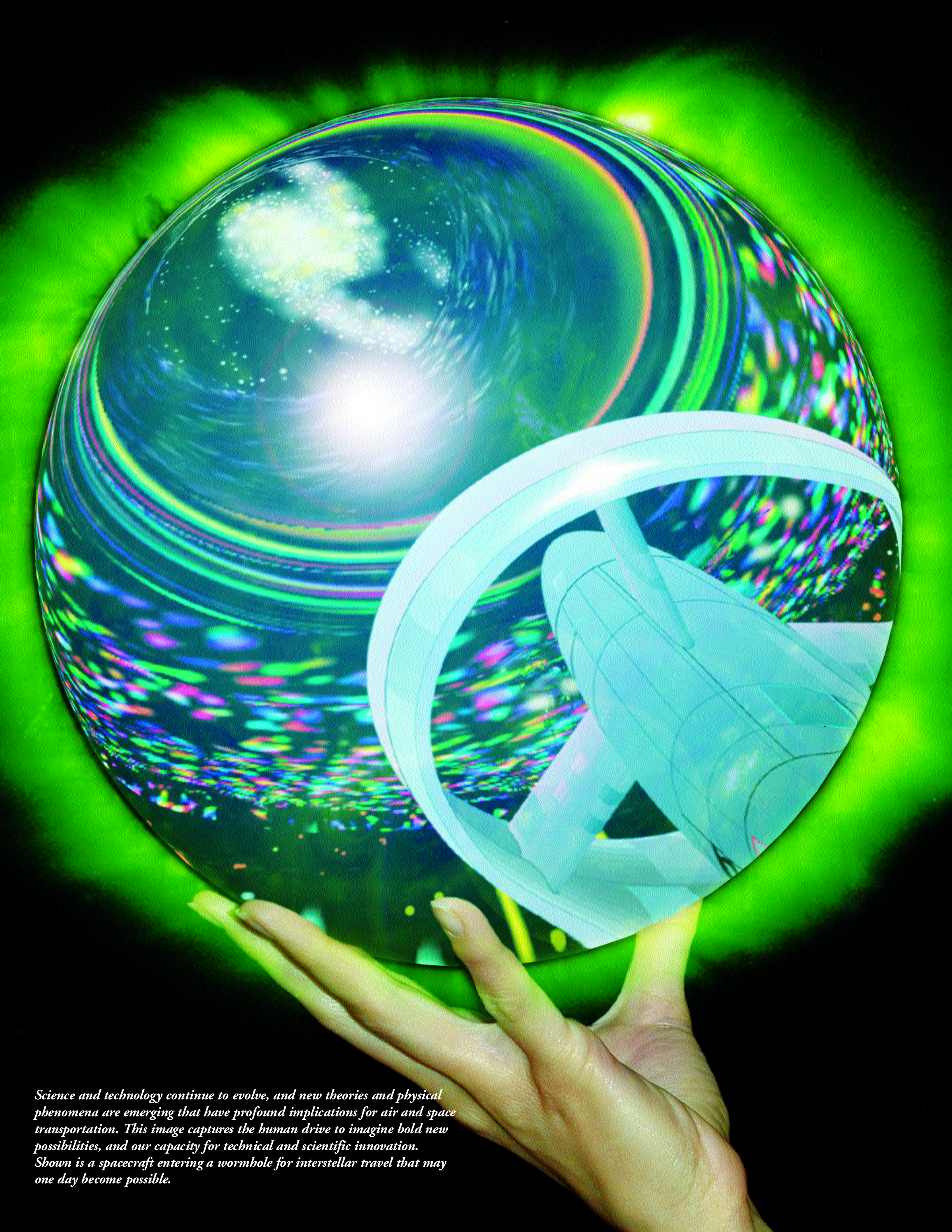
Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:

- Major increases in propulsion system performance and capability.
- A major reduction in overall vehicle system size and mass.
- Improvements in overall vehicle performance.

Key Strategy and Partnership Issues

We will work closely with NASA's Enterprises for Space Science, Earth Science, and the Human Exploration and Development of Space, as well as commercial customers to plan our technology efforts alongside their mission roadmaps. In order to achieve NASA's ambitious space exploration missions over the next several decades, revolutionary materials, structures, and in-space propulsion technologies must be developed. Close coordination with the Enterprises will enable timely research, development, and application of key technologies to support their missions.



Science and technology continue to evolve, and new theories and physical phenomena are emerging that have profound implications for air and space transportation. This image captures the human drive to imagine bold new possibilities, and our capacity for technical and scientific innovation. Shown is a spacecraft entering a wormhole for interstellar travel that may one day become possible.

Goal Three: Pioneer Technology Innovation

NASA's goal is to enable a revolution in aerospace systems.

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

Objective 9: Engineering Innovation
Develop advanced engineering tools, processes, and culture to enable rapid, high-confidence, and cost-efficient design of revolutionary systems.

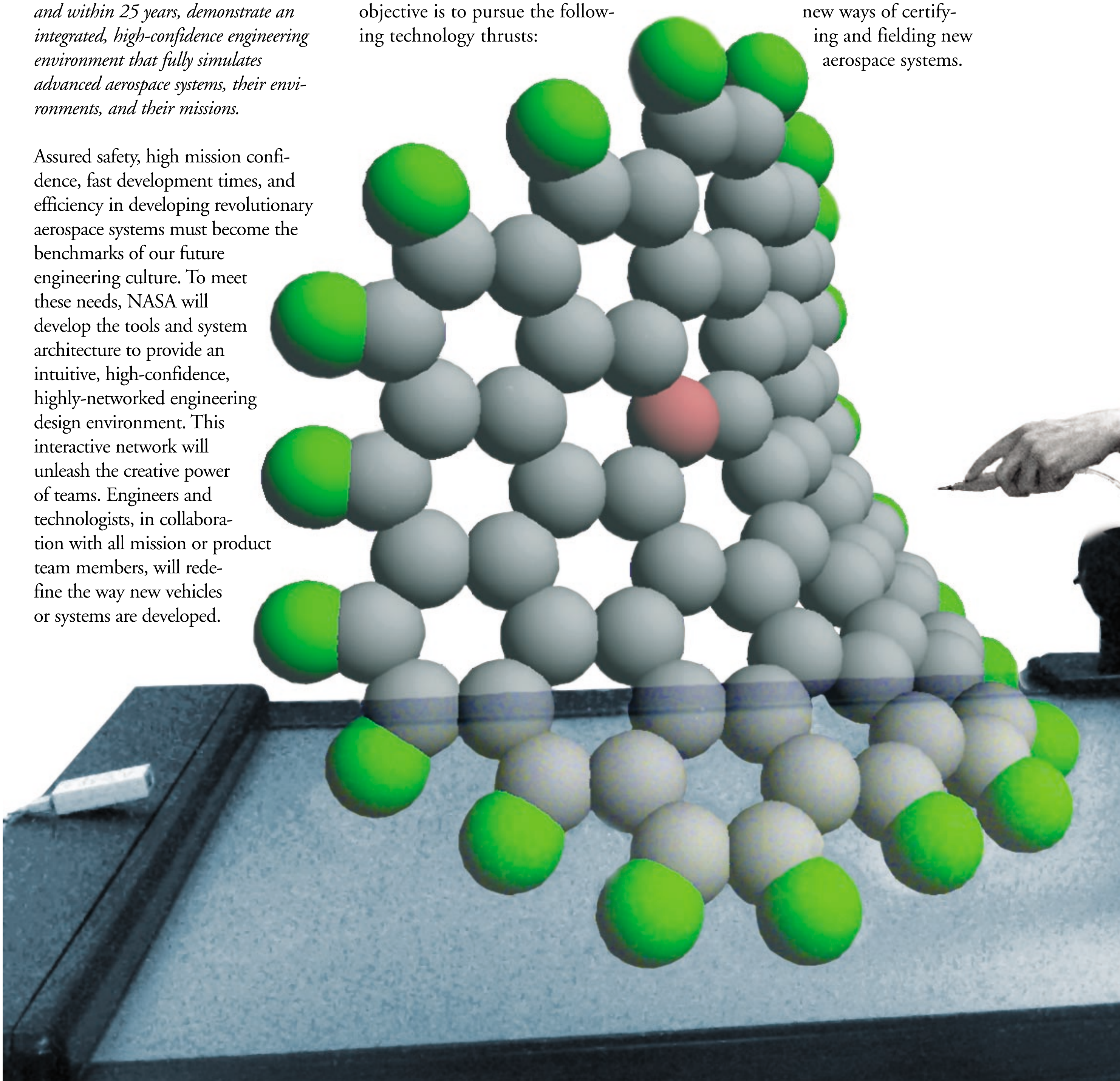
Within 10 years, demonstrate advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications; and within 25 years, demonstrate an integrated, high-confidence engineering environment that fully simulates advanced aerospace systems, their environments, and their missions.

Assured safety, high mission confidence, fast development times, and efficiency in developing revolutionary aerospace systems must become the benchmarks of our future engineering culture. To meet these needs, NASA will develop the tools and system 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 all mission or product team members, will redefine the way new vehicles or systems are developed.

Designing from atoms into aerospace vehicles, engineering teams will have the ability to accurately understand all key aspects of its systems, its operating environment, and its mission before committing to a single piece of hardware or software.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Process and Concept Innovation**—Develop new processes and concepts for accomplishing full-life-cycle ("cradle-to-grave") planning and design of new, revolutionary aerospace systems.
- **Validation and Implementation**—Develop technologies and concepts for new ways of certifying and fielding new aerospace systems.



Objective 9: Engineering Innovation

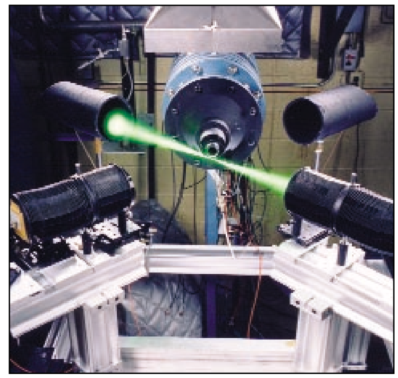
- **Information Technologies—** Develop computational capabilities and knowledge bases necessary to design new aerospace systems.
- **Advanced Engineering and Analysis Technologies—** Develop design tools and the ability to model any part of a new vehicle design during any part of the system's span and under all operating conditions and environments.

The metric related to these thrusts is the design confidence of advanced aerospace systems.

Outcomes

A successful effort would have the following outcomes:

- Ability to fully and accurately synthesize all aspects of an advanced aerospace system design in a virtual environment, with a full understanding of its capabilities and its safety and mission risk in its operational environment.
- High confidence in all key design parameters, such as safety, performance, and cost, throughout the design process.
- A fully collaborative engineering environment across all disciplines.



A complex new argon-ion laser measurement technique allows scientists to "see" sound. With this tool, researchers can very accurately measure turbulence parameters that will help them understand the physics of how a supersonic jet flow creates sound, enabling more efficient aerodynamic design.

Key Strategy and Partnership Issues

To ensure continuous progress, a steady investment in prioritized basic research is required, coupled with focused efforts to integrate and apply the new technologies and processes. NASA will use both small and large-scale mission applications and advanced concepts to validate integrated engineering environments, processes, and tool sets. NASA will partner with other government agencies, industry, consortia, and academia to bring about the needed innovations. Key partnerships include DoD, with their initiatives related to design and manufacturing, the National Science Foundation (NSF), the Department of Energy (DoE), and the National Institute of Standards and Technology (NIST).

The NASA Education and Research Network project is providing gigabit networking technology to demonstrate a 3-D simulator that allows users to see, move, and even feel simulated molecular structures. Christopher Henze, of Ames Research Center, uses a tool to manipulate a graphite molecular model with the Virtual MechanoSynthesis (VMS) 3-D simulator. VMS is an important tool to help scientists better understand how to design nano-electronic components, chemical- and bio-sensors, and nano-tubes. Gigabit networking, a means to deliver huge volumes of data to multiple distant users simultaneously, is important to VMS's viability.

Objective 10: Technology Innovation
Develop revolutionary technologies and technology solutions to enable fundamentally new aerospace system capabilities and missions.

Within 10 years, integrate revolutionary technologies to explore fundamentally new aerospace system capabilities and missions; and within 25 years, demonstrate new aerospace capabilities and new mission concepts in flight.

Scientists and engineers will need cutting edge technologies to accelerate progress and change the definition of what is possible in aerospace. NASA will aggressively explore fields with a high potential for creating advanced performance characteristics in structures and systems, such as information technology, biologically-inspired technology, and nanotechnology. The ability to build air and space vehicle structures and devices in new ways, perhaps atom by atom, can enable greater strength and functionality at a lower mass. New capabilities, such as self-repair of surfaces or components, automatic shape changes for optimal performance, autonomous systems, and cooperative inter-vehicle behavior, can enable safer, more reliable vehicles and systems.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Core Competencies**—Build and advance, within NASA the technology competencies that have potential for major benefits to aerospace applications.
- **Enabling New Missions**—Develop technologies for missions that are currently unrealistic, from personal air transportation to interstellar travel. This thrust will remove barriers such as high technology costs, limits to human endurance, and immense mission timeframes, to open exciting new possibilities.

Wings of fabric can be a commercial reality, due to extremely innovative and cost-effective techniques for stitching dry textile fabric preforms, then curing them with a resin film infusion. This composite technology developed at Langley Research Center offers the potential to greatly reduce airframe production and operation costs by increasing efficiency (eliminating the need for thousands of metal fasteners) and reducing weight.

Objective 10: Technology Innovation

• **Enabling New Capabilities**—Develop capabilities that are not possible today, such as autonomy sufficient to conduct an entire mission without human intervention, or self-repair of a vehicle's skin.

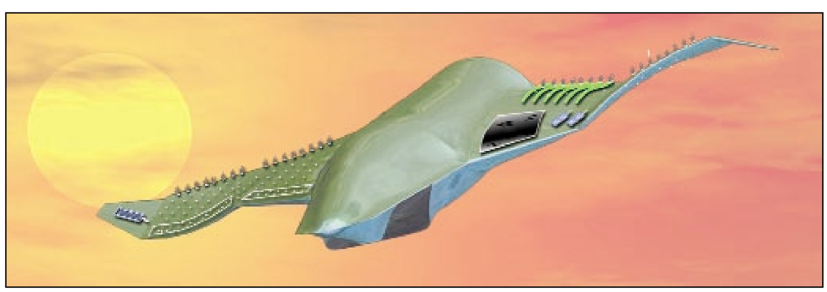
Outcomes

A successful effort would have the following outcomes:

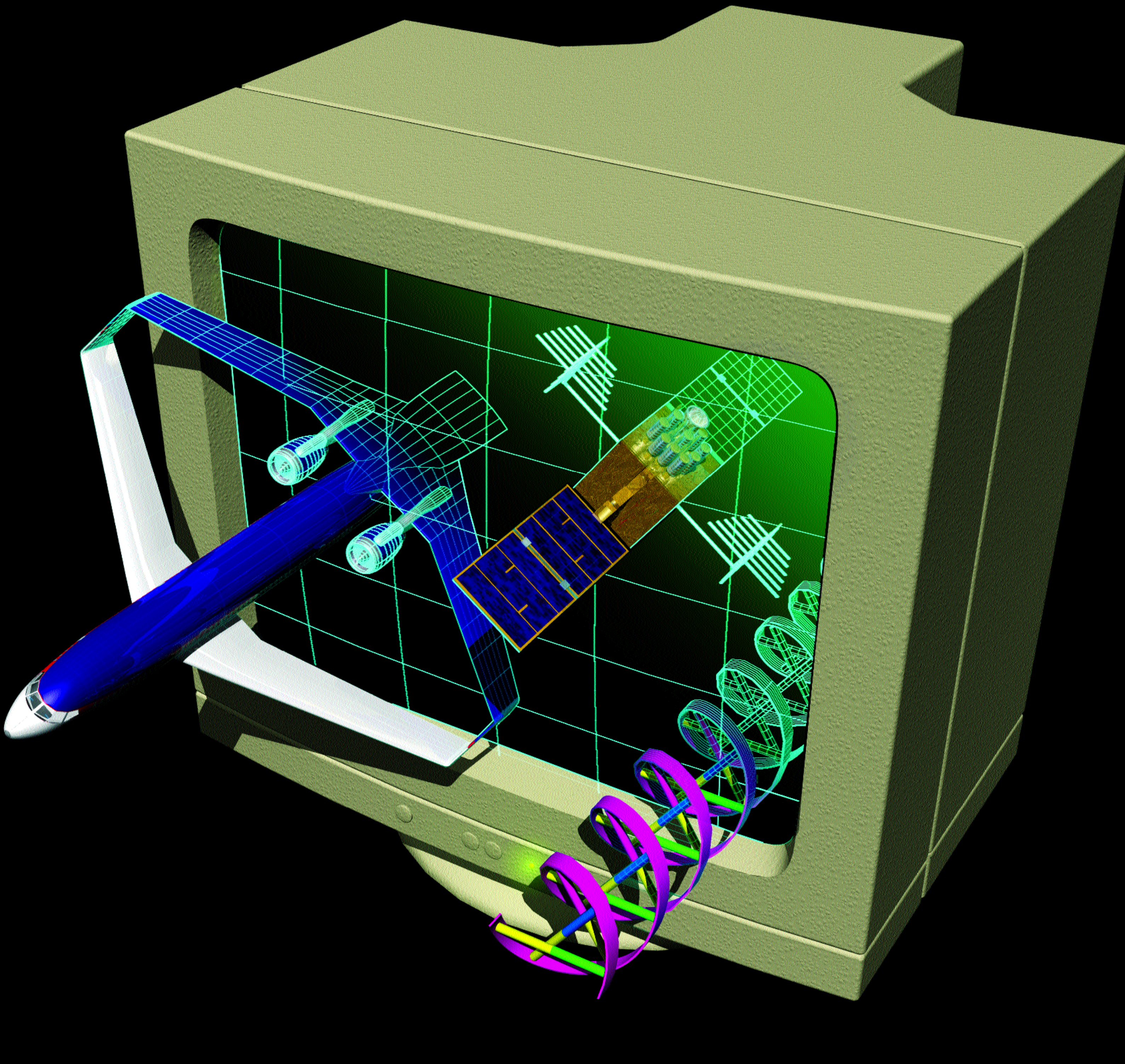
- Revolutionary levels of performance for aerospace systems, with extraordinary reductions in vehicle mass and increases in efficiency.
- Aerospace systems that will have greater capability for a given function, new functionality not possible today, and the ability to perform complex, safety-critical missions without human intervention.

Key Strategy and Partnership Issues

Consistent, sustained investment in basic research tied to advancing aerospace concepts and functionality is essential in fostering innovation in aerospace technology. NASA will develop applications, from the laboratory through flight, to integrate and demonstrate innovative technologies and revolutionary concepts. NASA will also make a sustained effort in modeling, to explore revolutionary concepts for both aviation and advanced space exploration systems, not only of vehicles but of entire transportation system architectures as well. To support this objective, NASA will augment its traditional technology competencies as well as build promising new competencies in information technology, biologically-inspired technology, and nanotechnology. NASA is planning strategic partnerships with the other NASA Enterprises, industry, academia, and with other government agencies such as DoD, DoE, the National Oceanic and Atmospheric Administration (NOAA), and the National Reconnaissance Office (NRO), to take advantage of complementary mission needs and technology expertise.



This graphic is a vision of an advanced vehicle concept that employs technologies such as embedded, distributed computing and sensors for vehicle control; active shape control for flight optimization; high-strength carbon nano-tube composite structures; distributed vectored propulsion systems; and self-healing, multi-function materials.



As we enter an era many refer to as the "New Economy," one constant is the value and applicability of the research and development activities taking place at NASA. Technology developed for aerospace applications can often be beneficially applied in other industries. Whether it is NASA working in tandem with private industry, or the commercial sector turning to NASA for technological assistance, many of these aerospace technologies have found their way into new products and services. This graphic portrays the potential of commercializing NASA-developed technology into a number of applications, such as advanced aviation, medicine, and space communications.

Goal Four: Commercialize Technology

NASA's goal is to extend the commercial application of NASA technology for economic benefit and improved quality of life.

Although NASA technology benefits the aerospace industry directly, the creative application of NASA's advanced technology to disparate design and development challenges has made numerous contributions to other areas such as the environment, surface transportation, and medicine. NASA achieves this by partnering with both aerospace and non-aerospace industry as well as academia. These partnerships involve the full range of NASA's assets: technological expertise, new technologies, and research facilities. The NASA Commercial Technology Network (NCTN) is a key mechanism for enabling technology transfer and commercialization. This network consists of the NASA-affiliated organizations across the U.S. that provide unique expertise and services to U.S. enterprises, facilitating the transfer, development, and commercialization of NASA-sponsored technology. NASA will also implement activities that support internal technology transfer, to share new technologies and innovations across all NASA programs and projects as well as with other federal agencies. An effective internal and external transfer effort augments our economy, benefits the public, and fosters the leveraging of technology across NASA programs. NASA will continue to improve its technology commercialization and outreach programs to ensure the widest application of NASA-developed technology to benefit the Nation.

Goal Four: Commercialize Technology

Under a NASA Small Business Innovation Research (SBIR) contract from the Jet Propulsion Laboratory, AESOP® (Automated Endoscopic System for Optimal Positioning) was developed by Computer Motion, Inc., in Santa Barbara, California. NASA hopes to use the robotic arm technology to service satellites, inspect payloads on the Space Shuttle, and to perform space repair missions that require exact and precise movements that exceed human dexterity. Here, doctors use AESOP® to control the motion of a slender camera inserted into a small incision in the patient undergoing endoscopic surgery. This voice-controlled positioning system eliminates the need for surgical staff to hold the camera in place, and provides an absolutely steady picture during minimally invasive surgeries.

Outcomes

A successful effort would have the following outcomes:

- Prompt identification and capture of new NASA technologies and innovations.
- Proactive development and implementation of commercial technology partnerships.
- Partnerships that result in economic benefits, quality-of-life improvements, and/or the sharing of technological innovations between NASA programs or with other federal agencies.

Key Strategy and Partnership Issues

Key to this NASA goal is early identification of those NASA activities with potential for technology transfer and commercialization, coupled with development of a sound technology transfer and commercialization plan. NASA will continue striving to implement and maintain a partnership portfolio with a value equivalent to from 10 to 20 percent of its annual R&D resources. The responsibility for this plan is shared jointly by each NASA activity manager and the Commercial Technology Offices located at each NASA center. Each NASA center has the flexibility to tailor the specific aspects of this responsibility on an activity-by-activity basis.

Glossary of Terms

Glossary of Terms

airframe. Assembled structure of an aircraft, together with the system components that form an integral part of the structure and influence aerodynamics, control, strength, integrity, or shape.

ATM. Air Traffic Management.

available seat miles (asm). A measure of aviation system capacity. It is the total vehicle miles flown on an annual basis by the commercial fleet, multiplied by the number of seats in those vehicles.

combustor. The jet engine component that ignites and burns the fuel-air mixture.

Day Night Level. Community noise impact measured at a specific airport location, averaged over a 24-hour period.

DoD. Department of Defense.

DoE. Department of Energy.

EPA. Environmental Protection Agency.

EPNdB. Effective Perceived Noise in Decibels.

FAA. Federal Aviation Administration.

Free Flight architecture. Free Flight is an innovative concept designed to enhance the safety and efficiency of the National Airspace System (NAS). The concept moves the NAS from a centralized command-and-control system between pilots and air traffic controllers to a distributed system that allows pilots, whenever practical, to choose their own route and file a flight plan that follows the most efficient and economical route.

GDP. Gross Domestic Product.

general aviation aircraft. Aircraft used for regional airline service, business transportation, recreation, specialized uses (such as ambulances and agricultural spraying), and pilot training.

ICAO. International Civil Aviation Organization.

intermodal. Having the ability to move from one element of the transportation network to another. The three main modes of transportation are surface, air, and water. Within each mode are additional elements that, ideally, would interconnect to allow for a widely distributed transportation system.

IPCC. Intergovernmental Panel on Climate Change.

ISTP. Integrated Space Transportation Plan.

IVHM. Integrated Vehicle Health Management.

LEO. Low-Earth Orbit.

LTO. Landing/Take-Off.

metrics. Quantifiable indicators that can be used as a measure of performance. The indicators are relevant to the system or technology and are stable over time.

NAS. National Airspace System.

NASA. National Aeronautics and Space Administration.

National Airspace System (NAS). A complex collection of the systems, procedures, facilities, aircraft, and people that support all aircraft operations in the United States. As directed by the FAA, NAS represents the overall environment for the safe operation of aircraft.

NCTN. NASA Commercial Technology Network.

Glossary of Terms

NIST. National Institute for Standards and Technology.

NOAA. National Oceanic and Atmospheric Administration.

NRO. National Reconnaissance Office.

NSF. National Science Foundation.
payload. The satellite, instrument package, or equipment carried into space by a launch vehicle.

R&D. Research and Development.

RLV. Reusable Launch Vehicle.

RPM. Revenue Passenger Miles.

SATS. Small Aircraft Transportation System.

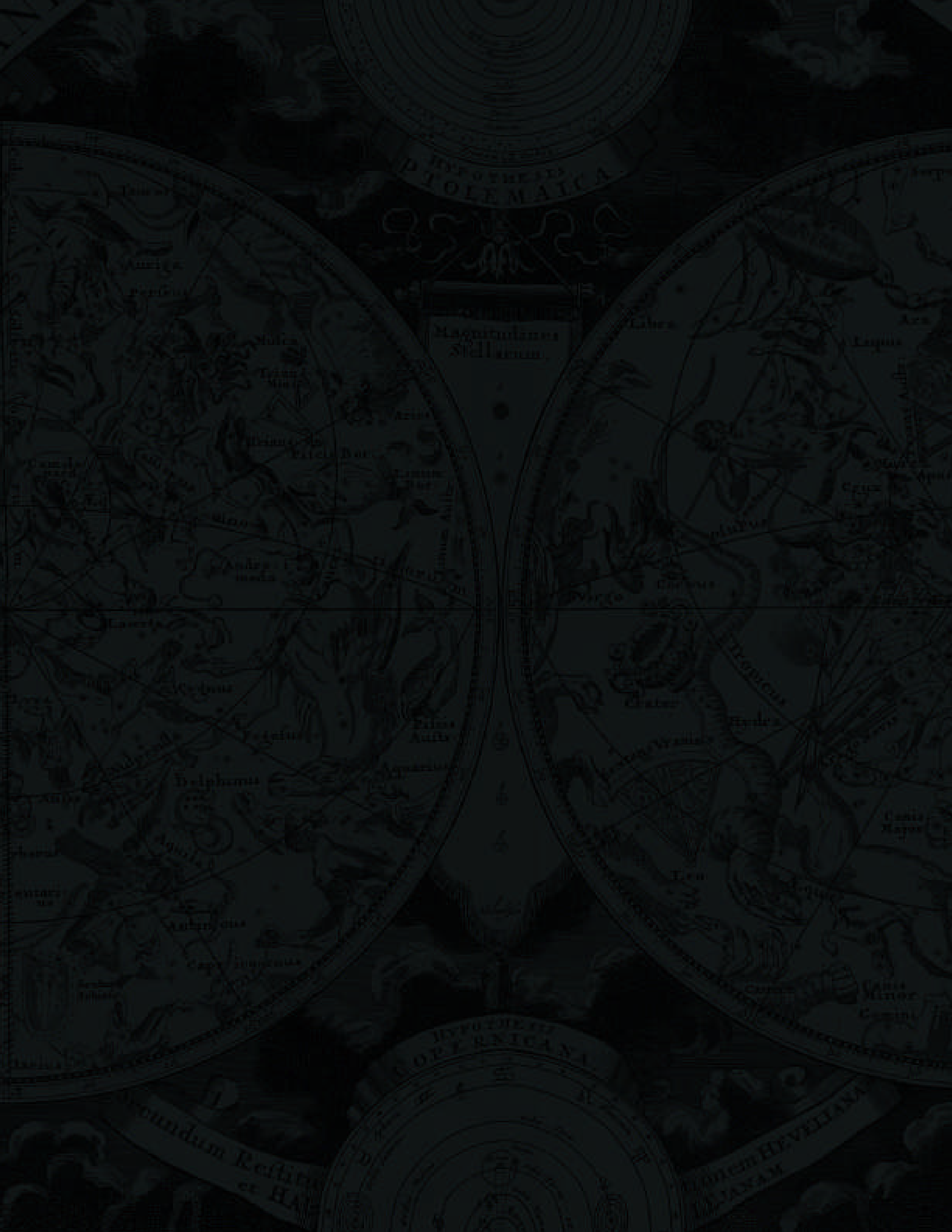
SHARP. Slender Hypersonic Aerothermodynamic Research Probe.

Stage 2, Stage 3, and Stage 4. The noise stringency standards for jet-powered aircraft, set by the FAA for aircraft operating in U.S. airspace. These standards are negotiated in an international context through the International Civil Aviation Organization (ICAO). Stage 2 compliant aircraft completed their operational phase-out in December 2000. Stage 3 standards are more stringent and are now in effect throughout the fleet. Stage 4 are the standards that are currently being debated by the ICAO.

STAS. Space Transportation Architecture Studies.

thrusts. Areas of research identified as having a potentially significant impact on an objective. The thrusts are a collection of technology disciplines, or smaller research initiatives, whose primary results could be leveraged to maximize their contributions toward the stated objective. Secondary benefits to other objectives are also likely.

tiltrotor. An aircraft that delivers lift from a system of rotating airfoils in the vertical mode. For efficient travel, the rotors are moved to the horizontal mode to operate like a turboprop aircraft.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Space Administration

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