SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY — **AERO-SPACE RESEARCH & TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Research and technology base	488,441	581,620	539,400	SAT 4.1-2
Focused programs	710,107	403,229	507,400	SAT 4.1-23
Investments	(7,000)	(7,200)	11,200	SAT 4.1-73
Total	1,198,548	984,849	1,058,000	

Distribution of Program Amount by Installation	FY 1999	FY 2000	FY 2001
Johnson Space Center	5,492	2,025	5,667
Kennedy Space Center	1,779	4,446	10,555
Marshall Space Flight Center	317,429	191,745	236,574
Stennis Space Center	22,774	29,658	10,760
Ames Research Center	205,818	197,034	211,477
Dryden Flight Research Center	86,581	98,521	99,224
Langley Research Center	280,983	198,913	237,734
Glenn Research Center	221,599	186,187	194,870
Goddard Space Flight Center	4,478	1,227	3,781
Jet Propulsion Laboratory	6,111	4,072	10,452
Headquarters	45,504	71,021	36,906
Total	1,198,548	984,849	1,058,000

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY BASE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Information Technology	66,592	77,800	115,979
Vehicle System Technology	138,493	157,537	136,275
Propulsion & Power	75,417	76,268	75,498
Flight Research	63,585	70,715	80,950
Operations Systems	43,353	17,000	17,475
Rotorcraft	27,201	26,900	26,654
Space Transfer & Launch Technology	64,300	136,500	70,569
Minority University Research and Education Program	7,000	7,200	(11,200)
Construction of Facilities	2,500	11,700	16,000
Total	488,441	581,620	539,400

PROGRAM GOALS

The goal for NASA's Research and Technology (R&T) Base is to serve as the vital foundation of expertise and facilities that consistently meets a wide range of aeronautical and space transportation technology challenges for the nation. The R&T Base is intended to provide a high-technology, diverse-discipline environment that enables the development of new, revolutionary, aerospace concepts and methodologies for applications in industry. The R&T Base has an objective to develop revolutionary concepts, highly advanced, accurate computational tools, and breakthrough technologies that can reduce the development time and risk of advanced aerospace systems that contributes to one or more of the Aero-Space Technology Enterprise goals and lay the foundation for future focused programs to address these goals: Global Civil Aviation, Revolutionary Technology Leaps and Low Cost Access to Space. This work constitutes a national resource of expertise and facilities to respond quickly to critical issues in safety, security, transportation, and the environment. These same technological resources contribute to the overall U.S. defense and non-defense product design and development capabilities.

STRATEGY FOR ACHIEVING GOALS

A major restructuring and replanning of the Aero-Space Enterprise's Base R&T program was accomplished during 1999 to integrate the Enterprise's existing space transportation and aeronautics Base R&T development programs into a single entity. This restructuring better aligned the required technology development efforts with core competencies and brought the expertise, resident in the aeronautics research centers, to bear on the technological challenges associated with space transportation. Secondly the integration of the space and aeronautics development needs resulted in a synergistic technology development plan that better utilized our resources, eliminated overlaps, and allowed dual use, between the space transportation and aeronautics users, to be included as part of the planning process.

Continuous advances characterize the technology environment for success in aerospace across a wide range of disciplines, as well as developments of revolutionary technology. The R&T Base is critical to technological preeminence in the worldwide aerospace market. Through basic and applied research in partnership with industry, academia, and other government agencies, NASA develops critical high-risk technologies and advanced concepts for U. S. aircraft, spacecraft, launch vehicles, and advanced turbomachinery-based engine industries. These advanced concepts and technologies allow safe, highly productive global air and space transportation systems that include a new generations of environmentally compatible, reliable, safe, and economical U. S. aircraft, spacecraft, and launch vehicles that are competitive in the marketplace.

The R&T Base is an essential element of the Enterprise, for it is here that new technologies that lead to future advanced aerospace products are conceived. The R&T Base provides a strong foundation for the fundamental understanding of a broad range of physical phenomena, development of computational methods to analyze and predict physical phenomena, and experimental validation of key analytical capabilities. It is this capability that allows NASA to provide authoritative data to national policy makers in areas such as the environmental impact of aero-space systems. The R&T Base also develops revolutionary concepts, highly advanced, accurate computational tools and breakthrough technologies that can reduce the development time and risk of advanced aerospace systems and high performance aircraft. A significant portion of the research and concept development in the R&T Base is performed through partnerships and cooperative agreements with the aerospace industry and other government agencies to facilitate rapid technology transfer. Also, the R&T Base supports the vast majority of the Enterprise's peer-reviewed fundamental research with academia and industry. The program also provides the capability for NASA to respond quickly and effectively to critical problems identified by other agencies, industry or the public. Examples of these challenges are found in: accident investigations, lightning and radiation effects on avionics, flight safety and security, wind shear, crew fatigue, reducing environmental impacts of aeronautical systems, structural fatigue, spacecraft/launch system anomalies, and aircraft stall/spin.

One of the key factors in aeronautical research is an extensive use of research facilities that are located at the four aeronautical research centers: 1) Ames Research Center, 2) Dryden Flight Research Center, 3) Langley Research Center, and 4) Glenn Research Center -- and the Marshall Space Flight Center (MSFC). Many facilities, such as the National Transonic Facility, the National Full-Scale Aerodynamics Complex, the Icing Research Tunnel and the fleet of research aircraft are unique in the United States and even the world. Other factors underpinning continued governmental support of aeronautical research include:

- The public-good character of much of the research (safety, environment, certification, national security),

- Large disincentives for private sector investment in long-term, high-risk aero-space R&T. Due to the long recoupment period for aero-space research and technology development, an individual company can rarely capture the full benefit of these investments.

- The extensive breadth and depth of technologies required to produce a superior aircraft or space transportation system,

- The unique cadre of experienced NASA technical personnel.

The Aero-Space Technology R&T is a framework of seven systems oriented, customer driven programs, that serve the needs of the full range of aeronautical vehicle classes. The seven R&T Base programs are:

1. Aero-Space Information Technology: The primary focus of this program is to perform leading-edge research in advanced computing systems and user environments, revolutionary software technologies and pathfinding applications in integrated design. The Intelligent Synthesis Environment (ISE) is aimed at making substantial progress toward fulfilling the NASA Administrator's vision for revolutionizing next generation science and engineering capabilities. ISE will achieve this vision by developing revolutionary ISE-related technologies; engineering practices and coordinating related on-going NASA activities, industry activities, other government agency initiatives and university research.

   The overarching goal of ISE is to develop the capability for personnel at dispersed geographic locations to work together in a virtual environment, using computer simulations to rapidly model the complete life-cycle of a product/mission before commitments are made to produce physical products. This capability includes processes, methods, tools, integration architecture and user environments which enable integrated end-to-end life-cycle design in a geographically distributed collaborative environment. ISE will bring this capability into practice on selected NASA application cases with reusable launch vehicles as the first priority application testbed. The implementation goal is to reduce design cycle time in half, with a comparable reduction in testing and costs due to rework

2. Aero-Space Vehicle Systems Technology: The program develops technologies that have application to all flight vehicles with emphasis in areas such as: conceptual design; aerodynamic and structural design and development; flight crew station design; and airborne systems design and testing.

3. Aero-Space Propulsion and Power Technology: The purpose of this program is to design and develop efficient, safe, affordable and environmentally compatible propulsion system technologies for subsonic and high speed transports, general aviation, high performance aircraft, and access to space.

4. Flight Research: The technology development under this program is aimed at remotely piloted aircraft, high performance aircraft, hypersonics, and tools and test techniques

5. Operations Systems: This program develops critical technologies in the areas of operational human factors, relevant cockpit systems, weather and hazardous environment characterization and avoidance systems, air traffic management, and communications, navigation and surveillance systems.

6. Rotorcraft: This program develops technology for improved flight safety; reduction of noise for passengers and the community; design tools for reduced design-cycle time and reduced manufacturing costs of rotorcraft.

7. Space Transfer & Launch Technology: The STLT Program is the technology-based program for unique space transportation requirements. Future revolutionary advances in space transportation technology will be developed in this program to reduce costs and increase reliability and performance across the entire mission spectrum. Advanced

technologies will be developed and ground-tested to bring them to readiness levels where they can either be adopted by industry, or if necessary, flight-proven. The STLT Program will focus on technological advances with the potential to increase the safety / reliability

In addition, STLT will make key technology investments for in-space transportation systems to reduce costs, system mass and trip time for future in-space missions. The STLT utilizes competitive technology selection and procurement processes wherever feasible in order to maximize the involvement of the myriad traditional sources of space transportation technology throughout the country, as well as to bring in potential new sources. An inter-center process has been established to prioritize STLT investments based on their system payoff in terms of improvements in mission safety, reliability, capability, cost, operability and responsiveness. The goals, objectives, and progress of the STLT will be evaluated on a yearly basis by an external, independent panel of nationally recognized experts to ensure program content is consistent with government and industry priorities, and that the program is yielding the maximum possible return on the taxpayers' investment.

a 2nd Generation Reusable Launch Vehicle (RLV) – Development of technologies required by a 2nd generation RLV. Currently includes the Fastrac Engine and RLV Focused Projects. RLV Focused activities will be strongly driven by industry needs. These projects support the Aero-Space Technology Enterprise's Goal 9.

b In-Space - Development of technologies for upper stages, Earth orbital and planetary transfer and interstellar precursor missions. The needs of the commercial sector, NASA Human Exploration and Development of Space and Science Enterprises guide in-Space projects. These projects support the Aero-Space Technology Enterprise's Goal 10.

c Advanced Launch Technologies – Development of technologies which advance the state-of-the-art in propulsion, airframe and launch vehicle systems, operations and integrated vehicle health management towards the long-term Aero-Space Technology Enterprise's Goal 9 technology objectives. Technology priorities are derived from the contribution to overall transportation system goals. While focused on long-term goals, many early Spaceliner demonstrations will support 2nd Generation RLV needs.

d Space Transportation Research – Research into very advanced, breakthrough concepts for revolutionizing space travel.

Accomplishments over the past year continue to provide a foundation for longer-term technology development, address national needs as outlined in the Enterprise's Three Pillars for Success, and provide research facilities operations and expert consultation for industry during their product development design and build processes. Conceptual studies took into consideration various state-of-the-art technologies to reduce aircraft and space transportation systems design, manufacturing, and operational costs. The conceptual studies addressed breakthrough technology requirements for future commercial and general aviation transports, rotorcraft, space access, missions to the planets and beyond, hypersonic vehicles, as well as high performance and high altitude remotely piloted aircraft. The R&T Base continues to sponsor and conduct research using cooperative programs, not only to leverage resources for technology development, but also to ensure timely technology transfers to U. S. customers.

SCHEDULE AND OUTPUTS

Information Technology

Adaptive coefficient based controller flight demonstrated in shadow mode on the F-15 ACTIVE aircraft.	Achieve neural net reconfiguration in flight.
Plan: March 1999 Actual: March 1999	An adaptive neural-net based intelligent flight controller was successfully demonstrated on the F-15 ACTIVE aircraft during flight tests.
Demonstrate prototype heterogeneous distributed computing environment Plan: September 2000	Demonstrate tools and software to link distributed computing test-beds at multiple NASA Centers into a single "virtual" supercomputing environment.
Demonstrate ability to adapt to loss of control surfaces and maintain control of aircraft Plan: March 2001	Combine Propulsion Controlled Aircraft (PCA) control laws with the Intelligent Flight Control System (IFCS) to demonstrate a new capability for adapting to absence or loss of any and all control surfaces resulting from failures or malfunctions.
Demonstrate prototype data communications scheme for NAS Plan: September 2001	Demonstrate a prototype data communications scheme for the National Airspace System.

Intelligent Synthesis Environment

CEE Prototypes Plan: 2nd Qtr, 2001	Establish prototype collaborative engineering environments
Methods and Tools Architecture Plan: 4th Qtr, 2001	Establish architecture for seamless interoperability of next generation methods and tools

Aero-Space Vehicle System Technology

Physics-based prediction of airframe noise components Plan: March 2000	Develop physics-based computation of airframe noise components including flap-side edge, slat, and landing gear.
Non-linear composite pressure structure Plan: September 2000	Fabricate and test non-circular composite pressurized structural sub-component and compare with analytical predictions.

Hyper-X Mach 7 Flight 2 Plan: December 2000	Envelope expansion of Airframe Integrated, Dual-Mode Scramjet powered vehicle in flight at Mach 7.
Complete Blended Wing Body (BWB) test vehicle Plan: March 2000	Complete and integrated blended-wing-body low-speed flight research vehicle prepared and delivered to Dryden Flight Research Center for final validation and testing. (December 2000)
Systems Analysis of Short Takeoff and Landing (STOL) & Extremely Slow Take Off and Landing (ESTOL) Plan: June 2001	Complete Systems Analysis of STOL & ESTOL studies.
Demonstration of "smart" panel technology Plan: September 2001	Smart Wing Phase II complete – wind tunnel test of a smart Uninhabited Combat Air Vehicle (UCAV) with hingeless control surfaces.
Mach 10 Research Vehicle Flight. Plan: September 2001	Demonstrate an airframe integrated, dual-mode scramjet powered vehicle in flight at Mach 10.

Propulsion Systems

Demonstrate 900°F SiC sensor on an engine. Plan: September 2000	Commercial grade, high temperature sensor demonstrated at 900°F.
Demonstrate 'smart' turbomachinery concepts to minimize pollutants throughout mission cycle. Plan: September 2000	Active combustion control strategy rig demonstrated, 20dB suppression of instability driven acoustic energy.
Complete Inlet Test for Pulse Detonation Engine Flight Research Project Plan: May 2001	Demonstrated unsteady inlet flow performance for PDE ground and flight research tests.
Demonstrate viability of hot section foil bearing Plan: September 2001	Complete Core Hot Section Radial Foil Bearing Rig Testing

Crack resistant blades Plan: September 2001	Provide alloys for blades that are more crack-resistant.

Flight Research

Complete low-altitude flight of Helios Plan: March 2000 Actual: December 1999	Demonstrate a solar-powered remotely piloted aircraft with wingspan greater than 245 feet suitable for flight to 100,000 feet in altitude or a duration of 100 hours once outfitted with high performance solar cells.
Demonstrate continuous "over the Horizon" control of RPA Plan: June 2000	Flight demonstration of reliable "over the Horizon" control of RPA utilizing low cost commercial satellite systems.
Complete development of laboratory (heavy weight) energy storage Plan: September 2001	Demonstration of fuel cells with 300 milliamps per square centimeter at a cell voltage of .8 volts and an electrolyzer with 500 milliamps per square centimeter at a cell voltage of 1.6 volts.
Demonstrate solar power RPA flight to 100,000 feet Plan: September 2001	Helios RPA achieves 100,000 foot altitude under solar power.

Aviation Operations Systems

Define effects of in-flight activity breaks on alertness Plan: July 2000 Revised: June 2000	Conduct a full-mission simulation experiment that utilizes in-flight activity breaks as the controlled variable; produce report documenting their efficacy.
Identify and evaluate existing crew strategies for reducing errors in the management concurrent tasks. Plan: May 2001	Determine how the demands of managing multiple concurrent tasks contribute to crew errors in aviation, document in report.
Downselect of ground-based remote sensor technologies for a prototype ground-based System to sense icing conditions. Plan: June 2001	Review, evaluate and select candidate remote sensing technologies, document in a NASA TM.

Rotorcraft

Flight demonstrate active control technology for rotorcraft interior noise reduction; provide interior noise prediction methods for a range of rotorcraft types. Plan: June 2000	Demonstrate cabin noise reductions resulting from improved interior panel isolator mount designs and from an active structural acoustic control system concept; validate improved interior noise analytical prediction tools covering a wide frequency range and alternative designs.
Develop and validate capability for large-scale rotor testing. Plan: September 2000	Wind tunnel demonstration of capability to test large-scale rotor systems (up to 50,000 lb. thrust and 6000 HP) using newly developed Large Rotor Test Apparatus.
Rotorcraft Crashworthiness. Plan: January 2001	Demonstration of strong correlation of analytic model predictions with full-scale water/soft-soil-impact test results; demonstration of analytic model for designing energy-attenuating rotorcraft structures for crashes onto water, soft soil and rigid surfaces.
Health and Usage Monitoring Systems (HUMS) Certification Protocol. Plan: February 2001	Detailed protocols for a sanctioned demonstration leading to rotorcraft component-life-credit certification -- accepted by both the FAA and the DoD. RITA diagnostic algorithms will be evaluated and a set of usage requirements will be generated. Preliminary design for HUMS implementation on various aircraft will be written. Plans for a limited flight evaluation of Cockpit Situational Awareness Algorithms will be developed.
Ultra-safe gear design guide. Plan: March 2001	Complete 2-D gear crack analyses and experiments. Document analysis and test results in a comprehensive report and technical conference paper.
Flight validate advanced control laws/modes for reduced pilot workload and increased safety in low visibility Plan: March 2000 Revised: September 2001	Achieve Level 1 pilot ratings in Rotorcraft Systems Concept Airborne Laboratory (RASCAL) UH-60 for flying tasks typical of civilian operations. Milestone rescoped and reworded to conduct flight validation based on baseline RASCAL control laws due to funding shortfalls.

Space Transfer & Launch Technology

LOX Densifier verification testing and completion of hydrogen densifier build Plan: September 2000 Revised: June 2000	"Complete RLV focused technologies tasks" milestone divided into five separate milestones (Hydrogen densifier, MMC & PMC, thrust cell chambers), advanced TPS panel, composite cryo tank, and composite LOx tank) to provide clarity and reflect different schedules. Validate design, technology and operational characteristics of X-33 scale liquid oxygen propellant densifier, and prove readiness for use in experimental propulsion ground test or flight test program. Completion of Hydrogen densifier assembly.
Complete fabrication of Metal Matrix Composite (MMC) & Polymer Matrix Composite (PMC) thrust cell chamber demonstration units Plan: August 2000	Delivery of 5 different demonstration units, each fabricated with different composite structural jackets surrounding a new copper alloy liner. Will demonstrate successful fabrication of thrust cell chambers using new material systems that offer weight savings up to 40%.
NSTAR Engine ground demonstration Plan: January 2000 Revised: September 2000	Complete NSTAR Mission Profile (100% design life) ground testing for Deep Space-1 (concurrent, identical firing of an NSTAR engine in a vacuum chamber with the actual firing sequence of the in-flight propulsion system).
Complete Small Payload focused technologies and select concepts Plan: September 2000 Actual: Deleted	Concepts will be selected for flight demonstration of a reusable first stage based on FY 1999 and FY 2000 technology development. Deleted as result of decision to terminate the Bantam project.
Advanced TPS panel development, fabrication and test Plan: September 2000	Database of metallic TPS coatings and materials. Advanced TPS concept validated through ground test. Metallic TPS is more robust and required significantly less maintenance than current ceramic tile and blanket TPS. Metallic TPS can also offer reduced weight, improved vehicle performance through higher temperature metallic materials and all-weather operation
Composite Cryogenic Tank and Integrated Structures Demonstration Plan: July 2001	Validation of PMC cryogenic LH2 and LOX tanks to include validation of compatible materials systems and processes, fabrication and joining of large-scale articles, and demonstrated thermal-structural performance. Significant weight reduction for RLV cryotanks and primary structure can be quantified through actual test data.
Complete preliminary design of LOX tank for X–34 Plan: March 2000	Hold preliminary design review of composite LOX tank for X–34. The tank being fabricated in this activity will become the first composite liquid oxygen tank to be flight tested. The long-term impact of utilizing low-cost lightweight composites in liquid oxygen tank applications will be to reduce the cost of access to space.

Combined Cycle Engine System Selection for first Flight Demonstrator Plan: September 2001	Engine preliminary design reviews complete. Establish preferred airbreathing engine concept for FY 05 flight demonstrator that will directly support the long term objectives of Goal 9.
Combined Cycle Flowpath Definition and Testing Completed for First Flight Demonstrator Plan: September 2001	Flowpath characterizations complete. Used as criteria for combined cycle demonstrator engine selection that directly supports the long term objectives of Goal 9.

ACCOMPLISHMENTS AND PLANS

Information Technology

In FY 1999, the Information Technology program further developed integrated design techniques, including wind tunnel flow quality and testing productivity enhancements, more accurate model positioning and balance calibration systems, on-line real-time test data and more versatile user interfaces. Of particular focus within the integrated design effort was the transition of the technology from aircraft to space transportation systems applications. Specifically, the integrated design tools was adapted and applied to thermal protection system design of reusable launch vehicles. Together with advanced instruments and data acquisition systems, this effort continued the development of capabilities for real-time design exploration of aerospace vehicles. An intelligent, neural-network flight control system was flown on an F-15 research aircraft, and work initiated to integrate this capability with propulsion control, health monitoring and diagnosis capabilities. Intelligent tools for an aviation safety data sharing network was developed and a prototype data-sharing network will be established. An effort to demonstrate real-time data sharing with a flight vehicle is planned. Next-generation computing systems was developed that take advantage of geographically distributed resources, requiring new capabilities in network quality of service, data storage, retrieval and analysis, and system operations including scheduling, planning, and accounting. Software technology developments contributed to enhancing the reliability of complex, flight-critical systems (such as flight control systems), and reducing the cost of producing, verifying, and validating these systems. Tools for ensuring and verifying the integrity of wireless data communications to enhance the safety of the future National Airspace System were developed and demonstrated.

In FY 2000, the Information Technology program will complete a demonstration of real-time aerospace design exploration. The developed environment will include remote connectivity, access to experimental data in real-time, capability to perform simulations in near-real-time, and access to databases with analysis tools to support design. All of these capabilities will be coupled with newly developed instrumentation and data systems to provide previously unavailable experimental data. In addition to reductions in access time to high-fidelity simulations data, specific goals of the system include a reduction in access time to experimental data by a factor of five, and a reduction in access time to archived database sources by a factor of two. Improvements in software technology will result in the development of verifiably correct program synthesis technology. Tools will be demonstrated to reduce time in software coding and testing. Specifically targeted applications will demonstrate these tools on real-world, complex software development activities meeting NASA mission requirements. Finally, the first prototype of a geographically-distributed heterogeneous high-end computing system will be developed and demonstrated for NASA supercomputing requirements. The developed software tools will link multiple NASA supercomputing assets seamlessly and transparently to the end-users. The overall computing capability enabled by this technology will allow for geographically dispersed engineering collaboration and greater peak computing power.

In FY 2001, the Information Technology Base Program will demonstrate an environment for aerospace hardware design that will provide real-time access to flight simulation data during a flight simulation test, with computational simulation data available as input to the flight simulation. This research will provide a capability for assessment of design impacts on aerospace vehicle controls and handling qualities earlier in the design cycle, leading to reduce design costs and improve designs. A cross-fidelity aerospace design system being developed in the IT program will enable the use of high-fidelity Computational Fluid Dynamics design codes in a design paradigm focused on rapid turnaround of computational solutions. Software technology being developed by the IT program will result in increases in safety and productivity for the National Airspace System. Automated program synthesis technology will provide a next-generation technique for reducing software development cycle time and cost. High-confidence assembly of programs via automated software integration will create a foundation for reuse of certified software components and systems. Intelligent Life-Extending Engine Control will yield substantial increases in aircraft engine lifetimes, resulting in reduced life cycle costs for maintaining a fleet of aircraft. Work done previously in the IT program in Intelligent Flight Controls will be extended into Propulsion Controlled Aircraft control laws and demonstrate a capability to adapt to loss of any and all control surfaces resulting from failures or malfunctions, up to and including propulsion-only flight. This technology can dramatically increase the safety of commercial aircraft. A satellite-based system for air-ground communications using multiple protocols will provide increased situational awareness capability both in the cockpit and on the ground. Research in advanced, high-performance computing will reduce turnaround time for aerospace vehicle design and simulation. The advanced computing system being implemented in the IT Base Program will enable access to distributed computing systems and on-demand connectivity to high data rate instruments, leading to enhanced engineering and scientific collaboration among geographically-dispersed investigators. This technology is likely to impact not only aerospace vehicle design, but also Earth and space science investigations and other applications requiring distributed collaboration, high-end information and computing resources, and access to high data rate instruments. As this system is being developed, software tools will also be developed to accurately predict system performance based on specific computational applications. These optimization tools will provide the capability to extend the dynamic supercomputing system designs, and to provide an evaluation capability for new, innovative supercomputing concepts.

Intelligent Synthesis Environment

The ISE Initiative planning process has followed a three-tiered approach during FY 1999 and the first quarter of FY 2000 :

ISE NASA planning workshop (all NASA Centers, JPL and NASA Headquarters)	Feb. 1999
Government planning workshop for ISE technologies	June 1999
Industry and University workshop for ISE technologies	Oct. 1999

In addition, a large number of technical workshops were held with industry and university participants to establish the state-of-the-art in ISE capabilities and technical working groups were established in each Initiative Element. A Non-Advocate Review

(NAR) of ISE was held at end of FY99. The ISE Initiative is coordinating all NASA Centers and NASA's four Enterprises, and is leveraging appropriate activities with other government agencies, the aerospace and non-aerospace industries, computer software and hardware vendors, suppliers, and universities. Pathfinder and pilot studies are being conducted in FY 2000 to identify high-payoff approaches for each of the ISE elements.

When fully developed, ISE will function as a networked collaboration among all geographically dispersed and professionally diverse personnel involved in defining, designing, executing, and operating NASA's missions. The long-term vision is that this collaboration will be in a full-sensory, immersive, virtual environment in which humans and computers can interact through 3-D sight, sound and touch in a computationally rich mission life-cycle simulation. ISE will enable NASA to rapidly assess multiple mission concepts and systems design options and predict total life cycle cost, schedule, risk and performance with much greater accuracy than is currently possible, before proposing or committing funds for development. By FY 2002 ISE will develop an initial set of advanced simulation-based, life-cycle analysis methods, including cost and risk. During FY 2003 ISE will demonstrate an initial integrated, end-to-end multidisciplinary life-cycle design capability for a selected set of ISE applications, with the highest priority on advanced reusable space transportation systems and reduced Shuttle/Space Station operations. By 2004, a new ISE-based approach to integrated science and engineering practice will be demonstrated, enabled by simulation-based engineering knowledge capture and advanced user interface capabilities in immersive environments.

Aero-Space Vehicle System Technology

In FY 1999, the VST program developed technologies in safety including complete simulations of crew workload displays. They will be used to help reduce accidents caused by human errors in the flight deck. Nondestructive evaluation techniques were developed for improvement in crack detection in thick structures by a factor of two. To enhance environmental compatibility, breakthrough technologies in active structural control that allowed for significant reduction in aircraft bending loads were developed. The VST Program addressed key technology barriers for future subsonic transports. This included developing aircraft controller strategies for enhancing performance and reconfiguration capabilities. Wind tunnel tests were conducted to understand the flow physics and the characterization of abrupt wing stall, an uncommanded, abrupt roll perturbation during elevated load factor turns. Validated design criteria to address the out-of-control "falling-leaf" phenomenon associated with fighter aircraft were provided. The Hyper-X Program continued to support the goals of the Access-to-Space Pillar. Testing setup began on the full-scale model of the Hyper-X vehicle. Comparison of CFD performance prediction and correlation with wind tunnel data also began. In addition, in support of the NASA Safety Initiative, a study was conducted to identify the causes of Controlled Flight into Terrain (CFIT). Based on this study and NRA was issued and thirteen contracts were awarded to develop and demonstrate approaches for fully operational and certifiable synthetic vision (7 awards) and health management (6 awards) systems. Preparation for flight evaluation of a crew-centered synthetic vision display was completed. Also a study that addressed the applicability of synthetic vision to General Aviation type aircraft was completed.

In FY 2000, the VST program will begin a deliberate shift in the focus of the program. The program will maximize the synergism between aeronautics and space transportation. Many of the fundamental technologies have obvious applicability in both these critical areas. The program will continue to develop technology in the areas of safety, environmental compatibility, general aviation, next-generation design tools, experimental aircraft and access to space. To enhance environmental compatibility, technologies will be developed to reduce emissions and drag using smart devices with active components. High-payoff, innovative control concepts will be developed and demonstrated. The BWB drop model test will be completed. Conceptual designs of two advanced configuration aircraft will be completed. High-fidelity multi-disciplinary methods for nonlinear problems will be demonstrated. The first flight test of the HXRV will be completed. Manufacturing methods for the new generation of advanced general aviation aircraft; additional training modules in the flight training curricula, the multifunction display guidelines, a low-cost communications, navigation and surveillance system, and a highly integrated open architecture avionics will be completed.

In FY 2001 the VST program will achieve a healthy balance between activities that contribute to aeronautics and those that contribute to space transportation. The program will continue to develop technology in the areas of safety, environmental compatibility, general aviation, next-generation design tools, experimental aircraft and fully support access to space goals. The program will complete the general aviation activities transferred from the Advanced Subsonic Technology Program including flight testing of the general aviation system concepts and publication of the general aviation standards and methods. Many important tasks will be completed in FY 2001 for space transportation including: extruding near-net sections of Russian Al-Li alloy 1441 for use in space transportation vehicles, the second Mach 7 flight and the Mach 10 flight of the Hyper-X vehicle and identifying protocols and methodologies for accelerated testing of space transportation materials. A key workshop will be held in 2001 to assess the state of turbulence research and determine future research needs to accurately predict of aerodynamic flow and noise production. New advanced vehicle concepts will be down selected in 2001 and the Blended Wing Body vehicle will pass integration testing and delivery review. Smart actuators will be incorporated into a hingeless Uninhabited Combat Air Vehicle (UCAV) for wind tunnel test this year. Finally, systems analysis will begin on advanced vehicle concepts for a Smart Vehicle System for use by the General Aviation community.

Propulsion and Power

The Propulsion Systems program develops technology that supports all Three Pillars for Success. During FY 1999, the General Aviation Propulsion project began pre-flight ground tests of the intermittent-combustion and turbine engines in preparation for flight demonstrations in FY 2000. Among other activities, advanced material and process systems capable of turbine inlet material temperatures above 2400°F was demonstrated. Work continued on the development of 900°F silicon carbide sensors models, and concepts will be delivered that enable reductions in cost and risk barriers for selected advanced turbine engine components. The High Performance Aircraft project continued active technology validation activities in coordination with DoD. Excellent progress was made in the development of the critical air-breathing launch vehicle component technology, which is scheduled for validation in FY 2000. The effort to improve engine safety also continued with emphasis on development of more crack resistant alloys for blades and disks, and an improved containment system.

During FY 2000, the General Aviation Propulsion project will conduct flight demonstrations of the intermittent-combustion engine and the turbine engine at the Oshkosh Air-show. These flights will demonstrate a new generation of general aviation propulsion systems that are revolutionary in affordability, ease of use, and performance. These new engines, with their smooth, quiet operation, promise to be the key to creating new demand for aircraft and revitalizing the U.S. general aviation industry. The Higher Operating Temperature Propulsion Components project will demonstrate a 900°F silicon carbide sensor in the harsh environment of an engine. If successful, this could lead to development of sensors for many commercial and military applications. Active combustion instability control will form the cornerstone of demonstrating "smart" turbomachinery concepts to minimize pollutants throughout a typical mission. The technology is enabling for stable operations under lean combustion conditions that can potentially lead to as much as 80% NOx reduction in the future. Validation of rocket-based combined cycle (RBCC) propulsion inlet, mixer-combustor, and integrated propulsion pod component is planned, along with the definition of an RBCC propulsion integration technology applications concept for semi-axisymmetric vertical take-off systems for access to space. A new effort to establish the feasibility of pulse detonation-based technologies to hybrid-cycle and combined cycle propulsion systems for meeting the aviation and access to space goals will be initiated. The effort to improve engine safety will continue to seek alloys for blades and disks, which are more crack-resistant for delivery in FY 2001. The fundamental aspects of noise generation and propagation, and the identification of advanced noise reduction concepts will continue. This activity will provide enabling capabilities for new, high-risk, high-payoff technologies that are of long term strategic importance in noise reduction. A new 2-stage low tip speed fan with swept stator vanes design which will significantly reduce fan noise will be completed. The Zero CO_2 Research project will be initiated. This project is focused on identifying the technologies needed to drastically reduce or eliminate CO_2 emissions from civil transport aircraft.

During FY 2001, the effort to improve engine safety will continue. The Ultra Safe Propulsion will continue with the development of an improved containment system. An assessment and conceptual design of pulse detonation engine-based hybrid cycle and combined cycle propulsion systems will be completed. Pulse detonation engines offer many advantages over conventional gas turbine engines that make them very attractive for subsonic, supersonic and access to space applications. NASA will complete an inlet test in support of the development of pure pulse detonation engines for military applications. Oil free technology will be a major step in the further reduction of engine acquisition and life cycle costs of general aviation along with increased reliability through the removal of one of the most maintenance intense systems on the engine. A complete core hot section oil-free radial foil bearing will be tested in a rig in FY 2001. An analysis of a liquid hydrogen optimized engine and airframe will be completed in support of the Zero CO_2 Research project. Hydrogen-fueled engines, as a substitute to hydrocarbon fuels, can curtail CO_2 emissions by reacting with the oxygen in the atmosphere to produce water but no CO or CO_2 byproducts. The permeability of lightweight polymer composite liquid hydrogen tanks will be determined. Reduction of the hydrogen permeability of polymer matrix composite tanks may allow the safe and efficient storage of low density liquid hydrogen in commercial transport aircraft. New energy conversion technologies will also be investigated. The fracture toughness of solid oxide fuel cell electrolytes for high pressure hydrogen/air fuel cells will be determined. The fundamental aspects of noise generation and propagation, and the identification of advanced noise reduction concepts will continue. Jet noise models which improve acoustic analogy models through gaining insight into flow physics and leading to ever quieter propulsion systems will be developed.

Flight Research

During FY 1999, the Flight Research program continued to develop high altitude, long-duration, uncrewed flight concepts through ERAST, including the demonstration of multistage turbocharged RPA to 60,000 feet for an 8-hour duration. A demonstration of an RPA for 4 hours above 55,000 ft was also accomplished. The Centurion solar-powered airplane, a vehicle with a wingspan greater than 200 ft., completed initial low altitude evaluation under battery power. This RPA technology will increase the Nation's capability to make scientific subsonic sampling high in the stratoshpere. In pursuit of improved aviation safety, the effort to help transition technology into use by the air transportation industry was completed. The Aviation Safety Flight Integration Plan draws technology from the other program elements, and make use of available aircraft to raise the technology readiness level. In pursuit of efficiency and affordability, an F-18 testbed aircraft is being modified to investigate Active Aeroelastic Wing (AAW) technology in preparation for the flight tests, which will begin in FY 2002. Under advanced concepts, the PHYSX test program, a Pegasus launch vehicle with a wing glove fixture measured the cross-flow boundary layer at hypersonic (Mach 8) speed, providing critical design data for vehicles that will provide access to space. The flight experiment was flown in November 1998 and was completely successful.

The Flight Research program in FY 2000 will be developing further capability for increased altitude using ERAST remotely piloted airplanes (RPA). The Centurion solar-powered RPA designed for flight to 100,000 feet will be modified to a wingspan configuration of greater than 245 ft., in a new prototype called Helios. This configuration will be more suitable for extreme endurance as well as flights to 100,000 ft. It will be demonstrated and ready for later upgrade to high-efficiency solar cells and maximum altitude and duration missions. In pursuit of efficiency and affordability, an F-18 testbed aircraft will continue its modification to investigate Active Aeroelastic Wing (AAW) technology. A new effort will be initiated under the X-plane goal, but with applicability to a number of the other goals. Under the name revolutionary concepts, or REVCON, the design and development of a blended wing body sub-scale X-plane will be initiated. This X-plane will be dropped at high altitude from under the wing of the B-52, with the objective of obtaining flight test data on the transonic characteristics of the revolutionary concept. With the first flight in 2001, the new shape is expected to offer major contributions to the goals of increased capacity, reduced emissions, increased throughput and increased mobility. REVCON also includes the development of a Pulse Detonation Engine (PDE), a revolutionary air-breathing jet that utilizes constant volume thermodynamic cycle to be tested on the SR-71 testbed. Under the reduced emissions goal, the advanced flight concepts will explore use of precision formation flight in order to reduce overall drag, and consequently reduce fuel burn. The concept will be demonstrated with two F-18 aircraft and autonomous formation flight system.

In FY 2001 the Flight Research program will demonstrate a solar powered RPA at 100,000 ft and complete development of a heavyweight energy storage system under the ERAST project. Both achievements will demonstrate technologies that will provide atmospheric satellites for commercial use and create the Nation's capability to make scientific subsonic sampling high in thestratosphere. The Revolutionary Concepts (REVCON), a new project started in FY 2000, accelerates the exploration of high-risk, breakthrough technologies in order to enable revolutionary departures from traditional approaches to air vehicle design. The first NRA under REVCON will down select to an implementation phase in FY 2000. Within REVCON the development of a PDE inlet, a revolutionary air-breathing jet propulsion concept utilizing constant volume thermodynamic cycle, will be completed. In pursuit of efficiency and affordability, an F-18 testbed aircraft will complete its modified and systems checkout in preparation of FY 20002 flights to investigate Active Aeroelastic Wing (AAW) technology. Within the Innovative Transport and Testbed Experiments and the Atmospheric Flight of Space Systems aerospace synergy supporting both safety and affordability will be demonstrated in the area of vehicle health management. Efforts in the area of structure health management and propulsion health management will be investigated, concentrating on optical sensors, engine sensors, and detection algorithms. Within the Advanced Systems Concepts, investigations into technology to advance Uninhabited Air Vehicles will continue, with the development of robust autonomous taxi capability.

Operations Systems

During FY 1999, the Aviation Operations System program was re-planned to respond to the President's safety goal of reducing aviation accidents by 5 fold in 10 years. A model of human memory constraints in procedure execution and reactive planning will be developed. This model will be used to guide design of automation to aid air traffic service providers, airline operations center personnel and flight crews to assure automation support consistent with human performance characteristics. Working with industry, the program continued to improve the effectiveness of ice protection systems and reduced development and certification cycle & costs for industry. International collaboration, needed for dramatic improvements in aviation safety, was strengthened by a joint Super-cooled Large Droplet (SLD) icing research conducted with AES (Atmospheric Environment Sciences) of Canada. To enhance safety, an increased emphasis was put on the development of procedures and innovations to clarify the roles and responsibilities of aircraft maintenance teams. In addition, to reduce weather related accidents, systems for communicating and displaying real time weather information to airborne and ground base users were pursued in collaboration with industry and DoD, FAA and NOAA/NWS through NASA Research Announcements. Multiple advanced weather information systems were developed, evaluated and demonstrated for providing graphical weather information in the flight deck. These systems were demonstrated with various packaged weather products using satcom broadcast, cellular phone and ground based 2 way broadcast infrastructure. The weather products included turbulence, weather radar (US only) satellite, and convective detection warnings. Rapid prototyping led to flight evaluations on a Cessna Citation, USAF C-135, FedEx Cessna Caravan and numerous general aviation aircraft.

During 2000, the Aviation Operations System program will continue its focus on developing more basic concepts, procedures and systems to remove the key barriers to significant improvements to the safety of the nation's aviation system. Fundamental modeling of human performance will incorporate visual motion and eye movement parameters in computational models of human vision. Automation system functional model decomposition methods are being matched to human performance constraints and biases. The result is a theory-based methodology for predicting operational error-vulnerability. This method will be empirically validated through a representative safety analysis for air-ground automation and operational procedures. Ultimately this will result in a computational model matching human/system performance and error trends.

For FY 2001, the focus of the program will be on technologies in areas emphasized as important by the Aero-Space Technical Advisory Committee (ASTAC), subcommittee for Aerospace Operations Systems. The two primary areas are weather (icing research) and training/countermeasures. Icing research will continue to be conducted, with primary emphasis on the development of a ground-based sensor suite to assist in detecting icing conditions. Training research, which is a new thrust, will concentrate on developing an understanding of the causes of errors during concurrent task management, with an eye toward later development of training tools to alleviate this type of error.

Rotorcraft

In FY 1999, the Rotorcraft program completed the integration of new basic physics knowledge with advanced, information technology tools to provide accurate, flexible modules suitable for use by industry in their integrated design systems. A new emphasis aimed at thick composite structures has reduced parts count and the cost of rotorcraft. Noise reduction work was performed in three areas: more effective noise reduction technologies for the rotor, both passive and active; additional attention to the reduction of power-train noise and vibration; and the assessment of operations that minimize noise impact on the ground, including the development of codes that can be used by community planners and airport operators. New innovative rotorcraft flight concepts were supported through technical cooperation with DOD and industry. Testing of baseline rotorcraft helical gear train configurations, to establish minimum lubrication conditions while maintaining ultra-safe operations, was completed.

Gear-crack propagation analysis tools, as well as specific gear experiments were used to develop three-dimensional (3D) boundary element/fracture mechanics analyses. Full-scale experiments were completed, validating conditions where two-dimensional (2D) analysis is accurate. Expanding on the key findings of the accident analyses, new efforts were initiated with helicopter operators and manufacturers to target near-term opportunities for accident reduction.

In recognition of the critical role that loss of situation awareness has played in previous fatal accidents, methods of measuring and predicting situation awareness was demonstrated in part-task simulation and efforts to improve detection and avoidance of obstacles, such as wires and poles, was initiated. During its fourth year, the NRTC has continued to focus on near-term opportunities to reduce and improve performance and increase activities in flight safety and reliability. The NRTC has coordinated projects in conjunction with alliances among the FAA, DOD, NASA and industry to assess near-term national needs with a view to maximize leverage of the NASA investment while minimizing duplication. Completing the flight evaluation of Differential Global Positioning System (DGPS) coupled to heliport precision-instrument approach has enabled a quantum improvement in integrating rotorcraft into the evolving transportation infrastructure. Demonstrating the structural characteristics of hybrid titanium/graphite-composite structures has provided for improved safety and affordability in engine compartments and other high temperature areas.

In FY 2000, the Rotorcraft program will conduct wind tunnel in conjunction with advanced active control research to reduce vibration, noise and improve performance. Building on the earlier fatigue life prediction of composite structure work, analytical and experimental techniques for tail rotor flexbeams will be established. Upon completion of evaluations of a number of innovative active and passive noise and vibration reduction concepts, the most promising techniques will be chosen for further research. Efforts to model the full flight vehicle for development of noise-abatement procedures will continue.

Accurate, flexible analysis modules suitable for use by industry in their integrated design systems will be completed. Rotorcraft safety will be emphasized through the development and evaluation of health and usage monitoring systems and predictive technologies. Methods of predicting and measuring pilot situation awareness will be developed and tested to allow designers the take this key factor into account when designing new systems. Using the situation awareness prediction model the effectiveness of new displays, and other pilot interface technologies for improving pilot situation awareness, will be studied. Specifications for the hardware and format of a cockpit display designed to improve pilot situation awareness will be completed. The NRTC solutions of industry-wide problems will benefit the performance, utility and public acceptance of both helicopters and tilt-rotor concepts. The developed technologies will improve flight-safety with health-management systems, enhance design/manufacture compatibility, and alleviate both interior and exterior noise. Flight safety will be addressed by continued development of crashworthy design methodologies that account for crash/hard landing on various surfaces, with delivery of completed milestone in FY 2001.

In 2001, the Rotorcraft Program will conduct a vigorous effort to develop technology and transfer it to industry through the FRIAR project, implemented through the National Rotorcraft Program and the Rotorcraft Industry Technology Association. There will be advances made in the areas of crashworthiness of Rotorcraft which will demonstrate advances to mitigate damage to airframe structures due to crash/harsh landings onto both soft and hard surfaces such as soil, concrete, or water. To improve flight safety and lessen the cost of maintenance, new HUMS (Health and Usage Monitoring Systems) protocols will be developed. HUMS will track wear and tear on critical parts as well as sense deterioration and give warnings. Plans for limited flight evaluations acceptable to both DoD and FAA will be developed. In the area of design tools for rapid prototyping, there will be a demonstration conducted for the new "express-tool" technology. This can reduce design to fabrication time by 50% where it is applied to complicated parts and assemblies. The SAFOR project is in close coordination with the FRIAR project and will deliver a Ultra-Safe Gear Design Guide to be published in FY 2001. This will conclude the provision of ultra-safe gear technology, which has been demonstrated in FY 2000 through testing and correlation with design tools, under the FRIAR Project. Under the FRIAR Project, in the area of Composite Structures Technology for Rotorcraft, a certification methodology will be delivered for inclusion in Military Standard Handbook 17. Under the DEAR Project, also in the Composite Structures Technology for Rotorcraft, aimed at provision of a new physics-based design tool for composite structures for Rotorcraft Airframes, a technology for prediction of stringer/skin separation mode of failure will be provided. Finally, under the SAFOR Project flight tests will be completed that demonstrates and validates control laws for low pilot workload under typical civil operations involving low visibility weather conditions.

Space Transfer and Launch Technology

In FY 1999, the STLT program completed several key Earth-to-orbit technology demonstrations. These included: the full duration firing of the Fastrac rocket engine which will power the X-34 experimental vehicle (1999 NASA Continuous Improvement Award Recipient); fabrication of a 250,000 lb.-thrust pressure-fed hybrid motor; the completion of the 1st phase of rocket-based combined-cycle flowpath testing with Aerojet and Rocketdyne engine concepts; and a proof of concept demonstration of a 50 ft. MagLev launch assist track which is the next step towards an operational launch assist capability.

In addition, the STLT program participated in the development of a long-term plan for Earth-to-orbit technologies, called Spaceliner 100. Spaceliner 100 provides a blueprint for future investments, which will dramatically increase the safety, reliability and decrease the cost of future transportation. While Spaceliner is focused on 3rd generation needs, many of the technologies will provide a direct benefit for 2nd generation launch systems. In FY 1999, NASA canceled the Bantam activity and directed tasks and resources towards Spaceliner identified needs.

The STLT program also completed several in-space technology demonstrations. These included including the successful performance of the NSTAR ion engine on the DS-1 mission, development and test of key non-toxic orbital propulsion components, test of a long duration, on-orbit cryogenic storage system and facilitation of an independent in-space propulsion planning activity. Research highlights included: hosting of the 10th Annual American Institute of Aeronautics and Astronautics Propulsion Workshop; completion of beamed power proof of concept demonstrations to altitudes of 125 ft using a 10kW laser; and the award of six Breakthrough Propulsion Physics activities in a wide range of topics, including experiments related to superconductor-gravity effects and verification of faster-than-light hypotheses. In FY1999, the Aero-Space Technology Program was integrated into the Aero-Space Base Research and Technology Program in order to fully leverage Aero-Space synergy.

In FY 2000, the STLT program will demonstrate several key Earth-to-orbit technologies. These include: delivery of a flight-certified Fastrac engine to the X-34 Program; development of a composite liquid oxygen tank for the X-34; development of a PETI-5 (high temperature material developed in the High Speed Research Program) composite wing for the X-37; ground test of the Ultra-Low-Cost Engine; extension of the MagLev track to 400 ft in length; downselection of a preferred airbreathing propulsion testbed approach; completion of liquid oxygen densifier verification testing and completion of hydrogen densifier fabrication; completion and test of advanced metallic reentry thermal protection system materials; and fabrication of composite rocket thrust cell chamber demonstration unit. Tasks originally initiated under the Bantam activity have been realigned with Spaceliner needs and include tasks such as advanced materials, advanced composite cryogenic tank development, high temperature thermal protection systems, and advanced control systems. A new Integrated Vehicle Health Management (IVHM) Project has been initiated to provide focus for this diverse discipline. The IVHM Project is a multi-year effort that will culminate in IVHM system-level technology and operations demonstrations using a virtual IVHM Testbed. Planned in-space demonstrations include completion of NSTAR ground engine testing and completion of the 500 hours of test on a 10kW hall thruster. In FY 2000, Space Transportation Research activities will be guided by peer review of the most promising breakthrough concepts and will continue to pursue propulsion concepts that have the potential for interstellar travel. Work on 3rd generation RLV technologies, also known as Spaceliner 100, will continue, although emphasis has principally shifted to 2nd generation RLV technologies.

Trade studies were also initiated to define the cost and capability of an advanced airbreathing test facility necessary to address requirements generated by Advanced Space Transportation Program. Contractors will be selected to initiate detail designs and specifications of the major systems such as propellant and pressurization systems, air storage and delivery, thrust measurement, instrumentation and control systems.

FY 2001 activities will be consistent with the Integrated Space Transportation Plan and guided by comprehensive systems analysis. 2nd Generation RLV technology investments will be strongly driven by industry needs and may include: component and subsystem demonstrations for composite materials and tank systems; ceramic and metallic thermal protection systems; continuation of cooperative partnerships with the DoD for the integrated powerhead rocket engine demonstration; low-cost rocket engine turbomachinery and injector concepts; lightweight valves, lines and ducts; long-life materials; robust sensors; advanced energy sources; microavionics; autonomous flight control and mission planning; low-cost range systems; completion of propellant densification testbeds; automated umbilicals; and containerized payloads. In-space investments include low-cost upper stage, Earth orbital, planetary and interstellar transfer technologies. Upper-stage technologies are focused on advanced peroxide based systems and will demonstrate advanced components (including catalyst beds and materials testing) and engine systems, including cooperative participation with the DoD on the upper stage flight experiment. Earth orbital and planetary investments will focus on the development of high-performance, lightweight propulsion technologies, including solar electric transfer, lightweight feed system components, planetary aeroassist and on-orbit cryogenic fluid management. Interstellar precursor technology development will focus on development of lightweight solar sail materials. Propulsion activities include the development of a long life / lightweight rocket engine testbed and an airbreathing propulsion testbed. Airbreathing activities will include technologies that support hydrogen and hydocarbon concepts in both a vertical and horizontal takeoff mode throughout the speed range. Crosscutting technologies will be pursued which support both rocket and airbreathing concepts, such as long life turbomachinery, revolutionary materials and smart sensors. Other Advanced Launch Technology investments include: development of rapid design and analysis tools; continued development of MagLev launch assist; low-drag aerodynamic structures; SHARP ultra-high-temperature ceramic materials; integrated smart/adaptive thermal-structures; morphing structures; drag modulation through electromagnetics and flow physics; adaptive intelligent systems; adaptive self-diagnosing/self-healing thermal protection systems; structurally integrated, wireless; micro/nano sensors and avionics; regenerative sensors; and autonomous/adaptive control and technologies for spaceport /range operations. Research activities will continue to be guided by concepts that have the potential for enabling future generations of RLV's and in-space transportation.

The advanced airbreathing test facility activities will be focused on the preliminary design review (PDR). This will be used to finalize the requirements, design approach and major procurements. All civil and site work is to be completed in FY 2001 and activities will be initiated on all ancillary systems.

The Space Transportation Architecture Phase III Study and subsequent planning efforts in 1999 and 2000 provided industry and government with an assessment of the type of reusable systems and architectures required to address an initial set of NASA and industry requirements. The initial definition of requirements and architectures allowed NASA to establish an Integrated Space Transportation Investment Plan and provide a comprehensive recommendation to the Administration for achieving increased safety, reliability and affordability goals for future RLV systems. Key to this activity was the identification and prioritization of technologies that are critical to reducing the technical risk sufficient for industry to commit to a commercial RLV system. The Space Transportation Architecture studies concluded that the highest priority areas for technology investment are Crew Survivability, main propulsion, integrated structures and reliable subsystems. NASA expects that these priorities will remain the key focus of 2nd generation technology efforts and will be the basis of industry risk reduction activities.

This effort also established a significant pre-cursor activity to the FY 2001 Systems Engineering and Requirements Definition task within the 2nd Generation RLV program. With the completion of the Integrated Space Transportation Plan, industry and government efforts began to address the critical elements of technical risk reduction and NASA unique requirements that are essential to achieving convergence with commercial RLV systems. This effort successfully combined industry and government resources and capabilities, which provided for the maximum use of new and existing RLV tools, models and methods.

BASIS OF FY 2001 FUNDING REQUIREMENT

AERO-SPACE FOCUSED PROGRAMS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
High-Performance Computing and Communications	20,600	24,200	24,200
High-Speed Research	180,700	---	---
Advanced Subsonic Technology	89,620	---	---
Aviation System Capacity	53,888	62,929	59,200
Aviation Safety	---	64,394	70,000
Ultra Efficient Engine Technology	---	68,306	35,000
Small Air Transport System	---	---	9,000
Quiet Aircraft Technology Program	---	---	20,000
2nd Generation RLV	365,299	183,400	290,000
Total	710,107	403,229	507,400

NASA's Aero-space focused programs address national needs, clearly defined customer requirements and deliverables, critical program decision and completion dates, and a specified class of research with potential application. Each of the focused programs is discussed in detail on the following pages.

BASIS OF FY 2001 FUNDING REQUIREMENT

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

(Thousands of Dollars)

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
High-Performance Computing and Communications	20,600	24,200	24,200

PROGRAM GOALS

The main objective of the Federal HPCC R&D programs is to extend U.S. technological leadership in high performance computing and computer communications. As this is accomplished, these technologies will be widely disseminated to accelerate the pace of innovation and improve national economic competitiveness, national security, education, health care, and the global environment. NASA's HPCC Program is a key contributor to four of the five current federal program component areas:

- High End Computing and Computation
- Large Scale Networking, including the Next Generation Internet
- Human Centered Systems
- Education, Training, and Human Resources

NASA's primary contribution to the Federal program is its leadership in the development of algorithms and software for high-end computing and communication systems which will increase system effectiveness and reliability, as well as support the deployment of high-performance, interoperable, and portable computational tools. As HPCC technologies are developed, NASA will use them to address aerospace transportation systems, Earth sciences, and space sciences research challenges. NASA's specific research challenges include improving the design and operation of advanced aerospace transportation systems, increasing scientists' abilities to model the Earth's climate and predict global environmental trends, further our understanding of our cosmic origins and destiny, and improving the capabilities of advanced spacecraft to explore the Earth and solar system. The HPCC Program supports research, development, and prototyping of technology and tools for education, with a focus on making NASA's data and knowledge accessible to America's students. These challenges require significant increases in computational power, network speed, and the system software required to make these resources effective in real-world science and engineering environments.

In support of these objectives, the NASA HPCC Program develops, demonstrates, and prototypes advanced technology concepts and methodologies, provides validated tools and techniques, and responds quickly to critical national issues. As technologies mature, the NASA HPCC Program facilitates the infusion of key technologies into NASA missions activities, the national engineering, science and education communities, and makes these technologies available to the American public. The Program is conducted in cooperation with other U.S. Government programs, U.S. industry, and the academic community.

STRATEGY FOR ACHIEVING GOALS

1) Infuse HPCCP technologies in to mission critical stakeholder Enterprise/Office processes, and document discernable improvements in the stakeholders' processes and, if possible, final products as a result of the use of HPCCP technologies.
2) Increase the computer and communication performance available for use in meeting NASA mission requirements.
3) Increase the interoperability of application and system software operating on high performance computing and communications systems available for use in meeting NASA mission requirements
4) Improve the portability of application software and data to new or reconfigured high performance computing and communications systems available for use in meeting NASA mission requirements.
5) Improve the reliability of user-requested events executing on high performance computing and communication systems available for use in meeting NASA mission requirements.
6) Improve the ability to manage heterogeneous and distributed high performance computing, storage, and networking resources available for use in meeting NASA mission requirements.
7) Improve the usability of high performance computing and communications tools and techniques available for use in meeting NASA mission requirements.

HPCC is a computing and communications research program that pursues technologies at various levels of maturity. Applications in the areas of Earth science, space science, aero-space technology, and education are used as drivers of HPCC's computational and communication technology research, providing the requirements context for the work that is done.

As a cross-cutting multi-enterprise initiative, the HPCC Program receives funds from the Aero-Space Technology (AT), Space Science (SS), and Earth Science (ES) Enterprises, and the Office of Human Resources and Education.

The HPCC Program is coordinated through the Aero-Space Technology Enterprise and is managed by NASA Ames Research Center. The Program has supporting work at nine other NASA field centers and the Jet Propulsion Laboratory (JPL) and is organized into five Projects:

- Computational Aerospace Sciences (CAS)
- Earth & Space Sciences (ESS)
- Remote Exploration and Experimentation (REE)
- Learning Technologies (LT)
- NASA Research and Education Network (NREN)

	FY 1999	FY 2000	FY 2001
Aero-space technology..	20,600	24,200	24,200
Earth Science...	14,500	21,900	21,800
Space Science..	8,400	19,500	24,900
Education Programs..	4,000	4,000	4,000

			0
Total direct HPCC (NASA-wide)...............................	47,500	69,600	74,900

The following discussion describes the projects managed by the Office of Aero-Space Technology.

Computational Aerospace Sciences

The CAS Project facilities the transfer of technology developed in NASA aerospace and information technology research efforts to routine use by operationally-oriented or product-oriented programs within the NASA Aero-Space Technology Enterprise. This will provide the aerospace community with key tools necessary to reduce design cycle times and increase fidelity in order to improve the safety, efficiency, and capability of future aerospace vehicles and systems. This has the additional benefit of establishing within the aerospace community a viable market for vendors of high performance computing hardware and software. CAS, because of this relationship with the general computer science community, provides input and direction for developing technology for aerospace application.

The CAS Project works with NASA Aero-Space Technology Enterprise Programs and the extended aerospace community to select high priority areas that have bottlenecks or limits that could be addressed through the application of high end computing. These challenging, customer-focused applications guide efforts on advancing aerospace algorithms and applications, system software, and computing machinery. These advances are then combined to demonstrate significant improvements in overall system performance and capability.

NASA Research and Education Network

The goal of the NASA Research and Education Network (NREN) Project is to provide a next generation network testbed that fuses new technologies into NASA mission applications. The capabilities that are realized by these new technologies will enable new methodologies for achieving NASA science goals. Moreover, these networking technologies will provide NASA missions with the advantages of enhanced data sharing, interactive collaboration, visualization and remote instrumentation. NREN will meet these goals through technology integration and collaborations within the multi-agency Next Generation Internet program.

The NASA Research and Education Network (NREN) Project is NASA's part of the Federal Next Generation Internet (NGI) initiative. The Next Generation Internet initiative is a multi-agency Federal partnership with industry and academia to develop significantly higher performance networking technologies and systems enabling next-generation distributed applications between scientists, engineers, and computing resources.

SCHEDULE AND OUTPUTS

Demonstrate 200-fold improvement over FY 92 baseline in time to solution for Grand Challenge application on TeraFLOP testbeds. Plan: June 1999 Actual: June 1999	Demonstrated 200 – fold improvement in time to solution utilizing a full combustor simulation
Demonstrate 500 times end-to-end performance improvement of Grand Challenge and/or NASA mission applications based on FY 96 performance measurements across NASA NREN testbeds over 622 Mbps wide area network. Plan: March 2000	Perform at least three demonstrations at 500 times more end-to-end performance improvement over FY 96 baseline. Additional time is required to address the newly selected NASA applications.
Establish an international Next-Generation Internet eXchange (NGIX) Plan: January 2000	Demonstrate connectivity across an international Next-Generation Internet eXchange.
Demonstrate multicast and quality of service (QoS) technology in a hybrid networking environment Plan: June 2000	Provide at least two demonstrations of multicast and QoS technology in a hybrid (wireless and ground) networking environment.
Demonstrate time-to solution improvements for grand challenge applications on HPCC testbeds Plan: September 2000	Demonstrate at least a 400-fold improvement over 1992 baseline in time-to-solution for one grand challenge application in the area of computational aerosciences.
Develop system software tools and techniques to enhance application performance Plan: June 2001	Software tools to reduce parallelization time from months to one week while maintaining 50% application performance compared with manual parallelization.

Develop tools and techniques to measure computing and communication capabilities Plan: September 2001	Tools to benchmark testbed performance in computing capability, database manipulation, and scheduling to evaluate alternate scheduling strategies and chose optimal approaches to reduce variability and improve predictability of turnaround time. Automated quality of service data collection tool for networks capable of measuring 2 service classes and scalable to at least 5 nodes.
Adapt application codes for high performance testbeds Plan: September 2001	3 relevant application codes parallelized; 3 data analysis codes parallelized; documented evaluation of parallelization tools. 3X performance in applications for aerospace through the integration of networking enhancements into application codes.
Demonstrate advanced networking tools and techniques on NASA mission-oriented applications Plan: September 2001	3 applications inter-operating on multiple QoS enabled networks; 50Mbps (aggregate internal) multicast; gigabit performance between 2 NASA sites; 2 applications utilizing enhanced hybrid networking.

ACCOMPLISHMENTS AND PLANS

In FY 1999, CAS demonstrated improvement in the time-to-solution for Grand Challenge applications using a newly-installed testbed. CAS applications exceeded the goal of performing at 200 times the established baselines. This activity was also supported by NREN/NGI technologies through NREN goals of enabling network-intensive applications. NREN addressed specific applications both relevant to NASA missions and providing the pacing requirements for further networking research and implementation.

While continuing to use high-end computing systems, CAS initiated more in-depth efforts to develop computational grids and increased its work on computational grid concepts through expanded collaborations with academia, NSF, and DARPA. The prototyping of a computational grid will seamlessly link NASA resources—computers, data, instruments, and people—into an interdisciplinary problem-solving and decision-making environment. This effort is driven by: (1) NASA requirements to make more effective and coordinated use of existing and future computational assets, and (2) the need for collaboration among individual groups that are using advances in software technology to develop sophisticated problem solving systems. By recognizing the similarity in the underlying approaches to meeting these needs, an overall system can be developed that provides an improved environment for resource management, while at the same time providing a uniform architecture for software development—from systems software (including security, resource management, etc.) to the domain applications.

In FY 2000, CAS will continue to improve time-to-solution for relevant applications while implementing initial software to demonstrate a prototype distributed high-performance testbed (computational grid). Along with the installation of HPCC's Earth and Space Science testbed, the CAS computational grid testbed will provide the vital computing resources required to achieve 1,000-fold improvements over established baselines. NREN will demonstrate applications that demand high-performance network capabilities, in some cases focusing its research on the same applications as CAS and ESS. NREN efforts will focus on the development and testing of mechanisms for scheduling guaranteed network quality of service to meet real-time bandwidth, latency and error tolerance requirements. This vital work supporting Next Generation Internet (NGI) will increase the quality, security and certainty of Internet transmissions and on the network capable of 1,000 times the capacity of the baseline.

In FY 2001, CAS will demonstrate 1,000-fold improvements over FY 1992 baseline in time to solution for relevant applications on high performance computing testbeds. These performance improvements will be partially supported through the demonstration of new software tools to benchmark testbed computing performance, database manipulation, and resources scheduling. In addition, CAS will complete the development of software tools to dramatically reduce parallelization time for high performance systems. Ultimately, the FY2001 accomplishments by CAS will allow for complete aircraft engine combustor and compressor simulation in three hours each, high-fidelity space transportation vehicle analysis in one week and the database generation for stability and contorls of aerospace vehicles within one week. CAS will demonstrate these capabilities on four NASA aerospace vehicle design activities. During this same time period, NREN will be providing the capability to monitor and benchmark performance of high-end networks, tools to enhance applications performance through the integration of networking enhancement into applications codes, and demonstrations of interoperation among high performance NASA and NGI networks.

BASIS OF FY 2001 FUNDING REQUIREMENT

HIGH-SPEED RESEARCH

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
High-speed research..	180,700	---	---

PROGRAM GOALS

NASA's High-Speed Research (HSR) program goal was to develop the technologies that industry needed to design and build an environmentally compatible and economically competitive HSCT for the 21st century available to enable an industry decision on aircraft production. As originally envisioned, an HSCT aircraft would carry 300 passengers at Mach 2.4 on transoceanic routes over distances up to 6,000 nautical miles at fares comparable to subsonic transports.

STRATEGY FOR ACHIEVING GOALS

In the early 1990's, studies indicated that an environmentally compatible and economically competitive HSCT could be possible through aggressive technology development. Since then, NASA concentrated its investments in the pre-competitive, high-risk technologies. While NASA has continued to be successful and is on track to meet the original program goals, recent market analyses and estimated industry development costs of $15 to $18 billion have made the HSCT considerably less attractive to NASA's industry partners. Cost of development in this amount puts the aircraft industry at significant financial risk. Current analyses indicate that further significant investments in technology development are required to ensure an economically viable HSCT. Consequently, the cost of development has led the major aircraft manufacturer to the conclusion that the introduction of an HSCT cannot reasonably occur prior to the year 2020. For these reasons, industry has reduced their commitment to this area and has scaled back their investments. Given other pressing needs in the Agency in general and aeronautics in particular, the HSR program was concluded at the end of FY 1999.

SCHEDULE AND OUTPUTS

Subcomponent Test Data (Materials and Structures). Plan: March 1999 Actual: September 1999	All data acquired during wing subcomponent testing and during seven fuselage subcomponent tests and four fuselage subcomponent tests have been compiled and released.
Component Materials Selection. Plan: March 1999 Actual: February 1999	M&S concepts were selected for wing component test article. M&S concepts for fuselage component test articles were selected. Selections are based on material performance and structural efficiency and uses analyses and test data.

Phase II Assessment of Atmospheric Impact. Plan: February 1999 Actual: February 1999	The assessment of environmental compatibility of HSCT incorporating HSR emissions reduction technology was completed and report issued, including the results from engine emissions characterizations, near field iterations, and operational scenarios applied to global chemistry and transport models, which were validated with laboratory studies and stratospheric atmospheric observations.
Full Scale Design Build 1 Designed; Plan: March 1999 Actual: Deleted	Due to program termination, the nozzle design effect was terminated after the Conceptual Design Review (CDR) in June1999. The preliminary and detailed design efforts will not be initiated nor completed.
1-Lifetime Accelerated Test Data. Plan: June 1999 Actual: July 1999	1-lifetime of data acquired during accelerated thermal-mechanical-fatigue testing of materials was compiled and released for use in validating analytical methods for predicting material degradation.
Full Scale Annular Combustor, Rig, and Liner Design - Configuration/Materials Plan: September 1999 Actual: Deleted	Complete detailed design of the selected HSCT scale combustor and life prediction analysis for the liner. Design temperatures and stresses in the liner are within the capabilities of the EPM developed material. Drawings are released for fabrication. Due to re-planning for termination of this program, the work toward this milestone was terminated.
Program Technologies Documented Plan: September 1999 Actual: November 1999	In-depth documentation of HSR Phase II technologies incorporated in the HSR Technology Concept Level 1 milestone of December 1998 was completed along with a concise summary of lessons learned in HSR work. Technology advances achieved in the HSR program will be appropriately integrated into ongoing and planned NASA programs where data restrictions allow.

ACCOMPLISHMENTS AND PLANS

As part of a planned orderly closeout at the end of FY 1999, the following activities were concluded: completed TIFS flight tests for external vision validation and validate a display, guidance, and control system; completed airframe materials durability composite database under isothermal without load; completed all subcomponent testing and analysis and thermo-mechanical fatigue tests of thick laminate joints; completed interim fabrication database of PETI-5; completed half-span aeroelastic test in LaRC Transonic Dynamics Tunnel, completed high-lift configuration evaluation; completed high-speed performance validation; complete an assessment of the environmental compatibility of the HSCT incorporating new emissions reduction technology; completed combustion environment testing of Ceramic Matrix Composite (CMC) liner parts for ultra low emissions combustor; competed conceptual design of full scale technology demonstrator nozzle; completed digital assessments of innovative ultra low noise nozzle concept, provided improved aeroacoustic scaling methodologies; completed initial assessment of "waverider " inlet concept; completed scale-up feasibility effects of nozzle advanced materials (superalloy);complete d nozzle materials characterization studies; completed down-selection process for turbomachinery disk and turbine alloy materials; completed a technology identification study to meet new requirements for “Lessons Learned” documentation; completed summary and lessons learned documentation for all technology areas for transfer, as appropriate, to other focused programs and base activities.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED SUBSONIC TECHNOLOGY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Advanced subsonic technology	89,620	---	---

PROGRAM GOALS

The goal of NASA's Advanced Subsonic Technology (AST) program was to develop high-payoff technologies, in cooperation with the Federal Aviation Administration (FAA), the U.S. aeronautics industry and academia, to benefit the civil aviation industry's international competitiveness and the public. These technologies were aimed at reducing travel costs while increasing safety, reducing civil aircraft impact on the environment, and increasing doorstep-to-destination travel speeds. The success of the AST program has resulted in significant contributions to technology readiness that will preserve our Nation's economic health and the welfare of the traveling public, and mobility and accessibility to more destinations in the national air transportation system.

STRATEGY FOR ACHIEVING GOALS

To focus resources on high priority national goals like aircraft engine emissions and airport crowding, the AST program was concluded in FY 1999. The AST program has been successful and progress was made toward meeting the current program goals. Aggressive technology transition plans have been pursued in order to mitigate the significant risk to successful technology transfer to industry as a result of early termination.

In order to continue progress toward the planned AST program goals in Noise Reduction and General Aviation the current technology development projects in these areas was transferred to the Airframe Systems Research and Technology Base program. This will result in these AST goals being accomplished as planned. In addition, key technology developments in the areas of Emissions Reduction and Environmental Assessment were transitioned to the Ultra-Efficient Engine Technology (UEET) program as required to meet UEET objectives.

SCHEDULE AND OUTPUTS

Enviornment

Emissions Reduction: Demonstrate reduction of future large engine emissions of NOx by 50 percent. Plan: September 1999 Actual: September 1999	The ability of the AST low emission combustor to achieve to reduce NOx levels 50 % below the 1996 ICAO regulations were demonstrated with the combustor installed in a PW 40000 development engine.
Environmental Assessment: UNEP/WMO Ozone/IPCC climate reports input. Plan: September 1999 Actual: September 1999	The second program-level assessment report was completed in preparation for the 2000 UNEP/WMO ozone and IPCC climate assessment report. The AST assessment report included results form engine emissions characterizations, near filed interactions, and operational scenarios were applied to global climate models and validated with laboratory studies and atmospheric observations. This report is a "current state of scientific knowledge" assessment of the impact of aircraft on the global environment.

Reduced Seat Cost

Airframe Materials and Structures: Conduct semispan wing test. Plan: September 1999 Actual: July 1999	Testing of the semispan advanced composite wing was conducted and verified the achievement of the weight (25 percent reduction) goal. In addition, seven wing cover panels were fabricated with the resulting verification of the achievement of the cost (20 percent reduction) goal.
Engine Systems: Demonstrate improved turbomachinery design. Plan: September 1999 Actual: September 1999	The Average Passage NASA (APNASA) code was validated for turbomachinery. Design and development cycle time improvements have been demonstrated.
Systems Evaluation: Release final ASAC. Plan: September 1999 Actual: September 1999	The final functionally validated Web-based aviation analysis system with integrated model architecture and advanced system models and databases was delivered and is capable of providing an assessment of potential technology benefits.
Airframe Methods: Three-dimensional high-lift analysis methods validated. Plan: September 1999 Actual: September 1999	Calibrated three-dimensional Navier-Stokes methodology that allows for the analysis of subsonic transport configurations including simulation of the propulsion system power effects was developed and validated.

General Aviation

Complete market assessments. Plan: March 1999 Actual: March 1999	Market assessments of current and latent market for advanced general aviation aircraft have been completed and domestic and international benefits assessed.

ACCOMPLISHMENTS AND PLANS

In **Environment**, an improved and updated community noise impact model to include noise impact minimized flight tracks were completed and released. Full-scale, static engine demonstrations of advanced engine and nacelle noise reduction concepts were conducted. Broadband engine fan noise was investigated in a model-scale, wind tunnel experiment. Sector and full annular testing of low emission combustor concepts were conducted which will meet the 50-percent NOx reduction goal for large engines. . A report was published was based on the "current state of scientific knowledge" assessment of the impact of subsonic aircraft on the global environment.

In **Reduced Seat Cost**, improved turbomachinery design codes were applied and validated to demonstrate increased capability (highly efficient, environmentally compatible and reliable) engine systems. Testing of the semispan advanced composite wing was conducted and verified the achievement of the weight (25 percent reduction) goals, and wing cover panels were fabricated with the resulting verification of the achievement of the cost (20 percent reduction) goal. An analysis method for an integrated aerodynamic design of the wing with the propulsion system was validated and provided to industry to contribute to a reduced design cycle time. Following completion of evaluations of the earlier release, the operational version of the ASAC computer code, including aviation databases and economic and aviation system analysis models, was released to complete the Systems Evaluation project.

In **General Aviation**, work was completed in ice protection and propulsion sensors and controls. The assessments of current and latent general aviation markets will be conducted. The AGATE “highway-in-the-sky” operating capability began final development, with the planned certification issues resolution for COTS-based avionics and display hardware and software architecture for the cockpit being addressed as part of the Vehicle Systems R&T Base Program. Flight training learning modules were developed for next generation AGATE cockpit systems.

BASIS OF FY 2001FUNDING REQUIREMENT

AVIATION SYSTEMS CAPACITY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Aviation Systems Capacity	53,888	62,929	59,200

PROGRAM GOALS

According to airline representatives, delays in the Air Traffic Control System cost U. S. operators approximately $3.5 billion per year in excess fuel burned and additional operational costs. The number of airports experiencing 20,000 hours of delay each year is projected to increase by 50 percent by 2003. Due to environmental issues and cost, only one major new U. S. airport—in Denver—was opened in the 1990's. With little ability to build new or expand current airports in the populated areas where they are needed, airport delays will continue to grow. More efficient and flexible routing, scheduling, and sequencing of aircraft in all weather conditions is critical to meeting capacity demands. The U. S. aviation industry is investing $6 billion over 20 years to increase airport capacity. However, a gap still exists between the industry's desired capacity and the ability of the National Airspace System to handle the increased air traffic. Another part of the solution to capacity demands is to off-load the major airports by developing short-haul routes among the 5200 public-use airports available throughout the country. Studies conducted by Boeing Commercial Aircraft, for NASA and the FAA, and by various state and local transportation authorities (e.g., Ports of New York and New Jersey Authority) have shown the civil tiltrotor to be a viable candidate for relief of air traffic congestion.

The ASC program supports on the Enterprise's Global Civil Aviation goal of "tripling the aviation system throughput in all weather conditions, by 2007, while maintaining safety". The goal of the Aviation System Capacity (ASC) program is to enable safe increases in the capacity of major US and International Airports through both modernization and improvements in the Air Traffic Management System and the introduction of new vehicle classes which can potentially reduce congestion, specifically: to increase National Airspace System (NAS) throughput while assuring no degradation to safety or the environment; to increase the flexibility and efficiency of operations within the NAS for all users of aircraft, airports and airspace; and to reduce system inefficiencies.

STRATEGY FOR ACHIEVING GOALS

The ASC program is composed of the Terminal Area Productivity (TAP), Advanced Air Transportation Technologies (AATT), and the Civil Tiltrotor (CTR) projects. The TAP project develops technology and procedures to support the aviation systems infrastructure by reducing system delays and enabling new modes of airport operation to support "Free Flight." The AATT project develops decision making technologies and procedures to provide all airspace users with more flexibility and efficiency, as well as enable new modes of operation that support the FAA commitment to "Free Flight." The CTR project develops technologies and procedures to overcome inhibitors to a civil tiltrotor operating within an improving and modernized air traffic system. The ASC program works closely with manufacturers, the airlines and the FAA, who are responsible for applying the candidate technologies as operational systems.

In the area of Air Traffic Management R&D, NASA and the FAA have an integrated research and technology development plan, approved by both the NASA Associate Administrator for Aero-Space Technology and the FAA Associate Administrator for Research and Acquisition. An Inter-Agency Integrated Product Team (IAIPT) is responsible for the strategic management of this area of research by the FAA and NASA, assuring that the efforts of both agencies are conducted to maximize the benefits of the research. The IAIPT reports to a NASA/FAA Executive Council, comprised of the appropriate Associate Administrators from both Agencies. Each agency is responsible for the conduct of its Programs. Oversight of the NASA Programs is provided through the NASA Advisory Council. The Ames Research Center is the lead center for the program and each of the three current projects, with the Langley and Glenn Research Centers providing supporting research.

The Terminal Area Productivity (TAP) project is focused on increasing capacity at airports. The objective is to provide technologies and operating procedures enabling productivity of the airport terminal area in instrument-weather conditions to safely match that in clear-weather or visual conditions. In cooperation with the FAA, NASA's approach in TAP is to develop and demonstrate airborne and ground technology and procedures to safely reduce aircraft spacing in the terminal area, enhance air traffic management (ATM) and reduce controller workload, improve low-visibility landing and surface operations, and to integrate aircraft and air traffic systems to address the problems described above. By the end of the decade, integrated ground and airborne technology will safely reduce spacing inefficiencies associated with single runway operations as well as the required spacing for independent, multiple runway operations conducted under instrument flight rules. Single runway operations are expected to increase by at least 12 to 15 percent under instrument weather conditions. Given the capabilities of future air traffic control automation and improved wake vortex knowledge, "dynamic spacing" between pairs of aircraft types in the landing sequence for an airport runway system is possible and desirable for maximum safety, capacity and efficiency.

The goal of the Advanced Air Transportation Technologies (AATT) project is developing technologies to enable the next generation of increases in capacity, flexibility and efficiency, while maintaining safety and not degrading the environment, of aircraft operations within the U. S. and global aviation system. In alignment with the national consensus for the operating paradigm of the future, called "free flight", the technical objective is to provide human-centered, error-tolerant automation to assist in short- and intermediate-term decision-making among pilots, controllers and dispatchers to integrate block-to-block planning services. This will allow all airspace users to choose the best flight path for their own purposes within the constraints of safety and the needs of other users. Specific objectives include: (1) enabling "free flight" to the maximum possible degree to allow users to maximize business/customer impacts by making trade-offs between time and routing; (2) improving the effectiveness of high-density operations in regions on the ground and in the air where free flight will not be possible, and (3) enabling operation in a smooth and efficient manner across boundaries of free flight and capacity-constrained flight regions.

While the tiltrotor has been shown to be a viable military aircraft (V-22 Osprey), insufficient research has been undertaken on technologies critical to civil applications such as noise, terminal area operations, safety, passenger acceptance, weight reduction, and reliability. The Civil Tiltrotor (CTR) project focuses on noise reduction; cockpit technology for safe, efficient terminal area operations; and contingency power. To achieve acceptable levels of external noise in the terminal area, prop-rotor noise must be reduced by six decibels A-weighted (dBA) over current technology. Complex flight profiles involving steep approach angles and multi-segmented approach paths will be developed to provide an additional six dBA reduction. To enable these approaches to be safely flown under all weather conditions, integrated and automated control laws and displays will be developed.

SCHEDULE AND OUTPUTS

Terminal Area Productivity:

Demonstrate Advanced Vortex Sensing System with transport of vortices and class-wise spacing Plan: September 1999 Actual: September 1999	Conducted demonstration of AVOSS technologies with transport of vortices and class-wise spacing features including performance of vortex transport models for use by FAA to potentially reduce approach spacing standards.
Conduct simulation of full CTAS coordinated with FMS Plan: April 2000 Revised: July 2000	Conduct full-mission simulation of Center-Terminal Radar Approach Control (TRACON) Automation System (CTAS) decision support tools operating in coordination with aircraft Flight Management System.
Complete demonstrations of all TAP-developed technologies and procedures Plan: September 2000	Complete all of the demonstrations for the TAP project. Demonstrate all TAP technologies in a realistic NAS environments achieving a 12 – 15 % increase in single runway throughput and proving the ability to space aircraft closer than 3,400 feet on parallel runways while meeting all FAA safety criteria.

Advanced Air Transportation Technologies:

Complete definition of expanded operational evaluation of advanced air transportation technologies for: application to complex airspace distributed air/ground traffic separation Plan: September 1999 Actual: September 1999	Completed studies and down-selected recommended approaches to expanded operational evaluation for complex airspace and distributed air/ground traffic separation.
Develop, demonstrate and transfer extended terminal area decision support tools for arrival and surface operations in support of the FAA Free Flight Phase 1 Program Plan: September 2000 Revised: June 2000	Conduct field evaluations of individual decision support tools for management of arrival and surface traffic. Transfer technology to the FAA Free Flight Phase 1 Program.
Develop and demonstrate transition airspace decision support tools for: ATC/airline operations center and ATC/cockpit information exchange Conflict resolution. Plan: September 2001	Develop and demonstrate transition airspace decision support tools. These tools will enable information exchange between ATC/airline operations centers and ATC/cockpits for collaborative decision-making. These tools will also enable prediction of aircraft conflicts both by ATC and flight crews.
AATT Product validation complete Plan: September 2004	Complete validation and assessment of NASA-developed advanced air transportation technology products that will result in a 30 % increase terminal area throughput.

Civil Tiltrotor:

Flight database of low-noise operating procedures Plan: July 1999 Actual: October 1999	Acquired an in-flight database for low-noise operating procedures. Obtained repeatable data points for the following approaches: 6 degree baseline, 3 degree straight, and two low noise profiles – double segmented, first a 3 degree, then a 9 degree. The low noise flight profiles were 7 dB less than the baseline – this met the program element goal.
Isolated Rotor database for low-noise rotor concepts and initial noise code (TRAC) Plan: December 1999 Actual: December 1999	Acquired rotor database for low-noise rotor concepts and for code validation.
Full-span database for low-noise rotor concepts and final noise code (TRAC). Plan: January 2000 Revised: March 2000	Complete full-span wind-tunnel testing of civil tiltrotor model to demonstrate low noise rotor concepts and acoustic code validation with wake and fuselage effects. Test delayed due to unavailability of wind tunnel because of technical problems
Comprehensive mission simulation database of integrated cockpit and operating procedures for complex, low noise flight paths Plan: September 2001	Conduct mission simulations to develop a comprehensive database for complex, low noise flight paths of a civil tilt-rotor with integrated cockpit and operating procedures. The simulations will integrate noise data, operating procedures and cockpit systems evaluated in earlier simulation and flight experiments.
Large scale database for validation of rotor noise reduction and validated design for noise capability (TRAC). Plan: September 2001	Acquire a large-scale database for validation of rotor noise reduction and validated design-for-noise capability.

ACCOMPLISHMENTS AND PLANS

During FY 1999, in the **Advanced Air Transportation Technologies** project, the definition of an expanded operational evaluation of advanced air transportation technologies for application to complex airspace and for distributing tasks between flight crews and ground controllers for safe air to air separation was completed. The **Terminal Area Productivity** project, conducted a demonstration of AVOSS technologies with transport of vortices and class-wise spacing features including performance of vortex transport models for use by FAA to potentially reduce approach spacing standards; and conducted a flight demonstration of the airborne information for lateral spacing (AILS) concept to enable independent approaches to parallel runways spaced 2500 feet apart. In the **Civil Tiltrotor** project, wind-tunnel testing of isolated rotor models acquired a database for five low noise rotor concepts. Using higher harmonic control, the principal annoying impulsive noise during approach, due to blade-vortex interaction, was virtually eliminated, resulting in 13.5 dB noise reduction. This exceeded the program element goal of 6 dB reduction. An in-flight database for low-noise operating procedures was also obtained. Compared to the baseline 3 and 6 degree approaches, two low noise profiles – double segmented (first a 3 degree, then a 9 degree) were 7 dB less than the baseline. This exceeded the program element goal of 6 dB for low noise flight approaches. The low noise flight profiles were first predicted by a computer model and then verified by the flight noise measurements on the XV-15 Research Aircraft. These flight tests were supported by simulation work conducted in the Vertical Motion Simulator, to assure Level 1 handling qualities.

During FY 2000, in the **Advanced Air Transportation Technologies** project, field evaluations will be conducted to evaluate and demonstrate individual decision support tools for management of arrival~~,~~ and surface operations in support of the FAA Free Flight Phase 1 Program. The **Terminal Area Productivity** project will be completed in FY 2000 with final demonstrations of all developed technologies and procedures. Program expected to demonstrate potential for an increase of 12 to 15% in airport throughput. Specifically, full-mission simulations will be conducted to demonstrate CTAS on the ground integrated with airborne FMS in the flight vehicles utilizing data-link capabilities to facilitate information exchange between CTAS FMS, and a demonstration of the AILS operational concept to closely spaced parallel runways interacting with other air traffic. In addition, a demonstration of all completed AVOSS technologies for use by FAA to potentially reduce approach spacing standards. In the **Civil Tiltrotor** project, wind -tunnel testing of a full-span tilt-rotor model will demonstrate low-noise rotor concepts and will validate acoustic codes with wake and fuselage effects.

During FY 2001, in the **Advanced Air Transportation Technologies** project, field evaluations will be conducted to demonstrate transition airspace decision support tools in support of 1) information exchange between air traffic service providers, airline operations centers, and flight crews, 2) conflict resolution. The decision support tools with information exchange will enable collaborative decision-making between ATC and the aircraft operators to optimize both ATC and airline operations. Conflict detection capabilities by both the ATC and aircraft will enable optimization of both overall traffic flow as well as individual aircraft flight trajectories. The **Civil Tiltrotor** project will acquire a comprehensive mission simulation database of integrated cockpit and operating procedures for complex, low noise flight paths of a civil tiltrotor. Also, a large-scale database will enable validation of both rotor noise reduction and a design-for-noise capability. The Tiltrotor Aeroacoustic Code computer program will enable the predictive capability.

BASIS OF FY 2001 FUNDING REQUIREMENT

AVIATION SAFETY PROGRAM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Aviation Safety Program	---	64,394	70,000

PROGRAM GOALS

The world-wide commercial aviation major accident rate has been nearly constant over the past two decades. While the rate is very low (approximately one hull loss per 2 million departures), increasing traffic over the years has resulted in the absolute number of accidents also increasing. The world-wide demand for air travel is expected to increase even further over the coming two decades - more than doubling by 2017. Without an improvement in the accident rate, such a traffic volume would lead to 50 or more major accidents a year — a nearly weekly occurrence. Given the very visible, damaging, and tragic effects of even a single major accident, even approaching this number of accidents would clearly have an unacceptable impact upon the public's confidence in the aviation system, and impede the anticipated growth of the commercial air-travel market. The safety of the general aviation (GA) system is also critically important. The current GA accident rate is many times greater than that of scheduled commercial transport operations. The GA market may grow significantly in future years, and safety considerations must be removed as a barrier if this growth is also to be realized. Controlled Flight into Terrain (CFIT) and loss of control are the two largest commercial accident types, with weather, approach and landing, and on-board fire as additional significant categories. Human error is cited above all other issues as the prime contributing factor. For General Aviation, weather issues, CFIT, and loss of control also dominate the accident statistics.

In February 1997, to aggressively address these issues, President Clinton announced a national goal to reduce the fatal accident rate for aviation by 80% within ten years. This national aviation safety goal is an ambitious and clear challenge to the aviation community. NASA responded to the President's challenge with an immediate major program planning effort to define the appropriate research to be conducted by the Agency. Four industry- and government-wide workshops were conducted in early 1997 to define research needs. Four hundred persons from over one hundred industry, government, and academic organizations actively participated in setting the research investment strategies. This led to NASA's aviation safety initiative and a redirection of the Aeronautics Research and Technology Base in FY 1998 to immediately begin aviation safety research. The Aviation Safety Program (AvSP) is NASA's next step in responding to the challenge. The goal of AvSP is to develop and demonstrate technologies that contribute to a reduction in aviation accident and fatality rates by a factor of five by the year 2007 compared to the 1994-1996 average.

STRATEGY FOR ACHIEVING GOALS

The NASA AvSP approach for contributing to the national goal is to develop and demonstrate technologies and strategies to improve aviation safety by reducing both aircraft accident and fatality rates. Program planning gives high priority to those strategies that address factors determined to be the largest contributors to accident and fatality rates as well as those that address multiple classes of factors. Research and technology development will address accidents involving hazardous weather, controlled flight into terrain, human-error-caused accidents and incidents, and mechanical or software malfunctions. The safety program will emphasize not only accident rate reduction, but also a decrease in injuries and fatalities when accidents do occur. The program will also develop and integrate information technologies needed to build a safer aviation system--to support pilots and air traffic controllers--as well as provide information to assess situations and trends that might indicate unsafe conditions before they lead to accidents. The focus of each program element is the development of one or more prevention, intervention, or mitigation strategies aimed at one or more causal, contributory, or circumstantial factors associated with aviation accidents.

The AvSP will work as partners with the Federal Aviation Administration (FAA) in implementing the program and will maintain close coordination with the Department of Defense and other government agencies. Additionally, the program will work in concert with the full spectrum of commercial, rotorcraft, and general aviation industry manufacturers, suppliers, and operators in implementing the effort. Langley Research Center (LaRC) is the program's Lead Center and works closely with program personnel at Ames (ARC), Glenn (GRC), and Dryden (DFRC) Research Centers.

The AvSP programmatic and technical approach has been developed in close cooperation with the FAA as well as the broad aviation community. The Aviation Safety Program Manager is a member of the Commercial Aviation Safety Team and the General Aviation Joint Steering Committee, the government/industry leadership groups developing and managing the overall National safety strategies. NASA aviation safety research and development efforts will therefore complement both FAA and industry activities as a coordinated overall effort.

Based on the AvSP goal, the criteria for program mission success is to develop technologies that, when implemented by the aviation community, will contribute to a reduction of the civil aviation rate. The program mission success criteria are to produce:

- Human-error assessment methodologies that allow system designs and procedures to be analyzed for error susceptibility – validated in piloted simulation

- Health and Usage Monitoring technologies that enable real time and trending status of critical on-board aircraft systems – demonstrated in flight

- Affordable technologies and systems for the data-linked communication and on-board graphical display of critical aviation weather information both nationally and internationally – demonstrated in flight

- Turbulence modeling and detection technologies that allow for predictive warning and/or avoidance of severe turbulence encounters - demonstrated in flight

- Synthetic Vision technologies and feasible, demonstrated system concepts that provide immediate clear day-equivalent visual awareness and avoidance of world-wide terrain and obstacles in any weather or light condition – demonstrated in flight

- Precision approach and landing technologies and displays that provide intuitive guidance and piloting decision support worldwide, at any runway, at any airport, for both general and commercial aviation – demonstrated in flight

- Advanced structural and material designs that demonstrate 20-40% improvement in crash survivability and fire hazard mitigation – demonstrated in simulation

- Integrated aviation system monitoring tools and infrastructure design operational for at least two major airlines and accessible both nationally and internationally, allowing regular operational assessments to identify unsafe trends before they become accidents

Associated with each technology development effort will be on-going activities by NASA and the FAA to motivate and assist in the implementation of program outputs into the aviation community. NASA researchers will stay involved to help program "outputs" become "outcomes." This process will mean that NASA will work with industry and FAA partners to progress technologies through implementation. This process will be assessed through an Implementation Readiness Level (IRL) scale complementing the TRL scale noted above.

The Technical Program is comprised of six major projects:

Aviation System Monitoring and Modeling (ASMM) projects provide decision-makers in air carriers, air traffic management, and other air services providers with unprecedented in-depth measures of the health, performance, and safety of the National Aviation System (NAS).

The three-fold approach of ASMM is to (1) develop advanced information technology linkages, data structures, and tools to readily access information pertaining to all aspects of the NAS operation; (2) develop tools to identify, analyze and characterize both normal and non-normal operations and uncover previously unrecognized situations that may indicate changes to levels of safety; and, (3) provide world-wide capabilities to obtain, access, and share relevant data on aviation operations among the aviation community.

System-Wide Accident Prevention (SWAP will purse research activities in three key areas identified from in-depth assessments as the highest priority applications: (1) Human Error Modeling, (2) Training, and (3) Maintenance Human Factors. Human Error Modeling efforts will target key aviation hazard issues (such as flight deck automation hazards, controlled flight into terrain, and others) to develop, test, and prove general design principles and operational improvements from a human-centered perspective. Training research efforts will target both training effectiveness improvements (training to performance levels over training to pass a test) as well specific training module developments for key safety issues such as flying in icing conditions. Maintenance Human Factors will make key investments in developing applications for procedural improvements and will as technologies for advanced displays and automation.

Single Aircraft Accident Prevention (SAAP) will pursue research activities in the following technology areas: (1) Health Management and Flight Critical Design Technologies, and (2) Control Upset Management. Health Management and Flight Critical Design technology developments will utilize advanced on-board measurement and diagnostic methodologies to monitor key flight systems for both hard failures and previously unrecognized trends leading to failures. Significant safety improvements and maintenance cost savings are expected. Control Upset Management technologies will target automated and pilot control techniques to prevent aircraft upsets resulting from systems failures or external inputs as well as techniques for recovering from unusual attitude conditions should an unavoidable upset occur.

Weather Accident Prevention (WxAP) projects will develop and support the implementation of technologies to reduce the fatal accident rate induced by weather hazards. All aircraft types are to be considered. WxAP will pursue research activities in the following technology areas: (1) Aviation Weather Information Dissemination and Presentation and (2) Turbulence Detection and Mitigation.

By developing precision navigation applications, advanced weather- penetrating sensors, high resolution terrain data bases, and graphical cockpit displays, **Synthetic Vision** technology development will provide commercial and general aviation pilots with clear out-the-window views regardless of the actual visibility conditions. In addition to the potentially very large safety improvements, which would result from such a revolutionary system, substantial operational benefits should also result from added all-weather aircraft capabilities.

The Synthetic Vision project will focus on technologies and system applications of terrain displays, enhanced visions systems, precision approach and landing guidance and displays, and low visibility surface operations.

Accident Mitigation (AM) projects will develop, enable, and promote the implementation of technology to increase the human survival rate in survivable accidents, and to prevent in-flight fires. The overall approach in AM is to reduce the physical crash dynamics hazards, minimize fire effects in order to allow more time for evacuation, and reliably detect/suppress in-flight fires. AM technologies are targeted at all classes of aircraft.

SCHEDULE AND OUTPUTS

Preliminary integrated program assessment Plan: January 2000	Complete a preliminary safety impact assessment of the AvSP integrated program.
Apply Aircraft Performance Monitoring System (APMS) to Air Traffic Control (ATC) Plan: June 2000 Revised: March 2000	Demonstrate application of APMS concepts & methodologies to ATC for performance monitoring
CD-ROM Icing Training Module Plan: September 2000 Revised: December 1999	Developed CD-ROM icing training module for General Aviation and commuter pilots.
Simulation Database for Adverse Conditions and Loss of Control Plan: September 2000	Complete development of a preliminary simulation database, mathematical models and 6 degree-of-freedom vehicle simulations to characterize adverse conditions, failures, and loss of control
Initial Aviation Weather Information Network (AWIN) Concept Flight Evaluation Plan: September 2000	Flight Evaluation of initial national capability for digital data link and graphical display of weather information.
Flight Demonstration of Runway Incursion Prevention Technologies Plan: September 2000	Concept demonstration of integration of air traffic control runway incursion information onto aircraft flight deck displays.
Flight Crew knowledge standards Plan: December 2000	Complete the development of flight crew knowledge and proficiency standards for automation.
Tools for causal and risk assessment Plan: September 2001	Demonstrate in an operational environment, tools for merging heterogeneous databases to aid causal and risk assessment.
Onboard health management system Plan: September 2001	Define an architecture for an integrated onboard health management system

SV retrofit concepts Plan: September 2001	Evaluation of concepts in simulations and flight tests utilizing situational awareness measurement tools developed for the analysis of SV retrofit concepts.
Reduce fuel system flammability Plan: September 2001	Successfully complete the experimental and analytic laboratory environment demonstration of fuel system modifications to reduce flammability.
Advanced Fire detection systems Plan: September 2001	Complete the design criteria for low false-alarm fire detection systems.
Safety Improvement Concepts developed Plan: September 2001	Conceptual designs of safety-improvement systems are completed for all projects in September 2001. .
Interim Integrated Program Assessment Plan: June 2002	Interim assessment impact assessment of AvSP integrated program completed. Projected impact on accident rates for research projects completed and provided in a summary report
Simulations and Flight Test Evaluations of Safety-Improvement Systems within AvSP Completed Plan: March 2003	Individual safety-improvement systems have been evaluated in simulators and flight tests:
Integrated Full-Mission Applications, Simulations, and Flight Demonstrations Plan: June 2004	Mission-capable safety-improvement systems have been integrated into full system and demonstrated in flight:
Final Integrated Program Assessment Plan: September 2004	Final Safety impact assessment of AvSP integrated program completed: - Projected impact on accident rates for research projects completed and provided in a summary report

ACCOMPLISHMENTS AND PLANS

In FY 2000 the first year of the program, the Weather Accident Prevention project will complete flight evaluation of an initial national capability for digital data link and graphical display weather information in an aircraft cockpit. This will be an assessment of cockpit "weather channel" concept for national and worldwide commercial airline and general aviation benefit. Selections of concepts for continued development will be conducted for clear air turbulence detection systems. The System-Wide Accident Prevention project will develop and demonstrate an icing training module on CD-ROM for general aviation and commuter pilots. This will enable the board dissemination of critical weather safety information to the national aviation community. Software application field tests will begin for maintenance human factors risk database, mathematical models, and six degree-of-freedom vehicle simulations to characterize adverse conditions, system failures and loss of control mitigation techniques. Synthetic Vision flight demonstration tests of FAA and NASA runway incursion technologies integrated onto an aircraft flight deck will be conducted at a major U.S. airport. These tests will provide technical and operational warning systems into current technology cockpits. The Aviation System Monitoring and Modeling project will demonstrate the application of Aircraft Performance Measurement System concepts and methodologies to Air Traffic Control systems for performance monitoring. This work will take successful aircraft-based monitoring technologies and apply them to the broader context of the national airspace system risk identification and performance improvements. Airline evaluations and operational use of aircraft performance measuring software and analysis tools will be conducted. In the Accident Mitigation projects area, on-board inert gas and oxygen generation system concepts for fire prevention and emergency use will be defined and structural crashworthiness design analysis prediction codes development selections will be conducted.

For FY 2001, Aviation System Monitoring and Modeling will demonstrate, and simulate of NASA-wide operation for ground and flight in an operational environment, tools for merging heterogeneous databases to aid causal analysis and risk assessment. The intent is for the primary products to be commercialized. System-Wide Accident Prevention will complete development of flight crew knowledge and proficiency standards for automation and deliver them to industry for evaluation and develop prototype-training materials for evaluating skill-specific maintenance resource management (MRM) intervention. Single Aircraft Accident Prevention will define architecture for integrated onboard health management systems. These designs will provide sufficient criteria to support development of concept prototype to be used for simulation and flight demonstrations. For the National Capability Demonstration, Weather Accident Prevention will develop system end-to-end atmospheric models and sensor simulation for selected hazards and sensor technologies and candidate hazard algorithms. Turbulence Detection will develop a simulation demonstration of turbulent-tolerant flight control algorithm. This simulation of system results in 80% or better detection rate for moderate turbulence within 1 minute of encounter. Accident Mitigation will demonstrate in an experimental and analytic laboratory environment, of a fuel system modification to reduce flammability, and validate system designs in an representative fire environment experiment, showing reliability and low false-alarm characteristics. Synthetic Vision will down-select concepts suitable for retrofit in commercial, business, and general aviation aircraft, and investigate the use of altimeter and weather radars as means for monitoring the integrity of Synthetic Vision Systems databases.

BASIS OF FY 2001 FUNDING REQUIREMENT

ULTRA EFFICIENT ENGINE TECHNOLOGY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Ultra-efficient engine technology..	---	68,306	35,000

PROGRAM GOALS

NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. Currently, a high priority national challenge is to ensure U.S. leadership in aviation in the face of growing air traffic volume, new safety requirements, and increasingly stringent noise and emissions standards. NASA's role in aeronautics is also to support the Department of Defense (DoD) in maintaining superior air defense capability. Propulsion has led the way for new generations of aircraft with breakthroughs in performance, reliability, and environmental compatibility. A prime example of NASA's contribution to technological advances in propulsion is the high bypass turbofan. This engine enabled the economic success of wide-body transport aircraft and achievement of new levels of fuel efficiency and dramatically reduced noise as compared to the earlier generation of jet aircraft. The attainment of Aero-Space Technology Enterprise goals requires comprehensive propulsion technology research and development spanning a broad range of aircraft applications from subsonic through hypersonic. The timing is right to invest in breakthrough technologies for a new breed of radically improved propulsion systems to power a new generation of aircraft required in the increasingly constrained airspace system.

NASA has a successful history of leading the development of aggressive, high payoff technology in high-risk areas, ensuring a proactive approach is taken to developing technology that will both be required for meeting anticipated future requirements, and for providing the technical basis to guide policy by determining feasible technical limits. The Ultra Efficient Engine Technology Program addresses the most critical propulsion issues facing the Nation in the new millennium: performance and efficiency. In order to sustain the desirable forecasted growth of this important industry, these issues must be addressed without dampening this growth and therefore must improve performance and efficiency without incurring environmental penalties. Additionally, it is important to sustain the high reliability and safe operation without impacting the economics of operations. These propulsion technologies will also be of significant benefit to military engines where performance improvement is the principal goal driving DoD propulsion development for future military aircraft.

STRATEGY FOR ACHIEVING GOALS

The Ultra Efficient Engine Technology Program is planned and designed to develop high-payoff, high-risk technologies to enable the next breakthroughs in propulsion systems to spawn a new generation of high performance, operationally efficient and economical, reliable and environmentally compatible U.S. aircraft. The breakthrough technologies are focused on propulsion component and high temperature engine materials development and demonstrations enabling future commercial and military propulsion systems which are greatly simplified, achieve higher performance, and have potential for much reduced environmental impact with a broad range of aircraft applications. Seven investment areas form the basis for the technical approach: materials & structures, to address the barrier technologies and expand the knowledge databases required for future designs of high temperature, long life, high performance propulsion systems; combustion, to develop the technologies necessary to minimize the emissions characteristics of future propulsion systems; turbomachinery, to develop highly coupled/loaded engine component technologies incorporating breakthrough features with potential for integrated propulsion demonstrations; propulsion - airframe integration to develop approaches and technologies for integrating next generation propulsion systems with revolutionary aerospace vehicle designs so as to maintain high levels of installed propulsion system performance; intelligent propulsion system controls to leverage the emerging intelligent systems (IS) technologies to apply to revolutionary propulsion system architectures; integration & assessments, to understand the complexity of interplay among technology benefit, tradeoff and impact; and integrated component technology validations to demonstrate the ability to integrate technologies and achieve revolutionary levels of sub system/system performance.

NASA's investments will develop the underlying understandings and design information to mitigate both the risk and cost of applying the technology-based solutions. The success of this program is dependent on partnerships to enable transfer of the resulting technology. As a result, a key element of this program is to develop high-payoff technologies, in cooperation with DoD, the Federal Aviation Administration (FAA), the Environmental protection Agency (EPA), the U.S. aeronautics industry and academia, to benefit the public.

The Glenn Research Center is the lead center for the UEET Program and five of the seven projects (combustion, materials and structures, turbomachinery, integration and assessment, and integrated component technology validation). Langley Research Center has project management responsibility for the propulsion-airframe integration project and Ames Research Center has project management for the intelligent propulsion system controls project. Goddard Space Flight center provides critically important supporting research in the atmospheric assessment subproject of the integration and assessment project.

SCHEDULE AND OUTPUTS

Combustion: Combustion research facility upgrade completed Plan: September 2000	Complete the development and fabrication of the upgrade to the Combustion Research Facility, a unique world class facility, which is required for testing of combustor configurations (flame tube and sector) required for future ultra high-pressure ratio engine cycles.
Combustion: Select 70% emissions reduction concept for full combustor evaluation Plan: September 2000	Demonstrate in a laboratory combustion experiment (flametube) an advanced turbine-engine combustor concept that will achieve up to a 70% reduction of oxides of nitrogen (NOx) emissions based on 1996 ICAO standard.
Materials & Structures: Complete high temperature engine material down-select Plan: September 2000	Complete selection of those materials systems that will be developed for complex geometries such as cooled turbine vanes with thermal barrier coating and capable of sustained 3100°F turbine rotor inlet temperatures

Turbomachinery: Validation of aero-performance prediction code Plan: September 2000 Actual: Deleted	Complete single stage cascade tests of turbine configurations which incorporate flow control to improve aerodynamic performance and use flow physics data set acquired to validate NASA's average passage (APNASA) computer code. Milestone was developed early in planning of UEET program. Final validation of aero-performance prediction code will occur in FY 2004 (level 1 program milestone).
Integration & Assessment: Complete baseline propulsion system development and technology assessments Plan: September 2000	Complete the development of baseline system configurations and the preliminary assessment of UEET revolutionary candidate technologies
Prediction of propulsion-airframe integration Plan: October 2000	Complete selection of the most promising simulation approach for predicting propulsion-airframe integration effects for unconventional aerospace vehicles.
Flow Control Concepts for advanced propulsion systems Plan: December 2000	Complete selection of the most promising flow control concepts that will be developed for application to the turbine components of advanced propulsion systems.
Definition of advance propulsion options Plan: September 2001	Complete definition of advanced propulsion options incorporating UEET low emissions combustor, high temperature materials and highly loaded turbomachinery candidate technologies.
1350 deg. turbomachinery disk alloy Plan: September 2001	Demonstrate the required materials properties in scaled-up forging for a 1350 deg F turbomachinery disk alloy.
Integration and Assessment: Complete interim assessment of UEET technologies Plan: September 2003	Complete the interim assessment of the projected system impacts of low emissions and improved performance technologies incorporating experimental results and simulation predictions completed to date.
Integration and Assessment: Complete final assessment of UEET technologies Plan: September 2005	Complete the final assessment of the projected system impacts of low emissions and improved performance technologies incorporating the complete suite of experimental results and simulation predictions completed in the UEET Program.

ACCOMPLISHMENTS AND PLANS

Combustion In FY 2000, a world class high pressure ratio combustion research facility upgrade will be completed to allow parallel operation of basic combustion research for combustion diagnostics and physics based model calibration and for flame tube and sector testing to validate advanced high performance combustor designs. This facility allows for realistic testing of combustion concepts applicable for the high pressure ratio engine cycles envisioned which will fully utilize the technologies developed in the UEET program to achieve revolutionary advances in gas turbine engine performance. In FY 2000, flame tube tests will be conducted to identify the most promising approaches for achieving the 70 percent NOx reduction goal. In FY 2001, the results of these flame tube tests will be used to design and fabricate sector configurations of ultra low emissions configurations for subsonic engine applications. Limited model tests will be conducted in government or industry facilities as appropriate to validate the emissions reduction potential. State of the art instrumentation will be used to measure particulate and aerosol characteristics of these advanced combustor configurations. These results will be used in atmospheric impact assessments to be accomplished as part of the Integration and Assessment project.

Materials & Structures: In FY 2000, the selection of those materials systems that will be developed to the subcomponent, complex part scale in this program will be completed. The suite of materials from which this selection will be made is focused only on those critical to enable the high performance 21st Century propulsion systems. An initial high priority activity completed in FY 2000 was the selection of the most promising approaches for developing a low conductivity thermal barrier coating, a critical constituent for a high temperature turbine airfoil material system. One critical material system, Ceramic Matrix Composites (CMC), is essential to both future commercial and military engines. This program is the only national effort in CMC's and is a key technology where DoD is reliant on NASA. CMC work in FY 2000 will be focused on establishing the upper temperature limit of the material developed in the High-Speed Research (HSR) Program. In FY 2001, scaled-up forging will be completed of candidate turbomachinery disk configurations utilizing the 1350 deg F advanced Nickel based material. These forgings will be used to demonstrate that the required materials properties, which have been demonstrated in laboratory scale (i.e. coupon tests), can be maintained when realistic size and configuration subcomponents are fabricated. The optimization of the composition and processing for the turbine blade bond coat will be completed in FY 2001. The bondcoat is another critical constituent of a turbine airfoil material system required for the high-pressure ratio engine cycles envisioned for the 21st century.

Turbomachinery: In FY 2000, flow control concepts will be selected for fan and compressor component applications. A key part of achieving revolutionary turbomachinery performance increases is the use of flow control to allow increased turbomachinery performance in fewer stages. These concept evaluations will be based upon CFD simulations using available computational tools. The most promising approaches will be evaluated through single stage, proof-of-concept tests. In FY 2001, a performance baseline will be established through low speed wind tunnel testing of a highly loaded, multi-stage fan. This baseline set of results will allow for the design, fabrication, and testing of a more revolutionary highly loaded fan design that will contribute to higher performance, lower weight propulsion system designs. Also in FY 2001, the selection of the flow control concept for the turbine will occur.

Propulsion-Airframe Integration: In FY 2000 a selection will be made of the computational fluid dynamics simulation tool to be used to evaluate the installed performance of the engine concepts being evaluated. In FY 2001, the design and fabrication efforts will be completed for a small-scale active flow control demonstration model. This model will utilize the sensors and actuators, selected during FY 2000 activities. Active flow control technologies show great promise for reducing length and therefore weight of advanced propulsion system inlet designs as well as internal flow passages.

Intelligent Propulsion System Controls: In FY 2000 and FY 2001, initial laboratory experiments are being conducted to assess active combustion control concepts for emissions reduction potential. Systems studies evaluations of payoffs of other intelligent control technologies will be completed. These studies will provide guidance for additional UEET technology development efforts.

Integration & Assessment: In FY 2000, revolutionary propulsion system concepts were defined for both low and high-speed vehicle applications. These propulsion system concepts will incorporate the suite of UEET technologies being developed in the other projects (i.e. ultra low emissions combustor, highly loaded turbomachinery, materials and structures, propulsion airframe integration, and intelligent propulsion system controls) and projections of the revolutionary advances in system and vehicle performance will be made. In FY 2001, a selection will be made of the propulsion system concept for which detailed, multi-disciplinary simulations will be conducted. These simulations will be performed using tools such as those provided by the High Performance Computing and Communications (HPCCP) and Intelligent Synthesis Environment (ISE) Programs.

Integrated Component Technology Validation: In FY 2000, plans were completed for a series of testbed demonstrations incorporating UEET component and materials technologies, which in partnership with the U. S. aeropropulsion industry and / or DoD to accelerate the technology transition to commercial and military customers. In FY 2001, design and fabrication efforts will be completed to allow the testing in FY 2001 - 2002 of the 2200° F CMC combustor liner in an available commercial engine testbed supplied by an industrial partner.

BASIS OF FY 2001 FUNDING REQUIREMENT

SMALL AIR TRANSPORT SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Small Air Transport System	---	---	9,000

PROGRAM GOALS

Community vitality and economic opportunity depends on access to rapid transportation, in particular air transportation. The new economy, driven by knowledge-based industrial development, will demand ever-safer national transportation system efficiencies. The exponential growth of e-commerce will create demand more speed and timesavings for people, goods and services to more destinations. Airports are magnets for new businesses, new jobs, new community revenues, and new standards of living. Today, the relatively few communities with airports capable of handling turbine-powered aircraft in near all-weather conditions create significant economic benefits compared to communities that are not served by such landing facilities. During the information age as time becomes the "scarce commodity," demand for aviation transportation is expected to outpace capacity provided by the system of about 400 hub-and-spoke airports. Thus, early in the 21st century, when speed is at a premium, the nation's doorstep-to-destination travel speeds will be in decline. The growing delays in the hub-and-spoke system will limit the economic expansion in this information age to well-connected regions and communities. Fortunately, more than 98 percent of the U.S. population lives within a 30-minute drive of over 5,000 public use landing facilities . The safe, efficient utilization of smaller aircraft and smaller, public use airports can provide a revolution in mobility, if the two major technical barriers impeding their use can be overcome: safety of flight and accessibility to these facilities.

Safety of flight. Small aircraft have accident rates more than 10 times that of commuter or large air carriers. A leading causal factor in current general aviation accidents and fatalities is marginal visibility resulting in loss of control or controlled flight into terrain. Plus, today's GA pilot is flying complex operations with antiquated avionics, with far less advanced training, in the worst meteorological conditions, and in the most complex lower-altitude airspace. The enabling technologies can be developed and integrated to bring the safety and mission reliability of single-pilot aircraft to levels equal those of airline operations.

Accessibility. Paradoxically, the Nation's airspace is not crowded; in fact airspace is plentiful. Runways at the large airports are crowded. However, the nation's infrastructure of over 5,000 smaller airports represents an underutilized capacity within the national airspace system. This underutilized capacity appears capable of handing virtually all of the growth that the hub-and-spoke system will not be able to accommodate as saturation occurs. The key inhibitors to the use of these underutilized facilities include the near-all-weather safe operational capabilities of smaller aircraft and the air traffic services infrastructure within this non-towered, non-radar airspace. The enabling technologies can be developed and integrated to give the nation near-all-weather access to virtually every runway end and helipad in the nation.

The challenges to increasing small aircraft contributions to economic development are to create the means in both vehicle and infrastructure technologies to: improve safety by reducing the accident rate of small aircraft to that of commercial transports, utilize the Nation's under-used airspace and landing facilities at non-hub airports in all weather conditions, and increase capacity for efficient operations of general aviation, commuter, regional, and runway independent aircraft near and within hub airport airspace. These SATS technologies will benefit air carriers as well. The deployment of SATS capabilities will: (1) help relieve hub airport and airspace congestion, (2) accelerate the emergence of free flight, and (3) provide air carriers with access to a third tier consumer base in communities too small to be served by existing regional jets.

The goal of the Small Aircraft Transportation System (SATS) program is to address these challenges by enabling a transportation system for safe accessibility to small, underutilized airports through the rapid integration of advanced technologies in next-generation aircraft. SATS vehicle and infrastructure technologies will provide safety levels vastly superior to automobiles and at least as safe as today's commercial air carriers by bringing advanced automation into the cockpit to allow the operator to focus on decision making and reduce training time and cost, and to enable virtual visual flight operations in instrument conditions at non-towered, non-radar landing facilities. SATS provides increased accessibility by more fully utilizing the existing 5,400 public-use facilities. The application of SATS technologies can expand hub-and-spoke capacity by smaller aircraft to use simultaneous non-interfering operations near and within Class B airports and airspace.

STRATEGY FOR ACHIEVING GOALS

The SATS Program will deliver an inter-city transportation system demonstration that integrates SATS vehicle and infrastructure features and capabilities. The SATS Program concept builds on previous lessons learned in public-private partnerships (*e.g.,* from the Advanced General Aviation Transport Experiments (AGATE) Alliance) to structure a Federal-States-Industry SATS Alliance. The essential power of an alliance is to influence those factors that would otherwise be outside the control of any individual member of a partnership. SATS plans to form a national partnership between NASA, the Department of Transportation, FAA, State governments, as well as the Department of Commerce, Industry, and Academia to focus on transportation system engineering, vehicle technologies, and enabling infrastructure technologies. SATS will leverage technologies from both past and current NASA and FAA programs, including NASA Base R&T activities, as well as new industry vehicle programs to implement a compelling demonstration of the SATS innovations.

Two types of demonstrations involving the partnership are the key products of SATS: technology development demonstrations and integrated system demonstration. States will select landing facilities in partnership with the Federal and Local Governments for demonstrations at which localized versions of SATS can be implemented. These demonstrations would validate SATS system technologies and concepts, such as "smart" airport, airborne Internet, simultaneous non-interfering approaches, AutoFlight, and wireless cockpit. These technology activities will support the aircraft, airports, and airspace/procedures design and development required for validation of SATS operating capabilities at small airports. The fidelity and breadth of the integrated system demonstration is planned to produce the full safety and system performance benefits required to enable a decision by industry as well as State and Local governments to accelerate deployment of SATS.

SATS Program products include:

- Simplified automotive-like flight controls and displays and virtual TerPs for “Autoflight”
- Integrated avionics standards and systems for tomorrow’s “Wireless Cockpit”
- “Smart Landing Facilities” to provide automation-enabled separation and sequencing in non-towered, non-radar airspace
- Client-server-based architecture for information services on an “Airborne Internet” to support collaborative air traffic management
- “Intermodal Transportation Systems Engineering” coordinated to integrate and coordinate national requirements, technologies, consumer/community response, and program deliverables
- “Public Outreach” for deployment of media and educational information supporting community understanding of SATS

SCHEDULE AND OUTPUTS

Initiate Federal - States Industry SATS Partnerships. Plan: September 2001	Partnership agreement signed by NASA and at least one state government and one industry member.
Initiate Virginia SATS - Lab Partnership. Plan: September 2001	Joint Sponsored Research Agreement with Virginia Space Grant Consortium partners is signed to develop a SATSLab comprised of aircraft, airports, and airspace for validation of SATS vehicle and infrastructure features and capabilities.
Baseline SATS Architecture and Operational requirements Plan: September 2002	SATS Concept of Operations is baselined following review and approval by SATS Alliance partners
Validate 20:1 Runway protection zone HITS approaches. Plan: September 2003	Design standards for establishing a 20:1 runway protection zone for Highway in the Sky (HITS) /Synthetic Vision approaches in near all instrument weather conditions.
Demonstrate "virtual" terminal procedures and autoflight Plan: September 2004	Validate “virtual” TerPs concept in simulation and flight with autoflight capabilities.
Transportation system assessments Plan: September 2005	Complete intermodal transportation system performance and impact simulation.

"Small Aircraft / Small Airport" System Integration Demonstration Plan: September 2005	Demonstrate integration of “virtual VFR” operations, “virtual TerPs,” automated “smart” airport traffic operations, and simultaneous non-interfering operations with integrated vehicle systems including intuitive vehicle controls, “plug & play” avionics, and cockpit automation.

ACCOMPLISHMENTS AND PLANS

In support of the milestones identified above, the following activities will be undertaken in FY 2001::

- SATS Concept of Operation drafted including vehicle features and capabilities, intermodal connectivity requirements, systems architecture, technology development needs, and projected economic benefits and costs.
- Initiation of the robust air vehicle and digital airspace technology research.
- Establishment of the partnerships with other agencies and state and local governments in anticipation of showcase technology demonstrations projects integrating SATS products.

BASIS OF FY 2001 FUNDING REQUIREMENT

QUIET AIRCRAFT TECHNOLOGY PROGRAM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Quiet Aircraft Technology Program..	---	---	20,000

PROGRAM GOALS

The goal of the Quiet Aircraft Technology program is to contribute to the 10-year noise objective of the Global Civil Aviation enabling technology goals, as stated in the Office of Aero-Space Technology Enterprise Strategic Plan, "Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within ten years, and by a factor of four within 25 years." The Quiet Aircraft Technology program is the next step in achieving the very ambitious and desirable 25-year goal for the public good. Achievement of the 25-year goal will fulfill NASA's vision of a noise constraint-free air transportation system with the objectionable aircraft noise contained within the airport boundaries. Part of this vision is a transportation system with no need for curfews, noise budgets, or noise abatement procedures. Benefits to the public of achieving these goals include increased quality of life, readily available and affordable air travel, and continued U.S. global leadership.

Until objectionable aircraft noise is contained within airport boundaries through successful implementation of advanced noise reduction technology, noise from subsonic airplanes will continue to be an issue resulting in polices and procedures, like curfews and noise budgets, for noise impact relief. While the results of previous NASA noise reduction research are incorporated in today's aircraft, even more aggressive technology is needed to address, not only the projected growth in operations, but also the public expectation for lower community noise impact.

For over 70 years, NASA with the FAA, industry, academia, and the Department of Defense have cooperatively developed critical aeronautical technologies for the future. Historically, NASA's perspective has been to take the long view and to make high risk, high potential payoff investments. The challenge to NASA is to develop critical technologies while fostering a national vision for aero-space technology development. NASA is unique in its expertise, facilities, and inherent government role to lead the technology development necessary to meet national community noise impact reduction requirements.

Noise impact of subsonic transportation is currently constraining the air transportation system through curfews, noise budgets and limits, and slot restrictions. The number of local noise related restrictions have grown worldwide from 119 airports in 1980, to 354 in 1994, to 595 in 1998**.** This dramatic growth in local noise-related constraints and the pressure for increased international noise certification stringency is indisputable evidence that the current noise impact status quo is not acceptable to the public. In addition noise issues are critically constraining the growth of the air transportation system by often delaying and sometimes inhibiting the expansion of needed airport capabilities – such as runway additions, expansions, or new airports. Today's noise-related constraints of the growth of aviation was predicted in the 1995 National Science and Technology Council (NSTC) Report *Goals for a National Partnership in Aeronautics Research and Technology.* The 1999 NSTC report *National Research and*

Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility further predicts increasing community noise impact after the phase-out of nosier Stage II airplanes as the number of operations continue to increase. Projections for air travel indicate a tripling of demand for air travel within the next two decades. New noise reduction technology is critically needed to enable this demand-driven increase in air travel. Additional pressure to reduce airplane noise results from cars, trucks, factories, and other sources of community noise becoming quieter. The demand for reduced community noise impact will continue until public expectations are met.

A benefit of achieving the 10-year noise goal is that the 65 Day Night (noise) Level (DNL) will be contained within the airport boundary for the majority of US airports. The significance of this is that this level of noise exposure is deemed so onerous that 65 DNL of noise exposure is a qualifying criteria for the FAA administered home noise insulation program. A benefit of achieving the 25-year noise goal is that the 55 DNL will be contained within most airport boundaries. The EPA has established that noise exposure less than 55 DNL is required to protect "public health and welfare". Containing the 55 DNL within the airport boundary achieves NASA's vision of objectionable airplane noise contained within the airport boundary.

STRATEGY FOR ACHIEVING GOALS

The goal of the Quiet Aircraft Technology program will build upon technology developed in the Advanced Subsonic Technology (AST) Program Noise Reduction Element and in the Base technology development programs to achieve the 10-year Three Pillars noise goal of a factor of two, 10 dB, perceived noise level reduction relative to 1997. Progress in the current planned noise reduction program, the AST and Base programs, is projected to be 5 dB relative to a 1997 baseline. The objective of the Quiet Aircraft Technology program is to develop technology for an additional 5 Effective Perceived Noise Level decibels (5 EPNdB) community noise impact reduction to a Technology Readiness Level (TRL) of 4. This 5 dB consists of both engine and airframe source noise reduction, and advanced operations to reduce community noise impact. Substantial cost sharing with industry would be required to take the developed technology beyond the planned technology readiness level to full-scale noise component reduction concept validation (TRL 6). Achievement of the 10-year National Noise Reduction goal will enable the projected growth in air travel while offering the potential to reduce community noise impact.

Through system analysis the rough order of technical performance required to achieve the required 5 EPNdB additional airplane system noise reduction beyond the AST Noise Reduction Program is 4 dB fan noise reduction, 4 dB jet noise reduction, 1 dB core noise reduction, 4 dB airframe system noise reduction, and validation of the 2 dB operational noise benefit identified in the AST Noise Reduction Program. Technologies which will be pursued to achieve these technical objectives include: computational aeroacoustics, active noise control, inflow distortion management, smart materials, embedded sensors, morphing/smart structures, multidisciplinary component optimization, micro-blowing, adaptive liners, propulsion airframe integration, airplane system optimization, unsteady flow/turbulence control, real-time minimal noise operations, and accurate single event prediction under realistic weather conditions.

SCHEDULE AND OUTPUTS

Demonstrate technologies to reduce community noise impact Plan: September 2000	Demonstrate separate flow jet noise reduction nozzles in flight Demonstrate advanced flight operations to reduce community noise impact Demonstrate advanced active control for GA interior noise
Discovery and initial assessment of concepts to achieve 3 dB airplane system noise reduction Plan: September 2001	Initial assessment of concepts to reduce airframe system noise 4 dB Initial assessment of concepts to reduce engine system noise 4 dB
Select Concepts to reduce airplane system noise and additional 3 db Plan: September 2002	Complete improved future airframe and engine system noise prediction models Select concepts to reduce airframe and engine system noise an additional 4 dB Identified an integrated airborne/ground system implement advanced low noise operations

ACCOMPLISHMENTS AND PLANS

In FY 1999 a suite of engine system noise prediction tools were completed. These predictive tools include source noise prediction models for engine fan tone and broadband noise, jet noise, and core noise. In addition, codes were developed to propagate the source noise predictions through the engine nacelles, including the effects of absorptive liners. These codes are based on fundamental physics, as much as possible, and not only are they used to discover and optimize new engine noise reduction concepts, these predictive codes form the basis to extend validated noise reduction concepts to applications not even envisioned today. In a flight test of a Beech 1900 a practical structural/ acoustic optimized active noise control concept was demonstrated to reduce propeller tone noise by over 10 dB. A community noise impact model referred to as the AirCraft Noise Impact Model (ACNIM) has been developed which incorporates airport noise prediction, census data, and satellite imagery, into a user friendly Geographical Information System (GIS) computer program. The airport noise prediction is performed using the FAA's Integrated Noise Model, which is the standard airport noise prediction tool used around the world. Incorporation of census data, which includes population data and population characteristics, allows the prediction of community impact. Satellite imagery is used in combination with the census data to determine more accurate land use and population locations. ACNIM also incorporates the capability to determine optimized aircraft ground tracks for minimal community noise impact. Results of studies with the developed models indicate that improved high-lift systems, in combination with advanced operational procedures have potential to reduce community impact by the equivalent of a 2-4 dB source noise reduction.

Plans in FY 2000 include the completion of a series of static engine tests to demonstrate engine system noise reduction including both source noise reduction and advanced nacelle concepts. A flight demonstration of a jet noise reducing advanced engine exhaust nozzle will be conducted. Advanced flight operations to reduce community noise impact will also be demonstrated in a flight test program. An improved airframe noise prediction code will be completed. An innovative high lift concept which promises to have low noise and high aerodynamic performance will be tested at model scale in a pressure wind tunnel. A structural/acoustic optimized passive/active noise control system will be flight tested in a General Aviation airplane. A series of system studies will be conducted to assess component noise reduction concepts required to meet the Enterprise 10-year, 10 dB noise impact reduction goal. In conjunction with the system studies an assessment will be made of the developed noise reduction technologies todate. This assessment will involve projecting model scale results to full-scale applications.

Plans in FY 2001 include the verification of technologies to reduce airframe noise 4 dB on a 26% model of a Being 777. An active noise control system for fan tones will be demonstrated in a static engine test. An initial landing gear airframe noise prediction model will be developed. Jet noise reducing engine exhaust nozzles and modeling of jet noise will be further developed. Results of the detailed system studies performed in FY00 will be used to investigate and initially define identified noise reduction concepts to achieve the 10-year community noise impact reduction goal.

BASIS OF FY 2001 FUNDING REQUIREMENT

2nd Generation RLV

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Systems Engineering & Requirements Definition	---	---	50,000
RLV Competition & Risk Reduction	---	---	95,000
NASA-Unique Systems	---	---	50,000
Alternative Access	---	---	40,000
X-33	277,299	111,600	---
X-34	35,500	40,500	17,900
Future X/Pathfinder	36,000	31,300	37,100
Bantam	16,500	---	---
Total	365,299	183,400	290,000

PROGRAM GOALS

Low-cost space transportation remains the key enabler of a more aggressive civil space program. A central tenant of the National Space Policy is the transition of routine space activities to the private sector to concentrate NASA resources on high-leverage science research, technology development, and exploration activities. By 2005, NASA will conduct a competitive launch services procurement to support the launch requirements of both robotic and human spaceflight operations. The objective will be to dramatically improve safety while significantly reducing the cost of such launch services, thus eliminating the current need for the Government to own and operate a full system.

The 2nd Generation RLV program will substantially reduce the technical, programmatic and business risks associated with developing a safe, reliable and affordable 2nd Generation RLV architecture. The program will invest in the technology development, business planning, design and advanced development efforts to enable at least two competitive options for a new architecture. The program will be implemented to assure that the full-scale development of any new systems can be initiated no later than 2005.

STRATEGY FOR ACHIEVING GOALS

The 2nd Generation RLV FY 2001-2005 program will be divided into four major investments areas: Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction, NASA Unique Systems and Alternative Access.

The Systems Engineering and Requirements Definition effort is critical to establishing the program direction and determining NASA recommendations for appropriate plans and budgets for systems that meet NASA unique requirements on commercial systems. This activity will combine industry and government capabilities to develop detailed technical and programmatic requirements necessary to link technology and other risk reduction efforts to competing architectures. This effort will place a priority on industry and NASA systems engineering activities that seek compatible architectural solutions between commercial industry and NASA requirements. Of paramount importance is achieving significant improvements in safety, reliability and affordability. Improved reliability and affordability can only be achieved through rigorous systems engineering that encourages a distillation of NASA requirements to be compatible with commercial capabilities.

The RLV Competition and Risk Reduction component is designed to allow the U.S. space launch industry to pursue significant technical and economic improvements. These advances must sufficiently reduce the risk in order to enable a competition by 2005 which includes a significant private sector commitment for RLV system development. NASA will pursue risk reduction efforts that will enable at least two competing architectures. The investment in 2nd Generation RLV risk reduction will be driven by the collective efforts of industry and the government and will be based on the direction of competing industry concepts per the precedents set in the X-33, X-34 and X-37 programs. The risk reduction activities will include business development and planning, technology investments, advanced development activities and flight demonstrations or experiments. Planning calls for multiple industry awards with sufficient government insight to assure success. Government partnerships will be established to obviate redundant proprietary development paths and maximize government investment. The selection of industry and NASA investments will be defined consistent with the results of the Systems Engineering and Requirements Definition activities and will be demonstrated (e.g., ground, flight, scale) in the most efficient and cost effective manner.

The third program element is concentrated on developing and demonstrating the designs, technologies and systems level integration issues associated with government unique transportation elements and systems. This will address the additional systems (e.g. crew transport vehicle, cargo carriers, rendezvous and docking systems) necessary to meet unique government mission requirements (e.g. crew transport, cargo return, emergency rescue and return, on-orbit service) using commercial launch vehicles. The content of this program element will be defined through the systems engineering and requirements definition process and will be concurrent with the RLV Competition and Risk Reduction activities. The affordability of an operational architecture to NASA and its compatibility with the commercial launch market will hinge on NASA's final requirements. NASA intends to explore 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. This program element will consist of contracted efforts in combination with government design, development and integration activities. Solicitations for industry involvement will be conducted in parallel with the RLV Competition and Risk Reduction solicitations. Crew Return Vehicle (CRV) Phase II outyear funding has been transferred to this program element, pending future decisions on whether to pursue a CRV separate from other systems to meet NASA-unique mission requirements on commercial launch vehicles.

The fourth program element, Alternative Access, seeks to take advantage of all potential sources of access to space on U.S. launch systems to meet the Agency's requirements. This element supports use of existing and emergent commercial launch vehicles that could launch NASA science payloads and potentially service Space Station requirements. NASA will use the Next Generation Launch Services (NGLS) acquisition as a means to develop contractual relationships with multiple emerging U.S. vendors to meet this objective. These contracts will be for fixed-price services for indefinite delivery indefinite quantity launch contracts.

SCHEDULE AND OUTPUTS

Receive Industry Proposals Plan: October 2000	Receive Industry proposals for evaluation on Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements within the 2nd Generation RLV program
Contract award Plan: January 2001	Award multiple industry contracts for Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements within the 2nd Generation RLV program

ACCOMPLISHMENTS AND PLANS

In FY 2001, the 2nd Generation RLV Program will solicit industry in the three major areas of Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems. Current planning calls for industry to respond to NASA by October 2000 with proposals consistent with the program objectives. Multiple contract awards are planned for January 2001. NASA will pursue risk reduction efforts that will enable at least two competing architectures and considers new design RLVs and Shuttle derived concepts. NASA centers will contribute to the effort according to their areas of expertise and in accordance with an overall integrated industry/NASA approach. The competing concepts must address NASA requirements while optimizing the convergence with commercial opportunities. Industry and government partnerships will be established to assure that the ownership and availability of technological advances will be with the implementing contractors.

Acquisition strategy for NGLS is currently underway. Marshall Space Flight Center has been assigned responsibility for this acquisition targeted to take advantage of commercially developed launch systems that to date have little to no demonstrated flight experience. Contracts are targeted for award later in 2000, with first launches feasible within 12-18 months of contract award, dependent on readiness of commercial launch services. These funds will enable the Agency to take advantage of commercially developed alternative access to space for select science and space station mission requirements. Funds will also be used to accommodate definition of mission unique requirements for candidate science and space station missions, in advance of launch service commitments. As the NGLS acquisition develops, NASA envisions the funding for this effort to transition from the Aero-space technology appropriation to the Human Space Flight (HSF) appropriation, which is the lead organization for the NGLS acquisition and where the International Space Station program resides.

BASIS OF FY 2001 FUNDING REQUIREMENT

X-33

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
X-33	277,299	111,600	---

PROGRAM GOALS

The X-33 objective is to demonstrate technologies and operations concepts with the goal of reducing space transportation costs to one tenth of their current level.

STRATEGY FOR ACHIEVING GOALS

NASA is utilizing an innovative management strategy for the X-33 program, based on industry-led cooperative agreements. As a result of industry's leadership of the program, the participants are not playing traditional roles, with government overseeing and directing the work of the industry contractors. Instead, government participants are acting as partners and subcontractors, performing tasks for industry because industry believes that these government team members offer the most effective means to accomplish the program objectives. The government participants report costs and manpower to the industry team leader, as would any other subcontractor. The industry-led cooperative arrangement allows a much leaner management structure, lower program overhead costs, and increased management efficiency.

The X-33 program Phase II selection was made in July 1996 based on specific programmatic, business planning, and technical criteria. NASA selected the Lockheed Martin Skunk Works to lead an industry team to develop and flight test the X-33.

The X-33 is an integrated technology effort to flight-demonstrate key Single Stage To Orbit (SSTO) technologies, and deliver advancements in: 1) ground and flight operations techniques that will substantially reduce operations costs for an RLV; 2) lighter, reusable cryogenic tanks; 3) lightweight, low-cost composite structures; 4) advanced Thermal Protection Systems to reduce maintenance; 5) propulsion and vehicle integration; and, 6) application of New Millennium microelectronics for vastly improved reliability and vehicle health management. X-33 will combine its results with the successes of the DC-XA, X-34 and complementary ground technology advances to reduce the technical risk of full-scale development of an operational RLV. The X-33 test vehicle will fly 13-15 times the speed of sound and will test the boundaries of current technology. Together, the DC-XA, X-34, and X-33 will provide a number of flight tests of key technology demonstrations prior to the decision to privately finance the development and operations of the next generation RLV system.

It is envisioned that private industry will have a primary role in the funding, development, and operation of a next-generation launch system. Therefore, business venture plans are as critical to the RLV program as any technical advancements made on the experimental vehicles. Programmatic and business plans for an operational commercial RLV, expressed in innovative industry-developed and /led business plans, will receive equal consideration with technology demonstrations in future decisions on developing an operational launch vehicle. These plans will address policy and legislative issues as well as private financing options, and will inform the Second Generation RLV decision.

SCHEDULE AND OUTPUTS

X-33 LH_2 Tank Delivery Plan: March 1999 Actual: April 1999	Completes design, manufacture, test and delivery to MSFC. Delayed because of tank redesign activities and issues with main joint fabrication/testing.
X-33 Thermal Protection System (TPS) Delivery Plan: December 1999 Revised: May 2000	Delivery of complete Thermal Protection System for X-33 flight demonstrator. Manufacturing process revised to improve producibility.
X-33 Vehicle to Roll out Plan: January 2000 Revised: Under Review	X-33 flight demonstrator vehicle rollout enabling final checkout. Delayed due to LH_2 tank failure. Failure investigation underway. Schedule impact will be determined after completion of investigation.
X-33 First Flight Plan: July 2000 Revised: Under review	The flight test program, based at Edwards Air Force Base, will fly at speeds greater than Mach 13. Delayed due to LH_2 tank failure. Failure investigation underway. Schedule impact will be determined after completion of investigation.

ACCOMPLISHMENTS AND PLANS

In FY 1999, the X-33 launch complex was completed and site activation begun. In addition, the structural testing of the liquid oxygen tank was successfully completed; the flight software was delivered and verification with validation continuing; the linear aerospike engine was delivered to Stennis and testing begun; the metallic TPS was flight qualified; and the liquid hydrogen composite tank was delivered to MSFC for testing. Three cryogenic and structural load tests of the hydrogen tank, based upon 105 % of maximum flight conditions, were completed. However, after the completion of the third test, a partial failure of the outer skin on one of the four lobes was observed. A failure investigation of the hydrogen tank, by a team of government and industry personnel, was initiated. Both NASA and the contractors remain fully committed to the X-33 program. The failure investigation team will make a report on the root cause of the failure in FY 2000. After reviewing the team's findings, NASA and the contractor will jointly agree on the approach necessary to recover from the hydrogen tank failure and then proceed with the development and execution of a recovery plan and schedule.

BASIS OF FY 2001 FUNDING REQUIREMENT

X-34 and Future X - Pathfinder

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Future X/Pathfinder	71,500	71,800	55,000

PROGRAM GOALS

The objective of the Future-X Pathfinder Program is to flight demonstrate advanced space transportation technologies through the use of flight experiments and experimental vehicles. The Program supports the 1996 National Space Transportation Policy's goal of dramatically reducing the cost of access to space through the development and flight demonstration of advanced space transportation technology. The Program leverages NASA's Space Transfer and Launch Technology (STLT) base research program which develops and ground demonstrates emerging core and focused space transportation technologies. The Program seeks to substantially reduce the cost of space access and to support commercial requirements, NASA mission NASA –unique 2nd Generation RLV requirements, unique, and Department of Defense space transportation requirements.

The Future-X Pathfinder Program is aligned within NASA's Office of Aero-Space Technology (OAT) Enterprise, and supports the strategic goals of OAT's third pillar, Access to Space. Specific Access to Space Pillar goals are to achieve a ten-fold reduction in the cost of placing payloads in low-Earth orbit in the next decade and an additional ten-fold cost reduction in the decade beyond. Future-X Pathfinder will also support a wide range of technology requirements for Earth-to-orbit and in-space transportation systems. Future-X Pathfinder will provide flight-tested technologies needed for lower cost, more reliable, simpler, and more operable space transportation systems.

The program utilizes innovative, streamlined and efficient management practices to accomplish frequent, high-quality demonstrations of precompetitive technologies with high payoff potential. The demonstrations and experiments will be conducted in a fashion that will promote the technology objectives to the fullest extent possible while maintaining sound engineering judgment.

STRATEGY FOR ACHIEVING GOALS

As part of NASA's core mission to advance the state-of-the-art in aeronautics and space transportation, the Agency will continue to develop and demonstrate advanced technologies through the use of experimental flight vehicles. The primary objective of this "Future X" program is to flight demonstrate technologies that can dramatically reduce the cost and increase the reliability of reusable space launch and orbital transportation systems. Future-X Pathfinder demonstrations build on STLT technologies by carrying out small-scale flight demonstrations every 12-24 months. Pathfinder projects demonstrate cutting-edge technologies with high payoff potential and are typically funded at between $1M and $150M.

The strategy behind flight demonstrators is driven by the need to force technologies and vehicle/system configurations from the laboratory or the computer screen into "real world" operating environments and demonstrate technologies, streamlined management, and operational procedures which can dramatically reduce space transportation system costs. Ground tests can simulate technology in a near-real-world environment but the "reality of flight" compels the program team to understand how each component technology functions as an integral part of the overall flight system. This approach drives a maturity level in, and provides a validation of, the technology and configuration development that cannot be achieved in any other test environment. Future-X Pathfinder demonstrations will be used to validate those technologies and vehicle/system configurations which must be flown to allow their application to existing and future space transportation systems.

The program currently includes the development and operation of the Pathfinder class X-vehicles (X-34 and X37) and a number of flight experiments. The program includes the development and flight demonstrations of a modular orbital flight testbed called the X-37 which will be the first experimental vehicle to be flown in both orbital and reentry environments.

The X-34 project will demonstrate technologies necessary for a reusable vehicle, but will not be a commercially viable vehicle itself. It will be a rocket-powered, Mach-8-capable flight demonstrator test bed to close the performance gap between the subsonic DC-XA and the Mach 13+ X-33. The X-34's objective is to enhance U.S. commercial space launch competitiveness through the development and demonstration of key technologies applicable to future, low-cost reusable launch vehicles. The X-34, now planned to fly for the first time in early 2000, will demonstrate flexible integration capability, high flight rate (25 flights per year), autonomous flight operations, safe abort capability, and a recurring flight cost of $500,000 or less. The X-34 program is procuring two flight vehicles, in keeping with the usual practice in X-vehicle programs, to ensure that the program meets its objectives without constraining the aggressiveness of the demonstration effort. Additionally, a third vehicle is being upgraded from structural test article to unpowered flight vehicle.

The fixed-price X-34 contract is being conducted by Orbital Sciences Corp. of Dulles, Virginia. NASA's Ames, Langley, Dryden, Marshall, Kennedy and White Sands complexes and Holloman Air Force Base all contribute to in the program. The government's work responsibilities include primary propulsion development, thermal protection system integration, wind tunnel support, and testing and flight operations.

The X-34 program has exercised an option for an additional 25 flights (total of 27 flights). The flight test plan includes flying unpowered flights in New Mexico, envelope expansion flights at Dryden Flight Research Center, and an operational flight series at Kennedy Space Center. These flights will demonstrate key embedded technologies and systems operations, as well as additional technology experiments and test articles. X-34 modifications and experiments will benefit from being comparatively small, thereby lowering the expense and risk of demonstrating the technologies, and making their integration into the vehicle less costly. The low-cost X-34 demonstrator will increase the scope and aggressiveness of flight demonstrations, thus increasing the return to the RLV program.

In addition to the ongoing X-34 project, NASA selected proposals and began funding new Pathfinder-class demonstrations in FY 1999. One new Pathfinder demonstrator and seven flight experiments were selected for initiation in FY 1999. Several of the selected experiments are still being negotiated, and details will be provided at a later time. These selections and future ones will enable NASA to continue pushing the state of the art in launch vehicles by demonstrating technologies that lead to increased safety and reliability while reducing cost. The selected Pathfinders include:

– the X-37 Space Plane technology testbed. This demonstrator vehicle is a modular orbital flight testbed which will be flown in both orbital and reentry environments;

– a Hall-effect Solar Electric Thruster system flight demonstration of new onboard in-space propulsion technologies;

– an experiment to demonstrate an onboard intelligent planning system for autonomous abort;

– an experiment to demonstrate technologies that will significantly reduce the access-to-space costs of small payloads;

– an experiment to demonstrate advanced technologies for an integrated vehicle health management system;

– an experiment to demonstrate ultra-high temperature ceramics for reusable, sharp hypersonic leading edges;

– an experiment to demonstrate propulsion technologies that will reduce the weight and size of advanced cryogenic upper stages;

– an experiment to demonstrate advanced in-space propulsion technologies using an electrodynamic tether.

SCHEDULE AND OUTPUTS

Conduct CDR on ProSEDS Plan: August1999 Actual: August 1999	Propulsive Small Expendable Deployer System (ProSEDS) tether flight experiment successfully passed Critical Design Review.
X-34 First Unpowered Flight Plan: September 1999 Revised: April 2000	The flight test program will expand in increments to assure success. Delayed due to longer than expected in vehicle fabrication, specifically the composite tank and flight wing.
X-34 First Powered Flight Plan: December 1999 Revised: August 2000	The flight program will expand the flight profile with initial, unpowered flights to be followed by powered flights that will reach Mach 8. Delayed due to delays in vehicle fabrication, specifically the composite tank and flight wing.
X-37 Roll out Plan: September 2001	X-37 Roll out
X-37 Atmospheric Drop test (unpowered) Plan: January 2002	

X-37 First Orbital Flight Plan: September 2002	
SHARP B2 final design Plan: February 2000	Successfully completes Final Design Review
SHARP B2 Launch Plan: June 2000	Sharp B2 launched on Minuteman III launch vehicle and recovered. Validates sharp, passive, Ultra High Temperature Ceramic (UHTC) leading edge in relevant entry environments
ProSEDS Complete Plan: December 2000	Device will deploy a 5-kilometer (km) bare wire tether coupled to a 10-km nonconducting tether. Earth's magnetic field will accelerate the wire and raise / lower orbit of a Delta II second stage. To be flown as a secondary payload on Delta II upper stage in August 2000
Delivery of IVHM experiment Plan: June 2001	The Integrated Vehicle Health Monitoring (IVHM) experiment is delivered for installation on X-34 vehicle A-3

ACCOMPLISHMENTS AND PLANS

X-34: The **X-34** project completed several critical milestones in FY 1999, including:

- completed independent NASA Safety and Mission Assurance review;
- delivered X-34 vehicle (A-1);
- X-34 roll out;
- completed X-34 System Verification Review;
- completed first X-34 Captive Carry Test.

In FY 2000, modifications to the A-1 vehicle will be completed. This upgraded vehicle, designated A-1A, will then undergo tow testing at Dryden/Edwards AFB. Following tow testing, the A-1A will undergo unpowered flight testing at White Sands Space Harbor. The A-2 vehicle will be delivered to White Sands, New Mexico to support vehicle static hot-fire testing with the Fastrac engine followed by initial powered flight testing in late summer.

In FY 2001, assembly and testing of the third X-34 vehicle will be completed and delivery to DFRC will take place. Envelope expansion flights will begin (8-9 flights) at Dryden/Edwards AFB with the A-2 vehicle. Also, the building and refurbishment of Fastrac engines to support powered flights will continue.

X-37: In FY 1999, the next generation of technology flight demonstration was initiated through the selection, announced in December 1998, of a new Advanced Technology Vehicle (ATV), now known as X-37, and seven experiments. Final agreement on the

X-37 and on several of the experiments was completed in FY 1999. Agreements on a number of the others are in work and will be completed in FY 2000. The Future X Pathfinder Program completed several critical milestones in FY 1999, including:

- awarded a cooperative agreement for the development of the X-37;
- completed the X-37 Kickoff Meeting;
- conducted Critical Design Review for the Propulsive Small Expendable Deployer System (ProSEDS) tether flight experiment;
- completed the X-37 System Requirements Review;
- completed the Preliminary Design Review for the SHARP-B2 ceramic thermal protection system experiment.

In FY 2000, final agreements for the remaining experiments will be negotiated and work initiated on these projects. The PDR for the Cryogenic Propellant Gauge experiment will be completed and launch of the ProSEDS experiment will occur. The Final Design Review for the SHARP-B2 experiment will be completed and the experiment will be launched on a Minuteman III launch vehicle. The contract for the Small Payload Experiment will be awarded. Modifications to the X-40A vehicle will be completed and drop tests (approach and landing tests) will begin at Edwards AFB as a precursor to the X-37 unpowered drop tests. Design and fabrication of the X-37 vehicle will continue and the Final Design Review will be completed. Additionally, X-37 Shuttle integration analyses will continue.

In FY 2001, the X-40A ALT flights will be completed and X-37-Shuttle integration analyses will continue. X-37 vehicle assembly, integration and testing will be completed, the X-37 vehicle will be rolled out, and pre-flight ground tests will begin. The ProSEDS experiment will be completed and delivery of the IVHM flight hardware for the X-34 (vehicle A-3) will occur.

	FY 1999	FY 2000	FY 2001
Integrated Space Transportation Program	**524,599**	**582,700**	**730,000**
2nd Generation RLV Program	365,299	183,400	290,000
Systems Engineering & Requirements Definition			50,000
RLV Competition & Risk Reduction			95,000
NASA-Unique Systems			50,000
Alternative Access			40,000
X-33	277,299	111,600	
On-Going Pathfinders (ends in FY 02)	71,500	71,800	55,000
X-34	*35,500*	*40,500*	*17,900*
X-37	*24,400*	*20,400*	*33,100*
Other Pathfinder Projects	*11,600*	*10,900*	*4,000*
Bantam	16,500		
Technology Base Program*	34,300	107,500	193,600
Future Space Launch Studies	30,000	30,000	
Shuttle Upgrades (HSF)	95,000	186,800	156,400
CRV Phase 1 (HSF)		75,000	90,000

* Technology Base Program as defined in this table includes all activities that directly or synergistically contribute to meeting space transportation technology goals.

BASIS OF FY 2001 FUNDING REQUIREMENT

AERO-SPACE TECHNOLOGY INVESTMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Education Program..	---	---	2,000
Minority University Research and Education Program	(7,000)	(7,200)	9,200
Total..	---	---	11,200

The Aero-Space Technology Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Aero-Space Technology Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Aero-Space Technology Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.