National Aeronautics and Space Administration

INTRODUCTION TO NASA'S

INTEGRATED SPACE TRANSPORTATION PLAN

AND

SPACE LAUNCH INITIATIVE

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TABLE OF CONTENTS

Introduction to NASA's Integrated Space Transportation Plan and Space Launch Initiative

Executive Summary

The National Aeronautics and Space Administration (NASA) is America's civil space Agency, fostering the human exploration and development of space, and conducting research that expands the limits of knowledge about ourselves, our home planet, and the universe at large. NASA missions not only push the envelope of air and space, they inspire and serve America, while benefiting the overall quality of life on Earth. As such, NASA is an investment in America's future, bringing to bear the best humanity has to offer as we boldly pioneer new technologies and new worlds.

Through cooperative teamwork, NASA and its partners in the U.S. aerospace industry and at universities across the country are initiating a resurgence in scientific and commercial excursions on the new frontier. Four decades of experience have helped NASA better understand the unlimited potential that the space environment has to offer and how to use it to our advantage. The International Space Station (ISS) is providing an unmatched platform for scientific research, physiological studies, and Earth observation. To refocus resources on the Agency's core missions such as this, it has formulated a plan to work shoulder-to-shoulder with private companies and academic institutions, both large and small, to find new ways to get valuable payloads off the ground more safely, more reliably, and at lower cost.

NASA's Integrated Space Transportation Plan (ISTP) is the long-range investment strategy for the Government to accomplish its mission objectives by enabling its partners, through risk reduction technology demonstrations, to develop new, privately owned and operated space transportation systems, with NASA as a customer. NASA's strategic goals for a next-generation Reusable Launch Vehicle (RLV) are to reduce the risk of crew loss to approximately 1 in 10,000 missions and to lower the cost of delivering payloads to low-Earth orbit to less than $1,000 per pound. The comprehensive approach outlined in the ISTP is based on national space policies and on recent Space Transportation Architecture Studies, as well as on a wealth of lessons learned from various experimental technology demonstrators and today's launch systems. When formulating this plan to reduce the cost of access to space, it became apparent that it would take many years to develop a new launch system to meet these goals. It also became clear that the Space Shuttle would need to be flown for an extended time during the development cycle.

America's Space Shuttle is the 1st Generation RLV and has served our Nation well for over 20 years. However, it currently requires a significant portion of NASA's resources to operate and maintain, limiting the Agency's ability to pursue other initiatives in the areas of scientific exploration and development of space. The ISTP's prime focus is to enable a 2nd generation vehicle around the beginning of the next decade. As the Space Shuttle will continue to be the primary launch vehicle until this time, it is necessary to keep it flying safely until a replacement vehicle is operational. Therefore, Space Shuttle safety upgrades have been included as the first element in the ISTP.

The second and main focus of the ISTP is the Space Launch Initiative (SLI). Often referred to as the 2nd Generation RLV Program, the SLI is a near-term business plan for NASA and its partners, including the Department of Defense (DoD), to join forces to investigate new space transportation architectures, while advancing the technologies required to profitably implement them. In the spring of 2001, multiple contracts will be awarded, under NASA Research Announcement 8–30, to design and develop new launch vehicles that can meet NASA's diverse, unique requirements while encouraging the U.S. launch vehicle industry to regain market share lost to international competition. It is anticipated that around mid-decade, at least two competing architectures will go forward into full-scale development and could be operational early next decade. In the interim, SLI's Alternate Access to Space Station element will demonstrate the capability to deliver cargo to the orbiting laboratory in the event of a Shuttle contingency or if the Shuttle is over-manifested.

NASA's vision to revolutionize space transportation is being realized through an evolutionary, phased approach embodied in the ISTP and SLI plans. In order for NASA to meet its mission needs, the Agency recognizes that privately owned and operated launch vehicles lofting NASA payloads on a regular basis is the right strategy to free up its resources for scientific pursuit on the new frontier. How we will achieve that goal is by building an infrastructure that can support space traffic well beyond today's limited capacity.

While upgrading the Space Shuttle to keep it flying safely until a follow-on vehicle is operational, 2nd Generation RLV Program activities in the Fiscal Year (FY) 2001 to 2006 timeframe will be directed towards technical and business risk reduction areas where Government and commercial launch needs converge. Economic analysis shows that more reliable and highly reusable vehicles with streamlined operations will lead to increased flight rates, lower insurance premiums, and drastically reduced costs per pound of payload launched.

The new Administration's plans for space launch opportunities are outlined in the President's "A Blueprint for New Beginnings." Accordingly, NASA's FY 2002 budget includes a significant 64-percent increase in SLI funding. This timely investment comes when contracts for developing technologies for 2nd Generation RLV architectures will be in full swing. The eventual payoffs could have a compounding effect, with benefits ranging from a more mission-focused civil space Agency to commercial applications that will also take advantage of advanced technologies to generate beneficial products and services for everyone. Just as satellites launched a communications revolution in the 1980s and 1990s, more reliable and less expensive launch services might well usher in a new era of scientific exploration and economic expansion.

From FY 2001 to FY 2006, approximately $4.85 billion will be invested in America's future, with the Space Launch Initiative providing clear near-term guideposts. (Budget details are provided in Figure 2 on page 16.) To ensure program success, NASA is bringing together some of the Nation's most talented scientists and engineers, while making available its extensive research, test, development, and evaluation facilities, some of which are one of a kind. Reviews performed by informed and impartial industry experts will examine NASA's requirements and industry partner progress at well-defined stages. Cost studies are aligning Government estimating techniques with those of industry, for accurate comparisons and accountability on

both sides. This approach will lead to at least two competing vehicle architectures around mid-decade, with operational vehicles by early next decade.

NASA, in conjunction with its external stakeholders, is continually refining its requirements, both primary (i.e., ISS servicing, satellite deployment) and secondary (i.e., satellite repair), to identify where civil and commercial interests overlap in order to make maximum use of the innovative solutions being developed on their behalf. The SLI program is employing a comprehensive systems engineering and integration methodology to ensure that every investment contributes significantly to the overall goals of greater safety and reliability, coupled with lower costs. To best direct the technology development investments, computer system models are being developed and verified which accurately predict the benefits of each technology toward potential space transportation architectures. This systems analysis will serve as the foundation by which to continually assess the SLI's progress toward the program's safety and cost goals. Once high-priority technologies are identified, matured, and merged into a flight-worthy vehicle, launch markets can be expanded, with NASA as a customer.

Frequently launching highly reliable reusable vehicles will drive costs down. The 2nd Generation RLV's financial base will include frequent missions to the Space Station outpost, commercial and scientific payload deliveries to orbit, excursions within our solar system, and exploration onward to the vast expanses of the universe. The Space Launch Initiative will invest in technology and business risk-reduction activities to enable private industry and academia to close the gap between where we are today and where we want to go, as well as enable fresh commercial markets.

The third and final component within the ISTP's broad scope will help America maintain leadership in space far into the foreseeable future. Technologies for 3rd generation spaceships around 2025, and even 4th generation systems around 2040, as well as for in-space transportation to send probes to the outer reaches of our solar system and onward to the stars, all are being explored today under the auspices of NASA's Advanced Space Transportation Program (ASTP). Rocket engines that breathe air rather than carrying heavy oxidizers on board, propellant-less electromagnetic propulsion, and solar-powered space sails represent just a few of many exciting prospects.

The ASTP will mature technologies that will provide the greatest total safety improvements and cost savings over the life cycle of a space transportation system or the life span of approved missions which would utilize that transportation system. In addition to pursuing technologies to reduce costs, the ASTP will seek to advance technologies that increase performance margin, thus enabling missions that are currently not technically or economically feasible. These missions include safe, routine Earth-to-orbit transportation; rapid human and robotic transportation to the planets and nearby celestial bodies; and interstellar missions. Fulfilling NASA's role as an investment in America's future, the ISTP's 3rd Generation RLV Technologies Development initiative is looking well beyond the immediate tasks at hand, further toward routine access with airline-like operations along a vastly enlarged highway to space.

To better acquaint the reader with NASA's plans, this document: (1) provides the background leading up to the formation of the ISTP; (2) summarizes Space Shuttle safety upgrades; (3) gives details on the Space Launch Initiative, including the 2nd Generation RLV Program, NASA-Unique Requirements, and the Alternate Access to Space Station elements; and (4) shares a vision for revolutionary 3rd Generation RLV technologies and beyond. It also addresses SLI management reforms, as requested in the FY 2002 Budget Blueprint for the Agency, within the context of broader activities.

NASA is fully committed to sharing its specialized experience by leading its partners in the development of safer, more reliable, and cost-efficient launch vehicles. Just as Government investment helped the airline industry grow strong through six generations of evolution over the last century, America's 40 years in space have blazed a trail upon which to build a highway to space, much as we built a highway in the sky.

It is fitting that the "Blueprint for New Beginnings" coincides with the dawn of a new millennium. That plan clearly acknowledges that opening new trade routes and advancing human knowledge in the 21st century will be enabled by transitioning launch services from the Government to the private sector. NASA embraces its role as the gateway to both near-term and long-range risk-reduction activities and investments, realizing that this is the right time to enhance America's capabilities and to better invest NASA's resources by refocusing on its core missions. NASA's Integrated Space Transportation Plan and Space Launch Initiative reflect both the needs of U.S. aerospace and the goals of America's civil space Agency. Watch as this bold new beginning unfolds into the next generation of spaceships for the next generation of explorers.

Introduction

For over 3 decades, the United States has been the world's leader in space exploration and utilization. Our achievements have inspired generations of Americans and people around the world. To maintain this important leadership role, we must develop safer, more affordable, and more reliable space transportation systems.

The President's Fiscal Year (FY) 2002 Budget Blueprint, released in February 2001, reaffirms NASA's commitment to work with the aerospace industry to explore new space transportation systems that will dramatically increase safety and reliability, and reduce costs. In this way, we will pave a highway to space much as the airline industry has built a highway in the sky, with resultant economic benefits.

NASA's Integrated Space Transportation Plan (ISTP) is the long-range investment strategy for the Government to accomplish its mission objectives by enabling its partners to develop new, privately owned and operated space transportation systems, with NASA as the initial paying customer. Based on studies conducted with both aerospace industry and academic partners, the ISTP contains top-level strategies developed to meet the objectives of reducing the cost of access to space, while improving the safety and reliability of transportation systems.

Within the ISTP, the Space Launch Initiative (SLI) is the central near-term business plan for maturing the technologies necessary for developing 2nd Generation Reusable Launch Vehicles (RLV). A recent increase in funding, as outlined in the FY 2002 Budget Blueprint, reflects the high priority placed on SLI goals. Also important within the ISTP are long-term investments in 3rd Generation RLV technologies to further NASA's goal of achieving space flight with airplane-like safety, reliability and cost. Lastly, the ISTP includes targeted upgrades to the Space Shuttle to keep it flying safely until the new 2nd Generation RLVs are operational.

This narrative provides background and details of the Agency's consolidated space transportation development approach, as we continue building the highway to space to enable further scientific exploration and economic expansion. It also addresses important program updates and addresses SLI management reforms, as requested in the FY 2002 Budget Blueprint.

Background

The U.S. space program is critical to achieving our country's National security, as well as scientific, technical, commercial, and foreign policy goals. Assuring reliable and affordable access to space through domestic space transportation capabilities is a fundamental goal of NASA, which takes direction from U.S. space policies. The current course of action also integrates the results of the recent Space Transportation Architecture Studies (STAS) and the FY 2002 Budget Blueprint directives.

In August 1994, the National Space Transportation Policy divided the responsibility for developing expendable launch vehicles (ELV) and reusable launch vehicles between the Department of Defense (DoD) and NASA**,** respectively. The Policy established that by the end of the 1990s, NASA would make a decision on the development of a 2nd Generation RLV. Additionally, under the Civil Space Transportation guidelines, NASA was directed to maintain the current Space Shuttle system until this replacement launch vehicle becomes operational.

In the fall of 1996, the National Space Policy reinforced the efforts to enable the development of a next-generation RLV. It reaffirmed our Nation's commitment to developing new launch vehicles which would ensure America's continued role as the world's space leader.

Within the National Space Policy guidelines, NASA is identified as the lead Agency for research and development in civil space activities. The Policy directs NASA to develop new and innovative space technologies, as well as smaller, more capable spacecraft that will improve performance and lower the cost of future space missions. In the Space Transportation section, it addresses the commercial launch sector, stating that "assuring reliable and affordable access to space through U.S. space transportation capabilities is fundamental to achieving National space policy goals." The National Space Policy provides these guidelines:

- Balance efforts to modernize existing space transportation capabilities and invest in the development of improved future capabilities.
- Maintain a strong transportation capability and technology base.
- Reduce the cost of current space transportation systems, while improving reliability, operability, responsiveness, and safety.
- Foster technology development and demonstration to support future decisions on the development of the next-generation RLV.
- Encourage, to the fullest extent feasible, the cost-effective use of commercially provided U.S. products and services.
- Foster the international competitiveness of the U.S. commercial space transportation industry, actively considering commercial needs and factoring them into decisions on improvements to launch facilities and vehicles.

In response to this direction, NASA initiated a series of experimental (X) technology demonstrators to aggressively address specific advances required to reduce space-launch costs and improve the operability of a 2nd Generation RLV. These projects were established

anticipating that commercial launch markets would greatly expand in the near term and would, in fact, significantly outnumber NASA's annual missions. However, the market projections did not materialize.

In 1996, the X-33 Project was begun to demonstrate in suborbital flight the technologies needed for a single-stage-to-orbit RLV, serving as the "technology pull," with private industry as the operator and NASA as the customer. It was the first project to combine the many elements necessary to reduce launch costs, focusing on structures, materials, engines, computers, operations, and maintenance considerations. In 1999, the first of two conformal, load-bearing, composite liquid hydrogen flight tanks failed following pressure and loads testing. This failure was due to microcracking leading to gaseous hydrogen infiltration, which produced higher than expected core pressures. After the contractor determined that the commercial launch market could not justify their continued private investment, the OMB and NASA agreed that additional Government funds to complete the X-33 flight program could only come from a 2nd Generation RLV competitive bid through the NASA Research Announcement (NRA) 8-30. When the X-33 proposal was evaluated competitively against other proposals, it was determined that the magnitude of Government investment required exceeded the benefits that could be derived from flight demonstration of the vehicle. Therefore, the X-33 program was concluded in March 2001, when the cooperative agreement between NASA and Lockheed Martin expired.

Also in 1996, the X-34 Project was created both to provide a suborbital low-cost technology testbed with streamlined operations and rapid turnaround, and to test the tenets of "faster, better, cheaper" program theories as applied to developing a launch vehicle. In the summer of 2000, a joint NASA/Orbital Sciences Corporation review revealed the need to redefine the project scope and schedule, including increases in technical insight, hardware testing and integrated systems assessments, along with a significant budget increase. Again, the X-34 program was required to compete for additional funding as part of the 2nd Generation RLV NRA 8-30 procurement process. When evaluated against other proposals, NASA determined that the benefits of continuing the X-34 program did not justify the additional investment, and the program was terminated in March 2001.

Based on the philosophy of major growth in the commercial launch market, these experimental demonstrator concepts were pursued to enable significant private-sector investment in a new RLV, once the technology and business risks were reduced through Government financing. These efforts also focused on the "faster, better, cheaper" mode of management and operation, with success-oriented schedules and limited Government involvement in the partnerships, and on breaking traditional paradigms related to launch-system programs. All have yielded valuable lessons as a new picture of commercial launch needs, and of NASA's unique mission requirements, has emerged.

Started in the summer of 1999, the X-37 Project is an ongoing RLV experimental technology demonstrator. It is designed to operate in both the orbital and reentry phases of flight. This autonomous space plane will demonstrate numerous advanced airframe, propulsion and operations technologies that can support various launch vehicle architectures and contribute to the 2nd Generation RLV goals, discussed below.

Concurrent with the technology demonstrator projects, NASA sponsored industry-led future launch studies to identify private-sector options for reducing NASA's launch costs, in order to support a decision about the next-generation RLV by the end of the 1990s. These studies incorporated separate efforts that were undertaken by NASA, DoD, and the aerospace industry. Within the framework of the future launch studies, NASA pursued a set of evaluative efforts referred to as the Space Transportation Architecture Studies (STAS). In the fall of 1998, following the National Space Policy directive to solicit participation from the private sector, NASA selected five industry teams to develop commercial space transportation architectures to meet the Agency's specific mission requirements. The STAS process enabled industry partners to directly influence NASA's space transportation budget development and program planning processes. These studies were conducted in four phases, with the final phase completed in the summer of 2000.

NASA's goals of safety, reliability, and affordability, as well as its special mission needs, were provided as guidelines for architecture development activities during the STAS process. These guidelines emphasized improvement in crew safety, reduction in operations costs, and performance of all relevant Earth-to-orbit and in-space operations necessary to support NASA's missions. They also: (1) expressed the need to support military and commercial applications to the fullest extent possible; (2) addressed development and utilization of enabling technologies and capabilities that would support the development of new space transportation architectures by the middle of this decade; and (3) encouraged private investment in, and operation of, future space transportation systems.

Over the progressive phases of the STAS, NASA's requirements evolved from a limited set of missions to a larger set encompassing robotic and human operations in space. Industry was encouraged to investigate innovative ways to address these potential future NASA missions with commercially oriented systems and were asked to evaluate the impact of individual mission requirements in an effort to better understand the necessary cost trades.

In response, the industry teams generated a diverse set of preliminary architecture options that met commercial requirements, as well as identified the space transportation systems required to perform NASA-unique missions. The integration of commercial and NASA-only options was the basis for identifying the driving technologies that must be matured prior to the full-scale development of a next-generation RLV.

At the time of these studies, the joint NASA/industry teams identified multiple designs, including new RLV "clean sheet" approaches and Space Shuttle-derived options that could compete by the mid-decade time frame. To determine priorities for technology investments, the teams evaluated technologies that were under development to support NASA's experimental technology demonstrators, as well as for various advanced space transportation programs, discussed below. *The results stated that additional Government investments were required to close the technology development gaps necessary to support next-generation RLVs.*

Through the wealth of knowledge gained from both the experimental technology demonstrators and STAS, NASA and industry have developed a greater understanding of future space transportation requirements and have gained insight into promising, emerging technologies.

The technology demonstrator projects were intended to mature and validate the high-payoff technologies needed for future systems, and they have achieved many breakthroughs. More importantly, they have also shown that many risks remain, and that additional investments and changes in management and implementation are necessary in order to realize NASA's safety, reliability, and affordability goals for future launch vehicles. Substantially revised launch market projections reveal that a more collaborative strategy, rather than a pure industry-led approach, is necessary to assure that NASA, DoD, and commercial needs will be addressed.

Building upon this knowledge and experience, NASA and its academic and industry partners developed the Integrated Space Transportation Plan, a comprehensive blueprint for meeting the Agency's goals of safe, reliable, and affordable access to space, while enabling the U.S. space industry to grow in vitality and importance to the economy. The ISTP is NASA's integrated investment strategy for all of its space transportation efforts and includes funding for: (1) Space Shuttle Safety Upgrades; (2) the Space Launch Initiative, referred to as the 2nd Generation RLV Program, and (3) technologies for 3rd Generation RLVs and beyond. The direction in the President's FY 2002 Budget Blueprint has been incorporated into the SLI management approach, and specific strategies are addressed in that section.

Integrated Space Transportation Plan

With the Integrated Space Transportation Plan, NASA defined a single, comprehensive investment strategy for all of its diverse space transportation missions. Created in the fall of 1999, the ISTP establishes the framework to define the Agency's investment priorities for both near-term and long-range goals. It contains detailed options required for industry to complete their business cases, as well as investments needed for NASA-unique missions. It is the basis for NASA and private-industry contribution, evaluation, and integration into future planning and decisions toward the development of commercially owned and operated 2nd Generation RLVs.

The ISTP enables NASA's goals for space access through the following top-level strategies:

- Focus on safety, reliability, cost, and NASA's mission requirements, while maximizing U.S. aerospace industry capabilities and commercial market leverage.
- Reduce technical and business risks to achieve significant increases in safety and reliability and drastic reductions in the cost of 2nd generation launch systems, with operations capability by early next decade.
- Enable a competition at an acceptable level of risk for a 2nd Generation RLV by mid-decade.
- Develop revolutionary technologies for 3rd Generation RLV concepts to achieve safety and reliability comparable to today's commercial airliners.
- Ensure continued safe access to space through Space Shuttle safety upgrades until a replacement alternative has been demonstrated.
- Support military and commercial applications to the maximum extent possible.

Building upon the Space Transportation Architecture Studies, the ISTP development process implemented a rigorous and thorough method of defining and understanding both Government and industry requirements, and of evaluating and recommending investment options. This process consolidated NASA and commercial technology requirements, and prioritized them based upon the importance of improving safety, followed by cost and applicability to multiple industry concepts.

The ISTP development approach defined a detailed process of evaluating technology investment options. Each technology was subjected to a cost/benefit analysis and then ranked based on potential payoff to safety, cost, and technical risk. All analyses were based on architecture-level economic metrics. Economic analysis focus areas included technology prioritization, incentive evaluation, architecture optimization, architecture evaluation, and "sanity checks." The results of the integration and analysis process served as the foundation for a series of roadmaps that illustrate the path required to advance key technologies deemed necessary to produce new, privately owned and operated launch vehicles that meet stated goals.

The primary focus of the ISTP is the Space Launch Initiative and a $4.85 billion risk-reduction budget for space transportation system development, which was confirmed by the FY 2002 Budget Blueprint. This near-term business plan provides the strategy and funding for 2nd Generation RLVs, as well as investments in NASA-unique systems and near-term alternate access to the International Space Station. The Space Launch Initiative is our Nation's comprehensive plan to increase the commercial development and civil exploration of space. Simply stated, it is the key to opening the space frontier.

Each ISTP element is described in the following sections:

- Space Shuttle Safety Upgrades.
- Space Launch Initiative:
    - 2nd Generation RLV Program, including a Systems Engineering and Requirements Definition phase and a Risk Reduction phase,
    - NASA Unique Systems, and
    - Alternate Access to Space Station.
- 3rd Generation RLV Technologies Development.

As illustrated in the timeline shown in Figure 1.0, the ISTP integrates all space transportation activities required to address NASA's current and future needs.

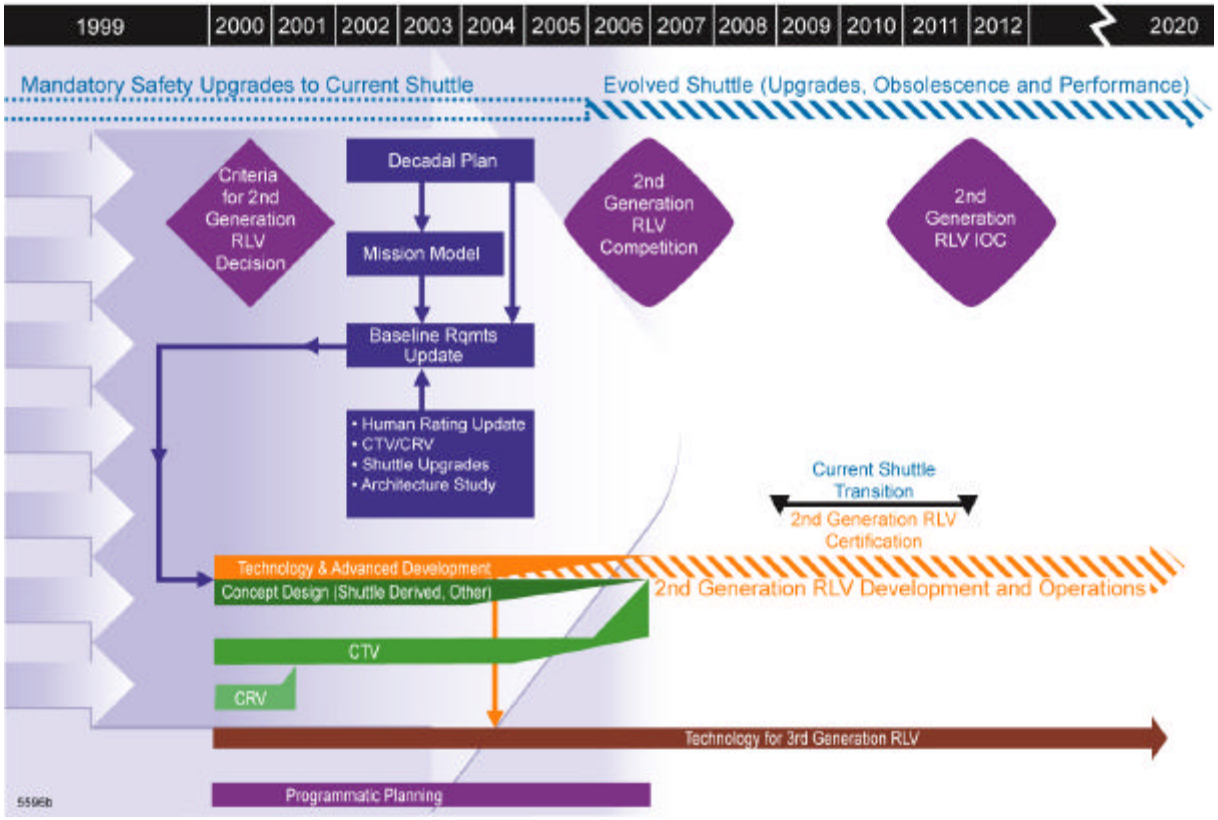

Figure 1. Timeline for addressing NASA's needs.

Space Shuttle Safety Upgrades

America's Space Shuttle, the world's 1st Generation RLV, has flown for 2 decades, serving our Nation with great success. As stated in the FY 2002 Budget Blueprint, "NASA will establish safety investment priorities for Shuttle safety upgrades and critical facilities." NASA is moving forward to keep this proven system performing safely until a 2nd Generation RLV is ready to fly early next decade.

Approximately $1.6 billion has been planned to address Space Shuttle improvements, including hardware and software upgrades, personnel, facilities, and other investments. NASA will continue to conduct independent reviews, including those by the NASA Advisory Committee, to assess how these funds can most effectively be used to increase Space Shuttle safety. The program's goals are to achieve:

- Major reduction in catastrophic failure risk when ascending to orbit.
- Significant reduction in catastrophic failure risk when in orbit and during reentry.
- Improved crew cockpit situational awareness, for managing critical operational events.

The development stage will conclude in 2005, and the fleet will be outfitted with the various upgrades by 2007. Additionally, the Agency must accomplish these goals without impacting its ongoing flight manifest.

Currently, three projects have been approved at the program level for implementation:

- Space Shuttle Main Engine (SSME) Advanced Health Management System (AHMS) Phase I
- External Tank Friction-Stir Welding
- Orbiter Main Landing Gear Tire/Wheel Improvement.

Proposed upgrade projects that are in the definition phase and moving toward Authority-to-Proceed (ATP) reviews in mid-2001, are:

- Cockpit Avionics Upgrade (CAU)
- Electric Auxiliary Power Units (EAPU)
- SSME AHMS Phase II
- Solid Rocket Booster (SRB) Thrust Vector Control/Auxiliary Power Units.

These investment areas are projected to improve the critical Space Shuttle ascent safety and reliability to approximately 1 in 1,000 missions. Other areas of investment may include crew escape system upgrades, combustion chamber upgrades, SRB pump modification, and redesigned solid propellant grain geometry. The implementation phase of such projects will occur only after sufficient design study and reviews have been completed in conjunction with corresponding cost/benefit analyses.

Space Launch Initiative

The Space Launch Initiative is the key to opening the space frontier for continued civil exploration and commercial development of space. NASA's strategic goals for a next-generation RLV are to reduce the risk of crew loss to approximately 1 in 10,000 missions and to lower the cost of delivering payloads to low-Earth orbit to less than $1,000 per pound.

Thus, the SLI is a comprehensive plan to dramatically increase the safety, reliability, and affordability of space transportation systems. It is a focused investment of approximately $4.85 billion between FY 2001 and FY 2006 for risk reduction and technology development efforts for at least two competing architectures. Through this initiative, NASA will reduce technical, cost, and business risks to acceptable levels to enable proceeding to full-scale development of a 2nd Generation RLV around the middle of this decade. A new system could be operational early in the next decade.

To meet these goals requires the capability to design, develop, and operate safe and reliable systems. This knowledge, combined with the fact that reduced launch costs will result from spreading infrastructure and operations costs over multiple launches, led to the four primary principles upon which the SLI is based:

- Commercial Convergence — NASA will seek to maximize convergence between commercial, NASA, and DoD missions, technology requirements, and operations considerations.
- Competition — NASA will seek to create an environment of competition to assure the best and most innovative ideas are supported and developed.
- Assured Access — NASA will provide access to the International Space Station (ISS) on more than one U.S. launch vehicle.
- Evolvability — NASA will develop systems that can affordably evolve to meet future mission requirements.

To meet the goals of substantially reducing space transportation costs while improving system safety and reliability, NASA will implement the following three-point risk-reduction strategy:

- Invest in technical, cost and market risk-reduction activities, driven by industry need, to enable full-scale development of commercially competitive, privately owned and operated, 2nd Generation RLVs around mid-decade, with operations early in the next decade.
- Develop an integrated architecture with systems that meet NASA-unique requirements that cannot be economically served by commercial launch vehicles alone.
- Demonstrate the capability to deliver cargo to the Space Station by alternate means

In this way, NASA will pursue risk-reduction efforts that will enable at least two competing industry-proposed architectures. All industry, academia, and Government laboratories are encouraged to compete in each element of the program. The Agency is considering architectural options that address NASA's long-term mission needs through the use of evolvable crewed and cargo systems. The combination of Government and commercial components requires a focused integration and comprehensive systems engineering effort in addition to the investigation of industry-defined and Government-unique risk-reduction activities. Thus, the Space Launch Initiative is being managed in three programmatic elements:

- 2nd Generation RLV Program, with a Systems Engineering and Requirements Definition phase and a Risk Reduction phase,
- NASA-Unique Systems, and
- Alternate Access to Space Station.

Figure 2 shows the projected funding profile for these SLI elements and reflects the FY 2002 Budget Blueprint estimates.

	FY01	FY02	FY03	FY04	FY05	FY06	Total
2nd Generation RLV Focused	271.7	475.0	765.0	1011.0	1064.0	1264.0	4850.7
1.0 Systems Engr & Rqmts. Definition	49.9	50.0	25.0	10.0	10.0	20.0	164.9
2.0 RLV Competition / Risk Reduction	95.0	287.0	556.0	811.0	599.0	789.0	3137.0
3.0 NASA Unique Systems	41.7	78.8	109.0	130.0	390.0	390.0	1139.5
4.0 Alternative Access	39.9	34.2	54.4	60.0	65.0	65.0	318.5
5.0 Pathfinder/X-37	45.2	25.0	20.6				90.8
5.1 X-37	41.4	23.8	20.6				85.8
5.2 Flight Experiments	3.8	1.2					5.0

Figure 2. Space Launch Initiative budget estimates ($M).

While providing a 64-percent increase in SLI funding for next fiscal year, the FY 2002 Budget Blueprint also outlines top-level management guidelines:

> ***Space Launch Opportunities***. *NASA's Space Launch Initiative provides commercial industry with the opportunity to meet NASA's future launch needs, including human access to space, with new launch vehicles that promise to dramatically reduce cost and improve safety and reliability. NASA will undertake management reforms within the Space Launch Initiative, including:*
> *1. ensuring vehicle affordability and competitiveness by limiting requirements to essential needs through commercial services;*
> *2. creating requirements flexibility, where possible, to accommodate innovative industry proposals;*
> *3. validating requirements through external, independent review;*
> *4. implementing a well-integrated risk-reduction investment strategy that makes investments only after requirements and vehicle options are well-understood, to ensure a viable competition by the middle of the decade for Station cargo and crew launch services;*
> *5. ensuring no set-aside funds for non-industry vehicles like the Space Shuttle; and*
> *6. achieving affordable, near-term successes in Next Generation Launch Services and Alternate Access to the Space Station and integrating these near-term activities into longer-term planning.*

The text below describes how NASA has initiated management reforms within the SLI that address these six priorities. Included is a summary of the 2nd Generation RLV Program approach. Also discussed are plans to meet NASA's special mission needs and for providing near-term alternate access to the Space Station.

2nd Generation Reusable Launch Vehicle Program

The overall goal of the 2nd Generation RLV Program is to substantially reduce technical and business risks associated with developing safe, affordable, and reliable RLVs. NASA's specific goals are to improve the safety of a 2nd generation system by two orders of magnitude — equivalent to a crew risk of 1 in 10,000 missions — and decrease the cost tenfold, to approximately $1,000 per pound of payload.

To ensure "vehicle affordability and competitiveness by limiting requirements to essential needs through commercial services," as well as to create "requirements flexibility, where possible, to accommodate innovative industry proposals," the Space Launch Initiative will be managed by a rigorous systems engineering process that will drive all programmatic decisions. The 2nd Generation RLV Program has been, and will continue to be, planned and implemented in complete cooperation with private-industry partners. However, NASA will continue to lead the effort and will ensure that risk-reduction activities contribute to the integrated architectures and will maintain the appropriate level of insight and involvement. In this way, at least two RLV options will be identified around mid-decade, leading to full-scale development, with operations early next decade.

The 2nd Generation RLV Program includes a Systems Engineering and Requirements Definition phase, as well as a Risk-Reduction phase. Systems Engineering and Requirements Definition objectives are to develop the detailed technical and programmatic requirements necessary to link technology and business risk-reduction efforts to competing architectures. NASA, in conjunction with its external stakeholders, is continually refining its requirements, both primary (i.e., ISS crew and cargo transfer) and secondary (i.e., satellite repair), to identify where civil and commercial interests overlap in order to make maximum use of the innovative solutions being developed on their behalf. Understanding the impact of requirements on the system will ensure that the overall architecture remains commercially competitive and affordable. It is also employed as the basis for critical decisions regarding architecture options and system characteristics to assure proper integration of the overall program. Detailed cost, safety, reliability, and performance models of space transportation flight and ground systems are being developed and validated. Architectural element trade studies are being performed using these models to determine how proposed systems relate to long-term ISTP goals. Risk Reduction objectives are to develop and maintain system-level requirements to meet safety, cost, and performance goals through integrated systems engineering. Each of these two phases is further discussed below.

2nd Generation RLV Systems Engineering and Requirements Definition Phase

The Systems Engineering and Requirements Definition focus is critical during the 2001–2005 time frame and is used as the basis for investment decisions in 2nd Generation RLV Risk Reduction activities. Specific tasks include:

- Development and assessment of NASA's unique mission needs, with requirements evaluation based on safety and cost goals, NASA and commercial needs, and maximum convergence of Government and commercial goals.
- System-level analysis, with rigorous trade studies to identify the technical and business risk reduction needed for various investments.
- Engineering systems-level analysis to develop detailed understanding of the environments that future RLV systems will encounter.
- Assessment of architectural elements as they relate to human-rating and survivability requirements.
- Analysis tool development, integration, and implementation.

NASA previously established a broad set of requirements and design reference missions to aid in the formulation of the first phase of the SLI. Those requirements were published as the point of departure for rigorous trade studies and evaluation by Government and industry.

Evaluation of the baseline requirements was completed in February 2001, and the goals and mission objectives have been classified as "primary" and "secondary" requirements. Generally, primary requirements include satellite delivery and Space Station cargo-and-crew support. Secondary requirements (e.g., satellite repair) include missions that can be met by adding architecture elements and other more stringent requirements that would require significant growth in the size and performance of the base system.

In order to validate "external requirements through external, independent review," NASA has initiated the External Requirements Assessment Team (ERAT), led by former Dryden Flight Research Center Director Kenneth Szalai, to provide a rigorous independent review of requirements and programmatic processes. The ERAT was chartered in the fall of 2000 and will remain in operation through out the life of the program. All records, including meeting minutes and recommendations, will be maintained as official program documentation. Initial program findings have been provided to senior NASA management and OMB. Following the ERAT review in April, 2001, final updated-and-clarified requirements will be released by authority to proceed for NASA Research Announcement 8–30 contract selections, to be awarded in the spring of 2001, as discussed below.

2nd Generation RLV Risk Reduction Phase

In keeping with the mandate to implement a "well-integrated risk-reduction investment strategy," NASA has developed a plan to enable a mid-decade competition such that critical technology demonstrations for each proposed architecture are adequately integrated, funded, and scheduled. NASA will baseline the risk -reduction investments for initial program phases. Significant 2nd Generation RLV Program milestones are shown in Figure 3.

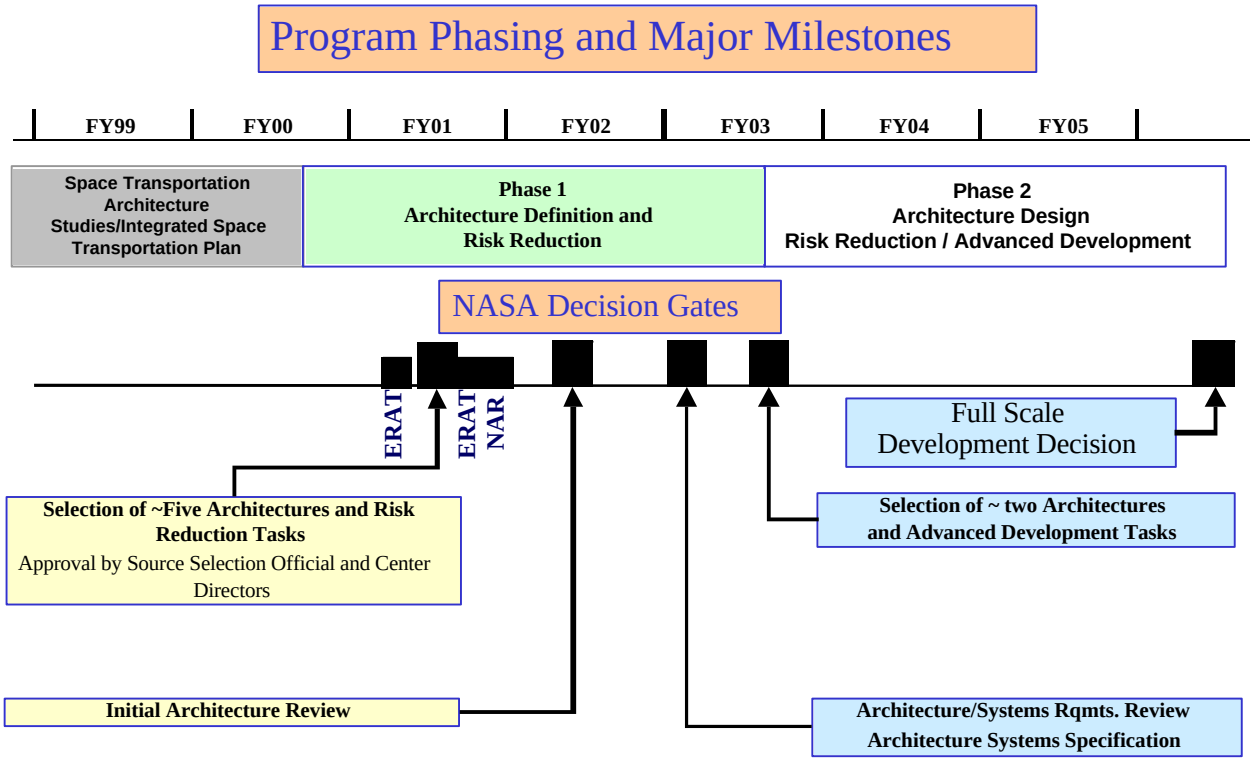

Figure 3. Significant 2nd Generation RLV Program milestones.

NASA is placing a high priority on the pursuit of technical and programmatic advances that will sufficiently reduce risks to enable a commercially competitive 2nd Generation RLV architecture which is to be privately owned and operated. Specific risk-reduction activities include business development and planning, and technology investments and advanced development, including ground and flight experiments. Investment in the 2nd Generation RLV activities will be driven by both Government and industry needs. Development of these capabilities will be consistent with the results of the Systems Engineering and Requirements Definition process.

NASA has initiated a broad set of risk-reduction activities, such as NRA 8–27 (FY 2000), which focused on detailed requirements evaluation, updated market projections, and risk-reduction priorities and plans. The final reports from these activities were completed in March 2001.

NRA 8–30 will result in award of multiple contracts in the spring of 2001, for specific risk-reduction activities and technology demonstrations. High-priority technology investment areas include: crew escape systems; highly reliable rocket propulsion systems; robust, reusable airframe technologies; advanced thermal protection systems; integrated vehicle health monitoring; and streamlined launch operations, among others.

A wide range of risk-reduction activities will be initiated during the first 2 years, followed by development efforts focused on the most promising technologies to assure at least two competing RLV options by mid-decade, leading to full-scale development, with operations beginning early next decade. Again, requirements are subject to regular, external, independent validation review. Decision milestones to stop or change projects, as needed, will assure overall program success.

By FY 2003, the risk-reduction investments will focus on the most promising architectures and systems. This focusing effort will continue to assure adequate competition of at least two architecture options. Gated procurements will be conducted, with opportunities to modify projects as needed.

Again, the ERAT will evaluate the integrated findings and validate the connectivity between goals, architectures, and risk-reduction selections. NASA will also conduct a Non-Advocate Review (NAR), with quarterly updates, to assure continued integration of the overall effort. The initial NAR will be completed by the end of September 2001. Overall program integration will be assured through the systematic use of systems engineering resources, processes, and staff. The program office will assure complete integration across the program, utilizing requirements integration and flowdown and risk management methodologies in all program areas (e.g., crew transfer vehicle, airframe, propulsion, integrated vehicle health management, etc.).

To ensure the 2nd generation vehicle is commercially viable, NASA, in collaboration with industry, continues to evaluate and support multiple architectures that can meet the program goals of safe, reliable, and affordable space transportation. The Agency is also committed to ensuring that the resulting architectures will enable convergence with NASA requirements and commercial and military missions, and will not pursue vehicles that cannot meet program goals.

The Agency will use the Space Shuttle as a “lessons learned” reference point and will invest in the continued study of applying SLI technologies to the Space Shuttle. The Shuttle integrated operations models will be used as a reference point to assess the competing SLI architectures and will assist the Agency and selected contractors in assessing potential benefits of proposed and maturing technologies. NRA 8–30 selections are being negotiated to achieve the proper investment balance relative to the total systems engineering effort. Other important considerations include staffing and cost credibility.

The 2nd Generation RLV Program office is bringing together the most experienced and qualified staff members from across the Agency. NASA is committed to providing the highest level of

talent available for this important initiative and is drawing from all its resources to ensure consistent staffing both at the program and project levels. Limited, but critical, outside hiring will be used to augment the program with world-class managers and engineers, where needed.

NASA continues to refine its cost credibility plan for ensuring confidence in, and consistency between, NASA, contractor, and independent vehicle cost estimates. This activity is aimed at reducing risk for the mid-decade competition and will include links to risk-reduction activities and cost uncertainty updates. This activity includes an integrated assessment of existing NASA and industry models and tools. A plan to initiate product delivery and tool integration has also been completed. It will be finalized by a senior manager assigned to the integrated modeling effort and reviewed by both the External Requirements Assessment Team and Non-Advocate Review group.

NASA-Unique Systems

Many of NASA's unique mission requirements cannot be served by commercial vehicles alone, since they often require human presence in space. This effort focuses on developing and demonstrating designs, technologies, and system-level integration issues associated with NASA-unique transportation elements such as a Crew Transport Vehicle (CTV), cargo carriers, rendezvous and docking system, crew escape system, crew situational awareness, and other architecture elements not required for commercial application. NASA-unique elements will be integrated with commercially provided Earth-to-orbit launch vehicles and other potential commercial systems to form the complete architecture for a 2nd Generation RLV system.

This SLI program element is being defined through the 2nd Generation RLV Systems Engineering and Requirements Definition process. In this manner, the NASA-unique requirements will ensure the Earth-to-orbit system will remain safe, competitive, and affordable within the larger architecture context. Solicitation for industry involvement is being conducted in parallel with the 2nd Generation RLV Risk Reduction process to aid in overall integration.

NASA is investigating the use of the lessons learned from Phase I of the Crew Return Vehicle (CRV) Program for application to potential crew transport vehicles. At OMB direction, NASA transferred funding for the CRV Program from 2nd Generation RLV Program to the International Space Station Program. An initial 2nd Generation RLV CTV/CRV requirements comparison activity has been completed. In addition, NASA has developed a strategy for efficiently integrating CRV/CTV systems analysis and risk reduction into 2nd Generation RLV architectures. The goal of this study was to determine the common and unique requirements of a CRV and CTV. Follow-on studies are scheduled in 2001, with a final decision due in 2003. As 2nd Generation RLV launch system architectures mature, coordinated CRV/CTV requirements, both unique and complementary, will flow into the risk-reduction activities. The CTV /CRV schedules and budgets are to be developed, based 2nd Generation RLV Risk Reduction solicitation evaluation results.

NASA intends to investigate innovative approaches with broad trade studies and a wide variety of systems solutions to efficiently address NASA-unique requirements. NASA will seek the development of unique assets that could be operated in conjunction with multiple commercially provided RLV assets to provide backup capability and enhance competition. NASA will explore systems that meet baseline requirements, but will also investigate the evolution of systems for other potential NASA missions, such as space exploration.

Alternate Access to Space Station

NASA will achieve "affordable, near-term successes in Next Generation Launch Services and Alternate Access to the Space Station, and [integrate] these near-term activities into longer-term planning." While the Next Generation Launch Services project is an ongoing, parallel effort to purchase commercial launch services, primarily for low-risk payloads, the Alternate Access to Space Station is a major element of the Space Launch Initiative. It is a focused near-term investment to ferry logistics supplies and cargo to the International Space Station, as well as to provide contingency backup or relief for the Space Shuttle. Thus, NASA and private industry have the opportunity to develop system designs and innovative procurement mechanisms for a launch vehicle capable of operating in the vicinity of the Space Station.

Established and emerging launch companies have a unique chance to provide near-term, commercial application for their systems, creating mutual benefit to private industry and NASA. The Alternate Access effort will adhere to National policy by restricting this commercial opportunity to U.S.-manufactured systems. Specific issues regarding the use of foreign components on U.S.-manufactured systems will be evaluated on case-by-case basis.

NASA will ensure proper integration with 2nd Generation RLV activities, synthesizing common elements and evaluating systems within the context of an integrated architecture. Ongoing system studies will determine if the planned Alternate Access schedule and budget profile is congruent with the acquisition or development of an alternate delivery system to the Space Station. Program definition and detailed program planning will be completed in FY 2001.

3rd Generation Reusable Launch Vehicle Technologies Development

As the long-term element of the Integrated Space Transportation Plan, NASA also is investing in select technologies aimed at reducing the cost of space transportation to hundreds of dollars per pound by 2025, while attaining safety and reliability comparable to today's airliners. Travel beyond low-Earth orbit and far-reaching interstellar missions require breakthrough technologies, and these are being addressed by 3rd Generation RLV Technologies Development.

For example, 3rd Generation RLVs could utilize a magnetic levitation track that accelerates vehicles up to 600 miles per hour before lift-off. Another revolutionary technology is a rocket engine that breathes oxygen from the air during the climb to orbit, rather than carrying heavy

oxidizer onboard. Electrodynamic tethers and solar-powered space sails also could become operational within the first half of this century. These are just a few cutting-edge technologies being developed by NASA's Advanced Space Transportation Program (ASTP), which is responsible for implementing the 3rd Generation Technologies and long-term research elements of the Integrated Space Transportation Plan.

The ASTP establishes and maintains a balanced research and technology program that addresses mid-term and long-term needs for 3rd generation Earth-to-orbit systems and in-space transportation for Earth orbital, deep space planetary exploration, and human exploration of space. The objective is to provide the technologies to reduce risk for operational system development, while addressing future breakthrough technologies beyond the next generation of space transportation systems.

The ASTP will mature technologies that will provide the greatest total safety improvements and cost savings over the life cycle of a space transportation system or the life span of approved missions which would utilize that transportation system. In addition to pursuing technologies to reduce costs, ASTP will seek to advance technologies that increase performance margin, thus enabling missions that are currently not technically or economically feasible. These missions include safe, routine Earth-to-orbit transportation; rapid human and robotic transportation to the planets and nearby celestial bodies; and interstellar missions.

The ASTP will focus on research and technology development in three areas: Hypersonics, In-Space Propulsion, and Long-Term Research. Based on the U.S. Air Force (USAF) Science Advisory Board Recommendation in December 2000, NASA and the USAF will collaborate in air breathing hypersonic technology development and demonstrations. NASA will team with other Government agencies in achieving the National Hypersonics Plan goals of controlling and exploiting the full aerospace continuum and dramatically improving the reliability of future generations of space vehicles. The In-Space Propulsion investments will be directed to space transportation applications within Earth orbit and to the edge of the solar system. The primary customer for these technologies is NASA's Science Enterprise. Lastly, the Long-Term Research investment area will pursue proof-of-concept research in revolutionary technologies that may lead to dramatic reductions in the cost of access to space and interplanetary and interstellar space mission travel times. Together, these 3rd Generation RLV Technology Development paths represent our investment in U.S. space leadership far into the foreseeable future.

Conclusion

With the creation of the Integrated Space Transportation Plan, NASA has defined a balanced program of investment for its diverse space transportation activities. The Space Shuttle will be maintained through focused safety investments as NASA aggressively pushes to 2nd and 3rd generation systems that will provide opportunities for the commercial development and scientific exploration of space. NASA is collaborating with private industry to maximize the opportunities for commercial launch services and is creating an environment of increased competition. Near-term opportunities for delivering select cargo to the Space Station are being pursued, with a priority on enabling commercial launch alternatives.

NASA has made significant progress in understanding future space transportation requirements and promising technologies, but much remains to be done to take these advances to the next level to achieve the goals of enabling safe, reliable, and affordable space transportation systems. Additional investment is required to reduce business and technical risks to acceptable levels. Government investment is required to bridge this gap to enable industry to close their business cases. Private industry will not and cannot make adequate investments in space transportation risk reduction and technologies. The aerospace industry is dependent on NASA pursuing technological advancements to maintain or improve U.S. competitive capability in the international launch market. The Nation's long-term investment through the Integrated Space Transportation Plan, and near-term investment through the Space Launch Initiative, is the necessary key to mitigate these risks, to encourage interest in private financing of future systems, and to open the door to the space frontier.