SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2002 ESTIMATES

BUDGET SUMMARY

OFFICE OF AEROSPACE TECHNOLOGY | **AEROSPACE RESEARCH & TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 2000 OPLAN REVISED	FY 2001 OPLAN REVISED	FY 2002 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Research and Technology Base program	563,866	564,726	637,000	SAT 4.1-2
Aerospace Investments	-----	11,200	-----	SAT 4.1-37
Fundamental Space Base program	-----	98,184	-----	SAT 4.1-38
Aerospace Base NASA Research Announcements (NRA) program	-----	39,912	-----	SAT 4.1-39
Focused programs	421,529	527,636	720,600	SAT 4.1-40
Aerospace Institutional Support	[708,953]*	[810,359]*	871,239*	SAT 4.1-89
Total	985,395	1,241,658	2,228,839*	
	[1,694,348]*	[2,052,017]*		

Distribution of Program Amount by Installation	FY 2000	FY 2001	FY 2002
Johnson Space Center	2,698	7,838	9,968
Kennedy Space Center	6,716	7,894	31,910
Marshall Space Flight Center	202,934	231,221	444,926
Stennis Space Center	36,738	27,563	36,074
Ames Research Center	203,249	272,572	448,454
Dryden Flight Research Center	100,618	99,857	141,983
Langley Research Center	193,131	246,687	482,026
Glenn Research Center	186,105	238,361	391,287
Goddard Space Flight Center	6,194	27,581	43,440
Jet Propulsion Laboratory	6,284	28,745	36,175
Headquarters	40,728	53,339	162,596
Total	985,395	1,241,658	2,228,839*

* Funding includes direct-program Institutional Support to Aerospace Technology Enterprise (from FY 2001 President's Budget, Mission Support section)

BASIS OF FY 2002 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY BASE

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Information Technology ......*(realigns to CICT in FY 2002)*................	74,346	118,410	-----
Construction of Facilities (Included above)	-----	*[6,000]*	-----
Computing, Information, & Communications Technology (CICT)	-----	-----	195,283
Construction of Facilities (Included above)	-----	-----	*[6,000]*
Vehicle System Technology...	148,819	151,641	157,457
Propulsion & Power..	78,495	85,768	94,840
Flight Research..	71,203	83,266	82,384
Aviation Operations Systems **	17,000	17,437	-----
Rotorcraft	26,900	31,584	-----
Space Transfer & Launch Technology	95,203	76,644	67,036
Construction of Facilities (Included above)	-----	*[10,000]*	*[11,974]*
Minority University Research and Education Program ***	7,200	[11,200]	-----
Construction of Facilities	14,700	-----	-----
Future Space Launch Studies	30,000	-----	-----
Fundamental Space Base	[101,275]*	[98,184]*	-----
Aerospace Base NRA's	[40,000]*	[39,912]*	40,000
Total...	563,866	564,726	637,000
	[705,141]*	[714,022]*	

* The total including Space Base Program as proposed in a transfer, beginning in FY 2001. This total is an accurate reflection of the Space Base – Aerospace Base merger, $705,141K in FY 2000 and $714,141K in FY 2002.
** Realignment in FY 2002 splits program to CICT and Propulsion & Power Programs.
*** Minority University Research and Education Program funding realigns to their respective base program's budget

PROGRAM GOALS

The goal of the Aerospace Research and Technology (R&T) Base is to develop the high payoff revolutionary technologies that will be required to support 21st Century Aerospace Vehicles and National Aerospace System. Also to provide 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 will pioneer the development of new breakthrough technologies such as nanotechnology and to consistently push the boundaries of our knowledge to explore the technologies that will lead to the next paradigm shift for aerospace systems. The R&T Base is also charged with ensuring the core competencies within and outside NASA's research centers that are necessary for NASA to accomplish its mission now and into the next millennium.

The Aerospace R&T Base operates and maintains research facilities operations and provides expert consultation for NASA Enterprises, industry and other agencies during their product development design and build processes. 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.

In addition, the Aerospace R&T Base supports crosscutting technology requirements for all NASA Enterprises. The technologies are generally broadly applicable to many potential missions and systems and focus on the early stages of the technology life cycle. Technologies developed under the program provide the foundation for most new vehicle, spacecraft, sensing, robotics, and information technologies eventually flown on NASA missions, and also provide the primary source of advanced concepts and technologies to enable breakthroughs in aerospace transportation. Potential customers throughout NASA's Enterprises are involved as advisors in the planning of research activities. Evaluation and insertion of emerging technologies and concepts for application to higher level mission system concepts and prototypes, and eventually to mission use closely coordinated with potential Enterprise users.

The five fundamental research programs provide the foundation of aerospace research for NASA. They cover all flight regimes from general aviation and commercial transports to high performance aircraft, reusable launch vehicles, and other space transportation vehicles. They address fundamental knowledge and long-term opportunities and have long-term horizon set on the 25-year goals. The broad mix of long-term, high-risk, high-payoff technologies provides many potential options for achieving the goals. While the fundamental research programs provide the basis for the applied research programs of the future, in some cases the technology transitions directly to the customer. The fundamental research programs serve as the vital foundation for the Enterprise's National resource of expertise.

STRATEGY FOR ACHIEVING GOALS

A major restructuring and replanning of the Aerospace Enterprise's Base R&T Base was accomplished during 1999 to begin the integration of the Enterprise's existing space transportation and aeronautics Base R&T development programs into a single entity. This restructuring effort has continued, and in the latest proposed change, the Aerospace & Space Fundamental Base (formally

Cross-Enterprise Technology) programs are being integrated and similar Aerospace Base R&T efforts consolidated. This restructuring better aligns the required technology development efforts with core competencies, reduces management overhead, and brings the expertise, resident in the aeronautics research centers, to bear on the technological challenges associated with space transportation and spacecraft systems. Secondly the integration of the space and aeronautics development needs results in a synergistic technology development plan that better utilizes our resources, eliminates duplication of effort, and allows multiple users, including the space transportation, aeronautics, and the other NASA Enterprises, to be included as part of the planning process. And finally, the character of the resultant program will become more innovative and revolutionary through the changes in the content and focus of individual activities.

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 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, the 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 aerospace 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 Aerospace Technology Enterprise's peer-reviewed fundamental research with academia and industry. The program also provides the capability for the Enterprise to respond quickly and effectively to critical problems identified by other NASA Enterprises, agencies, industry or the public. Examples of these challenges are found in: investigating accidents; determining lightning and radiation effects on avionics; improving flight safety and security; analyzing wind shear; studying crew fatigue; reducing environmental impacts of aeronautical systems; analyzing the causes and effects of structural fatigue; resolving spacecraft/launch system anomalies; and researching the causes of aircraft stall/spin.

The goals, objectives, and progress of the Aerospace R&T Base are evaluated on a yearly basis by an external, independent panel of nationally recognized experts. These external reviewers ensure that program content is consistent with the Enterprise's Strategic Plan, and that the program is yielding the maximum possible return on the taxpayers' investment. An additional annual review is conducted by an independent Inter-Center Systems Analysis Team that provides an assessment of each R&T activity's contribution to the accomplishment of the Enterprise's Goals.

– One of the key factors in aerospace research is an extensive use of facilities and R&D expertise that is located at the four research centers—Ames Research Center, Dryden Flight Research Center, Langley Research Center, and Glenn Research Center—and at other NASA Centers including the Marshall Space Flight Center (MSFC), Jet Propulsion Laboratory (JPL), Goddard Space Flight Center (GSFC) and Johnson Space Center (JSC). Many facilities and R&D capabilities at these centers are unique in the United States and even the world.

The Aerospace Technology R&T Base is a framework of five systems oriented, customer driven programs, that serve the needs of the full range of aerospace vehicle classes. The five R&T Base programs are:

- Computing, Information & Communications Technologies (CICT) Program will provide essential new enabling capabilities and specific deliverables to fulfill high-priority multi-Enterprise needs for future missions. CICT will provide tangible benefits to NASA missions of the future. These benefits include more rapid, safe and cost-effective mission planning and scheduling; more capable and resilient aerospace platforms; increased mission assurance through the delivery of more dependable avionics software; reduced need and support costs for “standing armies” of mission controllers currently required on a 24-hour by 7-day basis for international space station and selected deep space missions; and faster and cheaper high-performance computing and networking for the development, analysis and understanding of very large and complex NASA data sets. Example data sets would include aerospace, astrophysics, Earth science and astrobiology.

  The CICT program encompasses the following programs.

  - Information Technology Base
  - Aerospace Autonomous Operations
  - Bio-Nano Computing technology
  - Design for Safety
  - Aerospace Operations Research
  - Intelligent Systems

  The CICT includes a spectrum of investments that are needed for the Agency's missions. To ensure the high quality research, the program will be subject to external independent reviews and a significant potion of the research will be externally competed. To ensure strong ties to technology customers, a team of potential internal and external users will assess the relevance of the research to future NASA and commercial/government applications and provide recommendations for ongoing and future activities. The maturation of technologies to higher technology readiness levels will be guided by technology development agreements signed by the potential users of the technology and the program.

- Vehicle Systems Technology (VST): The VST program will pioneer the identification, development, verification, transfer, and application of high payoff aeronautical, space transportation, spacecraft, and science sensing systems technologies. Emphasis is on areas such as conceptual design; aerodynamic and structural design and development; smart materials and structures; flight crew station design; systems design and testing, and third-generation space transportation. Nano-structured materials technology is being investigated to enable tailoring, at the molecular level, breakthrough materials that will provide vast improvements in resiliency, life, and physical properties. Methods are sought to enable highly distributed, interactive, in-space and ground-based (Earth and planetary) sensing and observation networks that provide broad, continuous, and selectable coverage and maximum economies of launch and ground resources via advanced micro-systems, ultra-sensitive sensors, and shared duties. Advanced concepts for new future missions are both developed in-house and are solicited via an openly competed award process operated by an independent university-led center.

- Aerospace Propulsion and Power Technology: the purpose of this program is to conduct research in order to design and develop propulsion and power systems for a wide variety of applications. The technology areas include engines which will enable and ensure environmental compatibility and improve the safety and efficiency of the global air transportation system, systems for access to space, and systems for operating in space and on planetary surfaces. The program addresses critical air breathing, chemical and electric propulsion technology needs across a broad range of aerospace vehicle classes. For in-space operation it explores advanced methods for conversion of energy from solar and non-solar sources to on-board power and for the efficient storage and management of onboard power for space vehicles. This program also includes NASA's aircraft icing research activities.

- Flight Research: The objective of this program is to safely enable, conduct, and improve NASA's atmospheric flight research. The program promotes technology innovation, discovery of new phenomena, and the accelerated development of new aerospace concepts. Experimental aircraft and tools for aerospace innovation provide a mechanism to validate design tools and new technology. The early development and validation of new concepts are undertaken in a realistic environment, allowing lower cost development and more rapid transfer/ infusion of technology. Elements within the Flight Research Base R&T Program include:

  - The Environmental Research Aircraft and Sensor Technology (ERAST) project, which develops very-high-altitude/long-endurance, remotely piloted aircraft technology.
  - Revolutionary Concepts (RevCon), which will conduct flight research into advanced vehicle concepts.
  - Specific flight research activities, which are carried out on dedicated experimental aircraft such Active Aeroelastic Wing (AAW) and testbed aircraft such as the F-15B, and F/A-18.

Space Transfer & Launch Technology (STLT): The STLT program is the technology-base 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 for future launch systems. Advanced technologies will be developed and ground-tested to bring them to readiness levels where they can either be adopted by NASA missions and industry, or if necessary, flight-proven. Elements within the STLT program include:

- 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 Aerospace Technology

Enterprise's Goal 9 technology objectives. Technology priorities are derived from the contribution to overall transportation system goals. .

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

Prior to FY 2002, the Rotorcraft Program was included in the Aerospace R&T Base. This program sought to enable new vehicle concepts for vertical flight that alleviate airport congestion & delays and provide true door-to-door mobility for the traveling public. - After consideration of research priorities to relieve air system congestion within Aerospace Technology budget constraints, this program will be terminated at the end of FY 2001.

Also prior to FY 2002 the Intelligent Synthesis Environment (ISE) was included in Information Technology. ISE sought to radically change the manner in which NASA designs, develops and operates its flight systems and was focused on providing the research, development, acquisition, validation, demonstration and implementation of the revolutionary engineering and science tools and processes needed to fulfill the NASA Administrator's vision for revolutionizing next generation science and engineering capabilities. Due to rapid advances in commercial technology and budget constraints, this program will be terminated at the end of FY 2001, though key elements of the program will be folded into other related activities.

SCHEDULE AND OUTPUTS

COMPUTING, INFORMATION & COMMUNICATIONS TECHNOLOGIES (CICT)

INFORMATION TECHNOLOGY BASE

Real-time Data link for Airspace System Plan: June 2000 Actual: June 2000	Demonstrated multi-protocol technology for real-time data link between aircraft, satellite and ground. This eliminates the need for many separate data streams, and sets the stage for a shared bandwidth where safety and flight-critical data are guaranteed a high-priority distribution among the various types of data being transmitted
Demonstrate heterogeneous distributed computing environment Plan: September 2000 Actual: September 2000	Demonstrate tools and software to link distributed computing test-beds at multiple NASA Centers into a single "virtual" supercomputing environment. Demonstrated prototype heterogeneous distributed computing environment. Developed the underlying computing and data management fabric that will enable the aerospace environments of the future. Takes advantage of the large distributed computing/data developments that NASA has implemented for all Enterprises
Next Generation Intelligent Flight Control System Plan: June 2002	Develop and demonstrate in flight next-generation neural flight control technologies for aircraft and reusable launch vehicles. This will lower development costs, allow for rapid integration of improvements, and allow aircraft to recover from damage in flight.

Virtual Flight: Rapid Integration and Test Environment Plan: December 2000 Actual: December 2000	Demonstrated an environment for aerospace hardware designs that included remote connectivity and access to flight simulation data, computational simulation data and archival databases. This process established an environment where a vehicle design is accomplished rapidly through an integrated vehicle design process, to incorporate pilot-in-the-loop considerations early into the design process and to rapidly incorporate design modifications
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 up to and including propulsion only flight. This activity adds an assisting intelligence to the cockpit, beyond the presence of human pilots, enabling the human crew to operate a severely crippled aircraft safely under conditions, which would normally result in loss of the vehicle.
Remote Access to High Data-rate Instruments Plan: September 2001	Demonstrate remote connectivity to high data-rate instruments and distributed real-time access to instrument data. Integrates the acquisition of aerospace data resources with their management and knowledge extraction on the distributed compute fabric of the future.
Demonstrate prototype data communications scheme for NAS Plan: September 2001	Demonstrate a prototype data communications scheme for the National Airspace System.
Improvements in Aerospace Applications Plan: September 2002	Demonstrate improvement in time-to-solution for aerospace applications through high-end computing and end-to-end networking capabilities, enabling the rapid creation, sharing, and distributed analysis of experimental and high-fidelity computational databases in the design of aerospace vehicles and systems
Exploratory Computing Environments for Aerospace Applications Plan: September 2002	Develop prototype environments that are distributed across heterogeneous platforms, are dynamically extensible, and which support collaborative visualization, analysis, and computational steering for distributed aerospace systems with potential applications to other NASA missions. Integrated computing environments will have a large monetary impact on the speed, quality and cost of NASA mission.
Virtual Flight Synthesis Plan: September 2002	Develop capability to redesign aerospace vehicles during flight simulations exploiting high-end computing and advanced information management technologies. This activity combines rapid redesign with single flight test entry, to enable a new model of how flight simulations can be used as a design tool, by dramatically reducing time required for flight simulation during design, and improving fidelity of design with flight simulation data

Space Communication Link Plan: September 2002	Demonstration of Space Communication Link Technology Operating at 622 Mega-bit per second for Direct Space Data Distribution to Users

INTELLEGIENT SYSTEMS

Initial IS Program Assessment Plan: September 2001	Successfully complete reviews of the Intelligent Systems Program by External Technical Review Council and Mission Needs Council
Mars Mission Software Verification Study Plan: June 2002	Complete a case study demonstrating software verification and validation techniques that are applicable to Mars mission software, and benchmark current state-of-the-art. Emphasize automated techniques that improve software reliability. Automated techniques will enable an order of magnitude improvement in speed and cost of verification.
Human-Centered Computing Mars Exploration Rover Plan: August 2002	Participate as part of the MER 2003 flight team applying human-centered computing analysis and modeling techniques to evaluate and improve the man-machine system performance for operations and science. Opening the human-operator bottleneck will allow for increased science return during the brief 90-day lifetime of these rovers.

AEROSPACE AUTONOMOUS OPERATIONS

Assessment of Remote Agent software Plan: March 2000 Actual: March 2000	The Remote Agent software program demonstrated successful autonomous control of the Deep-Space One spacecraft, achieving 100% of objectives. In FY2000 we analyzed the results of the 1999 experiment, improved Remote Agent, and investigated several targets for deployment of the program in future missions. Remote Agent allowed goal-directed commanding and improved reactivity to environmental uncertainty and component failures, thus increasing the overall robustness of the vehicle.
Rover Field Test Plan: May 2000 Actual: May 2000	Performed joint ARC-JPL two-rover field test at Lunar Crater Volcanic Field demonstrating use of 3D science visualization tool to support science planning operations and enabling increased science productivity by providing a virtual Mars environment in which the scientist can access the data and identify targets of opportunity

Next Generation Intelligent Flight Control System Plan: June 2002	Develop and demonstrate in flight next-generation neural flight control technologies for aircraft and reusable launch vehicles. This will lower development costs, allow for rapid integration of improvements, and allow aircraft to recover from damage in flight.

DESIGN FOR SAFETY

X-37 IVHM Flight Experiment. Plan: March 2002	Captive carry flight of vehicle using a model-based health management system to perform real-time faults detection, isolation and recovery while operating on the vehicle's flight computer. This technology will increase vehicle robustness while radically reducing operational ground support.
Aerospace System Reliability and Cost Database Plan: September 2002	Demonstrate a prototype of a reliability and cost database of space transportation and exploration system mission failures. Include the definition of the appropriate taxonomy. Allowing prioritization of program technical activities and continuous analysis for significant or emerging safety trends.

AEROSPACE OPERATIONS RESEARCH BASE

Define effects of in-flight activity breaks on alertness Plan: June 2000 Actual: June 2000	Conducted a full-mission simulation experiment that utilizes in-flight activity breaks as the controlled variable, produced a report documenting their efficacy.
Predicting Error-Vulnerability Plan: June 2000 Actual: June 2000	Documented a formal methodology for analyzing human-automation systems in aerospace and other domains, including the demonstration of its application to a real human-automation problem in civil aviation. This methodology will increase safety by reducing or eliminating design errors which lead to mode confusion and error in the operation of aerospace human-automation systems
Identify and evaluate existing crew strategies for reducing errors in the management of concurrent tasks. Plan: May 2001	Characterize the demands of concurrent task management and patterns of error, and evaluate strategies for reducing and trapping errors. The benefits include developing training methods to better manage concurrent task demands and developing operating procedures to reduce excessive crew demands.

Cognitive/Physiological Tools for Evaluating Human Performance Plan: June 2001	Develop and document new tools and the supporting validation research within the context of concurrent task execution and hazardous states of awareness. The new tools will be used to improve the design, test and validation processes for efficient task management and crew procedures.
Model for Planning Flight Crew Scheduling Plan: June 2002	Develop initial bio-mathematical model enabling prediction of flight crew behavioral performance capability based on sleep and circadian variables to reduce the potential for human error in aerospace operations.

BIO / NANO COMPUTING TECHNOLOGY

Design Nanotechnology components Plan: September 2000 Actual: September 2000	Completed conceptual design of carbon nanotube "transistors" demonstrating 10,000 times size reduction over silicon-based technology, enabling reductions in mass and power requirements for future NASA missions
Controlled growth of vertically aligned carbon nanotubes Plan: September 2001	Develop a combinatorial chemistry approach to define optimum catalyst composition for carbon nanotube growth coupled with an electrical field enhanced nanotube alignment approach. This controlled growth of nanotubes is a necessary step for the development of nanosensors and electronic components.
Nanotechnology Simulations, Manufacturing and Components Plan: September 2002	Demonstrate feasibility of nanotechnology-based chemical and biosensors and of manufacturing approaches for low-power nanoelectronic components

INTELLIGENT SYNTHESIS ENVIRONMENT (ISE)

Baseline design capabilities and verify requirements Plan: September 2000 Actual: October 2000	Defined formats for reporting state-of-the-art and technology gap analysis; baseline NASA state-of-the-art capabilities for each prototype test application; established critical program element needs for each prototype test application (1R08)
ISE Capability Build 1: Proof-of-concept system Plan: July 2001	Near-term, state-of-the-art environment, user interface and infrastructure, validation on three prototype test applications, prototype measurement and assessment techniques

AEROSPACE VEHICLE SYSTEM TECHNOLOGY

Physics-based prediction of airframe noise components Plan: March 2000 Actual: March 2000	Develop physics-based computation of airframe noise components including flap-side edge, slat, and landing gear. Physics of noise generation was identified. Noise reduction concepts were optimized by computation and verified by experiment. Major benefit demonstrated by the use of a advanced low noise slat design with no aeronautic performance degradation
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 Revised : December 2001	Envelope expansion of Airframe Integrated, Dual-Mode Scramjet powered vehicle in flight at Mach 7. The revision of the planned flight is the result of slips in the precursor flight due to late contractor delivery and additional safety testing
Complete Blended Wing Body (BWB) test vehicle Plan: March 2000 Deleted	Blended-wing-body low-speed flight research vehicle prepared and delivered to Dryden Flight Research Center for final validation and testing
Systems Analysis of Short Takeoff and Landing (STOL) & Extremely Slow Take Off and Landing (ESTOL) Plan: June 2001	Complete systems analysis of STOL and ESTOL studies to understand the benefits of these vehicles to the small transportation system.
Demonstration of "smart" panel technology Plan: September 2001 Revised: March 2001	Obtain wind-tunnel performance data of hingeless control surfaces on a Full-span 30% geometric scale "smart" uninhabited combat air vehicle (UCAV) model
Mach 10 Research Vehicle Flight. Plan: September 2001 Revised: June 2002	Demonstrate an airframe integrated, dual-mode scramjet powered vehicle in flight at Mach 10. The revision of the planned flight is the result of slips in the two precursor flights due to late contractor delivery and additional safety testing.
Central Nervous System Validation Plan: March 2001	Real-time piloted simulation validation of the reconfiguration intelligence component of central nervous system

Protocols and Test Methods Needed For Accelerated Testing of Space Transportation Materials Plan: March 2001	Identify testing methodologies and protocols needed for testing of Space Transportation materials.
Hyper- X Mach 7 Flight 1 Plan: June 2001	Demonstrate an airframe integrated, dual-mode scramjet powered vehicle in flight at Mach 7. Schedule includes the impact of late contractor delivery and additional safety testing
Complete Blended Wing Body (BWB) Critical Design Review Plan: June 2001	BWB low speed vehicle passes Conceptual Critical Design Review.
Biologically Inspired Fabrication Plan: June 2001	Identify approaches for fabrication of structures inspired by biology.
Benchmark NTF ground-to-flight scaling on B777 Cruise Wing Configuration Plan: September 2001	Complete National Transonic Facility (NTF) testing of 777 baseline cruise wing configuration and NTF/CFD/flight assessment of cruise condition.
Large-Scale Component Validation of Noise Reduction Technology Plan: September 2001	Validate developed noise reduction technology at large scale to reduce technical risk of future technology implementation.
Highways in the Sky (HITS) and Datalink Infrastructure Facility (DIF) Validation Plan: September 2001	Complete integrated system flight and simulation testing of AGATE HITS operating capability, DIF system, and simplified flight controls.
Design Guidelines and Documentation Plan: September 2001	Publish design guidelines, system standards, certification bases and methods to document lessons learned in the AGATE project
Oscillatory flow control actuators Plan: March 2002	First demonstration of flow control via oscillatory blowing with leading and trailing edge actuators to enable simplified high-lift systems for high aspect ratio wings Simplified high-lift systems can lead to a3% reduction in total weight of a subsonic transport

Unstructured-grid CFD Plan: June 2002	Capability developed & demonstrated for viscous, solution-adaptive system using high-fidelity modeling, generating an unstructured-grid CFD from a geometry model for a complex aerospace vehicle in 1 day.
Aligned carbon nanotubes Plan: September 2002	Demonstrate the feasibility that carbon nanotubes can be fabricated in an aligned configuration
Non-Autoclave composite Plan: September 2002	Demonstrate adhesives for non-autoclave composite processing.

AEROSPACE PROPULSION AND POWER TECHNOLOGY

Demonstrate 900°F SiC sensor on an engine. Plan: September 2000 Actual: September 2000	Commercial-grade, high-temperature sensor demonstrated at 900°F. Pressure sensor was successfully tested in the de-swirl region of the AS 907 engine compressor
Demonstrate 'smart' turbomachinery concepts to minimize pollutants throughout mission cycle. Plan: September 2000 Actual: 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 Revised: Deleted	Demonstrated unsteady inlet flow performance for PDE ground and flight research tests. Deleted in favor of higher priority activities.
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 Technical Manual.

Demonstrate viability of hot section foil bearing Plan: September 2001 Revised: August 2001	Complete Core Hot Section Radial Foil Bearing Rig Testing. Proof-of-viability of hot section foil bearing.
Demonstrate the durability of cast Titanium Aluminum (crack resistant blades)for low-pressure turbine applications Plan: September 2001	Provide alloys for turbine aircraft engine blades that are more crack-resistant.
CD-ROM icing pilot training module Plan: June 2002	Produce a self-paced computer-based training module on icing weather training Provide access to in-flight icing hazards to large audience of pilots – supports home use and individual training. Reduce in-flight icing incidents and accidents.
Ultra Safe propulsion technologies Plan: September 2002	Validated structural concepts, which could be further developed into safety-certified, lighter-weight, lower-cost, and more robust containment systems. New composite/hybrid "hard wall" and fabric "soft wall" containment system structural concepts transferred to the AvSP for full-scale evaluation.
Smart low emissions fuel injection system Plan: September 2002	Demonstrate revolutionary fuel injector concepts in flame tube tests. Concepts will utilize advanced technology, including ceramics, MEMS technology, and active control aimed at achieving the 80% NOx reduction goal, and reducing particulate and aerosol emissions.
8-cm ion thruster laboratory test Plan: September 2002	Complete integration and wear test of 8 cm ion engineering model thruster and breadboard Power Processing Unit
Ion engine integration test Plan: September 2002	Conduct integration test of 5-kW PPU with 5/10 kW next-generation ion engine
PDE-combined/hybrid cycle feasibility Plan: September 2002	Quantitative assessment of the performance potential of Pulse Detonation Engine hybrid/combined-cycle propulsion including non-idealized loss mechanisms.
LH2 propulsion concepts Plan: September 2002	Issue report on conceptual application of LH2 propulsion concepts to subsonic transport aircraft, including propulsion system and airframe concept characterizations complete with mission emission characterizations.

High-temperature composites Plan: September 2002	Demonstrate reaction transfer molded polymer matrix composite with 550•F use temperature. (2R10)

AEROSPACE FLIGHT RESEARCH

Demonstrate continuous "over the Horizon" control of remotely piloted aircraft (RPA) Plan: June 2000 Actual: May 2000	Flight demonstration of reliable "over the Horizon" control of RPA utilizing low cost commercial satellite systems. RPA flew a series of direct commands from the ground station as well as a series of way point sets. Demonstrated the ability to extend RPA operating range to 200 nautical miles with continuous command and control.
X-45 Autonomous Taxi Software Plan: September 2000 Actual: July 2000	The taxi algorithms provided for autonomous UAV ground operations for guidance and control, taxi route planning, obstacle avoidance, and air traffic control. The taxi control laws (software) provide for autonomous UAV ground operations for guidance and control, taxi route planning, obstacle avoidance, and air traffic control. The software has been supplied to Boeing for integration in the full X-45 full vehicle software
Demonstrate functionality of autonomous station keeping for a two aircraft formation. Plan: March 2001	Effective system of aircraft that can maintain formation for transport technologies and DoD UCAV capabilities. Establishing practical operability of precision formation flight for drag reduction and consequently for reduced fuel burn.
Complete development of laboratory (heavy weight) energy storage Plan: September 2001	Demonstrate 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. Provide laboratory validated design tools that will enable flight-worthy energy storage systems capable of supporting high altitude, long-duration solar-powered aircraft for future science and commercial applications.

Demonstrate solar power RPA flight to 100,000 feet Plan: September 2001	Helios RPA is to achieve 100,000 foot-altitude under solar power. Flight validated design tools for solar powered aircraft capable of operating at extreme altitudes at low airspeeds, suitable for atmospheric sampling and commercial applications
Complete development, validation, and flight testing of a differential carrier-phase GPS coupled with an IMU using a Kalman filter. Plan: September 2001	Flight demonstration of capability to measure precise relative position among a formation of aircraft resulting in reduced fuel consumption.
Demonstrate robust taxi Capability with contingency planning for an autonomous vehicle (UCAV). Plan: September 2001	Taxi UCAV Air Vehicle #1 from the hanger to the runway takeoff point with no errors UCAV capable of ground operations in multi-vehicle environments.
Demonstrate turbo-prop RPA capabilities that exceed the minimum ESE altitude and duration requirements. Plan: September 2002	Flight validation of an experimental, consumable fuel, RPA design that will enable an enhanced prototype vehicle to meet the prescribed set of Earth Science Enterprise (ESE) RPA science platform requirements. First flight of the Predator B was conducted in early February 2001. All aircraft systems functioned correctly and development is continuing to meet the milestone

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 Actual: June 2000	Demonstrated cabin noise reductions resulting from improved interior panel isolator mount designs and from an active structural acoustic control system concept; validated improved interior-noise analytical prediction tools covering a wide frequency range and alternative designs. Specifically active noise control (ANC) applied to the MD Explorer aircraft demonstrated a 3-4 dB reduction at transmission “bull” gear-mesh frequencies and ANC applied to the S-76 aircraft achieved a 23 dB reduction in maximum cabin noise at the transmission “bull” gear mesh frequency, the major source of noise.

Develop and validate capability for large-scale rotor testing. Plan: September 2000 Actual: September 2000	The Large Rotor Test Apparatus (LRTA) allows wind-tunnel testing of helicopters and tiltrotors up to 50,000 lb. thrust and 6000 HP. Its performance has been validated through operational checkouts and extensive calibration activities. The LRTA provides a unique national capability to test large-scale rotors. This capability is necessary for understanding aerodynamic and dynamic phenomena that can not be adequately predicted or scaled, including rotor performance, dynamic stall, structural loading, and stability.
Rotorcraft Crashworthiness. Plan: January 2001 Revised: February 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: 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 to conduct flight validation based on baseline RASCAL control laws due to planned cancellation of Rotorcraft Program in FY 2002.
Rotorcraft Technology Documented. Plan: September 2001	Technology advances achieved in the Rotorcraft Program will be archived and documented for transfer as appropriate to DoD and NASA Aerospace Base R&T and Aerospace Focused programs.

SPACE TRANSFER & LAUNCH TECHNOLOGY (STLT)

LOX Densifier verification testing and completion of hydrogen densifier build Plan: June 2000 Actual: October 2000	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. The LOX densifier was demonstrated at 30 lbs./sec and the assembly of a 8 lb./sec liquid hydrogen densifier was completed.
Complete fabrication of Metal Matrix Composite (MMC) & Polymer Matrix Composite (PMC) thrust cell chamber demonstration units Plan: August 2000 Actual: August 2000	Will demonstrate successful fabrication of thrust cell chambers using new material systems that offer weight savings up to 40%. Based on the subscale chamber fabrication and testing of three polymer matrix and two different metal matrix materials, demonstrated feasibility of reducing current thrust chamber weights by more than 50% by applying composite materials. Each unit used composite materials for the chamber's structural jacket. Additionally, an advanced copper alloy was used for the hydrogen cooled chamber liner.
NSTAR Engine ground demonstration Plan: September 2000 Actual: May 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). Demonstration of 100% design life (87-kg xenon throughput) ground testing of the sister engine used for the Deep Space-1 mission was achieved when the engine had accumulated 10,375 hours of operation
Advanced TPS panel development, fabrication and test Plan: September 2000 Actual: September 2000	Demonstrated the utility of low-cost casting / rolling process for fabricating Titanium-Aluminum sheet (0.025 in thick), developed brazing and diffusion parameters, and fabricated truss-core ad honeycomb core from a nickel based alloy. Honeycomb sandwich panels were fabricated and successfully tested. Characterized a family of Conformable Reusable Insulation based on testing including arc jet and wind tunnel tests and includes effect of humidity exposure, wind/ rain exposure, radiant heat exposure, drop impact, repair, and re-waterproof.
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 Actual: January 2000	Hold preliminary design review of composite LOX tank for X–34. PDR was completed which included completion of the system and test requirements, conceptual design, component test definition, and test structure design.
RBCC Demonstrator concept design complete Plan: September 2001	Baseline concept for RBCC demonstrator will be established
Initial Flowpath Definition and Testing Completed for RBCC Demonstrator Plan: September 2001	Initial flowpath characterization complete. Used as criteria for combined cycle demonstrator engine selection.
RBCC Demonstrator SRR Completed Plan: June 2002	Successfully complete Systems Requirements Review on RBCC Demonstrator Engine. Requirements established for the ground demonstrator engine

ACCOMPLISHMENTS AND PLANS

Computing, Information & Communications Technologies (CICT)

In FY 2000, The IT Base Program demonstrated the first-phase prototype of a geographically-distributed heterogeneous high-end computational grid testbed to meet future NASA supercomputing requirements. The testbed integrated recent advances in computing hardware, network technologies, and system software that allows seamless and transparent access to testbed assets. The integration of these technologies allowed for geographically dispersed engineering collaboration and greater peak computing power, enabling improved time-to-solution for a range of NASA applications including, for example, the X-38 vehicle. The IT Base Program also completed a demonstration of real-time aerospace design exploration in FY00. The developed environment includes 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 have been coupled with newly developed instrumentation and data systems to provide previously unavailable experimental data to the aerospace vehicle designer. New capabilities include non-intrusive measurements of molecular flow, instantaneous detection of turbulent flow structures, advanced acoustical measurements and accurate spatial detection of experimental model attitude and deformation. In addition to reductions in access time to high-fidelity simulation data, specific improvements of the system include a reduction in access time to experimental data by more than a factor of five, and a reduction in access time to archived database sources by a factor of two. IT Base improvements in software technology included the development of verifiably correct automatic code generation (program synthesis). Tools developed/matured in this activity demonstrated a reduction in time required for software coding and testing, enabling new implementations to be generated in minutes for design changes that would formerly require days of re-coding. Moreover, the tools automatically generated detailed documentation explaining the implementation. Specifically targeted applications in aerospace guidance and navigation software were used to demonstrate these tools on real-world, complex software development activities meeting NASA mission requirements. The generated code consisted of calls to hundreds of software components. Also as part of the IT Base R&T Program, the Search and Rescue project (a Cospas-Sarsat satellite-based search and rescue system) was designed and developed in the 1970's by NASA and launched in the 1980's, with plans being developed for a replacement system. The objectives are to reduce the waiting time (to minutes from current 2 hours at the equator), false alarm rate (high currently), and number of ground stations. The U.S. National Search and Rescue Committee (NSARC), of which NASA is a member, has identified a possible opportunity to achieve such a capability through a partnership between the U.S. DoD, DoE and NASA. NASA is responsible for SAR R&D. During FY 2000, a preliminary concept was defined that enables ground stations to provide unambiguous location of distress beacons within 2 minutes with location error of about 6 to 7 km, and below 4 km after less than 5 minutes. The system has an ultimate potential of errors below 0.5 km in 2 minutes. The IT Program demonstrated Microwave Micro-Electro Mechanical Switches (MEMS) with 60% lower loss than conventional switches have been demonstrated. This improvement has significant impacts on antenna efficiency and cost for upcoming high rate phased array antennas needed for NASA Near-Earth missions. High performance printed antennas are particularly attractive for space applications because of its planar structure and lightweight. Enhancing the gain, bandwidth and functionality of an antenna will reduce the number of elements required in an array and improves the capacity of the communication systems. A 4x4 printed array with a suspended microstrip feeding-network was demonstrated at Ka-band. Measured results indicated 4-5% efficiency improvement and 2% bandwidth improvement as compared to standard microstrip corporate feeds. These antennas, with multi-function capability, can be used for multi-beam array applications

In autonomy as part of the Space Base Program, the first joint Ames-JPL rover field test was performed using both the Ames K-9 and JPL FIDO rovers. Over 3 days, the K9 rover executed 12 command cycles, traveled about 6 kilometers and yielded 3D models of 3 target rocks. In addition, it demonstrated the use of 3D visualization to help in science experiment planning and target selection. The Remote Agent Experiment was also completed following a successful experiment demonstrating for the first time the use of advanced artificial intelligence techniques to autonomously control a deep space mission using goal-directed commanding. In FY00, a full assessment of the Remote Agent Experiment was performed identifying both the key accomplishments as well as the existing limitations in the technology. Work was begun to address these limitations and to mature the component technologies for deployment within a number of on-going experiments.

During FY 2000, the focus of the Aerospace Operations Systems (AOS) was on developing more basic concepts, procedures and systems to remove the key barriers to significant improvements in the safety of the nation’s aviation system. Based upon a simulation study with airline flight crews, in-flight crew activity breaks were found to be effective as a countermeasure for pilot fatigue. The simulation study demonstrated that brief, hourly in-flight activity breaks reduce subjective sleepiness for up to 40 minutes during the circadian trough, reduce physiological sleepiness for at least 15 minutes during the circadian trough, and are valued by flight crews to be practical and operationally feasible. In operations research, a theory-based methodology for predicting operational error vulnerability was developed. The methodology defines the connection between a machine’s behavior, the task specification, the required user interface, and the user-model to ensure that correct and unambiguous interaction between a user and a machine is possible. In particular, the methodology enables the analysis of a given display and user-model for a specified task.

Finally, in FY2000, Bio/Nanotechnology theorists conceived carbon nanotube "transistors" four orders of magnitude smaller than possible with silicon technology. Experimental breakthroughs included development of Chemical Vapor Deposition methods to form nanotubes in a controlled manner (for example formation of nanotubes between pillars, growth of nanotubes in linear bundles and in-situ growth of nanotube tips for Atomic Force Microscopes). Other experimental breakthroughs during the year included use of protein nanotubes as "backbones" for self-assembly of new nanostructures. Each of these experimental achievements represents great progress toward creating new nanomaterials and nanosystems. An agency-wide team and representatives from industry and academia met in January 2000 to assess the strategic impact of nanotechnology on NASA's missions. This team determined that nanotechnology has enormous potential to revolutionize the way NASA conducts its business in each of its enterprises. Furthermore, a new multi-agency/multiple center cooperation effort with partnerships in nanotechnology development, was put in place. NASA has taken the lead in the grand challenges for spacecraft systems, aerospace structures and materials and is a senior partner in the areas of nanoelectronics and nanosensors.

FY2001

In FY2001, IT Base Program research in advanced computing will reduce turnaround time for aerospace vehicle design and simulation. These improvements will be partially supported through the development of new software tools to measure computing testbed and network performance, database manipulation, and resources scheduling. These tools are needed in order to evaluate alternate scheduling strategies and choose optimal approaches to reduce the variability and improve the predictability of distributed supercomputing resources. These tools will also be used to evaluate new, innovative supercomputing concepts. In addition, IT Base will complete the development of software tools to reduce the time required to adapt applications to new supercomputing systems and tools to enhance network performance. These technologies 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. These capabilities are likely to impact not only aerospace vehicle and system design, but also NASA science investigations and other applications requiring distributed collaboration, high-end information and computing resources, and access to high data rate instruments. Also, the IT 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 reduced design costs and improved designs. A cross-fidelity aerospace design system being developed in the IT Base program will enable the use of high-fidelity modeling codes in a design paradigm focused on rapid turnaround of computational simulation solutions.

The demonstration of a 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. Software technology being developed by the CICT program will result in increases in safety and productivity for the National Airspace System. Work done previously in Intelligent Flight Controls will be extended into Propulsion Controlled Aircraft control laws and will 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 work forms the basis for the technology integration effort being planned for future work in aerospace autonomous operations. 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. Finally, the IT Base Program will begin development of network protocol software modules to provide reliable multicast communications in satellite-based IP networks to increase network efficiency and reduce the costs of data transmission. This effort, for the delivering space-based multicast services, will involve the development protocol schemes at the link and transport layers. A new transport layer protocol will be developed to mitigate the effects of long propagation delays and satellite system error rates to support real-time applications in networks with high delay-bandwidth products and high-bit error-rates. Exploratory research will also be conducted to address data-compression, memory efficiency, intelligent routing, and network protocols for high-speed proximity networks will be developed. NASA will design, fabricate, and characterize bit phase shifters: low loss-rate, bandwidth efficient, radiation-hardened digital modulator application specific >50% magnitude from current state of the art. In addition, NASA will support initiation of the development of a proof-of-concept Search & Rescue system to demonstrate that identified performance potential can be achieved. MOUs between the USAF, NASA, and DOE, and other agreements with appropriate agencies are presently under development.

Several Design for Safety (DFS) workshops were held during FY2001 to refine the current understanding of system and mission failures of NASA aerospace and exploratory missions, along with potential solutions from government, industry, and academia. The first workshop was Design for Safety (DFS2000), which included nine technical sessions, with speakers from all NASA centers, aerospace companies (United Space Alliance, Honeywell, Loral, Lockheed Martin), information technology companies (In-Q-Tel Corporation, Lotus/IBM), academia (MIT, Stanford, Carnegie-Mellon, Rutgers, Georgia Tech, UC Berkeley) and other Government agencies (DOD, NSF, USAF and the FAA). Subsequent workshops were held, including the Resilient Systems & Operations workshop held at Dryden Flight Research Center in November 2000. The main products of the RSO workshop were a clear identification of Resilient Systems & Operations goals for flight control, ground systems, and diagnostic technologies that would adapt to known and unanticipated hazards. Additionally, plans for a partnership with the Air Force Research Laboratories were established, in the areas of concurrent airspace operations.

Aerospace Operations System (AOS) research in FY2001 will concentrate on developing an understanding of the causes of errors during concurrent task management, with an eye towards future development of training tools to alleviate this type of error. Fundamental modeling of human performance and the interaction of human operators with automated systems will continue. Tools will be developed and documented for evaluating human cognitive performance within the context of concurrent task execution and awareness of hazardous states. These tools are developed using a combination of empirical investigation, modeling, and direct measurement of brain activity.

Finally, Bio/Nanotechnology efforts in FY2001 will focus on the design and development of viable nanodevices based on carbon nanotubes for electronic and sensor applications. A variety of carbon nanotube configurations as electrodes and biosensors have been examined and compared to conventional carbon paste electrodes. A key advance has been the development of purification techniques to remove amorphous carbon from carbon nanotubes in order to improve signal-to-noise ratio in sensor applications. In addition, methods have been developed for the production of protein nanotubes.

FY2002

In FY2002, the IT Base element of CICT will continue to develop a seamless distributed computing and information system to support increased fidelity, higher confidence and reduced time-to-solution for aerospace applications. Collaborative visualization and computational steering across a heterogeneous distributed system will be demonstrated. IT Base will demonstrate these capabilities within relevant NASA aerospace design activities, including advanced space transportation vehicles. Along with these computing advances, IT Base will continue to develop improvements in advanced networking for NASA's future needs. Efficient network utilization through multicasting will be demonstrated. Quality of service and traffic engineering capabilities that allow for prioritization and assurance of network availability will also be demonstrated. The IT Base element will develop key capabilities for advanced safety and design concepts. This includes simultaneous acquisition, analysis and display of data from disparate instruments, as well as improvements in the quantity and quality of instruments used in an aerospace testing environment. The integration of advanced flight simulation facilities into a triad of aerospace vehicle design assets (together with experimental test facilities and high-fidelity computational capabilities) will be completed with the demonstration of an aerospace vehicle redesign during a single test entry within a flight simulation facility. Finally, IT Base accomplishments in high dependability software will include a demonstration of a factor of 10 improvement in automated techniques for scalable software verification. The IT Base will also develop, integrate, and demonstrate on-orbit a novel programmable Surface Acoustic Wave (SAW) correlator integrated into an advanced Microminiature SAW-based Wireless Instrumentation System (Micro-SWIS). The programmable SAW correlator addition to state-of-the-art very low power micro-radios will provide spread-spectrum benefits that are adaptable in real-time to the environment. It will allow much higher data rates and numbers of Micro-SWIS units to simultaneously communicate by radio. Of special interest for space applications, it allows Micro-SWIS real-time network and measurement synchronization in a harsh environment. In addition, we continue to support proof of concept development for a replacement Search & Rescue Spacecraft leading toward the completion of system definition in FY 2005

The Design for Safety (DFS) element of CICT will build a prototype of a reliability and cost database of aerospace system missions, including the definition of the appropriate taxonomy. This prototype would serve as a foundation for an infrastructure to map system safety problems and uncertainties to information technology solution classes, allowing for prioritization of program technical activities and continuous analysis for significant or emerging safety trends. DFS will also support an X-37 intelligent vehicle health management (IVHM) flight experiment that will demonstrate the use of the Livingstone model-based health management system for real-time fault detection, isolation and recovery. During FY02, the initial drop test will be performed, demonstrating the full integration of the IVHM software into the Boeing flight software. This will be followed by the orbital flights which will further showcase the diagnostic capabilities provided by this technology.

In Intelligent Systems (IS), FY 2002 will also see the completion of major steps towards autonomous science exploration, including the development of the conceptual high-level autonomy architecture for planetary rovers. A collaboration has been formed with the Mars 2003 mission team to demonstrate the benefits of advanced planning and scheduling technology for automated sequence generation. The technology will be integrated into existing tools to be used by the mission and will be considered for incorporation into the mission following the demonstration. This effort is expected to demonstrate a speed-up of a factor of four in the total amount of time required to generate an initial sequence, thus allowing increased interaction between the science and engineering teams while also increasing the overall robustness of the sequence generation process. The IS element will also demonstrate and benchmark the current state-of-the-art for automated software verification and validation using Mars Pathfinder code. This activity will demonstrate the benefits of existing techniques while establishing benchmarks for future comparisons. One of the end objectives of this activity is to dramatically increase the overall level of software reliability for future Mars missions by facilitating the eventual adoption of these techniques. Finally, the benefits provided by a systematic analysis of the interactions within an integrated human-machine system will also be demonstrated as part of the Mars Exploration Rover 2003 Human-Centered Computing activity. Modeling and analysis techniques will be used to evaluate the performance of this system under various operational conditions and alternative mission operations strategies will be evaluated and compared in an effort to maximize the overall system robustness while enabling increased science return. In addition, it will establish a Research, Education, and Training Institute (RETI) in intelligent systems.

Another key CICT activity in human-machine systems and operations will be conducted within the Aerospace Operations Research (AOR) element. Specifically, countermeasures for flight crew fatigue will enter a new phase with the development of tools to assist aircraft operators in scheduling flight crews. An initial bio-mathematical model will be developed to predict crew behavioral performance based on sleep and circadian variables. New perceptual measurement tools for evaluating display effectiveness as they support human performance will be validated. This research is conducted using a combination of psychophysical studies, eye tracking, image processing, visual system modeling, auditory system modeling, virtual environment technologies, and evaluations of the interactions between perceptual factors, displays and controls.

In FY 2002, the Bio-Nanotechnology element of the CICT Program will develop methodologies for producing revolutionary aerospace structural materials by exploiting the interface between biotechnology and nanotechnology. Emphasis will be on the development of evolvable (self-assembling) self-repairing systems for computing strategies and spacecraft components. Emphasis will be placed on increasing production of single wall carbon nanotubes and on characterizing the first-order behavior properties of carbon nanotube materials. In nanoelectronics, efforts will continue on controlling the growth, alignment and chirality of nanotubes and developing concepts for nanoelectronic devices and the modeling of their properties. Work will also continue on nano- and quantum-sensors and instruments, including single molecule detection and discriminators. In addition, it will establish a Research, Education, and Training Institute (RETI) in biotechnology and nanotechnology computing.

Finally, a cornerstone in CICT strategy for accelerated technology infusion is the Aerospace Autonomous Operations (AAO) element. AAO provides prototyping and mission insertion support to carefully selected projects from the other elements of CICT. Project selection is based on a clear identification of mission need coupled with the high promise of delivering new or more effective mission capabilities with a specific focus on software that can perform mission decision-making independent of human control. Selected projects will develop technologies to readiness levels suitable for mission readiness and mission insertion. The benefit areas for AAO include planning and scheduling for aerospace applications, health management, executives and distributed intelligence, and sensors/reflexes for aerospace applications. AAO provides support for test beds, flight demonstrations and/or system studies to promote the effective and efficient transition of emerging technologies into missions. For example, advances in neural flight controls research will be applied to candidate aircraft and space transportation vehicle simulations and will demonstrate reduced cost and enhanced vehicle performance. Other specific areas of AAO support include (1) Development or refinement of test beds such as the Mission Data System (MDS) at JPL for mission software development for Mars and other deep space missions; (2) A High Dependability Software Test Bed for the rigorous testing of new approaches to software development, verification and validation; (3)

Demonstration of a neural net-based Intelligent Flight Controller (IFC) for resilient systems development within a transport class testbed; (4) Detailed system studies evaluating both the technical and financial risks/benefits of incorporating new technologies such as Integrated Vehicle Health Management (IVHM), automated planning and scheduling software, or high-end computing into NASA's future missions. Furthermore, research to advance adaptive control technologies applicable towards future space transportation vehicles will be conducted in FY02.

Intelligent Synthesis Environment

The program implementation strategy was to produce a sequence of ISE technology capability builds based on definition, development and test phases. As a result of reviewing ISE progress and information technology priorities, the ISE Program will terminate at the end of FY 2001. FY 01 activities have been focused on the 2nd Generation RLV application to ensure a smooth transition of technology between ISE and the 2nd Generation RLV program. As part of the orderly closeout in FY 2001, the first ISE capability build, a proof-of-concept system, will be validated. ISE Build 1 will include an integration of performance disciplines, cost and risk modeling and conceptual life-cycle design space definition for new design problem synthesis in the life-cycle simulation program element. The environment program element will incorporate team collaboration tools, intelligent network capability at five NASA centers, secure audio/video/data conferencing capability, distributed runtime core capability and services, prototype synthesis framework, voice command and control of desktop applications and a graphical user interface into ISE Build 1. In addition, two dedicated immersive facilities are now available to demonstrate ISE capabilities. The product integration element will integrate Enterprise-specified discipline tools, implement the Enterprise-specified environment and architecture services and user interface capabilities into ISE Build 1. The cultural infusion element will create the ISE technology assessment methodology and feedback mechanisms to update and improve ISE tools and processes validated in ISE Build 1.

Aerospace Vehicle System Technology

In FY 2000, the VST program began a deliberate shift in the focus of the program to maximize the synergism between aeronautics and space transportation. Many of the fundamental technologies have obvious applicability in both these critical areas. The program continues 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 were developed to reduce emissions and drag using smart devices with active components. High-payoff, innovative control concepts were developed and demonstrated. The Blended Wing Body wind-tunnel model tests and conceptual designs of two advanced- configuration aircraft were completed. The first flight test of the Hyper-X Research Vehicle (HXRV) was delayed until FY 2001. Manufacturing methods for a new generation of advanced general aviation aircraft; additional training modules in flight training curricula, multifunction display guidelines, a low-cost communications, navigation and surveillance system, and a highly integrated open architecture avionics system were completed. The VST program also developed flexible patch-on actuators applicable to actuation of a wide range of film-based and highly packageable space structures as well as to non-aerospace applications. This actuator technology was chosen as one of the best inventions of the year 2000 in the annual R&D 100 Awards competition, sponsored by Industrial Research Magazine. The actuator was applied to active vibration and position control of smart inflatable structure that will enable large optical systems and gossamer spacecraft. In another gossamer technology advancement, analysis tools were developed to predict the mechanical properties, dynamic behavior, and effects of imperfections on the performance of membrane-based structures, crucial to the development of efficient and reliable gossamer structural concepts. In other areas of VST, a preliminary design tool was developed and made public to predict the simple effects of spacecraft charging on satellites. And finally, an on-line knowledge base was developed containing material out-gassing information from the American Society of Testing and Materials (ASTM) 1559 and quartz-crystal microbalance (QCM) flight data. Also synthesized first carbon nanotube doped thin film. Doping of 0.1% increased electrical conductivity by 1000xwhich could prevent build-up of static charge if applied to future spacecraft.

In FY 2001, the VST program will continue to exploit synergies between to aeronautics and space transportation technologies. The program will continue to develop technology in the areas of safety, environmental compatibility, general aviation, next- generation design tools, and experimental aircraft. The program will also support access to space goals. Activities transferred from the Advanced Subsonic Technology Program will be completed including large-scale validation of noise reduction technologies as well as 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 the first Mach 7 flight of the Hyper- X vehicle and identification of 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 aerodynamic flow and noise generation. Also, tests will be completed to provide a benchmark to the National Transonic Facility for ground-to-flight scaling on a cruise wing configuration of a transport aircraft. The annual OAT goals assessment will be completed to understand progress toward Enterprise goals. Hingeless control surfaces will be evaluated in wind tunnel testing. Systems analysis will begin on personal air vehicle concepts to understand benefits of these vehicles to the small transportation system. Real-time piloted simulation validation will be completed to determine potential viability of a vehicle central nervous system. Free-form ultra-lightweight structural component fabrication will be demonstrated: the first-order material/structural properties of carbon-nanotube-based materials will be characterized, an important first step to enable simulation tools that accurately predicts performance. The design of prototype carbon nanotube electromagnetic field sensor that will use less power than current sensor technology will be completed. The program will develop a thin-film polymer actuator for shape control of membrane structures. Analysis tools for film-based and gossamer structures will be validated via testing of a variety of components. These tools require development of test and measurement techniques. Development of an expert tool that will provide efficient, rapid and highly reliable selection of space-capable materials that meet the requirements of specific engineering applications will be completed. The program will also complete a 3-year test program to determine electrical properties of a wide array of spacecraft materials and will integrate this new information into relevant NASA databases and models.

In FY 2002, the VST program is focused on development of revolutionary new technologies to improve the performance of air vehicles and space transportation vehicles. The successful development of these technologies will support the Aerospace Enterprise Goals and Objectives. Tasks for space transportation will be completed including the second flight of the Mach 7 Hyper-X vehicle and first flight at Mach 10 as well as demonstration of adhesives technology necessary for large structural components. The annual OAT goals assessment and system studies of several revolutionary concepts will be completed. The first demonstration of micro-oscillatory blowing to enable simplified high-lift systems will be completed. Maturation and validation of high payoff transport aircraft technologies with potential safety, emissions, and cost benefits through partnership with industry and other government agencies will be conducted. To increase structural efficiency of polymer matrix materials, candidate processes for fabricating aligned carbon nanotubes composites will be evaluated. Conductivity sorting of carbon nanotubes will be conducted for selection of the best nanotubes for electronic and optical device applications. Adhesives for non-autoclave composite processing will be demonstrated to provide the technology required for large-structural components. Also in FY 2002, a new vehicle research thrust will be undertaken to explore advanced vehicle concepts and revolutionary new technologies to enable the development of advanced 21st Century Air Vehicles. Advanced materials and structural concepts will be developed to fully exploit the weight reduction potential of nanophase materials. Embedded sensors will be developed to provide real-time health monitoring of the structure. Intelligent systems made of smart sensors, microprocessors, and adaptive control systems will enable vehicles to monitor their own performance, their environment, and their operators in order to avoid crashes, mishaps, and incidents. Smart sensors and actuators embedded in the structure will provide an effective central nervous system for stimulating the structure to create physical responses such as changing shape. Research will also be conducted to develop microactuators that can be used to control aerodynamic flow about the vehicle. Advanced analyses methodologies will be formulated to model and thus predict the optimum locations for flow control devices to minimize airframe noise, reduce fuel burn, and enhance safety by providing additional control authority. This research will result in revolutionary new vehicle designs that are safer and more efficient than today's aircraft. These new air vehicles will be safer, fly quieter, burn less fuel, and have vastly improved high lift systems to enable safe takeoff and landing from short airfields to enable more of this countries 5400 rural/regional airports to be used.

Emphasis will be placed on flight systems, navigation and control, and sensing technologies to enable multiple small spacecraft to share in science observations and measurements distributed over vast areas will be investigated. The development of advanced capabilities coupled with component technologies to reduce launch and on-orbit power requirements will augment this effort to enable affordable continuous distributed science data acquisition for earth and planetary atmospheres and surfaces and for in-space science objectives.

NASA is pursuing fundamental investigations in nanotube research and other related areas at nano-scale dimensions, one-millionth of a millimeter. These investigations are expected to lead to applications materials with properties tailored to provide extraordinary physical properties that can enable breakthrough capabilities in aerospace systems. Efforts will focus on the development of new materials chemistries with nano-particles to provide radiation shielding films and composites and on the development and evaluation of advanced material processing methods for ultra-lightweight systems that cannot support themselves in Earth gravity. To obtain the maximum structural efficiency for polymer matrix materials, aligned carbon nanotubes will be demonstrated. Conductivity sorting of carbon nanotubes will be undertaken for selection of the best nanotubes for electronic and optical device applications. A model for polymer crystallization/chain packing will be developed to enable tailoring of material properties and design of novel microstructures. The feasibility of carbon nanotube (CNT) sensors for human respiratory health monitoring will be demonstrated. CNTs will be sorted according to diameter and length using field effects. Sorting is important to enable the production of mono-disperse distributions of CNTs for various applications that require uniformity.

New micro-meteoroid models will be developed and integrated with other Space Environmental Effects software and a revolutionary new model of the electron environment for all altitudes and reflecting solar cycle variations will be created to replace current models that are 20-years old or more.

Finally, VST will establish a Research, Education, and Training Institutes (RETI) in vehicle systems technology research. To ensure the highest quality research and training and infusion of new ideas, these RETIs will be subject independent, external reviews and recompetition at regular intervals, including mandatory sunsets after ten years.

Propulsion and Power

The Propulsion and Power (P&P) program develops technology that supports all Enterprise goals and objectives. During FY 2000, the General Aviation Propulsion project continued development of two engines (one turbine and one diesel) that can provide revolutionary advances in performance and cost and help to revitalize the U.S. general aviation industry. The turbine engine development has already lead to the announcement of a new general aviation aircraft venture known as Eclipse Aviation. Work was completed on the development of 900°F silicon carbide pressure sensors, and the sensors have been transferred to industry for use. The Emerging Survivable Aircraft Technologies project continued active technology validation activities in coordination with DoD. Excellent progress was made in the development of critical air-breathing launch vehicle component technology. Engine safety improvement efforts also continued with emphasis on development of more crack-resistant alloys for blades and disks, and an improved containment system. Also, 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 was initiated. A zero CO2 research project was also initiated. This project is focused on identifying the technologies needed to drastically reduce or eliminate CO2 emissions from civil transport aircraft.

The Aircraft Icing project made significant contributions to alleviation of aircraft icing hazards. A joint US and Canadian flight/ground experimental investigation to define performance of different ground sensing technologies in detecting atmospheric icing conditions was completed. With the Airline Pilots Association and the FAA, NASA developed and distributed an educational video on icing for increasing regional pilot awareness of icing hazards. Another major experimental investigation with the FAA regarding icing on modern airfoils was completed. It significantly advanced the state of the art in aircraft icing prediction tools by providing a broad base of information about ice accretions and the resulting effects on aerodynamic performance. Prior to this effort, the NACA four digit series airfoil sections created in the 1950's served as the state of the art. The final report documents ice accretions formed over a wide range of aircraft icing conditions and resulting aerodynamic performance degradation for airfoils representative of three classes of aircraft: commercial transport, business jet, and general aviation.

During FY 2001, validation of rocket-based combined cycle (RBCC) propulsion inlet, mixer-combustor, and integrated propulsion pod component is planned. The effort to improve engine safety will continue to seek alloys for more crack-resistant blades and disks for delivery in FY 2001. P&P will continue to work on controlling combustion instability in engines, thus enabling lower emissions operations. Oil-free turbomachinery will be developed, with a complete core-section radial-foil bearing tested. Oil-free turbomachinery could lead to simpler, easier to maintain engines. In the area of pulse detonation engines, design concepts for hybrid and combined cycle propulsion systems will be developed. 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. 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. New initiatives will include the Revolutionary Aeropropulsion Concepts project which has the goal of investigating systems that can produce up to 2 times the payload/range of current engine systems. Also, nanotechnology as applied to the harsh operating environments encountered in turbine engine systems will be investigated. Icing research will continue to be conducted across a broad range of fronts from modeling to database development to systems concepts to education outreach. During this year, the project's primary emphasis will be to review, evaluate and select candidate remote sensing technologies to serve as a prototype ground-based system to sense atmospheric icing conditions.

During FY 2002, efforts to improve engine safety will continue. The UltraSafe Propulsion project will develop new composite-containment system structural concepts that can be transferred to the Aviation Safety Program for full-scale validation. In order to reduce engine emissions, we will demonstrate revolutionary fuel injector concepts that utilize advanced technology, including ceramics, MEMS, and active combustion control to reduce NOx emissions by 80% and to further reduce particulate and aerosol emissions. Oil-free turbomachinery will be further developed, with testing of an oil-free core on a general aviation engine, wherein the shaft will be fully supported by an air bearing. The Zero CO_2 project will complete an assessment of hybrid fuel cells and liquid hydrogen optimized turbofan concepts, pointing the way toward feasible concepts for further development for reducing or eliminating CO_2 emissions. Pulse detonation engine technologies will be further matured, with the demonstration of critical sub-system performance in one or more PDE system concepts. The Revolutionary Aeropropulsion Concepts project will complete identification and preliminary performance assessment on possible future configurations for advanced aeropropulsion systems. This will result in an update of the portfolio for enabling technologies for extremely high-payoff future propulsion systems. In addition, the Propulsion and Power Program will focus on technologies applicable to engine designs for 2nd and 3rd generation reusable launch vehicles. These RLV technologies, aimed at enabling high performance, long life and high thrust to weight include air breathing combined cycle engines, advanced materials and structures and propellants, improved test instrumentation and new analysis/design tools. The activities will include both turbine-based and rocket-based combined-cycle propulsion concepts. Other novel propulsion concepts will also be addressed. The aircraft icing research will progress towards outyear milestones related to modeling, smart-icing systems and ground-based sensing of atmospheric icing conditions. In addition, it will establish two Research, Education, and Training Institutes (RETIs) in propulsion and power research. . To ensure the highest quality research and training and infusion of new ideas, these RETIs will be subject independent, external reviews and recompetition at regular intervals, including mandatory sunsets after ten years.

Flight Research

The Flight Research Base R&T Program continued, during Fiscal year 2000, to safely conduct, enable, and improve NASA's atmospheric flight research capability. Research activities were conducted in the Environmental Research Aircraft and Sensor Technology (ERAST) project with the initial low-altitude flights of the Helios aircraft, which has a 247-foot wingspan and an ultimate altitude goal of 100,000-feet. Preparations are underway to ship the Helios flight and ground support equipment for the summer 2001 deployment where flight to 100,000 feet altitude will be demonstrated. Full deployment will be completed in April 2001. Low-altitude flights are expected to begin late May 2001. The Helios aircraft has commercial market potential as a communications relay platform and Dryden has prepared an implementation approach to Helios technology commercialization for the NASA technology/commercialization office. As a highlight of ERAST FY 2000 flight activities, Dryden completed a GPRA milestone of demonstrating over-the-horizon control of a remotely piloted aircraft outside of controlled airspace using commercial satellite networks. This milestone validated a technology to meet the Earth Science Enterprise requirements for research aircraft to conduct in-situ atmospheric data collection. Also within the ERAST project, the Predator B successfully completed its initial flights in early February 2001. This is a significant achievement towards completing the September 2002 milestone of flight -demonstrating RPA capability to conduct science missions.

The Revolutionary Concepts (RevCon) project began in 1999 with a modified 'Quick Start' approach, and selected for a FY 2000 start the Blended Wing Body, Aerocraft (partially buoyant airship), and Pulse Detonated Engine projects. Both the Blended Wing Body, and Aerocraft projects were later dropped for lack of ability to meet scheduling. The Autonomous Formation Flight activity was instituted as a substitute project. The next generation of RevCon research activity was selected in August 2000 from a broad research solicitation. These projects, currently completing their Phase I evaluation, cover the spectrum of flight research activities. RevCon Phase-1 selections include revolutionary vehicle designs (Joined Wing, Smart Vehicle-Advance Technology Demonstrator), control technology (Reliable Autonomous Control Technology), rotorcraft (Swashplateless Flight, Variable Diameter Tilt Rotor), propulsion (Advanced Supersonic Propulsion and Integration Research, Reliable Propulsion for Aeronautical Vehicles, Shaped Memory Alloy-Variable Area Nozzle), and extreme aeronautical conditions (Apex) high-altitude, sub-sonic test vehicle.

The Flight Research Program also provided autonomous taxi control software to the X-45 program and continued its testbed research activities in FY 2000. The X-45 aircraft was received at Dryden mid-November 2000. Complete aircraft system evaluation and ground vibration tests were initiated in preparation to meet the 2001 milestone.

Fiscal Year 2001 promises to be a productive year of flight research in the Flight Research Base R&T Program. In ERAST, the Flight Research program will demonstrate a solar-powered RPA at 100,000 ft. Also, toward completing the FY 2003 milestone of sustainable flight over 96 continuous hours, ERAST will finish development of a prototype energy storage system. Both achievements will demonstrate technologies that will enable atmospheric satellites for commercial use and enable the Nation to undertake scientific subsonic sampling high in the stratosphere. Changes in the RevCon project due to policy, program, and budgetary decisions will necessitate a reduction in ongoing activities and a restructuring of the approach and execution of the project. The Autonomous Formation Flight project will maintain commitments to initiate flight test to validate control algorithms. The remainder of the program will be reviewed, and restructured, with the resulting program presented to our stakeholders as soon as possible.

In pursuit of efficiency and affordability, in the Advanced Systems Concepts project will continue modification and systems checkout of an F-18 testbed aircraft in preparation for FY 2003 flights to investigate Active Aeroelastic Wing (AAW) technology and the X-45 will validate its autonomous taxi algorithms. Flight testbed activities this year may include: DFRC aerostructures test wing, flight evaluation of the propulsion flight test fixture, airborne Schlieren imaging system, supersonic natural laminar flow phase II, and laminar flow experiment.

Research activities for FY 2002 will be driven by the re-scoping of RevCon, reviewing ERAST plans against additional endurance goals, and other innovative flight research experiments. Continuing from the 'QuickStart' RevCon, the Autonomous Formation Flight project will demonstrate the benefits of formation-flight in drag-reduction. Other flight research on testbed aircraft, in FY 2002, may include innovative research in: Continuous Moldline Technology, Propulsion Flight Test Fixture with a test article, the UCLA Lobed Injector Experiment, Laminar Flow Experiment #3, and preliminary Pulse Detonation Engine testing.

ERAST will continue with the development and demonstration of a turbo-prop UAV for routine flight operations in the National Airspace System with capabilities that exceed the minimum Earth Science Enterprise altitude and duration requirements. Flight testbed activities in FY 2002 year may include: Continuous Moldline Technology, Propulsion Flight Test Fixture with a test article, the UCLA Lobed Injector Experiment, Laminar Flow Experiment #3, and preliminary Pulse Detonation Engine testing.

Rotorcraft

In FY 2000, the Rotorcraft program continued to provide new technologies for improved safety, reduced noise and vibration, rapid & economical design methods, and transferred them to the U.S. rotorcraft. Noteworthy accomplishment in Rotorcraft included:

- In the area of rotor aeromechanics and acoustics, rotary wing systems were improved to increase efficiency, while reducing vibration and noise, through innovative application of active controls. Improvements were demonstrated through wind tunnel tests. A new capability was developed and calibrated for large-scale wind tunnel testing of rotary wing systems up to 50,000-lb thrust and 6000 HP. A number of innovative active and passive noise and vibration reduction concepts were identified and selected for further research. These include the Active Twist Rotor, the Low-noise Platform Rotor, and the Modulated Rotor Design. Active noise controls were flight demonstrated to reduce cabin interior noise by up to 23 dB for selected gear mesh frequencies that are the main source of noise. The computer prediction model TRAC (Tilt-rotor Acoustics Code) was validated using data from flight tests with a MD 900 helicopter. The model is accurate within several decibels and can be used to predict the noise on the ground for a wide variety of flight-path descents. TRAC can be used to optimize approach and landing paths to produce minimum-noise footprints.

- In the area of Composite Structures for rotorcraft, improved methods for fatigue life prediction were developed and applied to design of flex beams for tail rotor systems.

- Moreover, the program developed technology for improved safety. Health and usage monitoring systems and predictive technologies were developed and evaluated. A proof-of-concept demonstration was completed for the world's first ultra-safe gear. Methods of predicting and measuring pilot situation awareness were 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 were studied and specifications for hardware and format of cockpit displays defined to improve pilot situation awareness. A new website for rotorcraft safety was established.

- Project NRTC has developed and transferred technology to industry to improve the performance, utility, and public acceptance of both helicopter and tilt-rotor concepts. The developed technology will 1) improve flight-safety through the use of health-management systems and crash-proof designs, 2) enhance design and manufacture through the use of integrated design and manufacturing tools, and 3) alleviate both interior and exterior noise through active control technologies and optimized flight paths near communities.

After consideration of research priorities within Aerospace Technology budget constraints to relieve air system, the Rotorcraft Program will be terminated at the end of FY 2001. As part of the orderly closeout of program activities, the FY 2001 funds will be prioritized to provide the following accomplishments. An Ultra-Safe Gear Design Guide will be published, completing the provision of ultra-safe gear technology, which was first demonstrated in FY 2000 through testing and correlation with design tools. In the area of Composite Structures Technology for Rotorcraft, a certification methodology will be delivered for inclusion in Mil-Std Handbook 17. Also, a new physics-based design tool for composite structures will be provided for prediction of stringer/skin separation mode of failure. Flight tests will be completed that demonstrate and validate control laws for low pilot workload under typical civil operations involving low-visibility weather conditions. There will be advances made in the areas of crashworthiness of rotorcraft that will demonstrate mitigation of 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 of HUMS 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.

Space Transfer and Launch Technology

Space Transfer and Launch Technology (STLT) is executed by the Advanced Space Transportation Program Office (ASTP) at NASA MSFC. The STLT Program is the technology base program for space transportation. 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 while reducing launch costs beyond the 2nd Generation RLV Program. In addition, it will make key technology investments for in-space transportation systems to reduce costs, system mass and trip time for future in-space missions with a primary emphasis on enabling new robotic missions.

The STLT consists of four investment areas:

- 2nd Generation Reusable Launch Vehicle (RLV) – Development of technologies required by a 2nd Generation RLV. Currently includes the RLV Focused Project. Requirements and funding for this project are provided by the 2nd Generation RLV Program.

- In-Space – Development of technologies for robotic missions such as solar system exploration, Earth-Sun connection, Mars exploration, low cost earth orbital transfer and earth observation. In-Space projects are largely guided by the needs the Space

Science Enterprise. These projects support OAT Goal 2 and 3, Objectives 7, 8 and 10.

- 3rd Generation - Development of technologies which advance the state-of-the-art in propulsion, airframe and launch vehicle systems, operations and integrated vehicle health management. Spaceliner technology priorities are derived from the contribution to transportation system safety and cost goals and are envisioned to support future Department of Defense, commercial and civil space transportation needs. These projects support the long-term elements of OAT Goal 2, Objectives 6 and 7.

- Space Transportation Research – Research of very advanced, breakthrough concepts for revolutionizing space travel. These projects support OAT Goal 3, Objective 10.

In FY2000, the STLT completed several technology demonstrations, including: fabrication of an Advanced Ceramic Matrix and Metal Matrix Composite thrust cell chamber; completion of over 2000 two-dimensional unsteady Computational Fluid Dynamics (CFD) runs for optimization of turbine performance which showed a gain of 10 points of efficiency at design conditions over standard design practices; development of an Automated Tape Placement Device with attached E-Beam Gun for ply-by-ply, cure on the fly fabrication capabilities of E-Beam curable resins; completion of a 500-hour test of a 10kW Hall Electric Thruster; completion of ProSEDS hardware fit check on the Delta upperstage; fabrication and test up to 150 psi of two polymer matrix composite liquid hydrogen ducts; accumulation of over 1 hour of test time on the Rocketdyne Rocket Based Combined Cycle (RBCC) A-5 engine ; assembly and initial testing of a liquid oxygen densification unit; successful hot-fire of the TRW Ultra-Low Cost Engine (Pintle); completion of a comprehensive planning process for FY2001 and out activities consistent with the Integrated Space Transportation Plan (ISTP); establishment of the Space Transportation Information Network (STIN) for managing and disseminating technology development data, on the internet; establishment of over 20 standing Technology Working Groups (NASA, DoD, DoE, industry and academia); and creation of the Integrated Technology Assessment Center (ITAC) to aid ASTP in prioritizing technology investments based on sound systems analysis.

FY2001 activities will be consistent with the Integrated Space Transportation Plan and guided by comprehensive systems analysis. 2nd Generation RLV technology investments will include composite aerospike ramps, composite lines and ducts, long life, lightweight thrust cells, advanced combustion devices, large-scale testing of hydrogen propellant densification and development of the integrated powerhead demonstrator. In-space activities include cryogenic fluid management, electrodynamic tethers, electric propulsion, solar sails and aeroassist technology development. In addition, significant planning efforts for in-space activities will be conducted with the Space Science, Earth Science and Human Exploration and Development of Space Enterprises. The focus of 3rd Generation activities will be on revolutionary propulsion and airframe technologies. In propulsion, work will begin with the RBCC engine consortium to conceptually define and conduct select future component and subsystem ground and flight test demonstrations of a flight-weight RBCC engine systems. Crosscutting technologies will be pursued which support both rocket and air breathing concepts, such as long life turbomachinery, revolutionary materials, and numerical simulation of propulsion systems and smart sensors. Other 3rd Generation investment areas include: development of rapid design and analysis tools; flow control through plasma aerodynamics; morphing structures; SHARP ultra-high temperature ceramic materials; integrated smart/adaptive thermal-structures and intelligent thermal protection systems; structurally integrated, wireless, micro/nano sensors and avionics; regenerative sensors; autonomous/adaptive control; and technologies for spaceport /range operations. In addition, advanced research activities will continue to be guided by concepts that have the potential for enabling future generations of RLV's and interstellar travel.

FY2002 activities will continue work initiated in FY01. STLT will continue to develop improved systems analysis capabilities to ensure that STLT investments are addressing high- priority needs and are making progress towards the Enterprise and program goals. STLT will continue to increase university participation in long-term research and technology. 3rd Generation activities will be tied closely with the future needs of the United States Airforce as defined by the National Hypersonic Propulsion Plan. Propulsion activities will be centered around completing the systems requirements review for the 1st flight-weight rocket-based combined cycle engine system and completing key component and subsystems level propulsion and airframe demonstrations. In addition, STLT will develop the technologies required for a Mach 4 revolutionary turbine-accelerator propulsion system and a hydrocarbon ram/scramjet. In-Space Transportation activities will be funded and managed in the Space Sciences Enterprise beginning in FY 2002.

Special Interest Programs

In FY 2000 and 2001, this funding area covered a variety of high-visibility projects and tasks that are of special interest for Headquarters attention including Congressional mandates, inter-agency and inter-governmental partnerships, jointly funded university/industry agreements, flight experiments, and exploratory technology initiatives. To concentrate Enterprise activities on high priority, high performance programs within Aerospace Technology budget constraints, these efforts will be terminated at the end of FY 2001

FY 2001 funds will be used for the orderly closeout of the following activities:

- The development of AirSEDS tethered satellite mission
- The Ultra-Low Power (ULP) program will focus on developing the technologies required to enable missions to use ULP electronics including integral bias circuits and level translation technology. Work will include optimizing the cell library to double the onset threshold for Single-Event-Upsets (SEU's). Additionally, new circuit types will be designed using ULP demonstrating the wide applicability of this technology. This will be the last year of funding for this program
- The Commercial Space Centers at Auburn, Texas A&M, Maryland and Florida Atlantic Universities
- The Polymer Energy Rechargeable System (PERS) project and Glennan Initiative

The FY 2001 Congressional Budget provided an augmentation to the Space Base budget for Nanotechnology ($5 million) in addition to the already on-going Rice University study of improved methods for producing carbon nanotube materials. NASA is pursuing fundamental investigations in quantum effects, atom imaging and manipulation, nanotube research, and other related areas at the nano-scale of dimensions, one-millionth of a millimeter. These investigations are expected to lead to applications such as lighter, smaller, and more capable spacecraft; biomedical sensors and medical devices; powerful, small, low-power computers; radiation-hard electronics; and materials with properties tailored to provide extraordinary physical properties.

The NASA funding of the National Robotics Engineering Consortium will be completed as planned in the original 5-year agreement. The consortium is expected to continue under funding from commercial customers it has developed successfully under the NASA partnership. Final year activities include the completion of 10 new patent applications.

NASA Research Announcements (NRA's):

The Aerospace Base Technology program uses open competition solicitations to broadly compete a significant portion of the program to ensure that the best ideas from all sources are made available for NASA missions.

In FY 2001, seeking high-payoff technologies that can revolutionize future space-flight systems, NASA announced the selection of 111 proposals totaling over $120 million over three years as a part of its Cross-Enterprise Technology Development (CETD) NRA, released in FY 2000. Over the next two-to-three years, principal investigators in 30 states, chosen from a field of more than 1200 offers, will explore promising new ideas that have potential for enabling the achievement of many of the Agency's long-range goals in space science, Earth science, and human exploration of space.

The broad range of studies sponsored under the CETD NRA and to be conducted by universities, industry, and private and government laboratories will address ten general technology areas. New sensors will be developed for the gathering of previously unavailable science data from remote sources. The automation of spacecraft functions will be studied to enable complex new missions with greatly reduced human intervention. New component technologies including advanced materials, micro-devices and support systems will be developed that could significantly reduce the mass, cost, and on-board resource needs of future spacecraft. The funds requested in FY 2002 will continue the funding of these multi-year proposals. The next CETD NRA competition is planned for FY 2004.

BASIS OF FY 2002 FUNDING REQUIREMENT

AEROSPACE TECHNOLOGY INVESTMENTS

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Educational Program	---	2,000	-----
Minority University Research and Education Program......................	(7,200)	9,200	
Total...	-----	11,200	-----

The Aerospace 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 Aerospace 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 Aerospace 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. In FY 2002 this section will be transferred to the NASA respective program office.

BASIS OF FY 2002 FUNDING REQUIREMENT

FUNDAMENTAL SPACE BASE PROGRAM

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Fundamental Space Base	-----	98,184	-----
Total	-----	98,184	-----

NASA has combined the Fundamental Space Base program and the Space Base NASA Research Announcements effort with the Aerospace Base beginning in FY 2001. This combination integrates the management of the programs, thus enhancing efficiency, as well as fostering synergy with the Aerospace Base.

BASIS OF FY 2002 FUNDING REQUIREMENT

AEROSPACE BASE NASA RESEARCH ANNOUNCEMENT (NRA) PROGRAM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Aerospace Base NASA Research Announcement (NRA's)	-----	39,912	-----
Total..	-----	39,912	-----

NASA has combined the Fundamental Space Base program and the Space Base NASA Research Announcements effort with the Aerospace Base beginning in FY 2001. This combination integrates the management of the programs, thus enhancing efficiency, as well as fostering synergy with the Aerospace Base.

BASIS OF FY 2002 FUNDING REQUIREMENT

AEROSPACE FOCUSED PROGRAMS

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
High-Performance Computing and Communications	24,200	22,151	-----
Aviation System Capacity	62,929	68,449	100,600
Aviation Safety	64,394	70,844	70,000
Ultra Efficient Engine Technology	68,306	47,894	40,000
Small Air Transport System	-----	8,980	15,000
Quiet Airplane Technology Program	18,300	19,956	20,000
2nd Generation RLV	-----	271,501	475,000
X-33	84,600	-----	-----
X-34	64,300	17,861	-----
Future –X / Pathfinder *	34,500	-----	-----
Total	421,529	527,636	720,600

* Future X / Pathfinder program remains unchanged and is only reflecting a realignment in FY 2001 to the 2nd Generation RLV Program.

NASA's Aerospace 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 2002 FUNDING REQUIREMENT

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
High-performance computing and communications	24,200	22,151	-----

PROGRAM GOALS

The main objective of the Federal HPCC R&D programs has been to extend U.S. technological leadership in high-performance computing and computer communications. As this has been accomplished, these technologies were 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 has been 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 has been 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 have been developed, NASA has been using 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 has supported 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.

In support of these objectives, the NASA HPCC Program has developed, demonstrated, and prototyped advanced technology concepts and methodologies, provided validated tools and techniques, and responded quickly to critical national issues. As technologies have matured, the NASA HPCC Program has facilitated the infusion of key technologies into NASA missions activities, the national engineering, science and education communities, and 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 has pursued technologies at various levels of maturity. Applications in the areas of Earth science, space science, aerospace technology, and education have been used as drivers of HPCC's computational and communication technology research, providing the requirement context for the work done.

As a crosscutting multi-enterprise initiative, the HPCC Program has received funds from the Aerospace Technology (AT), Space Science (SS), and Earth Science (ES) Enterprises, and the Office of Human Resources and Education. In 2000, NASA concluded the process of refreshing the HPCC Program. The purpose of the "program refresh" was to better reflect each Enterprise's strategic plans in the HPCC Program. The "program refresh" also served to reinforce the crosscutting Enterprise needs across the projects in the areas of testbeds, system software, and applications.

The HPCC Program has been coordinated through the Aerospace 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 has been 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 2000	FY 2001	FY 2002
Aerospace technology	24,200	22,151	-----
Earth Science	21,900	21,700	21,800
Space Science	14,600	24,900	-----
Education Programs	4,000	4,000	4,000
Total direct HPCC (NASA-wide)	64,700	72,751	47,600

The following discussion describes the projects managed by the Office of Aerospace Technology.

Computational Aerospace Sciences

The CAS Project facilitates 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 Aerospace Technology Enterprise. Work to date has provided 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 had 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, has provided input and direction for developing technology for aerospace application.

The CAS Project has worked with NASA Aerospace 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 were 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 has been to provide a next-generation network testbed that fuses new technologies into NASA mission applications. The capabilities 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. The goal of the NASA Research and Education Network (NREN) Project.

SCHEDULE AND OUTPUTS

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 Actual: March 2000	Performed three demonstrations with 500 times more end-to-end performance improvement over FY 96 baseline.
Establish an international Next-Generation Internet eXchange (NGIX) Plan: January 2000 Actual: January 2000	Demonstrated connectivity across an international Next-Generation Internet eXchange.
Demonstrate multicast and quality of service (QoS) technology in a hybrid networking environment Plan: June 2000 Actual: June 2000	Provided 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 Actual: 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. Accomplished using NPSS with an aircraft engine compressor simulation

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 perfoance testbeds Plan: September 2001	3 relevant application codes parallelized and 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; and 2 applications utilizing enhanced hybrid networking.
Research and Education Network (NREN) Project. Plan: September 2001	Technology advances achieved in the Research and Education Network (NREN) Project will be archived and documented for transfer as appropriate to other Aerospace Base R&T and Aerospace Focused programs.
Computational Aerospace Sciences (CAS) project. Plan: September 2001	Technology advances achieved in the Computational Aerospace Sciences (CAS) project will be archived and documented for transfer as appropriate to other Aerospace Base R&T and Aerospace Focused programs.

ACCOMPLISHMENTS AND PLANS

In FY 2000, HPCC CAS demonstrated improved time-to-solution for aerospace applications, as well as implementing the initial system software required for the creation and use of a distributed high-performance testbed (computational grid). With the successful installation, testing, and operations of a first-of-a-kind, 512 processor single-image SGI ORIGINS system, the CAS computational grid testbed provided the vital computing resources that demonstrated over 300 GFLOPS on benchmarking codes (more than 1,000-fold improvements over previously established baselines). Along with the dramatic improvements in computational capabilities, the HPCC NREN Project demonstrated key applications that required high- performance network capabilities, in some cases in partnership with CAS. In FY 2000, the NREN Project focused 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 supported the Federal Next Generation Internet (NGI) efforts, increased the quality, security and certainty of Internet transmissions, and demonstrated these improvements on a network capable of 1,000 times the capacity of established baselines.

After consideration of research priorities within Aerospace Technology budget constraints, the CAS and NREN projects will be terminated at the end of FY 2001. As part of the orderly closeout of these projects, CAS will build upon the successes demonstrated in benchmarking codes and work towards dramatic improvements over FY 1992 baselines in time-to-solution for relevant aerospace applications on high performance computing testbeds. These performance improvements will be partially supported through the development and demonstration of new software tools to measure testbed computing performance, database manipulation, and resources scheduling. These tools are needed in order to evaluate alternate scheduling strategies and choose optimal approaches to reduce the variability and improve the predictability of supercomputing resources. In addition, CAS will complete the development of software tools to dramatically reduce the time required to adapt applications to parallel high-performance systems. Specifically, CAS will develop tools to automatically reduce code parallelization time (from months to one week) while maintaining at least 50% of the applications performance when compared with manual parallelization. During this same time period, NREN will be providing the capability to monitor and measure 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 2002 FUNDING REQUIREMENT

AVIATION SYSTEMS CAPACITY

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Aviation Systems Capacity..	62,929	68,449	100,600

PROGRAM GOALS

The FAA "Aerospace Forecasts 2000-2011" report predicts that U.S. scheduled domestic enplanements will increase 55% over the next 12 years and that total international passenger traffic between the U.S. and the rest of the world will increase by 91%. This rate is higher than the population and economic growth rates. Also, 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, which are ultimately passed on to the consumer. Flight delays continue to escalate. The number of delayed flights in the National Airspace System has more than doubled in just the last 6 years. Due to environmental issues and cost, only one major new U. S. airport – in Denver – was opened this past decade. With little ability to build new or expand current airports in the populated areas where they are needed, the capacity of the nation's air transportation system will not meet consumer demand, airport delays will continue to accelerate, and the nation's economy and mobility will be adversely impacted.

To meet these growing capacity demands, more efficient and flexible routing, scheduling, and sequencing of aircraft in all weather conditions are critically needed. The U. S. aviation industry is investing $6 billion over 20 years to increase airport capacity. However, a gap still exists between the demanded 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 runways at major airports by developing simultaneous independent operations for short-haul civil tiltrotor aircraft. Studies conducted by Boeing Commercial Aircraft for NASA and the FAA and by various state and local transportation authorities (e.g., Port of New York and New Jersey Authority) have shown civil tiltrotor to be a viable candidate for relief of air traffic congestion.

The ASC program supports the Enterprise's objective of "while maintaining safety, double the aviation system throughput in all weather conditions within10 years and triple within 25 years". 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), the Virtual Airspace Modeling (VAM), and the Short Haul Civil Tiltrotor (SHCT) projects. The TAP project, which was completed in FY 2000, developed revolutionary technology and procedures to enable safe clear-weather airport capacity in instrument weather conditions. The AATT project develops decision-making technologies and procedures to enable substantial increases in the throughput, predictability, flexibility and efficiency of the national air transportation system in the context of the FAA commitment to "Free Flight". The SHCT project develops technologies and procedures to overcome the most critical inhibitors to a civil tiltrotor operating within an improving and modernized air traffic system. The VAM Project will develop revolutionary new operational concepts for the aviation system beyond "Free Flight" and the capability to validate these concepts and their benefits in high fidelity simulation and modeling. The ASC program works closely with manufacturers, the airlines, the FAA, and the technology customers who collectively will identify operational requirements and will apply 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 Aerospace 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, which was successfully completed in FY 2000, focused on increasing capacity at airports under instrument meteorological conditions. The objective was to provide technologies and operating procedures to enable productivity of the airport terminal area in instrument-weather conditions to safely match that in clear-weather or visual conditions. The specific objectives included: (1) increasing current non-visual operations for single runway throughput by 15%; (2) reducing lateral spacing requirements for independent operation on parallel runways below 3400 feet; and (3) demonstrating instrument-weather runway occupancy time equivalent to that in clear weather. The TAP project developed and demonstrated: (1) airborne and ground technology and procedures that will enable safe reduction in aircraft spacing in the terminal area; (2) enhanced air traffic management (ATM) and reduced controller workload; (3) improved low-visibility landing and surface operations; and (4) integrated aircraft and air traffic systems to address the problems described above.

The goal of the Advanced Air Transportation Technologies (AATT) project is to develop 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 approach 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.

The goal of the new Virtual Airspace Modeling Project is to provide by 2007 the foundations for setting the direction for the future air traffic management system beyond "Free Flight". This project enables NASA to initiate the first steps toward fulfilling the 25-year strategic goal to " triple the capacity of the aviation system within 25 years, based on 1997 levels". The Virtual Airspace Modeling Project will establish a virtual airspace simulation environment with a never-before-achieved level of fidelity for the real-time test and validation of new and innovative solutions to the nation's aviation system problems. This capability will be key to evaluating revolutionary air traffic management operational and technological that could dramatically reduce airport congestion and delays while maintaining or increasing air system safety.

While the tiltrotor technology is viable for a military aircraft (e.g. 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 Short Haul Civil Tiltrotor (SHCT) 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 6-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:

Conduct simulation of full CTAS coordinated with FMS Plan: July 2000 Actual: August 2000	Successfully conducted 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 Actual: October 2000	Completed all of the demonstrations for the TAP project. Demonstrated 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. This completes the TAP Project.

Advanced Air Transportation Technologies:

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 June 2000 Actual: June 2000	Completed field evaluations of individual decision support tools for management of arrival and surface traffic. Transferred technology to the FAA Free Flight Phase 1 Program. FAA is currently deploying systems to operational air traffic control facilities. Tools are in daily use at several air-traffic control facilities.
Develop and demonstrate transition airspace decision support tools for: ATC/airline operations centers 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.
Develop and demonstrate an inter-operable suite of decision support tools for arrival, surface and departure operations Plan: March 2002	Conduct a high-fidelity human-in-the-loop simulation demonstration of the inter-operable suite of decision support tools.

Short Haul Civil Tiltrotor:

Full-span database for low-noise rotor concepts and final noise code (TRAC) Plan: January 2000 Revised: March 2000 Actual: March 2000	Completed correlation of Tilt-Rotor Aeroacoustic Code (TRAC) with full-scale flight database for XV-15. Correlation completed for level flight, low-noise 3-degree and low-noise 9-degree approaches. TRAC predicted and validated the XV-15 noise profiles.

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 cockpits 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.

Aviation System Technology Advanced Research:

Requirements and preliminary design of VAST complete Plan: September 2002	Complete the definition of the requirements and the preliminary design of a Virtual Airspace Simulation Technology (VAST) environment for unparalleled real-time testing and validation of new and innovative air traffic management concepts.
Identification of first new operational concept complete Plan: September 2002	Complete the identification of the first new revolutionary air traffic management operational concept for investigation using the VAST capability.

ACCOMPLISHMENTS AND PLANS

The **Terminal Area Productivity** (TAP) project was completed in FY2000 with the conduct of the final demonstrations of developed technologies and procedures. Full-mission simulations were conducted to demonstrate integration of airborne flight management systems (FMS) with ground-based ATC decision support tools (CTAS). A simulation was conducted to develop the operational procedures for the Airborne Information for Lateral Spacing (AILS) concept for simultaneous independent approaches to closely spaced parallel runways while interacting with other air traffic. In addition, an integrated demonstration of all the completed technologies for the Aircraft Vortex Sensing System (AVOSS) was conducted at the Dallas Ft.-Worth airport. The TAP project met or exceeded all three of its performance goals: (1) Increase non-visual single-runway throughput by 12 to 15%; (2) Reduce lateral spacing below 3400 feet for independent operations on parallel runways; and (3) Demonstrate equivalent instrument/clear weather runway occupancy time.

During FY 2000, the **Advanced Air Transportation Technologies** (AATT) project completed the development, field evaluation and transfer of three decision support tools to the FAA Free Flight Phase 1 Program for the management of arrival and surface operations in the terminal area: Traffic Management Advisor (TMA), Passive Final Approach Spacing Tool (pFAST); and the Surface Movement Advisor (SMA). NASA delivered source code, documentation and assistance in the operational software validation process. The FAA is currently deploying these decision support tools at key sites throughout the National Airspace System to improve the capacity of the extended terminal area airspace. Each of the tools is currently in daily use at several air-traffic control facilities in the NAS. These tools are the backbone of the FAA's introduction of decision support tools to improve the efficiency of the nation's Air Traffic Control System. The AATT Project also completed initial development and simulation; with live traffic data, of the Direct-to (D2) decision support tool to enable controllers to more directly route en route traffic for increased operational efficiency. The functionality of the tool was validated at Dallas-Ft. Worth with simulated traffic under normal Host maintenance procedures where the Host is taken off-line for testing during a light traffic period. Three beta test flights were successfully completed of the En-route Data Exchange (EDX) tool in which United Airlines B-777 aircraft state (position, velocity, weight, winds, etc.) and intent information was down linked to the Center-TRACON Automation System (CTAS) lab at Ames. This downlinked information will allow improved CTAS trajectory prediction capability based on increased accuracy aircraft information. Currently 10 United Airlines B-777 aircraft are equipped and are capable of automatically reporting aircraft status and intent information.

The Short **Haul Civil Tiltrotor** project demonstrated correlation of the Tilt-Rotor Aeroacoustic Code (TRAC) prediction with a full-scale flight database for the XV-15 tiltrotor. The correlation was completed for level flight, low-noise 3-degree and low-noise 9-degree approaches. TRAC predicted and validated the XV-15 noise profiles. In large-scale wind tunnel test, demonstrated a breakthrough level of noise reduction for the rotor of -12.5 dB for a low-noise approach condition using higher harmonic control (HHC) (a high frequency oscillation of the rotor blades). These reductions greatly exceed the project goal of 6dB. In conjunction with industry, conducted a flight research program to validate noise reduction flight profiles. Candidate flight path profiles were developed analytically and refined in piloted simulation. The flight investigation further refined the profiles and measured the noise footprints. The low-noise profiles were 7dB less than the baseline and meet the project goal of 6dB. A piloted simulation also was conducted to further refine the requirements for control and displays in adverse weather. These flight and simulation studies provide key results for the final mission simulation to be conducted next year.
During FY2001, the **Advanced Air Transportation Technologies** project will conduct field evaluations to demonstrate transition airspace decision support tools in support of (1) Information exchange between air traffic service providers, airline operations centers, and flight crews and (2) Conflict resolution. The decision support tools for information exchange (EDX) will demonstrate 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 **Short Haul Civil Tiltrotor** project will be completed in FY2001. The project will conduct a comprehensive mission simulation to integrate all of the knowledge learned from the previous simulation and flight investigations: low-noise flight paths, integrated displays, advanced control laws, and operating procedures. The simulation will examine integrated cockpit and operating procedures for complex, low noise flight paths of a civil tiltrotor operating in a full-mission environment. Also, a large-scale tiltrotor database will be acquired for use in validation of both rotor noise reduction and a design-for-noise capability. The Tiltrotor Aeroacoustic Code (TRAC) computer program will enable the predictive capability.

During FY2002, the **Advanced Air Transportation Technologies** project will demonstrate through simulation an interoperable site of decision support tools for arrival, surface and departure operations. Development work in FY2002 will lead to the transfer of surface management system technology to the FAA Free Flight Phase 2 Program in FY2004. The capability will reduce arrival and departure delays and inefficiencies that occur on the airport surface due to surface issues and downstream restrictions.

During FY2002, the **Virtual Airspace Modeling** project will develop the requirements and preliminary design for a high fidelity modeling and simulation environment for the real-time investigation and validation of revolutionary operational and technological concepts for the next generation of aviation system. The project will also identify and define the first new operational concept for future investigation using the new virtual airspace simulation technology capability.

BASIS OF FY 2002 FUNDING REQUIREMENT

AVIATION SAFETY PROGRAM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Aviation Safety Program	64,394	70,844	70,000

PROGRAM GOALS

The worldwide commercial aviation major accident rate has been nearly constant over the past 2 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 worldwide demand for air travel is expected to increase even further over the coming 2 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 near 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. 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 GA, weather issues, CFIT, and loss of control also dominate the accident statistics.

In February 1997, to aggressively address these issues, a new national goal to reduce the fatal accident rate for aviation by 80% within 10 years was established. This national aviation safety goal is an ambitious and clear challenge to the aviation community. NASA responded to the 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 augment aviation safety research. The Aviation Safety Program (AvSP) is NASA's next step in responding to the challenge. The goal of the AvSP is to develop and demonstrate technologies that contribute to a reduction in the aviation accident fatal rate by a factor of 5 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 fatal accidents as well as those that address multiple classes of factors. Research and technology development will address accidents involving hazardous weather, CFIT, 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 project 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 GA industry manufacturers, suppliers, and operators in implementing the effort. Langley Research Center (LaRC) is the program's Lead Center and works as a team 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 accessible both nationally and internationally, allowing regular operational assessments to identify unsafe trends before they become accidents – operational with at least two major airlines

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.

The Technical Program is comprised of six major projects:

Aviation System Monitoring and Modeling (ASMM)--This project provides decision-makers in air carriers, air traffic management, and other air services providers with unprecedented in-depth measures of health, performance, and safety of flight operations in the national aviation system. Capitalizing on revolutionary advances in information technologies and digital communications, ASMM applications will enable definition of operational and safety baselines and trends, and identification of developing conditions that could compromise aviation safety. ASMM outputs will also provide technology and procedure developers with the capability for reliable predictions of the system-wide effects of potential changes introduced into the aviation system.

System-Wide Accident Prevention (SWAP)--This project addresses aviation safety issues associated with human error and procedural non-compliance, which are broadly applicable throughout the national aviation system. Since human error is cited as a factor in 60%-80% of aviation accidents, generally reducing or mitigating the effect of human error will result in significant improvements in the fatal accident rate.

Single Aircraft Accident Prevention (SAAP)--This project develops and supports the implementation of safety technologies for in-flight applications. Current accident categories that SAAP will address are loss of control in flight and pilot errors resulting from hardware and/or software failures. Human factors issues and considerations cut across all of these categories and will be an integral part of the technology development process. Both commercial transport and GA vehicle classes are included.

Weather Accident Prevention (WxAP)--This project will develop and support the implementation of technologies to reduce the fatal accident rate induced by weather hazards. Graphical cockpit weather displays and pilot decision making support tools will be developed for avoiding icing, thunderstorms, and other weather issues. In addition, forward looking sensors for detecting severe turbulence conditions will be demonstrated in flight.

Synthetic Vision Systems (SVS)--CFIT commercial transport accidents and a significant percentage of GA accidents result from visibility-induced pilot errors (when terrain, obstacles, or the horizon are not visible at night or in poor weather). By developing precision navigation technologies, high-resolution terrain databases, weather penetrating sensors, and graphical cockpit displays, SVS project development will provide commercial and GA pilots with clear out-the-window views regardless of the actual visibility conditions. Specific technology applications include display of terrain, precision approach and landing guidance and displays, and low visibility surface operations.

Accident Mitigation (AM)--This project will develop, enable, and promote the implementation of technologies to increase the human survival rate in survivable accidents, and to prevent in-flight fires. The number of survivors can be increased in accidents that are of the severity level where some, but not all, passengers survive. Fatalities are the result of impact factors, fire/smoke, or some combination of both. Project technology developments include crashworthy structural and system design methods as well as in-flight and post-crash fire prevention.

SCHEDULE AND OUTPUTS

Preliminary integrated program assessment Plan: January 2000 Actual: January 2000	Complete a preliminary safety impact assessment of AvSP integrated program Assessment Status: Reviewed and concurred by the Aviation Safety Program Executive Council
Apply Aircraft Performance Monitoring System (APMS) to Air Traffic Control (ATC) Plan: March 2000 Actual April 2000	Demonstrate application of APMS concepts & methodologies to ATC for performance monitoring Status: Performance Data Analysis and Reporting Systems (PDARS) software in daily operation at Southern California ATC site.
CD-ROM Icing Training Module Plan: December 1999 Actual: May 2000	Developed CD-ROM icing training module for General Aviation and commuter pilots. Status: Interactive CD-ROM developed and distributed to General Aviation commuter pilot community

Simulation Database for Adverse Conditions and Loss of Control Plan: September 2000 Revised: January 2001	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 Status: Wind tunnel model developed and ready for testing. Wind tunnel upgrade repair delayed test entry by 2 months.
Initial Aviation Weather Information Network (AWIN) Concept Flight Evaluation Plan: September 2000 Actual: November 2000	Flight Evaluation of initial national capability for digital data link and graphical display of weather information. Status: AWIN system developed and operated on Boeing 757 test aircraft. Two major airlines ready to begin in-service system evaluation.
Flight Demonstration of Runway Incursion Prevention Technologies Plan: September 2000 Actual: October 2000	Concept demonstration of integration of air traffic control runway incursion information onto aircraft flight deck displays. Completed airborne and ground-based systems testing at Dallas / Ft. Worth airport in October 2000. Pilot comments confirmed that the system provided increased situational awareness of the airport to aid in runway incursion avoidance and surface safety. Demonstrations were conducted for representatives from the Office of the President, FAA/ DoT. Airport, airline, and major news media. Status: Flight testing and concept demonstration successfully completed at Dallas/Ft. Worth airport
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 Revised: March 2002	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
SVS retrofit concepts Plan: September 2001	Evaluation of SVS concepts in simulations and flight-tests. Measurement tools developed for the analysis of SVS 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.
Flight Demonstration of Forward- Looking Warning System Plan: June 2002	Flight test of turbulence detection system results in 90% or better detection rate for moderate turbulence within 1 minute of encounter.
Demonstration of Flight Critical System Validation Method Plan: June 2002	Documented results of closed-loop laboratory test methods for the validation of complex flight critical system architectures.
Computational Models of present and future contexts Plan: June 2002	Perform computational modeling of operational situations that have high error probabilities, along with potential solutions for error reduction or mitigation.
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
NAOMS adds the GA pilot community to the survey system Plan: September 2002	Active participation by a significant sector of the GA community with 60% of questionnaires returned

Demonstrate national capability for graphical display of weather information Plan: September 2002	Transport and GA graphical displays that provide timely, affordable, and quality U.S. weather information access and flight path relevant presentation.
Analysis tools for structural Crashworthiness prediction Plan: September 2002	Existing codes updated and documented and crash dynamics predictions validated with crash test data delivered to industry.
Demonstrate loss of control and Recovery models in high-fidelity 6 –DOF simulation environment Plan: September 2002	Deliver results of enhanced six-degree of freedom simulations with documentation of math models characterizing vehicle dynamics for outside of the normal envelope conditions.

ACCOMPLISHMENTS AND PLANS

In FY 2000, the first year of the AvSP, the System-Wide Accident Prevention project has developed and demonstrated an icing training module on CD-ROM for GA and commuter pilots. This enabled the broad dissemination of critical weather safety information to the national aviation community. The Aviation System Monitoring and Modeling project has demonstrated the application of Aircraft Performance Measurement System concepts and methodologies to ATC systems for performance monitoring. This work has taken successful aircraft-based monitoring technologies and applied them to the broader context of the national airspace system risk identification and performance improvements. The software tools are now in daily use at multiple air traffic control facilities. Airline evaluations and operational use of aircraft performance measuring software and analysis tools have also been conducted. In the Accident Mitigation project, on-board inert gas and oxygen generation system concepts for fire prevention and emergency use have been defined and structural crashworthiness design analysis prediction codes development selections will be completed in the near future. The Weather Accident Prevention project demonstrated, in flight, commercially ready graphical weather display systems that will now enter in-service evaluations with multiple airlines. The Synthetic Vision Systems project completed concept evaluation flight tests at the terrain-impacted airport in Asheville, North Carolina, and initiated Runway Incursion Prevention testing in Dallas/Ft. Worth airport.

For FY 2001, the System-Wide Accident Prevention project 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. The Single Aircraft Accident Prevention project will deliver results of enhanced six-degree of freedom simulations with documentation of math models characterizing vehicle dynamics for outside of the normal envelope conditions. Single Aircraft Accident Prevention also will define architectures for integrated onboard health management systems. These designs will provide sufficient criteria to support development of concept prototypes to be used for simulation and flight demonstrations. The Weather Accident Prevention project will complete flight evaluations of an initial national capability for digital data link and graphical weather information displays in an aircraft cockpit. This will result in a cockpit "weather channel" for national and worldwide commercial airline and GA benefit. Flight-testing and selection of concepts for continued development will be conducted for clear-air turbulence detection systems. The Accident Mitigation project will demonstrate, in experimental and analytic laboratory environments, a fuel system modification to reduce flammability, and validate system designs in a representative fire environment experiment, showing improved reliability and low false-alarm characteristics. The Synthetic Vision Systems project will down-select concepts suitable for retrofit in commercial, business, and general aviation aircraft, and investigate the use of weather-penetrating sensors as means for independently monitoring the integrity of Synthetic Vision Systems. This project will also conduct flight demonstration tests of FAA and NASA runway incursion technologies integrated on an aircraft flight deck, which will be completed at Dallas/Ft. Worth Airport.

In FY 2002, the Aviation System Monitoring and Modeling project will demonstrate tools for merging heterogeneous air service providers' databases to aid causal analysis and risk assessment. Also, this project will add provisions to include the GA pilot community to the NAS Operational monitoring service (NAOMS) survey system. The System-Wide Accident Prevention project will determine, through simulations, the error probabilities of present and future hazard/risk contexts and the probability of reducing the likelihood of error given proposed mitigation strategies. The Single Aircraft Accident Prevention project will demonstrate high-fidelity 6 degree of freedom simulation models of loss of control and recovery conditions, as well as simulations of subsystem concepts for the prevention and recovery from these conditions. Also, this project will demonstrate through flight testing a proof of concept system for rotorcraft health and usage management. The Weather Accident Prevention project will demonstrate a national capability for digital data link and graphical display of weather information. This project will also demonstrate a forward-looking, onboard turbulence warning system. In the Accident Mitigation project, analysis tools for aircraft structural crashworthiness prediction will be validated.

BASIS OF FY 2002 FUNDING REQUIREMENT

ULTRA EFFICIENT ENGINE TECHNOLOGY

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Ultra-efficient engine technology..	68,306	47,894	40,000

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 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 Aerospace 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 and transitioning 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 application. Seven investment areas form the basis for the technical approach: emissions reduction, to develop the technology necessary to address efficient high temperature, high pressure, high performance systems and to reduce emissions; materials & structures, to address the barrier technologies and expand the knowledge databases associated with high temperature; 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 controls to leverage the emerging intelligent systems and information technologies along with propulsion component and materials 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 understanding 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 six of the seven projects (emissions reduction, materials and structures, turbomachinery, intelligent propulsion controls, propulsion system 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 sub project management for portions of the emissions and materials and structures projects. Goddard Space Flight Center provides critically important supporting research in the atmospheric assessment subproject of the integration and assessment project.

SCHEDULE AND OUTPUTS

Emissions Reduction: Combustion research facility upgrade completed Plan: September 2000 Actual: 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. The design and fabrication of the rig was completed according to schedule (September 2000). The rig will be operational the second quarter of FY 2001.

Emissions Reduction: Select 70% emissions reduction concept for full combustor evaluation Plan: September 2000 Actual: September 2000	Demonstrate in a laboratory combustion experiment (flame tube) 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. (0R1) Flame tube tests performed at NASA Glenn Research Center demonstrated NOx reduction levels of up to 83%.
Materials & Structures: Complete high temperature engine material down-select Plan: September 2000 Actual: September 2000	Complete selection of those materials systems that will be developed for complex geometry such as cooled turbine vanes with thermal barrier coating and capable of sustained 3100°F turbine rotor inlet temperatures Completed selection of thermal barrier coating after evaluating over 33 chemistries. The selected thermal barrier coating is projected to have capabilities far in excess of the current state-of-the-art. The ceramic matrix composite (CMC) material selected is based upon the CMC material developed in the High Speed Research's (HSR) Enabling Propulsion Materials (EPM) project.
Intelligent Propulsion Controls: Plan: September 2000 Actual: September 2000	Complete initial laboratory studies of approaches for active combustion control. Initial laboratory studies were successfully completed through initial flametube tests at the Ames Research Center.
Integration & Assessment: Preliminary Technology Benefits Assessment Plan: September 2000 Actual: September 2000	Assess UEET technology impacts on meeting program goals. Assess all UEET technology impacts on meeting program goals for at least three classes of aircraft. Include assessment of performance, weight, and environmental indicators. Completed assessment of UEET technology impacts for four classes of aircraft—a 300 passenger large subsonic transport, a 50 passenger regional jet transport, a 300 passenger supersonic civil transport, and a 10 passenger supersonic business jet.
Propulsion-Airframe Integration: Prediction of propulsion-airframe integration Plan: October 2000 Revised: September 2001	Complete selection of the most promising simulation approach for predicting propulsion-airframe integration effects for unconventional aerospace vehicles. (1R02D) The milestone was slipped to allow for additional comparisons to be made with existing test data sets so as to reduce the risk in the selection process.

Turbomachinery: Flow Control Concepts for advanced propulsion systems Plan: September 2000 Revised: September 2001	Complete the selection of the most promising flow control concepts that will be developed for application to the turbine components of advanced propulsion systems. (1R02a) Milestone split into flow control concepts for three components—compressor, turbine, and fan. The compressor flow control concept selection was completed in June 2000, the fan is expected to be completed in March 2001, and the turbine is expected to be completed in September 2001.
Integration and Assessment: Definition of advanced 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. (1R02c)
Materials and Structures: High Temperature Turbomachinery Disk Alloy Plan: September 2001	Demonstrate by September 2001 the upper temperature limit of a turbomachinery disk alloy as a function of stress.
Integrated Component Technology Validation: Aspirating Seal Demonstration Plan: March 2002	Demonstrate engine aspirating seal technology in partnership with industry.
Integrated Component Technology Validation: Integrated Component Technology Demonstrations Plan: April 2002	Develop an Integrated Component Demonstration Plan for collaborative tests of engine demonstrators incorporating UEET technologies for large and small thrust class engines.
Emissions Reduction: Initial Low NOx Combustor Sector Test Plan: September 2002	In sector combustor tests, demonstrate initial 70% low NOx reduction, relative to 1996 International Civil Aviation Organization (ICAO) standards, for Landing/Takeoff conditions in subsonic engines.
Materials and Structures: Ceramic Thermal Barrier Coating System Plan: September 2002	Select a low conductive ceramic Thermal Barrier Coating (TBC) to achieve a significant increase in temperature capability.

ACCOMPLISHMENTS AND PLANS

Emissions Reduction: In FY 2000, a world class high pressure ratio combustion research facility upgrade was 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. Initial tests in this upgraded facility will occur in FY2001. In FY 2000, flame tube tests were conducted to identify the most promising approaches for achieving the 70 percent NOx reduction goal. These tests conducted at GRC demonstrated NOx reduction levels of up to 83% in flame tubes, the first step in combustion hardware testing. In FY2001, the flame tube tests will continue and the results will be used to design and initiate fabrication of sector configurations (the next step in combustion hardware testing) of ultra-low emissions configurations for subsonic engine applications. Model tests will be conducted in FY2001 and 2002 in both industry and government facilities as appropriate. The most promising configurations determined from the sector tests will be tested in full annular rig configurations, the third step in combustion hardware testing. 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 FY2000, the selection of those materials systems that will be developed to the subcomponent, complex part scale in this program was completed. The suite of high temperature 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 FY2000 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. Over 33 chemistries for potential TBC's were investigated in laboratory tests conducted at GRC and the most promising chemistry was selected. 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 FY2000 focused on establishing the upper temperature limit of the material developed in the High-Speed Research (HSR) Program. Effort also was initiated in FY2000 to evaluate the Ultra-High Temperature Ceramic (UHTC) material initially developed by ARC for Shuttle applications for gas turbine combustor liner application.

In FY2001, the upper temperature limit will be established for the advanced Nickel based material developed in the HSR Program for turbomachinery disk applications as well as for the single crystal Nickel based turbine blade material also developed in the HSR Program. The feasibility of the ultra-low thermal conductivity TBC will be established in FY01 through laboratory testing. Work was also initiated in FY2001 to evaluate the feasibility of Silicon Carbide nanotubes for structural applications related to gas turbine engines and to develop computational materials tools to develop the chemistry of next generation single crystal Nickel based alloys

In FY2002: optimization efforts relative to the TBC will be completed and efforts initiated to support a rig test of coated turbine blades in the FY2005 time period; initial laboratory tests will be completed to evaluate the design features of the CMC turbine vane; and evaluations of the ARC UHTC material for combustor liner applications will be completed.

Turbomachinery: In FY2000, a number of computationally based studies were initiated to evaluate approaches, including flow control, for achieving ultra-high loading of rotating turbomachinery components (fan, compressor, and turbine). A key part of achieving revolutionary turbomachinery performance increases is the use of flow control to allow increased turbomachinery performance in fewer stages. Fewer stages will enable a smaller, lighter engine that will save fuel costs. The flow control concepts were selected for compressor component applications in FY2000 based upon these studies. Work was also initiated on the design of a two-stage proof-of-concept compressor configuration, which would demonstrate experimentally the feasibility of the approaches being pursued in the UEET Program for achieving stage loading far in excess of the current state-of-the-art. Work was initiated in FY2000 on the design of a unique turbine component test facility (dual spool turbine facility (DSTF)) required for demonstrating the UEET program goals. This facility will allow for realistic configuration testing of highly loaded, closely coupled turbine designs emphasizing the understanding of the flow physics.

Flow control concepts for the fan and turbine components will be selected in FY2001 again based upon computational simulations. The most promising approaches for these components will be evaluated through proof-of-concept tests. (The fan component tests will be done in partnership with NASA's Quiet Aircraft Technology Program.) In FY2001, the detailed design of the unique world class turbine test facility will be initiated with completion scheduled for FY2002. In FY2001, evaluations will be conducted of a NASA developed turbine heat transfer simulation (GlennHT) using data supplied by industry. This simulation tool emphasizes the physics based modeling approach to predicting heat transfer as opposed to correlation approaches that represent the current state of the art.

In FY2002: the experimental testing of the two-stage proof-of-concept highly loaded compressor configuration will be completed and the results used in the design efforts of a four stage configuration. (This four stage configuration has projected performance levels (in terms of loading and efficiency) far in excess of the current state-of-the-art); the detailed design of the DSTF facility will be completed; and the initial evaluation of the GlennHT simulation tool will be completed.

Propulsion-Airframe Integration: In FY2000 a selection was to be made of the computational fluid dynamics simulation tool to be used to evaluate the installed performance of the engine concepts being evaluated. However this milestone was slipped to FY2001 to allow additional available experimental data to be employed in the selection process which will reduce the risk of the decision. In FY2000, evaluation efforts were conducted of candidate sensors and actuators required for the active flow control concepts being pursued.

In FY2001, 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 that were selected during FY2000 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. In FY2001, the selection will be made of a simulation tool to be used for evaluating installed engine performance on revolutionary air vehicle configurations.

In FY2002, laboratory tests will be completed to evaluate the feasibility of the active flow control and shape control concepts being evaluated. Efforts will be initiated in FY2002 for the FY2003 test of a blended wing body (BWB) configuration for experimental evaluation of the computational methodology being utilized in the program.

Intelligent Propulsion Controls: In FY2000 and 2001, initial laboratory experiments are being conducted to assess active combustion control concepts for emissions reduction and turbine engine life extension potential. The initial tests conducted in FY2000 at Stanford University have yielded very positive results. Efforts in FY2001 and 2002 will focus on evaluating the most promising approaches in more realistic combustor configurations (as part of the emissions reduction project). Parallel efforts are being conducted to model the active combustion control concepts using tools such as the National Combustor Code (NCC) and the Large Eddy Simulation (LES) methods. These computational tools initially will be calibrated/validated through comparison with experimental tests and then be used to guide the experimental efforts in the outer years of the program.

Efforts will be completed in FY2001 to determine projected system payoffs of intelligent control architectures for future gas turbine engines. These studies will provide guidance for additional UEET technology development efforts in the outer years of the project. Initial experimental and analytical efforts in the project will focus on the evaluation and selection of promising approaches for wireless sensors that will be a key part of any intelligent engine architecture of the future. In FY2001, the UEET Program will partner with the RevCon program to acquire data on a wireless sensor installed on an engine of the NASA C-17 testbed aircraft at DFRC. This real world data will provide important early on understanding which will help guide the direction of the project.

Integration & Assessment: In FY2000, revolutionary propulsion system concepts were defined for an array of 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 FY2001, a selection will be made of the propulsion system concept for which detailed, multi-disciplinary simulations will be conducted in FY2002 and beyond. 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. In FY2001 additional reference propulsion systems and vehicles will be added to the evaluation (i.e. hypersonic cruise/access to space and military transport). In FY2001, the metrics evaluation process will be finalized that will be used to track and report the status of the UEET Program to interested/involved stakeholders and customers on a regular basis. In FY2001, the initial results of the partnership efforts with the EPA to evaluate the impacts of UEET technologies on reducing the impact of future commercial aviation on the atmosphere and therefore improved quality of life will be completed. Partnership efforts with EPA and FAA will continue in FY2001 and 2002 to better understand the impacts of the trades which occur between emissions reductions (local air quality and cruise), airport noise reduction, and global warming (fuel burn reduction) and the impact on quality of life.

Integrated Component Technology Validation: In FY2000, plans were completed for an initial series of testbed demonstrations in partnership with industry to demonstrate two UEET technologies--CMC combustor liner and high temperature engine seals-–on existing engine test beds. In FY2001, design and fabrication efforts were completed to allow the testing in FY2002 of the 2200 deg F CMC combustor liner and an advanced high temperature engine seal designs. (These tests are being conducted in partnership with the industry with over 50 percent of the costs paid for by the industrial partner.)

In FY2000 studies were initiated with industry to determine additional opportunities for incorporating UEET component and materials technologies in partnership with DOD and/or the U. S. aeropropulsion industry using existing/available assets to accelerate the technology transition to commercial and military customers. The plans will be completed in FY2001 for the large thrust class engines (>20,000 lbs.) while the plans for smaller thrust class (<20,000 lbs.) will be completed early in FY2002. These studies also provide industrial partner perspectives on gas turbine designs required meeting the UEET goal of technologies for a 15 percent fuel burn reduction by 2005. This 15 percent reduction over 6 years of the program (or 2.5 percent per year average) represents a revolutionary challenge to the industry which has a history of 1 percent reduction in fuel burn per year in incremental improvement.

BASIS OF FY 2002 FUNDING REQUIREMENT

SMALL AIR TRANSPORT SYSTEM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Small Air Transport System..	-----	8,980	15,000

PROGRAM GOALS

The nation's commercial air transportation system has reached a plateau. The system's current capacity is limited, and the limits are being reached. One solution lies in off-loading the large hub airports by expanding access to the over 5000 smaller airports, most without control towers, that can serve small cities and communities across the country. New small, efficient aircraft that can use these airports in all weather will allow point-to-point transportation rates two to three times faster than highway speeds. The mobility that this would allow is important to community vitality and economic opportunity which increasingly depends on access to rapid point-to-point transportation, in particular air transportation. Today, communities with airports capable of handling smaller aircraft in near all-weather conditions create significant economic benefits compared to communities that are not served by such landing facilities. The vision of the Small Aircraft Transportation System (SATS) program is inter-modal connectivity between public and private, air and ground modes of travel, in essence a true integration of the National Airspace System with the interstate highway system, intra-city rail transit systems, and hub-and-spoke airports.

The goal of the five-year Small Aircraft Transportation System program is to develop key airborne technologies and provide a proof-of-concept evaluation for precision guidance of small aircraft to virtually any touchdown zone at small airports. The objective is to allow the use of underutilized airports (including those without control towers, radar, or precision instrument approaches) as well as underutilized airspace (such as the low-altitude, non-radar airspace below 6,000 feet and the enroute structure below 18,000 feet). If successful, the initial SATS operating capabilities have the potential to create alternative means to respond to the demand for increased throughput in the National Airspace System in the near term. In the future, the SATS technology investments create potential alternatives for addressing the nation's challenge of unmet transportation demand related to the spreading of congestion on highways and in the major airport system.

STRATEGY FOR ACHIEVING GOALS

The approach for the SATS program is to enable the adoption of three operational capabilities that are not possible in the current NAS environment. These capabilities are:

– Higher Volume Operations at Non-Towered/Non-Radar Airports. Simultaneous operations by multiple aircraft in non-radar airspace at and around small non-towered airports can create accessibility to virtually any landing site in the nation in near all-weather conditions. This SATS operating capability has the potential to create an alternative to growth of NAS and can provide a lower infrastructure cost alternative.

– Lower Landing Minimums at Minimally Equipped Landing Facilities. Highway in the Sky graphical flight path guidance with artificial vision can create near all-weather access to any touchdown zone at any landing facility while avoiding land acquisition and approach lighting costs, as well as ground-based precision guidance systems such as ILS.

– Flight Systems for Improved Total System Performance. Human-centered automation will provide intuitive, easy to follow flight path guidance superimposed on a depiction of the outside world. Software enabled flight controls and flight planning will increase single-crew operational safety and mission reliability to two-crew levels. This SATS operating capability can lead to higher levels of safety and throughput for increasing numbers of users in the NAS.

To enable these operational capabilities, the program is focused on developing the key airborne technologies to support the creation and evaluation of SATS operating capabilities. The enabling technologies include: self-sequencing and separation systems, airborne Internet, software-enabled controls, emergency auto-land, and “highway-in-the-sky” guidance. Coordination with other NASA programs, particularly the Aviation Safety and Aviation Systems Capacity programs, will be maintained to ensure technologies being developed in those programs can be leveraged to support the SATS concept and facilitate success. Coordination with the ASC program is also important to ensure that a fourth operational capability, enroute procedures and systems for integrated fleet operations, is addressed to enable integration of SATS-equipped aircraft into the higher en route air traffic and controlled terminal airspace. These technologies would enable near all-weather operations by new generations of such aircraft at virtually any landing facility in the nation. Near all-weather means operational reliability in instrument meteorological conditions except those classified as severe or hazardous (i.e., severe icing, severe turbulence, thunder storm activity, etc).

The outcome of the five-year proof of concept includes experimental data from flight and simulation evaluations as well as analysis of the implications of technologies on transportation system decision-making. A significant part of the strategy for achieving the SATS goal is participation by the Federal Aviation Administration (FAA). A Memorandum of Agreement between NASA and the FAA will guide this participation and ensure that the technology development and proof-of-concept evaluations addresses issues associated with aircraft certification, flight standards, air traffic, and airports. It will also be the documentation that provides for sharing of resources and the conduct of joint planning and implementation. Similar memoranda will be established with state and local governments and local airport authorities, as participation by these organizations is also important for the success of SATS.

The technologies targeted for development are aimed at smaller aircraft used for personal and business transportation missions within the infrastructure of smaller airports throughout the nation. These missions include transportation of goods and travel by individuals, families, or groups of business associates. Consequently the aircraft are of similar size to typical automobiles and vans used for non-commercial ground transportation. They may be used for on-demand, unscheduled air-taxi transportation of these same user types. Various forms of shared ownership and usage will likely be a most common means of use. While the aircraft are not specifically designed for commercial operations, the targeted technologies would provide benefits to commuter and major air carrier operations in the hub-and-spoke system as well. For FAA regulatory purposes, SATS technologies are targeted toward aircraft with a maximum take-off weight (MTOW) less than12, 500 pounds.

SCHEDULE AND OUTPUTS

Partnership Alliance Established Plan: September 2001	The mechanism for partnering with NASA has been defined and established with at least one agreement signed with an external partner (state/local government, industry, or university
Systems Engineering Documents Baselined Plan: December 2001	Complete preparation of the baseline System Engineering documents (including the Operational Requirements Document, Functional Architecture, and Technical Requirements Document) for SATS concept and place under configuration management.
Technology Downselect For Flight Experiments Plan: December 2002	Select candidate technologies for experimental flight evaluations and complete FAA operational approval process.

ACCOMPLISHMENTS AND PLANS

In FY2001, initial baseline designs of the 2005 proof-of-concept evaluations were develop for two candidate geographic regions. These baseline designs form the basis for the system-level operational requirements and functional architecture needed for selection of candidate technologies during the 2003 flight experiments. Teams consisting of both public and industry partners developed the designs. NASA's partnership with the FAA was also firmly established with the signing of a Memorandum of Agreement between the agencies that provides the mechanism for transfer of resources from NASA to the FAA needed to conduct joint planning for the SATS Program. Additional activities for FY2001 include baseline measurements of the performance, stability and control, and noise contours for several flight research test beds that will be used in both the flight experiments in FY2003 and the proof-of-concept evaluations in FY2005. A key component for periodic assessment of the program was developed: a multi-disciplinary system model for assessing the impact of technology advances on doorstop-to-destination time (mobility and accessibility), economic and environmental impacts, and system cost. This will allow tracking of progress towards program goals and guidance for technology investments for the program.

Plans for FY2002 include completion of the program's baseline system engineering documents, including the Operational Requirements Document, Functional Architecture, and Technical Requirements Document. These documents form the basis from which all technology investment and downselect decision will be made. A key activity will be the development of a simulation environment in which the collaborative sequencing and self-separation algorithms can be assessed. Design philosophies that will guide the development of the flight-deck technologies will also be established. These products will allow the program to begin ground-based experiments in FY2002 that will be used to establish the technology sets that will be evaluated during the FY2003 flight experiments. In support of these experiments, modifications to the flight research test beds that will facilitate hardware and software evaluations will also begin in FY2002. The systems architecture for the "airborne internet", the high-bandwidth digital communications system necessary to enable the three operating capabilities, will be defined. Additional environmental and economic impact studies to support the program assessment process will be initiated in FY2002 as will a total vehicle integration and design study. This design study will form the basis for the vehicle portion of the system cost assessment.

BASIS OF FY 2002 FUNDING REQUIREMENT

QUIET AIRCRAFT TECHNOLOGY PROGRAM

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Quiet Aircraft Technology Program	18,300	19,956	20,000

PROGRAM GOALS

The goal of the Quiet Aircraft Technology program is to contribute to the objectives of the Global Civil Aviation enabling technology goals, as stated in the Office of Aerospace 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.” 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.

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 criterion 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.

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 aerospace 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 257 in 1980, to over 832 in 2000. 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.

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.

STRATEGY FOR ACHIEVING GOALS

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 that 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.

The Quiet Aircraft Technology program will develop and validate technology in the laboratory for an additional 5 Effective Perceived Noise Level decibels (5 EPNdB) community noise impact reduction. 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 (TRL) (laboratory validation) to full-scale noise-component-reduction concept validation. 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.

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
Identify community noise impact reduction technology required to meet the 10-year, 10-db Enterprise Goal Plan: March 2002	Identify advanced concepts for airframe system noise reduction to be developed in QAT Define requirements for advanced noise abatement flight profiles Identify advanced concepts for engine system noise reduction to be developed in QAT
Initial version of improved aircraft systems noise prediction code delivered for NASA Plan: September 2002	Develop improved aircraft system noise prediction model accounting for placement of noise sources on non-conventional aircraft platforms, account for acoustic interactions between noise sources and platform and be user-friendlier.

ACCOMPLISHMENTS AND PLANS

In FY 2000 static engine tests were conducted on a Pratt & Whitney 4098 to demonstrate engine system noise reduction including both source noise reduction and advanced nacelle concepts. In these tests, an advanced "sugar scoop" inlet configuration and optimized inlet liner treatment validated a 2dB engine system noise reduction. A flight demonstration of a jet noise-reducing advanced engine exhaust nozzle has been slipped until March 2001 because of delays in negotiating industry participation. Advanced flight operations to reduce community noise impact (as much as 10dB on approach) were demonstrated in a flight test program. An improved semi-empirical airframe noise prediction code was completed. An innovative high lift concept demonstrating low noise and high aerodynamic performance was tested at model scale in the NASA-Langley Low Turbulence Pressure Tunnel and a detailed Boeing 777 landing gear was tested in the NASA-Ames 7x10 wind tunnel. Both these tests validated component contributions toward achieving the 4dB-airframe system noise reduction goal. A structural/ acoustic optimized passive/active noise control system was flight tested in a General Aviation airplane and identified the windshield as a major transmission path for interior noise. A series of system studies was 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 is being made (and will conclude in the first quarter of FY01) of the developed noise reduction technologies to date. This assessment will involve projecting model scale results to full- scale applications. In conjunction with the FAA, a flight test was conducted at NASA-Wallops to investigate airframe-shielding effects on perceived engine noise for wing- and aft-mounted engine configurations. These data will be used to improve the accuracy of community noise impact models, which is of particular interest to the FAA in formulating response to increased demands for regulatory stringency.

Plans in FY 2001 include the verification of technologies to reduce airframe noise 4 dB on a 26% model of a Boeing 777 in the NASA-Ames 40x80 wind tunnel, conducted under the Noise Reduction Element of the AVST Base technology program. This data will also be used for noise source prioritization in the QAT program. An active noise control system for fan tones will be demonstrated in a static engine test of a Pratt & Whitney 4098 engine. A flight demonstration of several engine system noise-reducing concepts (a variable area nozzle, "sugar scoop" inlet and a jet noise-reducing advanced engine exhaust nozzle) will be conducted on a Lear and Falcon jets. This data will also be used for a new mathematical model and prediction code for airframe shielding of engine noise. Jet noise-reducing engine exhaust nozzles and modeling of jet noise will be further developed. A test of active interior noise reduction concepts will be conducted. Improved interior noise measurement techniques will be 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, 10-dB community noise impact reduction goal. Unconventional aircraft configuration concepts will be reviewed and new concepts will be developed, including modifications of existing unconventional concepts. Concepts that show promise for substantial noise reduction (progress toward the enterprise 20-dB goal) with reasonable prospect of addressing performance issues will be selected for further study. Tools to model actual airport operations (e.g. de-rated take-off thrust and step-down approach trajectories) and actual atmospheric absorption characteristics (e.g. temperature and humidity) will be developed, thus enabling improved airport noise prediction. Noise abatement flight profiles and aircraft operational characteristics will be analyzed to generate operational and automation requirements enabling the design of guidance algorithms and airborne tools.

Plans for FY 2002 include the development of propulsion-airframe aeroacoustics as a systems approach to aircraft noise reduction. A physical description of key noise generating effects due to the engine nacelle pylon geometry and engine exhaust nozzle interaction with the airframe will be developed through noise and flow experiments and CFD analysis. The sensitivity of noise levels to a range of refractive atmospheric characteristics (e.g. wind and temperature gradients) will be determined in order to improve the accuracy of community noise impact models. Current models do not model the difference between upwind and downwind-perceived noise although those differences have been measured to be 5-10dB. Develop a new aircraft system noise prediction model that will account for the placement/movement of individual noise sources on non-conventional aircraft platforms, account for acoustic interactions between the noise sources and platform and be user-friendlier. Initial computer simulations will be developed for the required coordination between the air traffic management system and aircraft on-board systems to achieve consistent low noise operations in a wide range of airspace. Source diagnostics tests will be completed which will give engine component designer's insight into the fundamental physics of the mechanisms that generate broadband fan noise. The data generated by these tests will be used to improve the computational algorithms used in computer codes to predict engine noise. The design of an advanced concept for reduced jet noise will be initiated for testing at laboratory scale later in the QAT program.

BASIS OF FY 2002 FUNDING REQUIREMENT

SPACE LAUNCH INITIAITIVE

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Systems Engineering & Requirements Definition	-----	49,890	50,000
RLV Competition & Risk Reduction	-----	94,791	287,000
NASA-Unique Systems	-----	41,708	78,800
Alternative Access	-----	39,912	34,200
Future-X/ Pathfinder *	-----	45,200	25,000
2nd Generation RLV	-----	271,501	475,000
X-33	84,600	-----	-----
X-34	64,300	17,861	-----
Future X/Pathfinder *	34,500	-----	-----
Space Launch Initiative	183,400	289,362	475,000

* Future X/Pathfinder program remains unchanged and is only reflecting a realignment in FY 2001 to the 2nd Generation RLV Program.

PROGRAM GOALS

Low-cost, reliable space transportation remains the key enabler of a more aggressive civil space program. A central tenet of the National Space Policy has been 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 the 2005 time frame, NASA plans to enable a competition for NASA launch services, including human space flight, using commercially competitive, privately owned and operated, Earth-to-orbit Reusable Launch Vehicles (RLVs). The objective will be to dramatically improve safety while significantly reducing the cost of launch services.

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, design, and advanced development efforts to enable at least two competitive options for the mid-decade competition.

STRATEGY FOR ACHIEVING GOALS

The 2nd Generation RLV Program is divided into five major investment areas: Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction, NASA Unique Systems, Alternate Access to Station (AAS), and the Pathfinder program

The Systems Engineering and Requirements Definition effort is critical to establishing vehicle requirements and guiding investments to ensure viable competing architectures. 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.

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 in the 2005 timeframe. 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 NASA needs and competing industry concepts. The risk reduction activities will include 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 return on 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 NASA-unique transportation elements and systems. This element will address the additional systems (e.g. crew transport vehicle, cargo carriers, rendezvous and docking systems) necessary to meet unique NASA mission requirements (e.g. Space Station crew transport, cargo return, emergency rescue and return, satellite launch) 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. 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 are being conducted in parallel with the RLV Competition and Risk Reduction solicitations.

The fourth program element, Alternate Access to Station, 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 and includes necessary risk reduction activities to meet NASA's requirements. NASA will use the Next Generation Launch Services (NGLS), Small Expendable Launch Vehicle Service (SELVS), and NASA Launch Services (NLS) acquisition path as a means to develop contractual relationships with multiple emerging and existing U.S. vendors to meet this objective. These contracts will be for fixed-price services for indefinite delivery indefinite quantity launch contracts

The Pathfinder program was a separate focused activity in prior years, but has now been consolidated within the 2^{nd} Generation RLV program, in keeping with the common objectives of both activities. The objective of the Pathfinder program is to flight-demonstrate advanced space transportation technologies through the use of flight experiments and experimental vehicles, in support of the goal of dramatically reducing the cost of access to space. The Pathfinder Program utilizes innovative, streamlined and efficient management practices to accomplish high-quality demonstrations of 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.

The Pathfinder Program currently includes the development and operation of the X-37 experimental vehicle as well as a number of flight experiments. These projects were begun prior to the 2^{nd} Generation RLV program activities and, therefore, the technologies being addressed may not completely align with those required by the 2^{nd} Generation Program. However, through close coordination, these issues are being addressed, and all future activities selected in the Pathfinder Program will be explicitly linked to the 2^{nd} Generation RLV program requirements.

The X-37 Space Plane is a flying testbed, a modular demonstrator vehicle that will be the first experimental X-vehicle to be flown in both orbital and reentry environments. This project is being worked under a cooperative agreement with the Boeing Co. of Seal Beach, CA. The DoD has provided additional funds for a number of technologies of interest to them.

Currently, the X-37 is slated to fly two missions on the Space Shuttle, beginning in 2003. However, results from the Second Generation Program's NRA8-30 procurement could influence not only these plans, but also future plans for the X-37.

In addition to the X-37, the Pathfinder Program has a number of additional flight experiments. These experiments will conclude in 2001 and include:

- A Hall-effect Solar Electric Thruster system flight demonstration of new onboard in-space propulsion technologies;
- An experiment to demonstrate ultra-high temperature ceramics for reusable, sharp hypersonic leading edges;
- An experiment to demonstrate advanced in-space propulsion technologies using an electrodynamic tether.

SCHEDULE AND OUTPUTS

Receive Industry Proposals Plan: October 2000 Actual: December 2000	Received Industry proposals for evaluation on Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements within the 2^{nd} Generation RLV program

Contract award Plan: January 2001 Revised: April 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
Initial Architecture Review Plan: February 2002	Initial review of competitive 2nd Generation launch architectures, vis-à-vis progress to that point in Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements. This review is required prior to the next stage of the program, which will include a competitive down-selection focused on funding advanced development activities required to bring at least 2 viable concepts to readiness for the final competitive selection in the 2005 timeframe.
X-37 Roll out Plan: September 2001	X-37 Roll out
X-37 Atmospheric Drop test (unpowered) Plan: January 2002	Unpowered approach and landing tests of the X-37 vehicle.
X-37 First Orbital Flight Plan: September 2002 Revised: June 2003	Delayed due to Shuttle Manifesting. Revised date reflects earliest possible accommodation on the Shuttle, with the actual flight date depending on Shuttle availability.
ProSEDS Complete Plan: December 2000 Revised: August 2001	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 rise / lower orbit of a Delta II second stage. To be flown as a secondary payload on Delta II upper stage in August 2001.

ACCOMPLISHMENTS AND PLANS

In FY 2001, the 2nd Generation RLV Program solicited industry in the three major areas of Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems. Industry responded to NASA in December 2000 with proposals consistent with the program objectives. Multiple contract awards are planned for April 2001. NASA will pursue risk reduction efforts that will enable at least two competing architectures. 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.

A requirements/concepts study of potential Alternate Access to Station (AAS) responses was undertaken. These studies addressed a light payload, rapid response version and an augmentation heavy payload version. Results assessment of the AAS study by an Inter-center team (MSFC, LaRC, KSC, and JSC) are now in the final stage. AAS is currently involved in the 2nd Generation evaluation effort (January/February 2001) to determine if synergism opportunities exist. The next phase of the AAS effort is anticipated to be the demonstration of technologies required for autonomous rendezvous proximity operation in the orbital environment.

In FY2001, approach and landing tests of the X-40A will be completed and X-37-Shuttle integration analyses will continue. Trade studies for alternate launch platforms such as an Expendable Launch Vehicle (ELV) will also be initiated. Fabrication, assembly and integration of the X-37 will be completed and the X-37 will be rolled out and pre-flight ground tests will begin.

In FY 2001, launch of the ProSEDS experiment will occur. Data analysis on the material from the SHARP-B2 experiment will be completed and a final report will be generated.

In FY 2002, the 2nd Generation RLV program will complete the initial review of competitive launch architectures, vis-à-vis progress to that point in Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements. This review is required prior to the next stage of the program, which will include a competitive down-selection focused on funding advanced development activities required to bring at least 2 viable concepts to readiness for the final competitive selection in the 2005 timeframe.

In FY 2002, approach and landing test flights of the X-37 will be conducted and preparations for the first Shuttle or ELV flight will begin.

BASIS OF FY 2002 FUNDING REQUIREMENT

X-33

	FY2000	FY2001	FY2002
	(Thousands of Dollars)		
X-33	84,600	-----	-----

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 utilized an innovative management strategy for the X-33 program, based on industry-led cooperative agreements. In following this management strategy, the participants did not play traditional roles, with government overseeing and directing the work of the industry contractors. Instead, government participants acted as partners and subcontractors, performing tasks for industry because the government-industry team believed that these government team members offered the most effective means to accomplish certain program objectivesThe industry-led cooperative arrangement allowed a much leaner management structure, lowered 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 has been an integrated technology effort to flight-demonstrate key technologies required for the next generation of reusable launch vehicles (RLV), and deliver advancements in: 1) ground and flight operations techniques that will substantially reduce operations costs for an RLV; 2) lighter, reusable conformal cryogenic tanks; 3) lightweight, low-cost composite structures; 4) advanced Thermal Protection Systems to reduce maintenance; 5) aerospike engine propulsion and vehicle integration; and, 6) application of New Millennium microelectronics for vastly improved reliability and vehicle health management.

SCHEDULE AND OUTPUTS

X-33 Thermal Protection System (TPS) Delivery Plan: May 2000 Actual: May 2000	Delivery of complete Thermal Protection System for X-33 flight demonstrator. Manufacturing process revised, to improve industry's ability to produce. The X-33 program will come to completion when the cooperative agreement between NASA and Lockheed Martin expires on March 31, 2001. The X-33 program was not selected for additional funding in the 2nd Generation NRA8-30 procurement as NASA determined that the benefits to be derived from continuing the program did not warrant additional government investment.
X-33 Vehicle to Roll out Plan: January 2000 Deleted	X-33 flight demonstrator vehicle rollout enabling final checkout. The X-33 program will come to completion when the cooperative agreement between NASA and Lockheed Martin expires on March 31, 2001. The X-33 program was not selected for additional funding in the 2nd Generation NRA8-30 procurement as NASA determined that the benefits to be derived from continuing the program did not warrant additional government investment.
X-33 First Flight Plan: July 2000 Deleted	The flight test program, based at Edwards Air Force Base, was to fly at speeds greater than Mach 13. The X-33 program will come to completion when the cooperative agreement between NASA and Lockheed Martin expires on March 31, 2001. The X-33 program was not selected for additional funding in the 2nd Generation NRA8-30 procurement as NASA determined that the benefits to be derived from continuing the program did not warrant additional government investment.

ACCOMPLISHMENTS AND PLANS

In FY 2000 the composite hydrogen-tank failure investigation team released its findings that unanticipated micro cracking of the tank lobe's inner skins at cryogenic temperatures, allowing liquid hydrogen leakage, was the root cause of the failure. The design of the aluminum replacement tanks was essentially completed and the long-lead manufacturing needs initiated. Flight and simulation software installation in the Integrated Test Facility at the Dryden Flight Research Center continued for verification and validation. In addition, the linear aerospike single-engine testing at the Stennis Space Center was successfully completed, demonstrating the operational ranges of the engine systems including throttle capability for required for vehicle control. Flight engines 2 & 3 were mated in their flight configuration and installed in the Stennis Center's A1 test stand for dual-engine testing. Vehicle assembly and check out continued at a slowed pace with work-arounds due to the absence of the hydrogen tanks.

In September 2000, NASA and Lockheed Martin agreed on a path forward for the X-33 program. Based on that agreement, the focus of the program was concentrated in two areas: completing the design and beginning the production of the liquid hydrogen tanks and qualifying the flight engines for the X-33 vehicle. Ninety-five percent of the hardware on the program has been built, tested and delivered to the Palmdale assembly facility. This excludes the two flight engines and the aluminum liquid hydrogen tanks.

The vehicle's two flight engines have been joined in a dual configuration and placed in the test stand for simultaneous firings. Cold flow tests took place in December 2000 and concluded in mid-January 2001. Initial hot-fire ignition tests were successfully completed in February 2001.

Following The Preliminary and Critical Design Reviews, the team at Lockheed Martin Space Systems, Michoud Operations set to the task of building a production "pathfinder" panel to validate feasibility of weight reduction strategies. They began with a piece of aluminum weighing 1 1/2 Tons (2950 lbs.) and reduced the weight to 175 lbs. The unique size and shape of the X-33's liquid hydrogen tanks makes this process significantly more complex than that used on the aluminum liquid oxygen tank already complete and installed on the X-33.

Work continued on the tank design to identify any interface changes that need to be made as a result of the switch to aluminum. Since most of the X-33 vehicle hardware has already been built, the LH2 metal tank is designed to emulate the composite tank as much as practical to minimize the interface changes and program costs.

The X-33 Nose Cap entered the last stages of production and nearing completion. Made of an extremely durable carbon-carbon material with an operating range from minus 250° F to about 3,000° F, it is highly resistant to the fatigue loading that would be experienced during ascent and entry.

The robust metallic thermal protection shield (TPS) is 95 percent complete with 1,224 of the panels delivered The panels are attached using only four bolts, making application and removal much simpler and efficient than current methods. The metallic panels have been proven to withstand temperatures near 1,800 degrees Fahrenheit in a series of wind tunnel and arc-jet tests.

The avionics bay was fully wired and put through a series of on-going systems checks resulting in "powering-on" the forward third of the vehicle. During these checks, the power is brought up incrementally to several systems using flight software, ground power supplies and ground software. To date the X-33 has been successfully "powered-on" more than 75 times.

Manufacturing progress continued with the recent completion of the aft thrust structure which would house the two linear aerospike flight engines, the umbilical connections and the reaction control system thrusters while enclosing and protecting the rear of the vehicle.

The body flaps, which would control pitch of the vehicle in flight, are structurally complete and have been through a series of successful "fit" checks. The canted fins are 75 percent complete, awaiting application of the carbon-carbon thermal protection material on the leading edge of the fins. The vertical fins, which house the rudders, are now 100 percent complete.

The rudder actuators are in final checkout and soon will be installed to fully complete the fins. In concert with the canted fins, the vertical fins would stabilize the X-33 in flight.

The X-33 program will come to completion when the cooperative agreement between NASA and Lockheed Martin expires on March 31, 2001. The X-33 program was not selected for additional funding in the 2nd Generation NRA8-30 procurement, as NASA determined that the benefits to be derived from continuing did not warrant additional government investment.

BASIS OF FY 2002 FUNDING REQUIREMENT

X-34

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
X-34	64,300	17,861	---

PROGRAM GOALS

The X-34 objective is to demonstrate technologies and operations concepts with the goal of reducing space transportation costs to one tenth of their current level. The Pathfinder Program formally managed the X-34 project. This project competed for funds under the 2nd Generation RLV Risk Reduction NRA 8-30 but was not selected. NASA's OAT selected to terminate the project in March 2001.

SCHEDULE AND OUTPUTS

X-34 First Unpowered Flight Plan: April 2000 Deleted	The flight test program will expand in increments to assure success. Additional funding for X-34 risk reduction competed within the SLI evaluation of 2nd Generation RLV NRA 8-30 proposals. The X-34 was not selected for funding under the NRA8-30 as NASA determined that the benefits to be derived from continuing the X-34 program did not warrant additional government investment. The program was cancelled in March 2001.
X-34 First Powered Flight Plan: August 2000 Deleted	The flight program will expand the flight profile with initial, unpowered flights to be followed by powered flights that will reach Mach 8. Additional funding for X-34 risk reduction competed within the SLI evaluation of 2nd Generation RLV NRA 8-30 proposals. The X-34 was not selected for funding under the NRA8-30 as NASA determined that the benefits to be derived from continuing the X-34 program did not warrant additional government investment. The program was cancelled in March 2001.

Delivery of IVHM experiment Plan: June 2001 Revised: Deleted	The Integrated Vehicle Health Monitoring (IVHM) experiment is delivered for installation on X-34 vehicle A-3. Additional funding for X-34 risk reduction competed within the SLI evaluation of 2nd Generation RLV NRA 8-30 proposals. The X-34 was not selected for funding under the NRA8-30 and the program was cancelled in March 2001.

ACCOMPLISHMENTS AND PLANS

In 2000, the X-34 A-1A vehicle assembly was completed and began testing at Dryden Flight Research Center. The vehicle underwent a series of captive-carry flights and high-speed ground tow tests. The X-34 A-2 vehicle assembly is in process and subsystem tests were performed as required. The X-34 A-3 vehicle-airframe fabrication began in 2000 as scheduled.

The main propulsion system for the X-34 vehicle, the MC-1 engine, continued testing including a full-duration firing. To date, the engine has undergone approximately 45 hot-fire tests. The flight engine was delivered to Orbital Sciences Corporation and was integrated with A-2 vehicle.

Approximately ten operational and vehicle technologies embedded in the design and hosted as test articles continue to progress through planned milestones.

In FY2000, the program was thoroughly reviewed by a NASA Risk Evaluation team.

In FY2000, a NASA and Orbital Sciences Corporation review revealed the need to redefine the project scope, budget, and schedule. The redefined project included additional risk reduction hardware and testing that would significantly improve the likelihood of mission success. NASA required that X-34 risk reduction funding should be competed for within the SLI ISTP competitive process.

Additional funding for X-34 risk reduction competed within the SLI evaluation of 2nd Generation RLV NRA 8-30 proposals. The X-34 was not selected for funding under the NRA8-30 and the program was cancelled in March 2001.

BASIS OF FY 2002 FUNDING REQUIREMENT

AEROSPACE INSTITUTIONAL SUPPORT

	FY 2000 OPLAN 1/18/01	FY 2001 PLAN 3/1/01	FY 2002 PRES BUDGET
	(Thousands of Dollars)		
Research and Program Management (R&PM)	[649,990]	[722,995]	781,631
Labor	[513,523]	[589,551]	602,775
Travel	[13,156]	[14,965]	16,385
Research Operations Support (ROS)	[123,311]	[118,479]	162,472
Construction of Facilities (CoF) - (Non-Programmatic)	[58,962]	[87,363]	89,607
Institutional Support to Aerospace Technology	**[708,953]**	**[810,359]**	**871,239**

Distribution of Program Amount by Installation			
Johnson Space Center	[3,049]	[3,176]	3,220
Kennedy Space Center	[16,163]	[14,580]	13,863
Marshall Space Flight Center	[88,267]	[95,082]	97,210
Stennis Space Center	[14,861]	[22,285]	14,626
Ames Research Center	[121,010]	[148,403]	152,728
Dryden Flight Research Center	[55,984]	[58,125]	54,277
Langley Research Center	[185,710]	[199,490]	214,184
Glenn Research Center	[141,797]	[178,923]	177,072
Goddard Space Flight Center	[8,871]	[11,447]	11,980
Jet Propulsion Laboratory	[4,875]	[5,837]	8,552
Headquarters	[68,366]	]73,011]	123,527
Total	{708,953}	{810,359}	871,239

Aerospace Technology Full-Time Equivalent (FTE) Workyears	**4345**	**4713**	**4710**

* Numbers in brackets are the prior year totals to reflect a correct representation of the cross-year funding levels.

PROGRAM GOALS

The two primary goals of this budget segment is to:

1. Acquire and maintain a civil service workforce, that reflects the cultural diversity of the Nation and, along with the infrastructure, is sized and skilled consistent with accomplishing NASA's research, development, and operational missions with innovation, excellence, and efficiency for the Aerospace Technology Enterprise.

2. Ensure that the facilities critical to achieving Aerospace Technology Enterprise program goals are constructed and continue to function effectively, efficiently, and safely, and that NASA installations conform to requirements and initiatives for the protection of the environment and human health.

RESEARCH AND PROGRAM MANAGEMENT (R&PM): program provides the salaries, other personnel and related costs, travel and the necessary support for all administrative functions and other basic services in support of research and development activities at NASA installations. The salaries, benefits, and supporting costs of this workforce comprise approximately 79% of the requested funding. Administrative and other support is approximately 19% of the requests. The remaining 2.0% of the request are required to fund travel necessary to manage NASA and its programs.

CONSTRUCTION OF FACILITIES (CoF): budget line item provides for discrete projects required for components of the basic infrastructure and institutional facilities and almost all are for capital repair. NASA facilities are critical for the Aerospace Technology Enterprise, to sustaining the future of aeronautics and advanced space transportation, which both support military and private industry users. NASA has conducted a thorough review of its facilities infrastructure finding that the deteriorating plant condition warrants an increased repair and renovation rate to avoid safety hazards to personnel, facilities, and mission; and that some dilapidated facilities need to be replaced. Increased investment in facility revitalization is needed to maintain a facility infrastructure that is safe and capable of supporting NASA's missions.

ROLES AND MISSIONS

The detail provided here is for the support of the Aerospace Technology Enterprise institutions - Ames Research Center, Dryden Flight Research Center, Glenn Research Center, Langley Research Center, Marshall Space Flight Center, Stennis Space Center, and Goddard Space Flight Center.

AMES RESEARCH CENTER (ARC)

The Aerospace Technology Enterprise funds approximately 69% of ARC's Institution cost. ARC conducts aeronautics research in ground-based and airborne automation technologies, human factors, and operational methodologies for safe and efficient airspace operations. They provide Agency-wide leadership in conducting research and technology development to enable and foster the intelligent vehicle of the future through the implementation of integrated vehicle health management as a vehicle discipline. They provide high-fidelity flight simulations to support national goals in aviation safety and capacity, as well as vehicle development requirements. They conduct research, spanning computation through flight, for high-performance aircraft, to improve efficiency, affordability, and performance. They are also developing an integrated set of experimental and computational technologies built around an embedded information systems backbone, to provide rapid, accurate vehicle synthesis and testing capabilities.

ARC scientists and technologists conduct research on advanced thermal protection systems and perform arcjet testing to meet national needs for access to space and planetary exploration. Ames is the lead center for information technology efforts in the Space Base program (formerly called Cross-Enterprise Technology). In addition, Ames is the lead center for the Intelligent Systems program, which provides critical, next-generation information technology capabilities for NASA missions and activities.

DRYDEN FLIGHT RESEARCH CENTER (DFRC)

The Aerospace Technology Enterprise funds approximately 75% of DFRC's Institution cost. DFRC develops, manages, and maintains facilities and testbed aircraft to support safe, timely, and cost-effective NASA flight research and to support industry, university, and other government agency flight programs. Dryden FTEs conceive, formulate, and conduct piloted and unpiloted research programs in disciplinary technology, integrated aeronautical systems, and advanced concepts to meet current and future missions throughout subsonic, supersonic, and hypersonic flight regimes. DFRC will also provide flight test support for atmospheric tests of experimental or developmental launch systems, including reusable systems. DFRC's flight research programs are conducted in cooperation with other NASA installations, other government agencies, the aerospace industry, and universities.

GLENN RESEARCH CENTER (GRC)

The Aerospace Technology Enterprise funds approximately 72% of GRC's Institution cost. As the NASA Lead Center for Aeropropulsion, GRC conducts world-class research critical to the Agency Aerospace Technology Enterprise goals of developing and transferring enabling technologies to U.S. industry and other government agencies. The Center's Aeropropulsion programs are essential to achieving National goals to promote economic growth and national security through safe, superior, and environmentally compatible U.S. civil and military aircraft propulsion systems. The Aeropropulsion program at GRC spans subsonic, supersonic, hypersonic, general aviation, high-performance aircraft, as well as access-to-space propulsion systems. The program pursues innovative applications of research in turbomachinery materials, structures, internal fluid mechanics, instrumentation and controls, interdisciplinary technologies, and aircraft icing. GRC has research expertise in world-class facilities critical to ensuring U.S. leadership in aviation. FAA, EPA, and DOD in particular depend on NASA GRC research for advancements in emissions, noise, engine performance and new materials.

As the NASA Center of Excellence in Turbomachinery, GRC expertise is critical to advancing the Agency's goals in our aeronautics and space programs and enables GRC to be a cost-effective resource across multiple Agency programs. Turbomachinery-based areas of expertise include air breathing propulsion and power systems, primary and auxiliary propulsion and power systems, on-board propulsion systems, and rotating machinery for the pumping of fuels/propellants.

LANGLEY RESEARCH CENTER (LaRC)

The Aerospace Technology Enterprise funds approximately 78% of LaRC's Institution cost. The LaRC conducts advanced research in fundamental aerodynamics; high-speed, highly maneuverable aircraft technology; hypersonic propulsion; guidance and controls; acoustics; and structures and materials. They are developing a technology base for improving transport, fighter, general aviation, and commuter aircraft. These LaRC scientists and technologists are conducting an aeronautical research and technology program to study current and future technology requirements and to demonstrate technology applications. They conduct theoretical and experimental research in fluid and flight mechanics to determine aerodynamic flows and complex aircraft motions. They are also conducting research to develop technologies and capabilities that permit the integration of widely distributed science, technology, and engineering teams and that provide advanced tools enabling the teams to create innovative, affordable products rapidly.

LaRC develops innovative new airframe systems to improve safety, reduce emissions and cut noise levels. These new airframe systems technologies will improve environmental compatibility, increase capacity, and reduce cost per seat mile of commercial transport and general aviation aircraft. LaRC technologists conduct control and guidance research programs to advance technology in aircraft guidance and navigation, develop aircraft control systems, improve cockpit systems integration and interfacing techniques, and enhance performance validation and verification methods. LaRC also conducts research in aircraft noise prediction and abatement. LaRC personnel are pioneering the development of new materials, structural concepts, and fabrication technologies to revolutionize the cost, performance, and safety of future aircraft structures while creating radically new aircraft designs. LaRC provides Agency wide leadership and strategically maintains or increases the agency's preeminent position in structures and materials by serving as the NASA Center of Excellence for Structures and Materials.

LaRC scientists and technologists also conduct aeronautics and space research and technology development for advanced aerospace transportation systems, including hypersonic aircraft, missiles, and space access vehicles using airbreathing and rocket propulsion. Specific technology discipline areas of expertise are aerodynamics, aerothermodynamics, structures, materials, hypersonic propulsion, guidance and controls, and systems analysis. They also conduct long-range studies directed at defining the technology requirements for advanced transportation systems and missions. In addition, they develop technology options for realization of practical hypersonic and transatmospheric flight.

MARSHALL SPACE FLIGHT CENTER (MSFC)

The Aerospace Technology Enterprise funds approximately 27% of MSFC's Institution cost. The MSFC is the NASA Lead Center for space transportation systems development. The MSFC FTE's plan, direct, and execute research, technology maturation, advanced design and development, and sustaining engineering for NASA's next-generation space transportation systems. These systems include reusable launch vehicles and other associated transportation systems and subsystems. MSFC will integrate program and project level planning, research, and development to ensure a well-balanced space transportation development program that meets the Agency's aggregate needs in a coordinated and integrated manner. MSFC people will develop technology in vehicle and propulsion systems, advanced manufacturing processes, and materials and structures. The Center will conduct technology efforts, under contract including cooperative agreements, with the U.S. launch vehicle industry, to improve the competitiveness of current systems.

STENNIS SPACE CENTER (SSC)

The Aerospace Technology Enterprise funds approximately 25% of SSC's Institution cost. SSC supports the development of new and innovative propulsion technologies by providing propulsion test capabilities for the Space Launch initiative, including both 2nd Generation and 3rd Generation systems.

GOODDARD SPACE FLIGHT CENTER (GSFC)

The Aerospace Technology Enterprise funds approximately 3% of GSFC's Institution cost. GSFC directs the Wallops Flight Facility which provides institutional and technical support to LaRC, other NASA centers, and commercial users, who conduct flight studies of new approach and landing procedures using the latest in guidance equipment and techniques, pilot information displays, human factors data, and terminal area navigation.

HEADQUARTERS

The Aerospace Technology Enterprise funds approximately 38% of Headquarters' Institution cost. The Enterprise's Institutional Support figure includes an allocation for funding Headquarters activities based on the relative distribution of direct FTE's across the agency. A more complete description can be found in the Mission Support/two Appropriation budget section.