NASA STTR 2005 Phase I Solicitation

Small Business Technology Transfer

Ames Research Center Topic T1

NASA Ames Research Center is located at Moffett Field, California in the heart of Silicon Valley. Ames was founded December 20, 1939 as an aircraft research laboratory by the National Advisory Committee for Aeronautics (NACA). In 1958, Ames became part of National Aeronautics and Space Administration (NASA). Ames specializes in research geared toward creating new knowledge and new technologies that span the spectrum of NASA's interests.

Sub Topics:

T1.01 Information Technologies for System Health Management, Autonomy, and Scientific Exploration

Lead Center: ARC

Information technology is a key element in the successful achievement of NASA's strategic goals. Modern tools and techniques have the capability to redefine many design and operational processes as well as enable grand exploration and science investigations. This subtopic seeks innovative solutions to the following information technology challenges:

- Onboard methods that monitor system health and then automatically reconfigure to respond to failures and sustain progress toward high-level goals. Special emphasis will be on computational techniques for coordinating multi-agent systems in the presence of anomalies or threats;

- Onboard, real-time health management systems that perform quickly enough to monitor a flight control system (including spacecraft and fixed or rotary wing aircraft) in a highly dynamic environment and respond to anomalies with suggested recovery or mitigation actions;

- Integrated software capabilities that allow automated science platforms, such as rovers, to respond to high-level goals. This could include perception of camera and other sensor data, position determination and path planning, science planning, and automated analysis of resulting science data;

- Data fusion, data mining, and automated reasoning technologies that can improve risk assessments, increase identification of system degradation, and enhance scientific understanding;

- Techniques for interconnecting and understanding large heterogeneous or multidimensional data sets or data with complex spatial and/or temporal dynamics;

- Computational and human/computer interface methodologies for inferring causation from associations and background knowledge for scientific, engineering, control, and performance analyses;

- Software generation tools that capture designer intent and performance expectations and that embed extra knowledge into the generated code for use by automated software analysis tools doing validation and verification, system optimization, and performance envelope exception handling;
• Tools and techniques for program synthesis and program verification of high-assurance software systems; and

• Innovative communication, command, and control concepts for autonomous systems that require interaction with humans to achieve complex operations.

T1.02 Space Radiation Dosimetry and Countermeasures

Lead Center: ARC

As NASA embarks on a new exploration agenda, the study of the space radiation environment and its effects on living things and support technologies will be critical for the success of long-term missions. Our current understanding of the space radiation environment, particularly high atomic number and energy particles (HZE particles) and energetic protons, and its interaction with materials, technological systems, and living things is limited compared to our understanding of Gamma and X-rays. NASA has established a space radiation laboratory at Brookhaven National Labs capable of generating HZE particles and protons, and supports a facility at Loma Linda University Medical Center capable of generating energetic protons to enable research studies. We seek innovative technology solutions in the following areas:

Advanced Dosimetry Systems

• Real-time dosimetry providing dose and particle types and energies for use onboard spacecraft and planetary habitats;
• Real-time and cumulative dosimeters for characterizing space environments including planetary surfaces;
• Alarm systems for Solar Particle Events; and
• Microdosimetry for research applications including implantable dosimeters for biological studies.

Radiation Hardened Electronic Systems

• Methods for hardening pre-existing technologies; and
• Novel materials and circuit design.

Shielding Materials and Systems

• Multi-use materials for spacecraft and habitat fabrication (high strength, high shielding characteristics, embedded dosimetry, or warning devices);
- Materials for advanced EVA suits; and
- Alternative non-materials based shielding technologies.

Life Support Systems Composition and Monitoring

- Technologies to monitor the composition and health of biological components (microbial and plant) of life support and bio-remediation systems; and
- Development of radiation resistant organisms for life support and bio-remediation systems.

Biological Markers of Human Radiation Exposure

- Identify markers of radiation damage that can be obtained in a minimally invasive manner; and
- Technological systems to identify and quantitate biological markers onboard spacecraft and planetary habitats.

Astronaut Health Countermeasures

- Pharmaceuticals to counteract the deleterious effects of space radiation exposure;
- Gene therapy and other biological approaches; and
- Markers for genetic susceptibility to space radiation damage.

Dryden Flight Research Center Topic T2

Flight Research separates "the real from the imagined" and makes known the "overlooked and the unexpected." -Hugh L. Dryden. The Dryden Flight Research Center, located at Edwards, California, is NASA's primary installation for flight research. Projects at Dryden over the past 50 years have lead to major advancements in the design and capabilities of many civilian and military aircraft. The history of the Dryden Flight Research Center is the story of modern flight research in this country. Since the pioneering days after World War II, when a small, intensely dedicated band of pilots, engineers, and technicians dared to challenge the "sound barrier" in the X-1, Dryden has been on the leading edge of aeronautics, and more recently, space technology. The newest, the fastest, and the highest - all have made their debut in the vast, clear desert skies over Dryden.
Sub Topics:

**T2.01 Flight Dynamic Systems Characterization**

Lead Center: AFRC

This topic solicits proposals for innovative, linear or non-linear, aerospace vehicles dynamic systems modeling and simulation techniques. In particular:

Research and development in simulation algorithms for computational fluid dynamics (CFD), structures, heat transfer, and propulsion disciplines, among others: in particular, emphasis is placed on the development and application of state-of-the-art, novel, and computationally efficient solution schemes that enable effective simulation of complex practical problems such as modern flight vehicles, like X-43 and F-18-AAW, as well as more routine problems encountered in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered an important part of this topic.

Aeroelasticity and aeroservoelasticity, linear and non-linear: vehicle stability analysis is an important aspect of this topic. Primary concern is with the development and application of novel, multidisciplinary, simulation software using finite element and other associated techniques.

**T2.02 Advanced Concepts for Flight Research**

Lead Center: AFRC

This topic is intended to be broad and to solicit and promote technologies for the following:

- Automated online health management and data analysis;
- 21st Century air-traffic management with Remotely Operated Aircraft (ROA) within the National Air Space; and
- Modeling, identification, simulation, and control of aerospace vehicles in-flight test, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts.

Proposals in any of these areas will be considered.

Online health monitoring is a critical technology for improving transportation safety. Safe, affordable, and more efficient operation of aerospace vehicles requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local and wide area networks. Online health monitoring is a general
concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of online emphasizes algorithms that minimize the time between data acquisition and decision making.

The challenges in Air Traffic Management (ATM) are to create the next generation systems and to develop the optimal plan for transitioning to future systems. This system should be one that seamlessly supports the operation of ROAs. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.

Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influences of structural dynamics, thermal dynamics, steady and unsteady aerodynamics, and the control system. The benefit of this effort will ultimately be an increased understanding of the complex interactions between the vehicle dynamics subsystems with an emphasis on flight test validation methods for control-oriented applications. Proposals for novel multidisciplinary nonlinear dynamic systems modeling, identification, and simulation for control objectives are encouraged. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance and load control (including smart actuation and active aerostructural concepts), autonomous health monitoring for stability and performance, and drag minimization for high efficiency and range performance. Methodologies should pertain to any of a variety of types of vehicles ranging from low-speed, high-altitude, long-endurance to hypersonic and access-to-space aerospace vehicles.

Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this topic is the development of sensors, sensor systems, sensor arrays, or instrumentation systems for improving the state-of-the-art in aircraft ground or flight-testing. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight testing by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This topic solicits proposals for improving airborne sensors and sensor-instrumentation systems in all flight regimes-particularly transonic and hypersonic. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.

This topic further solicits innovative flight test experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment. The emphasis of this topic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and that require a demonstration in an actual-flight environment to fully characterize or validate advances.
The NASA Glenn Research Center at Lewis Field, in partnership with other NASA Centers, U.S. industries, universities, and other Government institutions, develops critical technologies that address national priorities for space and aeronautics applications. NASA Glenn's world-class research and technology development is focused on space power, space flight, electric and nuclear space propulsion, space and aeronautic communications, advanced materials research, biological and physical microgravity science, and aerospace propulsion systems for safe and environmentally friendly skies. One-third of NASA Glenn's program responsibilities are in space and microgravity, one-third in space exploration systems, and one-third in aeronautics. We support NASA's commitment to safely return the shuttle to flight through ballistic impact testing, rudder speed brake actuator analysis, on-orbit repair of the wing, leading edge research, aging analysis, and wind tunnel tests of the external tank. NASA Glenn has two sites in northern Ohio. Situated on 350 acres of land adjacent to the Cleveland Hopkins International Airport, the Cleveland site in northeast Ohio comprises more than 140 buildings including 24 major research facilities and over 500 specialized research and test facilities. Plum Brook Station is 50 miles west of Cleveland and has four major world-class facilities for space research available for Government and industry programs. The staff consists of over 3200 civil service and support service contractor employees. Scientists and engineers comprise more than half of our workforce with technical specialists, skilled workers, and administrative staff supporting them. Over 60 percent of our scientists and engineers have advanced degrees, and 25 percent have earned Ph.D. degrees.

Sub Topics:

T3.01 Aerospace Communications

Lead Center: GRC

The research sought under Aerospace Communications focuses on the development of innovative communications, architectures, networks, and subsystems that significantly increase the capacity and connectivity among satellites, spacecraft, aircraft and ground networks thereby enabling new applications and services. These technologies are aimed at improving the power, bandwidth, and cost efficiency of communications at millimeter-wave frequencies and higher, and the interoperability, reliability, security, and quality of services of aerospace networks. The goal is to address the requirements of: NASA's Vision for Space Exploration, National Airspace System capacity, safety, and transportation initiatives; NASA's mission-unique applications; and NASA's utilization of emerging commercial communications services.

Innovations solicited include:

- Development of monolithic microwave integrated circuit (MMIC)-based arrays and array feeds, large-aperture inflatable antennas, miniaturized antennas, and trade-off studies among different antenna technologies for space applications. Potential lower cost, space-fed, active array and reflectarray approaches are also of interest as well as other MMIC and non-MMIC-based approaches (e.g., MEMS-,
ferroelectric-, and optical-based approaches);

- Radio Frequency (RF) and optical propagation phenomena through atmosphere and turbulent media, development and validation of communication systems for aviation safety and aviation capacity, and other related electromagnetic phenomena;

- Digital communications, navigation, and surveillance technologies required for aeronautical communications, navigation, and surveillance (CNS) and space communications systems. Specific technologies include: software-defined radios; low-power, reconfigurable transceivers; multi-function, multi-mode digital avionics; network interface controllers, hubs, and routers for space; bandwidth- and power-efficient digital modems; advanced signal processing techniques; and integrated microelectronic or optoelectronic devices;

- Research and development of advanced microwave materials, devices, and circuits as well as the technologies required for integrating individual circuit components into microwave subsystems. Research in high-power transmitters focused on improving efficiency, RF power output, reliability, operating life, and communications qualities (such as linearity of a traveling wave tube amplifier for use in space communications). RF power combining techniques at Ka-Band frequencies are also of interest;

- Research on semiconductor circuits for transmit and receive modules in operational frequency bands designated for NASA's Exploration Systems vision. Specific technologies under development include: wide bandgap semiconductors, such as gallium nitride and silicon carbide; III-V semiconductors; silicon germanium; radio frequency micro-electromechanical systems (RF MEMS) devices/circuits; radio frequency integrated circuits including transmission lines and passive components; and microwave circuit packaging techniques;

- Cryocooled ultra-sensitive receivers for use in terrestrial antenna arrays for reception of signals from deep space and for inter-satellite links;

- Emerging technologies such as, multi-Gb/s photonic and nano-electronics based devices and circuits; and

- Research and development of advanced aerospace communications network architectures, protocols, standards, technologies, and network-based applications. Specific areas of interest include transmission control protocols, modifications, and enhancements to mitigate variable delays and high latency, next generation transport protocols, mobile-Internet protocols/routing, ad-hoc networking, and quality-of-service protocols, design, and implementation of advanced hybrid architectures to support NASA applications.

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**T3.02 Space Power and Propulsion**

**Lead Center: GRC**

Development of innovative technologies and systems are sought that will result in robust, lightweight, ultra-high efficiency, lower cost, power and in-space propulsion systems that are long-lived in the relevant mission environment and that enable future missions. The technology developments being sought would, through highly-efficient generation and utilization of power and in-space propulsion, significantly increase the system performance, thereby enabling future NASA missions.

Innovations are sought that will significantly improve the efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, flexibility/reconfigurability, and autonomy of space power systems. In power generation, advances are needed in photovoltaic cell structure including the incorporation of nano-materials;
module integration including monolithic interconnections and high-voltage operation; and array technologies including ultra-lightweight deployment techniques for flexible, thin-film modules, and concentrator techniques as well as dynamic power generation systems for nuclear power conversion. In energy storage systems, advances are needed in batteries-primary and rechargeable-regenerative fuel cells, and flywheels. Advances are also needed in power management and distribution systems, power system control, and integrated health management.

Innovations are sought that will improve the capability of spacecraft propulsion systems. In solar electric propulsion technology, advances are needed for ion, Hall, and advanced plasma thrusters including cathodes, neutralizers, electrode-less plasma production, low-erosion materials, high-temperature permanent magnets, and power processing. Innovations are needed for xenon, krypton, and metal propellant storage and distribution systems. In small chemical propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Also, advances are sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems and nano- and autonomous systems that include nano-materials, high temperature shape memory alloys, and piezoelectric materials as well as control systems for autonomous, adaptive engine control and sealing.

Goddard Space Flight Center Topic T4

The mission of the Goddard Space Flight Center is to expand knowledge of the Earth and its environment, the solar system, and the universe through observations from space. To assure that our nation maintains leadership in this endeavor, we are committed to excellence in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies.

Sub Topics:

**T4.01 Earth Science Sensors and Instruments**

*Lead Center: GSFC*

As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

This subtopic is to solicit advanced remote sensing technologies to enable future Earth Science measurements.

**Active Remote Sensing Instruments (Lidar)**
Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth science missions. Instruments are solicited that enable or support the following Earth science measurements:

- High spatial and temporal resolution observations of the land surface and vegetation cover (biomass);
- Profiling of clouds and aerosols;
- Wind measurements (direct-detection technology only);
- Tropospheric and stratospheric ozone and CO$_2$ (profiling and total column); and
- Measurement of the air/sea interface and mixed layer.

Systems and approaches will be considered that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV, long-duration balloon, or aircraft). New systems and approaches are sought that will:

- Enable one of the Earth Science measurements listed above;
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal resolution, accuracy, range of regard); and/or
- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same measurement capability.

**Passive Remote Sensing Instruments for Unmanned Aerial Vehicles (UAVs)**

Spectral imaging devices for remote sensing onboard UAVs are also desired. In particular, uncooled infrared and thermal spectral imager instruments, with the following specifications, are solicited:

- Instrument must be less than 2 lbs and no larger than 0.05 m$^3$ in volume;
- Must operate autonomously in coordination with the onboard flight plan;
- Must have a built-in data acquisition system;
- Spectral bands must all be coregistered and the data must be GPS time tagged;
- Spectral bands should be centered at 3.75, 3.96, and 11 microns as well as a band in the visible at 0.6 microns; and
- Quantization bit resolution should be 10-bit minimum.

**Microwave Measurements Using Large Aperture Systems**

New breakthrough technologies are sought for the construction of extremely large (tens of meters and larger diameter) microwave antenna systems. The microwave wavelengths will be determined according to the geophysical measurement of interest. Antenna concepts may include large single apertures or apertures composed of multiple elements that are operated synergistically to produce the desired performance. The proposed antenna
systems must:

- Be compact upon launch, which can be achieved either through folding technologies or from some assemblage of small components into the larger final system in space;
- Achieve high precision surface form factors. Surface characteristics of the microwave antenna must be accurate enough to produce microwave beam patterns with adequately small side lobes; and
- Include beam-scanning capabilities. The beam scanning must be facile and over many beam widths so as to enable cross-track scanning if in LEO, or scanning over the full globe if at GEO. Beam widths must be small enough to resolve the few kilometer scales needed for many geophysical observations.

T4.02 Space Science Sensors and Instruments

Lead Center: GSFC

Sensors and Instruments for space science applications are:

**Analytical Instrumentation**

Technical innovations are sought for sensitive, high-precision, analog electronics for measurements of low voltages, currents, and temperatures. Work on cryogenic transition edge detection techniques for X-ray astronomy in particular, and IR sensors with high quantum efficiency. New robust, efficient integration techniques that are scalable to commercial manufacturing efforts are sought.

- High-resolution IR sensors with high quantum efficiency, especially novel ion-implanted silicon devices, and arrays. Sensitivities better than 10-16 W per root Hz;
- Cryogenic devices, such as SQUID amplifiers and SQUID multiplexers, superconducting transition-edge temperature sensors, and miniature, self-contained low-temperature He refrigerators;
- Analog application-specific integrated circuits (ASICs) with large dynamic range (>105) and low power (Valley 2009);
- Novel packaging techniques and interconnection techniques for analog and digital electronics.

**Optics**

Larger telescopes in space (compared to the 6 m James Webb Space Telescope) demand lighter weight materials and new concepts. For example: designs including inflatable structures for lenses, mirrors, or antennas. Order of magnitude increases are envisioned. Applications of new materials could bring a new dimension to astronomy.

**Goals for future NASA Optical Systems**

<table>
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<tr>
<th></th>
<th>X-ray Mirrors</th>
<th>UV Mirrors</th>
<th>Visible \nScanning</th>
<th>Lidar \nTelescope</th>
<th>NIR\ Earth \nScience \nSystems</th>
<th>Far Infrared \nto submillimeter \nWavelength</th>
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</thead>
<tbody>
<tr>
<td>Energy Range</td>
<td>0.05-15 keV</td>
<td>100-400 nm</td>
<td>400-700 nm</td>
<td>355-2050 nm</td>
<td>0.7-4 mm</td>
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<tr>
<td>Size</td>
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<td>1-2 m</td>
<td>6-10+ m</td>
<td>0.7-1.5 m</td>
<td>3-4 m</td>
<td>10-25 m</td>
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Areal Density 2/grazing incidence 2 2 2 2 2

Surface Figure l/150 at l = 633 nm Diffraction Limited at l = 300 nm l/10 at l = 633 nm l/75 at l = 1 mm l/14 at l = 20 mm

* Near-infrared

- Large-area, lightweight (2) focusing optics, including inflatable or deployable structures;
- Novel laser devices (e.g., for lidars) that are tunable, compact, lower power and appropriate for mapping planetary (and lunar) surfaces. Future lidar systems may require up to ~1.5 m optics and novel designs; and
- Fresnel-zone X-ray focusing optics to form large X-ray telescopes with small apertures but high angular resolution-better than 1 milli-arc-second. Besides newly developed optics, these missions will require formation flying of spacecraft to an unprecedented level.

Mars and Lunar Initiative Technologies
The new Exploration Initiative (Code T) will embark upon an ambitious plan of robotic and human exploration of Mars with intermediate work to be done on the Moon. A broad program of analysis and resource identification is being planned, including X-ray and Gamma-ray spectroscopy. Exploiting the existing resources will be an important part of these initiatives rather than moving resources from place to place. These resource investigations will be conducted from orbit and from landers, both of which have differing requirements. On missions to Mars and other planets, instruments are typically limited to ~5-10 kg maximum.

- Low-weight, high throughput X-ray diffraction systems at 60 keV so that sample spectra can be accumulated in minutes or hours, not days;
- Laser-based X-ray generators (up to 60 keV), both compact and lightweight;
- Improved scintillator resolution for Gamma-rays up to 10 MeV; and
- High spatial resolution X-ray detectors, for producing ~50 meters or less maps from orbiting spacecraft, also with high throughput.

Computing
Massively parallel computer clusters for ever more complicated problems (in General Relativity, electrodynamics and "space weather," for example) are becoming more important. Ways to increase performance and reliability and lower cost are called for.

- Novel computing techniques for simulations (including hydrodynamics, stellar evolution, general relativity calculations, etc.);
- New high-performance, low-cost, reliable massively-parallel computers (i.e., Beowulf clusters); and
- Validation tools and software for space weather simulations and modeling.

UAV and Balloon-craft Technologies
Both remotely piloted (unmanned airborne vehicles ) and balloon instrumentation technologies are sought. New techniques and materials for forming "super-pressure" balloons and ways of formation flying or station-keeping with balloons would enable new science from this inexpensive platform, especially in the unmanned exploration of other planets.

- Super-pressure balloon manufacturing technologies;
- Station-keeping and trajectory control devices for balloons;
- New architectures and technologies for remote sensing applications; and
• Trajectory simulation tools and software.

Johnson Space Center Topic T5

To achieve the Agency's mandate of a robust space exploration program, the Johnson Space Center's roles and goals are focused on advancing the development of highly effective and innovative crew support and robotics/virtual digital human technologies. Extensive mission durations and harsh environments will dictate that future space explorers will need significantly improved hardware and systems to permit them to achieve these objectives. The Johnson Space Center, recognized as a Center of Excellence for human operations, seeks innovative solutions to these major challenges for human space explorers.

Sub Topics:

T5.01 Advanced Crew Support Technology

Lead Center: JSC

Advanced Crew Support Technologies will be essential to provide capabilities to enable humans to live and work safely, effectively, and efficiently in space during long-duration missions away from Earth as outlined by the Vision for Human Exploration of Space. Special emphasis is placed on development of technologies that will have a dramatic impact on reduction of mass, power, volume and crew time, and increased safety and reliability. Areas being solicited include Advanced Life Support and Extravehicular Activity including development of direct energy conversion, energy storage, and applications utilizing nanotechnologies relevant to these areas. Research and technology development with dual uses pertinent to Earth-based applications to improve environmental sustainability are of interest.

Life Support and Habitation (LSH)

Closed-loop life support systems were identified by the President's Commission on Implementation of United States Space Exploration Policy as an enabling technology critical to attainment of exploration objectives within reasonable schedules and affordable costs. Subsystems are needed to fully recycle air and water, recover resources from solid wastes, and produce food from plants. Requirements include: safe operability in micro- and partial-gravity, high reliability, minimal use of expendables, ease of maintenance, and low system volume, mass, and power. Specific areas of interest include:

• Waste Management: Technologies to safely and effectively manage dry and wet solid wastes expected on near-term missions (plastics, food scraps, clothing, paper, tape, hygiene materials, and/or feces) performing the following functions: compaction, stabilization, dewatering, storage, and control of odor release;

• Water Recovery: technologies in two specific areas are solicited: 1) low-temperature catalysts for destruction of organic carbon and nitrogen residuals in processed wastewater that operate at temperatures below 100°C; 2) technologies for recovery of water from brines generated from primary and secondary water processors including distillation and reverse osmosis systems that do not require use of consumable media;

• Filtration of Air and Water: techniques and technologies for separation and removal of particulates from water and gas streams, including air, potable water, and wastewater, that are regenerable, do not require consumable materials, have low pressure drop, and are suitable for use in micro- and hypo-gravity including consideration for collection and disposal of the solid phase;
Food Provisioning and Galley: proposals are being sought in two areas: 1) Development of a non-metallic, high barrier packaging material with less mass and volume and/or is biodegradable, recyclable, or reusable, to minimize a potentially significant trash management problem. All packaging materials must have adequate oxygen and water barrier properties to maintain the food's 3- to 5-year shelf life. 2) Development of efficient and reliable food preparation or food processing equipment that can be used in hypogravity and reduced atmospheric pressure;

Habitation Systems: Clothing Management Systems for reuse of clothing during long duration spaceflight, including clothes washing and drying technologies and which consider new advances in fabrics and materials;

Crop Systems: new or more efficient technologies for lighting systems for crop growth, for use for fresh vegetable production within spacecraft or crop production systems on planetary surfaces. Lighting technologies must provide high irradiance and meet the spectral requirements for crops. These may include development of highly efficient electric light sources, highly efficient systems for collection, distribution, and re-emission of solar radiation or selectively transparent materials for direct solar lighting;

Nanomaterials Applications: proposals are also solicited for development of advanced life support technologies that utilize unique properties of nanomaterials that are not possible with conventional materials, with emphasis on applications using single wall carbon nanotubes; and

Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety and maintainability commensurate with in-cabin applications in crewed vehicles.

Advanced Extravehicular Activity (AEVA)

Complex missions require innovative approaches for maximizing human productivity and for providing the capability to perform useful work tasks. Requirements include reduction of system hardware weight and volume; increased hardware reliability, durability, operating lifetime, and increased human comfort. Specific areas of interest are as follows:

Lightweight Structural and Protective Materials: proposals are sought for development of lightweight structural and protective materials for use in space suits to provide integral shell structure strength, impact, and puncture protection from shape edges, micrometeoroids and orbital debris, radiation protection, and prevention of abrasion, adhesion, and mitigation from Lunar and Martian dust;

Protective Suits for Hazardous Environments: proposals are sought for development of a protective suit based on EVA technologies and concepts for Homeland Security and hazmat applications including hazardous materials handling and minimizing exposures to chemical and biological agents;

Airlocks with minimum gas loss and volume: proposals are sought for development of both in-space and surface vehicle airlocks that minimize gas loss during depressurization and repressurization operations and also require minimum volume for airlock hatch and EVA crewmembers.

Nanomaterials Applications: proposals are also solicited for development of technologies for Advanced Extravehicular Activity that utilize unique properties of nanomaterials that are not possible with conventional materials with special emphasis on applications using single wall carbon nanotubes; and

Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in operating temperature range, in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety commensurate with in-cabin and exterior applications in crewed vehicles.
T5.02 Robotics and Virtual Digital Human Technologies
Lead Center: JSC

An Integrated Approach with Digital Virtual Humans (DVH) and Robotic Simulations

NASA is targeting a new level in space exploration operations. Critical advancements in crew and ground support technologies will be needed as NASA develops new operational capabilities to support multiple-manned, robotic, and long-duration/distance missions. Two potential areas for research are the ever-evolving Robotics and 3D DVH training procedures and simulation technologies providing operational robustness and intelligence. Furthermore, advanced capabilities for information integration and real-time interaction provide foundation for more simulation interaction between the two technologies. More advanced inter-system support capabilities (performance, maintenance, etc.) coordinated with a reliable knowledge base will be needed.

Proposals that improve operator efficiency via advanced displays, controls, and telepresence interfaces and improve the ability of humans and computers to seamlessly control robotic systems are sought. Specific technology requirements include the following hardware:

- Thermal feedback device for protecting the Robotic End-Of-Effector from grasping a hot/cold object that will damage its hand;
- Tactile feedback interface for collision awareness between workspace and avatar objects and robotic structure;
- Force feedback device for operator awareness of manipulator and payload inertia, gripping/slipping force, and forces and moments due to contact with external objects;
- Stereographic/autostereoscopic display systems for high-fidelity depth perception, field of view, and high resolution; and
- Spatial tracking for user appendages (i.e., head, arms, legs, fingers, and eyes) and avatar/robotic motion.

Based on the new Mission Control Center System (MCCS) Architecture framework, integrated support for Digital Virtual Human (DVH) in the loop and teleoperational interfaces are also the focus of this solicitation. Proposals offering innovation in the form of 3D visualization and simulation capabilities of robotic systems (direct manipulation, telerobotics, telepresence, etc.) with relation to the 3D DVH in the loop concept are being sought. The application targets would be flight and ground operations development, analyses, planning, training, and support. The main result desired is an interactive system that enhances operator and IVA/EVA procedure tasks efficiency via the teleoperational technologies and distributed collaborative virtual environments. The introduction of the DVH in a Virtual Reality (VR) robotic scenario is necessary for task and robotic device design, development, testing, planning, training, and operations functioning as integrated systems.

The core element of this project is the implementation of the Digital Virtual Human (DVH). This innovative human modeling technology comprises a combination of anatomical, biomechanical, and anthropometric functionality to fully simulate the somatic components and systems of the human body. Based on the tenets of the Visible Human Project, this DVH technology provides the opportunity to simulate real-world problems on the DVH in a simulated,
virtual environment (VE) interfacing with virtual objects. The main objective is to apply a high-fidelity DVH in a scenario that "re-creates" a real world. Scenes involving the DVH imply rich, complex problems to solve, visualize, and predict outcomes. The DVHs will have a key role in Shared VEs and truly interactive scenarios based on real-time data/information. More complex DVH embodiment increases natural interaction within the environment. The users' more natural perception of each other (and of autonomous actors/avatars) increases their sense of being together and thus the overall sense of shared presence in the environment.

Immersive technologies such as Virtual Reality (VR), Digital Virtual Human (DVH), and 3D DVH training procedure and simulation modeling have become a significant vehicle for NASA's effort to generate and communicate knowledge/understanding to K-12 levels through university/academic institutions to continuing education modalities. The ability to share aerospace-related operation simulations such as International Space Station and Space Shuttle/Space Transport System (STS) operations, robotics, intravehicular/extravehicular activities, Mission Control Center Systems (MCCS) conduct, interplanetary space flight, and microgravity simulation provides opportunity for educational and commercial growth for NASA and its research and development partners.

Human/Robotic Operations in Space

- Small, low power machine advanced vision systems for tracking a moving, articulated object;
- Machine vision techniques including the construction of image mosaics, for detection of unspecified changes in objects being inspected under diverse or changing lighting and viewing conditions;
- Small, lower power, range/range-rate sensors;
- Control interfaces that allow for seamless human/robot operations;
- 3D path planning systems and intelligent trajectory assessment feedback during teleoperations;
- Miniaturized motor control and drive electronics;
- Miniaturized sensing systems for manipulator position, rate, acceleration, force and torque; and
- Reduced-part-count miniaturized propulsion hardware (e.g., compressed gas storage with output pressure regulation via valve control only).

Kennedy Space Center Topic T6

NASA's launch headquarters, John F. Kennedy Space Center (KSC), is America's gateway to the universe and its busiest launch and landing facility. KSC at the Cape Canaveral Spaceport is NASA's Spaceport Technology Center, a world-class resource for the space transportation industry. KSC is helping to set the standard for future spaceports everywhere. Designers of new space transportation systems and architectures are integrating KSC-
developed spaceport and range technologies into those designs to lower not only the costs of building the flight and ground systems but also of maintaining and operating them. Visionary approaches and strategies being developed today at KSC are laying the groundwork for the Cape Canaveral Spaceport and other spaceports and ranges of the future. We want to continue to offer safe and cost-effective space access for our nation and international partners’ needs.

Sub Topics:

T6.01 Self-Healing Repair Technologies

Lead Center: KSC

It is highly desirable to develop technologies for polymeric materials used in electrical wire insulation that have the ability to self-heal. One example of self-healing is the repair process for composite materials, which uses the stress induced by a microfissure to rupture microcapsules of repair materials. In this system, a monomer is microencapsulated and then dispersed along with a catalyst. Once the microcapsules rupture, the monomer is polymerized by the dispersed catalyst and the microfissure is filled. Applications for self-healing processes for materials can be found in areas where failures could result in catastrophic consequences. For example, failure of structural members in spacecraft or aircraft; failure of electrical wire insulation materials used in spacecraft, aircraft, or buildings; or failure of polymer membranes used in critical separations in space exploration or medical devices. The key to any self-healing process is to use the change that occurs during the onset of the failure to initiate the repair process. This change could be the result of an impact to the insulation or the beginning of the electrical breakdown of the insulation. What is required would be an action that provided sufficient energy to start a second reaction or process that ultimately produced and/or bonded the repair material to the damaged insulation.

Wire insulation failure is considered a major problem on spacecraft and proposals should support concepts to develop self-healing technologies that have the ability to repair damaged Kapton or Teflon wire insulation. Of particular importance will be the methods needed to induce the self-repair process in wire insulation that has been manufactured. It is important to recognize the impact of the manufacturing process used to produce the insulated wire on the final product. These methods must produce a flexible, watertight seal over the damaged area. The physical and chemical properties of the final repair material should be similar to the initial insulating materials.

Proposals are also sought for innovative technologies and technology concepts in combining or bonding self-healing materials to conductor materials for an integrated, advanced, next-generation wiring system. Technologies for advancing conductor materials to allow for this integrated system should be considered since this is a topic area of concern in the Human and Robotic Technology Program.

T6.02 Batteryless, Wireless Remote Sensors

Lead Center: KSC

Recently, an innovative communication scheme was demonstrated that increases the attractiveness of using Surface Acoustic Wave (SAW) sensors as the basis for wireless, passive, sensor networks. It now appears feasible that a moderate number of sensors could be distributed throughout a volume of space and interrogated remotely and individually. Such a capability is of interest to the space program in that it may provide a lightweight (no wires and small sensors), low maintenance (no batteries), sensing network that can be used in harsh environments (predicted temperature ranges are from cryogenic through 900° C). NASA is currently funding work on a distributed temperature-sensing network but seeks other advances in this area.
At the recent 2004 IEEE International Ultrasonics, Ferroelectrics, and Frequency Control 50th Anniversary Joint Conference, two papers on Orthogonal Frequency Coding for SAW Sensors were presented. This new communication scheme for SAW devices and sensors appears to offer the capability to develop sensing networks where individual sensors can be interrogated from among a distributed array of devices. It also appears to provide scaling of the system in both number and range while suffering minimal degradation in the time resolution of the echoed signals. Consequently, NASA has recently decided to fund the development of a demonstration system using this concept and using a selected sensor (most likely temperature).

But, further advances are sought in this area, particularly, but not limited to, the area of novel sensors. Both the Space Shuttle as well as future vehicles could benefit from distributed strain sensors allowing high resolution monitoring of airframe stress. Embedded sensors within high pressure dewars might indicate fracturing before destructive failure occurs. Sensors that can operate within a cryogenic environment without the heat loss associated with wires could offer level, pressure, or temperature monitoring capabilities that are difficult or impossible to achieve with current technology. Embedded corrosion sensors or other process monitors could provide useful data. For example, it might be advantageous to locate moisture sensors under the Shuttle's thermal protection system materials. Also, there is interest in distributed leak detection systems, where, for example, hydrogen could be detected before it accumulates to the 4% explosive level in air. In addition to sensor development, improvements to the overall system are sought. For example, improvements are desirable in antenna design or system architecture that increase range or sensitivity.

The goal is to provide new sensors and capabilities that are compatible with the Orthogonal Frequency Coding scheme recently demonstrated under NASA funding in order to increase the range of applicability of this concept.

Langley Research Center Topic T7

In alliance with industry, other agencies, academia, and the atmospheric research community in the areas of aerospace vehicles, aerospace systems analysis, and atmospheric science, the Langley Research Center undertakes innovative, high-payoff activities beyond the risk limit or capability of commercial enterprises and delivers validated technology, scientific knowledge, and understanding of the Earth's atmosphere. Our success is measured by the extent to which our research results improve the quality of life of all Americans.

Sub Topics:

T7.01 Personal Air Transportation Technologies for Flight Demonstration

Lead Center: LaRC

NASA is performing technology research for future, on-demand, personal air transportation that is more robust and consumer focused than current commercial airline operations. The current studies involve the investigation of
missions, concepts, and technologies for the purpose of augmenting on-demand personal transportation mobility and capacity over the next 20 years. The intent of this research is to perform the analyses and demonstrations required to provide radical improvements to the key metrics that currently inhibit market growth of these small, personal-use vehicles. Initial markets would build on the near-term, existing general aviation infrastructure with takeoff and landing field lengths of approximately 2500 feet. Next-generation general aviation markets will encompass a class of vehicles that have utility, comfort, public acceptance, efficiencies, cost, and ease of use which can be more closely associated with automobile-like characteristics. Long-term markets would involve mission concepts that are capable of much closer proximity operations and the ability to perform near door-to-door transportation service, but with significantly greater speed and reach.

This PAV research will include focused technology efforts leading towards the following goals and objectives:

1) Reducing small aircraft certified flyover community noise by 24 dbA from the state-of-the-art values of approximately 84 dbA while still achieving reasonable cost and efficiency with integrated vehicle concepts capable of 200-mph performance. This noise reduction equates to a tenfold reduction in the perceived noise so that these aircraft are no noisier than current motorcycle regulations. The intent of this effort is to demonstrate that significant increases in small aircraft operations can be acceptable to communities, as these vehicles are designed with technologies that permit them to be good neighbors. These community noise reductions should also provide a significant reduction in cabin noise which will provide improved comfort levels for passengers.

2) Reducing the aircraft acquisition cost on the order of 60% from current price levels while still at relatively modest production volumes of approximately 2000 units/year. This effort will include investigation of advanced quality assurance certification processes and procedures instead of the current quality control methods. Significant industry investment has not occurred because a sizable market is not envisioned at cost levels where only a small fraction of the population can enter the market. Future production of such vehicles could be on the scale of limited production luxury cars, however the demonstration of affordable vehicles at relatively low volume is a critical step for market growth that would provide the capital for rapid expansion.

3) Simplify the operation of small aircraft such that the specialized skills, knowledge, and associated training are reduced to levels comparable to operating an automobile or boat. This reduction must be achieved during near-all-weather operations and with a level of safety that is superior to comparable operations today.

4) Additional mid-term and long-term technology investigations could also include efforts that provide improved performance, efficiency, and short field length takeoff and landing capability. Implicit to all these investigations will be enhancing the vehicle safety, versatility, ease of entry, interior environment, visibility, and maintenance and operations cost.

Research that can be demonstrated, through flight or ground experiment, will be especially helpful in establishing a credible foundation from which personal mobility technologies can proceed in the private marketplace. Information is desired on current research efforts in these focused areas for respondents interested in partnering with NASA on collaborative investigation. It is anticipated that subsystem design and testing will be performed on selected technologies or concepts.
Innovative concepts are being solicited for the development of non-destructive evaluation (NDE) and health-monitoring technologies for vehicles and structures involved in exploration missions. The highest priority is structural health monitoring systems that provide real time in situ diagnostics and evaluation of structural integrity. Emphasis is focused on highly miniaturized, lightweight, compact systems that deliver accurate assessment of structural health. The sensors, data acquisition and analysis systems and associated electronics must perform in high stress and hostile conditions expected on launch vehicles and space environments. Diagnostic systems intended for external inspection of space vehicles and structures will be highly autonomous, remotely operated and preferably non-contacting.

Evaluation sciences include ultrasonics, laser ultrasonics, optics and fiber optics, video optics and laser metrology, thermography, electromagnetics, acoustic emission, X-ray and terahertz radiation. Innovative and novel evaluation approaches are sought for the following materials and structural systems:

- Adhesives and bonded joints, sealants, bearings, coatings, glasses, alloys, laminates, monolithics, material blends, wire insulating materials, and weldments;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.

Proposals should address the following performance metrics as appropriate:

- Characterization of material properties;
- Assessment of effects of defects in materials and structures;
- Evaluation of mass-loss in materials;
- Detection of cracks, porosity, foreign material, inclusions, and corrosion;
- Dis-bonded adhesive joints;
- Detection of cracks around fasteners such as bolts and rivets;
- Real-time and in situ monitoring, reporting, and damage characterization for structural durability and life prediction;
- Repair certification;
• Environmental sensing;

• Planetary entry aero-shell validation;

• Micro-meteor and orbital debris impact location and damage assessment;

• Electronic system/wiring integrity assessment; wire insulation integrity and condition (useful life) and arc location for failed insulation;

• Characterization of load environment on a variety of structural materials and geometries including thermal protection systems and bonded configurations;

• Identification of loads exceeding design;

• Monitoring loads for fatigue and preventing overloads;

• Suppression of acoustic loads;

• Early detection of damage; and

• In situ monitoring and control of materials processing.

Measurement and analysis innovations will be characterized by:

• Advanced integrated multi-functional sensor systems;

• Autonomous inspection approaches;

• Distributed/embedded sensors;

• Roaming inspectors;

• Shape adaptive sensors;

• Concepts in computational models for signal processing and data interpretation to establish quantitative characterization;

• Advanced techniques for management and analysis of digital NDE data for health assessment and lifetime prediction; and

• Biomimetic, and nano-scale sensing approaches for structural health monitoring that meet size and weight limitations for long duration space flight.
Continued technological innovation is critical to a strong manufacturing sector in the United States economy. The Federal Government has an important role in helping to advance innovation including innovation in manufacturing, through small businesses. The President issued an executive order directing Agencies, to the extent permitted by law and in a manner consistent with the mission of the Agency, to give high priority within such programs to manufacturing-related research and development. NASA is interested in innovative manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system. The nation's ability to decrease the cost and schedule required to develop new space transportation systems that are required to support NASA's exploration missions is hampered by inadequacies in our design tools and databases. Space transportation systems operate at the extremes of our materials capabilities, therefore any shortcomings in our ability to predict the internal operating environments during the design process will almost always lead to redesigns during the development of the system. These redesigns are costly and always compromise the project's schedule. One way to address this issue is to increase the fidelity and accuracy of the tools used to predict the internal operating environments during design.

**Sub Topics:**

**T8.01 Aerospace Manufacturing Technology**

**Lead Center: MSFC**

Continued technological innovation is critical to a strong manufacturing sector in the United States economy. NASA is interested in innovated manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system. Specific areas of interest in this solicitation include innovative manufacturing, materials, and processes relevant to propulsion systems and airframe structures for next-generation launch vehicles, crew exploration vehicles, lunar orbiters and landers, and supporting space systems. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components. Only processes that are environmentally friendly and worker-health oriented will be considered.

Proposals are sought, but are not limited to, the following areas:

**Polymer Matrix Composites (PMCs)**

Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing (e.g., e-beam, ultrasonic); damage tolerant and repairable structures; advanced materials and manufacturing processes for both cryogenic and high-temperature applications; and improved thermal protection systems (e.g., integrated structures, integral cryogenic tanks and insulations).

**Ceramic Matrix Composite (CMCs)**

Materials and processes that are projected to significantly increase safety and reduce costs simultaneously while decreasing weight for space transportation propulsion. Innovative material and process technology advancements that are required to enable long-life, reliable, and environmentally-durable materials.

**Metals and Metal Matrix Composites (MMCs)**

Advanced manufacturing processes such as pressure infiltration casting (for MMCs); laser engineered near-net shaping; electron-beam physical vapor deposition; in situ MMC formation; solid state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites; advanced materials such as metallic matrix alloys compositions, which optimize high
ductility and good joinability; functionally graded materials for high- or low-temperature application; alloys and nanophase materials to achieve more than 120 ksi tensile strength at room temperature and 60 ksi at elevated temperature above 500° F; new advanced superalloys that resist hydrogen embrittlement and are compatible with high-pressure oxygen; innovative thermal-spray or cold-spray coating processes that substantially improve material properties, combine dissimilar materials, application of dense deposits of refractory metals and metal carbides, and coating on nonmetallic composite materials.

**Manufacturing Nanotechnology**

Innovations that use nanotechnology processes to achieve highly reliable or low-cost manufacturing of high-quality materials for engineered structures.

**T8.02 Advanced High Fidelity Design and Analysis Tools For Space Propulsion**

*Lead Center: MSFC*

The pace at which the United States, through NASA, explores space will largely be driven by the cost of developing the systems required to make future explorations practical. The nation's ability to decrease the cost and schedule required to develop new space transportation systems that are required to support NASA's exploration missions is hampered by inadequacies in our design tools and databases. Space Transportation systems operate at the extremes of our materials capabilities, therefore, any shortcomings in our ability to predict the internal operating environments during the design process will almost always lead to redesigns during the development of the system. These redesigns are costly and always compromise the project's schedule. One way to address this issue is to increase the fidelity and accuracy of the tools used to predict the internal operating environments during design.

Universities are at the leading edge of development of new, “first principles” physical models of development of new high-fidelity numerical approaches for simulating operation of space transportation systems and of developing experimental approaches and data required to validate these tools. Transition of these technologies, however, from an academic setting to a production, applications-centered environment, where it can be applied to the design of NASA's space transportation systems, requires focused effort. Efficient and timely transfer of these capabilities from the university setting to the operational (production) setting is required to reduce the developmental risks associated with NASA's space transportation systems and to maximize the return on NASA's investments at the nation's colleges and universities.

This subtopic solicits partnerships between academic institutions and small businesses for the purpose of developing novel design and analysis approaches and the methods by which to validate them into useful production tools that can be used to develop NASA's space transportation systems. Examples of specific areas where innovations are sought follow:

- Efficient, three-dimensional (3D), time-accurate analysis tools for modern rocket engine combustion
chamber and turbomachinery environments and performance;

- Efficient, three-dimensional (3D), time-accurate analysis tools for predicting the environment and loads internal to valves, lines, and ducts in modern rocket engines;

- Practical 3D, steady and time-accurate, multidisciplinary analysis (MDA) tools for design of space transportations systems components and subsystems;

- Practical approaches for predicting the time-varying, 3D flow field in cases involving relative motion between objects;

- Practical Large Eddy Simulation (LES) tools for the analysis of high pressure reacting flows;

- Automated hybrid grid generation tools and grid adaptation tools;

- Efficient and accurate fluid properties routines for the range of conditions applicable to rocket engines;

- Automated approaches for extracting key engineering information and flow features from 3D flow simulations;

- Automated approaches for validating and assuring quality of application software;

- Practical, unsteady, 3D cavitation models for implementation into Reynolds-Averaged Navier-Stokes (RANS) analysis codes;

- Advanced instrumentation and diagnostic techniques necessary for acquisition of steady and unsteady code validation data; and

- Validation data for all of the tool types mentioned above.

Stennis Space Center Topic T9

The John C. Stennis Space Center (SSC) in south Mississippi is NASA's primary center for testing and flight certifying rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Because of its important role in engine testing for four decades, Stennis Space Center is NASA's program manager for rocket propulsion testing with total responsibility for conducting and/or managing all NASA propulsion test programs. Stennis Space Center tests all Space Shuttle main engines. These high-performance, liquid-fueled engines provide most of the total impulse needed during the Shuttle's eight and one-half-minute-flight to orbit. All shuttle main engines must pass a series of test firings at Stennis Space Center prior to being installed in the back of the orbiter. The Earth Science Applications Directorate is NASA's Program Manager for Earth Science Applications. The Directorate matches NASA's scientific and technical knowledge with issues of national concern and the needs of our partners. Partners include local, state, and tribal governments, commercial industry, with educational and other non-profit institutions. Through the Directorate's co-funded partnerships, public and private sector decision makers learn how to apply new technologies to critical environmental, resource management, community growth, and disaster management issues. The Directorate also provides the remote sensing community with a comprehensive array of manmade and natural ground targets, measurement systems, and benchmark processes to help test airborne and space remote sensing systems against performance specifications and customer needs. Stennis
Space Center began "re-inventing Government" decades ago before the concept became popular. Over the years, SSC has evolved into a multiagency, multidisciplinary center for Federal, state, academic, and private organizations engaged in space, oceans, environmental programs, and the national defense. In addition to NASA, there are 30 other agencies located at Stennis. Of approximately 4500 employees, about 1600 work in the fields of science and engineering. These agencies work side by side and share common costs related to infrastructure, facility, and technical services which makes it cheaper for each to accomplish its independent mission at SSC.

Sub Topics:

T9.01 Rocket Propulsion Testing Systems

Lead Center: SSC

Proposals are sought for innovative technologies and technology concepts in the area of propulsion test operations. Proposals should support the reduction of overall propulsion test operations costs (recurring costs) and/or increase reliability and performance of propulsion ground test facilities and operations methodologies. As a minor element in a proposal for this topic, the offeror may include specific educational related research, technology advances, or other deliverables that address and support the Agency's education mission such as the enhancement of science, technology, engineering, and mathematics instruction with unique teaching tools and experiences. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies

Innovative, nonintrusive sensors for measuring flow rate, temperature, pressure, rocket engine plume constituents, and effluent gas detection. Sensors must not physically intrude at all into the measurement space. Low-millisecond to sub-millisecond response time is required. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH₂) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH₂). Flow rate sensors must have a range of up to 2000 lb/s (82 ft/sec) for LOX and 500 lb/sec (300 ft/s) for LH₂. Pressure sensors must have a range up to 15,000 psi. Rocket plume sensors must determine gas species, temperature, and velocity for H₂, O₂, hydrocarbons (kerosene), and hybrid fuels.

Rugged, high accuracy (0.2%), fast response, temperature measuring sensors and instrumentation for very high pressure, high flow rate cryogenic piping systems. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH₂) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH₂). Response time must be on the order of a few milliseconds to sub-milliseconds.

Phenomenology, modeling, sensors, and instrumentation for prediction, characterization, and measurement of rocket engine combustion instability. Sensor systems should have bandwidth capabilities in excess of 100 kHz. Emphasis is on development of optical-based sensor systems that will be nonintrusive in the test article hardware or plume.

Improvement in Ground-Test Operation, Safety, Cost-effectiveness, and Reliability

Smart system components (control valves, regulators, and relief valves) that provide real-time, closed-loop control, component configuration, automated operation, and component health. Components must be able to operate in cryogenic temperatures (as low as 160R for LOX and 34R for LH₂) under high pressure (up to 15,000 psi) high flow rate conditions (2000 lb/s - 82 ft/s for LOX; 500 lb/sec - 300 ft/s for LH₂). Components must be able to operate in the elevated temperatures associated with a rocket engine testing environment. Response time must be on the order of a few milliseconds to sub-milliseconds.
Improved, long-life, liquid oxygen compatible seal technology. Materials and designs suitable for oxygen service at pressures up to 10,000 psi. Both cryogenic and elevated temperature candidate materials and designs are of interest. Typical temperature ranges will be either -320°F to 100°F, or -40°F to 300°F. Seal designs may include both dynamic and static use. Plastic, metal, or electrometric materials, or combinations thereof are of particular interest.

Miniature front-end electronics to support embedding of intelligent functions on sensors. Requirements include: computational power comparable to a 200 MHz PC with approximately 32 MB of RAM and similar non-volatile storage; analog input/output (I/O) (at least two of each with programmable amplification and anti-aliasing filters plus automatic calibration); digital I/O (at least eight) communication port for Ethernet bus protocol (one high speed and one low speed); support for C programming (or other high level language); and a development kit for a PC. The package should occupy a space no larger than 4" x 4" x 2". The system should include an embedded temperature sensor, an embedded stable voltage calibration source, and programmable switching to connect calibration source input and output.

New and innovative acoustic measurement techniques and sensors for use in a rocket plume environment. Current methods of predicting far-field and near-field acoustic levels produced by rocket engines rely on empirical models and require numerous physical measurements. New and innovative acoustic prediction methods are required which can accurately predict the acoustic levels a priori or using fewer measurements. New, innovative techniques based on energy density measurements rather than pressure measurements show promise as replacements for the older models.

Development of tools that integrate simple operator interfaces with detailed design and/or analysis software for modeling and enhancing the flow performance of flow system components such as valves, check valves, pressure regulators, flow meters, cavitating venturis, and propellant run tanks.

New and improved methods to accurately model the transient interaction between cryogenic fluid flow and immersed sensors that predict the dynamic load on the sensors, frequency spectrum, heat transfer, and effect on the flow field, are needed.

Modeling of atmospheric transmission attenuation effects on test spectroscopic measurements. Atmospheric transmission losses can be significant in certain wavelength regions for radiometric detectors located far from the rocket engine exhaust plume. Consequently, atmospheric losses can result in over-prediction of the incident radiant flux generated by the plume. Accurate atmospheric transmission modeling is needed for high-temperature rocket engine plume environments. The capabilities should address both the losses from ambient atmosphere and localized environments such as condensation clouds generated by cryogenic propellants.

**Application of System Modeling to Ground Test Operations in a Resource Constrained Environment**

New innovative approaches to incorporating knowledge and information processing techniques (prepositional logic, fuzzy logic, neural nets, etc.) to support test system decision making and operations. A requirement exists to develop, apply, and train intelligent agents, behavioral networks, and logic streams for rocket engine testing modes of operations and practice. Applications must operate statistically well on small and disparate data sources. The resulting products are inferential, representative, and they capture tacit and explicit knowledge. Statistical analysis must be supported.
Techniques to reduce required sample size to maintain acceptable levels of confidence in cost data. In order to use appropriate models and to manage the cost of data acquisition and maintenance, the minimization of required data sample sizes is critical.

Measurements and data are the product of ground testing. High accuracy, precision, uncertainty bands, and error bands are important elements of the data that is generated; this must be quantified. Techniques and models to determine these parameters for active test facilities are required.

T9.02 Integrated Life-Cycle Asset Mapping, Management, and Tracking

Lead Center: SSC

To support NASA's need for reliable and low-cost asset management in all of its programs including Earth-based activities, robotic and human lunar exploration, and planning for later expeditions to Mars and beyond, the Earth Science Applications Directorate at Stennis Space Center seeks proposals supporting NASA's requirements for asset management. With proper physical infrastructure and information systems, identification tags should allow any item to be tracked throughout its life cycle. When combined with Earth and lunar GIS, and related supporting documentation, any significant asset should be located, through time and space, as well as organization. Starting with programmatic requirements and design data, assets would be tracked through manufacture, testing, possible launch, use, maintenance, and eventual disposal. Innovative technology and information architectures should integrate and visually map infrastructure, assets, and associated documentation with the ability to link to program structure, budget, and workflow. Innovative solutions will facilitate information flow between the various NASA Centers and Programs. The system must maintain signature authority and restrict unauthorized moves. Ideally, if fully implemented, any remote item could be actively located throughout the NASA system with minimal delay. Any tagged item should be able to be queried at its location to retrieve associated records, e.g., maintenance, inspection, configuration management, chain-of-custody, engineering specifications, etc. A simple operator interface would provide "finger-tip knowledge" about the asset. It should be possible to provide secure access to this information for both domestic and international partners. The proposed solution will minimize capital cost and human work effort required for inventory and tracking of nonconsumable assets while exceeding the performance of current systems. Note that tagged assets may be subject to extreme environments in space and on Earth.

The innovation may eventually interoperate with a holistic information system, and may not preclude other uses for a terrestrial and lunar GIS such as:

- Operational infrastructure support AM/FM (automated mapping / facilities management);
- Asset and resource management, including waste disposal;
- Lunar landing and facility site selection, and optimization;
- Conceptual site infrastructure and layout design;
- Surface navigation;
• Emergency response information; and

• A comprehensive portal for Earth and lunar mapping data, both image- and vector-based.

Information Technologies for System Health Management, Autonomy, and Scientific Exploration Topic T1.01

Information technology is a key element in the successful achievement of NASA's strategic goals. Modern tools and techniques have the capability to redefine many design and operational processes as well as enable grand exploration and science investigations. This subtopic seeks innovative solutions to the following information technology challenges:

• Onboard methods that monitor system health and then automatically reconfigure to respond to failures and sustain progress toward high-level goals. Special emphasis will be on computational techniques for coordinating multi-agent systems in the presence of anomalies or threats;

• Onboard, real-time health management systems that perform quickly enough to monitor a flight control system (including spacecraft and fixed or rotary wing aircraft) in a highly dynamic environment and respond to anomalies with suggested recovery or mitigation actions;

• Integrated software capabilities that allow automated science platforms, such as rovers, to respond to high-level goals. This could include perception of camera and other sensor data, position determination and path planning, science planning, and automated analysis of resulting science data;

• Data fusion, data mining, and automated reasoning technologies that can improve risk assessments, increase identification of system degradation, and enhance scientific understanding;

• Techniques for interconnecting and understanding large heterogeneous or multidimensional data sets or data with complex spatial and/or temporal dynamics;

• Computational and human/computer interface methodologies for inferring causation from associations and background knowledge for scientific, engineering, control, and performance analyses;

• Software generation tools that capture designer intent and performance expectations and that embed extra knowledge into the generated code for use by automated software analysis tools doing validation and verification, system optimization, and performance envelope exception handling;

• Tools and techniques for program synthesis and program verification of high-assurance software systems; and

• Innovative communication, command, and control concepts for autonomous systems that require interaction with humans to achieve complex operations.
As NASA embarks on a new exploration agenda, the study of the space radiation environment and its effects on living things and support technologies will be critical for the success of long-term missions. Our current understanding of the space radiation environment, particularly high atomic number and energy particles (HZE particles) and energetic protons, and its interaction with materials, technological systems, and living things is limited compared to our understanding of Gamma and X-rays. NASA has established a space radiation laboratory at Brookhaven National Labs capable of generating HZE particles and protons, and supports a facility at Loma Linda University Medical Center capable of generating energetic protons to enable research studies. We seek innovative technology solutions in the following areas:

**Advanced Dosimetry Systems**

- Real-time dosimetry providing dose and particle types and energies for use onboard spacecraft and planetary habitats;
- Real-time and cumulative dosimeters for characterizing space environments including planetary surfaces;
- Alarm systems for Solar Particle Events; and
- Microdosimetry for research applications including implantable dosimeters for biological studies.

**Radiation Hardened Electronic Systems**

- Methods for hardening pre-existing technologies; and
- Novel materials and circuit design.

**Shielding Materials and Systems**

- Multi-use materials for spacecraft and habitat fabrication (high strength, high shielding characteristics, embedded dosimetry, or warning devices);
- Materials for advanced EVA suits; and
- Alternative non-materials based shielding technologies.

**Life Support Systems Composition and Monitoring**

- Technologies to monitor the composition and health of biological components (microbial and plant) of life support and bio-remediation systems; and
- Development of radiation resistant organisms for life support and bio-remediation systems.
Biological Markers of Human Radiation Exposure

- Identify markers of radiation damage that can be obtained in a minimally invasive manner; and
- Technological systems to identify and quantitate biological markers onboard spacecraft and planetary habitats.

Astronaut Health Countermeasures

- Pharmaceuticals to counteract the deleterious effects of space radiation exposure;
- Gene therapy and other biological approaches; and
- Markers for genetic susceptibility to space radiation damage.

Sub Topics:

Flight Dynamic Systems Characterization Topic T2.01
This topic solicits proposals for innovative, linear or non-linear, aerospace vehicles dynamic systems modeling and simulation techniques. In particular:

Research and development in simulation algorithms for computational fluid dynamics (CFD), structures, heat transfer, and propulsion disciplines, among others: in particular, emphasis is placed on the development and application of state-of-the-art, novel, and computationally efficient solution schemes that enable effective simulation of complex practical problems such as modern flight vehicles, like X-43 and F-18-AAW, as well as more routine problems encountered in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered an important part of this topic.

Aeroelasticity and aeroservoelasticity, linear and non-linear: vehicle stability analysis is an important aspect of this topic. Primary concern is with the development and application of novel, multidisciplinary, simulation software using finite element and other associated techniques.

Sub Topics:

Advanced Concepts for Flight Research Topic T2.02
This topic is intended to be broad and to solicit and promote technologies for the following:
• Automated online health management and data analysis;

• 21st Century air-traffic management with Remotely Operated Aircraft (ROA) within the National Air Space; and

• Modeling, identification, simulation, and control of aerospace vehicles in-flight test, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts.

Proposals in any of these areas will be considered.

Online health monitoring is a critical technology for improving transportation safety. Safe, affordable, and more efficient operation of aerospace vehicles requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local and wide area networks. Online health monitoring is a general concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of online emphasizes algorithms that minimize the time between data acquisition and decision making.

The challenges in Air Traffic Management (ATM) are to create the next generation systems and to develop the optimal plan for transitioning to future systems. This system should be one that seamlessly supports the operation of ROAs. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.

Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influences of structural dynamics, thermal dynamics, steady and unsteady aerodynamics, and the control system. The benefit of this effort will ultimately be an increased understanding of the complex interactions between the vehicle dynamics subsystems with an emphasis on flight test validation methods for control-oriented applications. Proposals for novel multidisciplinary nonlinear dynamic systems modeling, identification, and simulation for control objectives are encouraged. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance and load control (including smart actuation and active aerostructural concepts), autonomous health monitoring for stability and performance, and drag minimization for high efficiency and range performance. Methodologies should pertain to any of a variety of types of vehicles ranging from low-speed, high-altitude, long-endurance to hypersonic and access-to-space aerospace vehicles.

Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this topic is the development of sensors, sensor systems, sensor arrays, or instrumentation systems for improving the state-of-the-art in aircraft ground or flight-testing. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight testing by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This topic solicits proposals for improving airborne sensors and sensor-instrumentation systems in all flight regimes-
particularly transonic and hypersonic. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.

This topic further solicits innovative flight test experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment. The emphasis of this topic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and that require a demonstration in an actual-flight environment to fully characterize or validate advances.

Sub Topics:

Aerospace Communications Topic T3.01
The research sought under Aerospace Communications focuses on the development of innovative communications, architectures, networks, and subsystems that significantly increase the capacity and connectivity among satellites, spacecraft, aircraft and ground networks thereby enabling new applications and services. These technologies are aimed at improving the power, bandwidth, and cost efficiency of communications at millimeter-wave frequencies and higher, and the interoperability, reliability, security, and quality of services of aerospace networks. The goal is to address the requirements of: NASA's Vision for Space Exploration, National Airspace System capacity, safety, and transportation initiatives; NASA's mission-unique applications; and NASA's utilization of emerging commercial communications services.

Innovations solicited include:

- Development of monolithic microwave integrated circuit (MMIC)-based arrays and array feeds, large-aperture inflatable antennas, miniaturized antennas, and trade-off studies among different antenna technologies for space applications. Potential lower cost, space-fed, active array and reflectarray approaches are also of interest as well as other MMIC and non-MMIC-based approaches (e.g., MEMS-, ferroelectric-, and optical-based approaches);

- Radio Frequency (RF) and optical propagation phenomena through atmosphere and turbulent media, development and validation of communication systems for aviation safety and aviation capacity, and other related electromagnetic phenomena;

- Digital communications, navigation, and surveillance technologies required for aeronautical communications, navigation, and surveillance (CNS) and space communications systems. Specific technologies include: software-defined radios; low-power, reconfigurable transceivers; multi-function, multi-mode digital avionics; network interface controllers, hubs, and routers for space; bandwidth- and power-efficient digital modems; advanced signal processing techniques; and integrated microelectronic or
optoelectronic devices;

- Research and development of advanced microwave materials, devices, and circuits as well as the technologies required for integrating individual circuit components into microwave subsystems. Research in high-power transmitters focused on improving efficiency, RF power output, reliability, operating life, and communications qualities (such as linearity of a traveling wave tube amplifier for use in space communications). RF power combining techniques at Ka-Band frequencies are also of interest;

- Research on semiconductor circuits for transmit and receive modules in operational frequency bands designated for NASA's Exploration Systems vision. Specific technologies under development include: wide bandgap semiconductors, such as gallium nitride and silicon carbide; III-V semiconductors; silicon germanium; radio frequency micro-electromechanical systems (RF MEMS) devices/circuits; radio frequency integrated circuits including transmission lines and passive components; and microwave circuit packaging techniques;

- Cryocooled ultra-sensitive receivers for use in terrestrial antenna arrays for reception of signals from deep space and for inter-satellite links;

- Emerging technologies such as, multi-Gb/s photonic and nano-electronics based devices and circuits; and

- Research and development of advanced aerospace communications network architectures, protocols, standards, technologies, and network-based applications. Specific areas of interest include transmission control protocols, modifications, and enhancements to mitigate variable delays and high latency, next generation transport protocols, mobile-Internet protocols/routing, ad-hoc networking, and quality-of-service protocols, design, and implementation of advanced hybrid architectures to support NASA applications.

Sub Topics:
Space Power and Propulsion Topic T3.02
Development of innovative technologies and systems are sought that will result in robust, lightweight, ultra-high efficiency, lower cost, power and in-space propulsion systems that are long-lived in the relevant mission environment and that enable future missions. The technology developments being sought would, through highly-efficient generation and utilization of power and in-space propulsion, significantly increase the system performance, thereby enabling future NASA missions.

Innovations are sought that will significantly improve the efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, flexibility/reconfigurability, and autonomy of space power systems. In power generation, advances are needed in photovoltaic cell structure including the incorporation of nano-materials; module integration including monolithic interconnections and high-voltage operation; and array technologies including ultra-lightweight deployment techniques for flexible, thin-film modules, and concentrator techniques as well as dynamic power generation systems for nuclear power conversion. In energy storage systems, advances are needed in batteries-primary and rechargeable-regenerative fuel cells, and flywheels. Advances are also needed in power management and distribution systems, power system control, and integrated health management.

Innovations are sought that will improve the capability of spacecraft propulsion systems. In solar electric propulsion technology, advances are needed for ion, Hall, and advanced plasma thrusters including cathodes, neutralizers, electrode-less plasma production, low-erosion materials, high-temperature permanent magnets, and power processing. Innovations are needed for xenon, krypton, and metal propellant storage and distribution systems. In small chemical propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Also, advances are sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems and nano- and autonomous systems that include nano-materials, high temperature shape memory alloys, and piezoelectric materials as well as
control systems for autonomous, adaptive engine control and sealing.

Sub Topics:
Earth Science Sensors and Instruments Topic T4.01
As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

This subtopic is to solicit advanced remote sensing technologies to enable future Earth Science measurements.

Active Remote Sensing Instruments (Lidar)
Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth science missions. Instruments are solicited that enable or support the following Earth science measurements:

- High spatial and temporal resolution observations of the land surface and vegetation cover (biomass);
- Profiling of clouds and aerosols;
- Wind measurements (direct-detection technology only);
- Tropospheric and stratospheric ozone and CO₂ (profiling and total column); and
- Measurement of the air/sea interface and mixed layer.

Systems and approaches will be considered that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV, long-duration balloon, or aircraft). New systems and approaches are sought that will:

- Enable one of the Earth Science measurements listed above;
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal resolution, accuracy, range of regard); and/or
- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same
measurement capability.

**Passive Remote Sensing Instruments for Unmanned Aerial Vehicles (UAVs)**

Spectral imaging devices for remote sensing onboard UAVs are also desired. In particular, uncooled infrared and thermal spectral imager instruments, with the following specifications, are solicited:

- Instrument must be less than 2 lbs and no larger than 0.05 m³ in volume;
- Must operate autonomously in coordination with the onboard flight plan;
- Must have a built-in data acquisition system;
- Spectral bands must all be coregistered and the data must be GPS time tagged;
- Spectral bands should be centered at 3.75, 3.96, and 11 microns as well as a band in the visible at 0.6 microns; and
- Quantization bit resolution should be 10-bit minimum.

**Microwave Measurements Using Large Aperture Systems**

New breakthrough technologies are sought for the construction of extremely large (tens of meters and larger diameter) microwave antenna systems. The microwave wavelengths will be determined according to the geophysical measurement of interest. Antenna concepts may include large single apertures or apertures composed of multiple elements that are operated synergistically to produce the desired performance. The proposed antenna systems must:

- Be compact upon launch, which can be achieved either through folding technologies or from some assemblage of small components into the larger final system in space;
- Achieve high precision surface form factors. Surface characteristics of the microwave antenna must be accurate enough to produce microwave beam patterns with adequately small side lobes; and
- Include beam-scanning capabilities. The beam scanning must be facile and over many beam widths so as to enable cross-track scanning if in LEO, or scanning over the full globe if at GEO. Beam widths must be small enough to resolve the few kilometer scales needed for many geophysical observations.

Sub Topics:
- Space Science Sensors and Instruments Topic T4.02
- Sensors and Instruments for space science applications are:

**Analytical Instrumentation**

Technical innovations are sought for sensitive, high-precision, analog electronics for measurements of low voltages, currents, and temperatures. Work on cryogenic transition edge detection techniques for X-ray astronomy in particular, and IR sensors with high quantum efficiency. New robust, efficient integration techniques that are scalable to commercial manufacturing efforts are sought.
• High-resolution IR sensors with high quantum efficiency, especially novel ion-implanted silicon devices, and arrays. Sensitivities better than 10-16 W per root Hz;
• Cryogenic devices, such as SQUID amplifiers and SQUID multiplexers, superconducting transition-edge temperature sensors, and miniature, self-contained low-temperature He refrigerators;
• Analog application-specific integrated circuits (ASICs) with large dynamic range (>105) and low power;
• Novel packaging techniques and interconnection techniques for analog and digital electronics.

Optics
Larger telescopes in space (compared to the 6 m James Webb Space Telescope) demand lighter weight materials and new concepts. For example: designs including inflatable structures for lenses, mirrors, or antennas. Order of magnitude increases are envisioned. Applications of new materials could bring a new dimension to astronomy.

Goals for future NASA Optical Systems

<table>
<thead>
<tr>
<th></th>
<th>X-ray Mirrors</th>
<th>UV Mirrors</th>
<th>Visible Scanning</th>
<th>Lidar Telescope</th>
<th>NIR' Earth Science Systems</th>
<th>Far Infrared to submillimeter Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Range</td>
<td>0.05-15 keV</td>
<td>100-400 nm</td>
<td>400-700 nm</td>
<td>355-2050 nm</td>
<td>0.7-4 mm</td>
<td>20-800 mm</td>
</tr>
<tr>
<td>Size</td>
<td>1-4 m</td>
<td>1-2 m</td>
<td>6-10+ m</td>
<td>0.7-1.5 m</td>
<td>3m-4 m</td>
<td>10-25 m</td>
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<tr>
<td>Areal Density</td>
<td>2/grazing incidence</td>
<td>2</td>
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<tr>
<td>Surface Figure</td>
<td>l/150 at l = 633 nm</td>
<td>Diffraction Limited at l = 300 nm</td>
<td>l/150 at l = 500 nm</td>
<td>l/10 at l = 633 nm</td>
<td>l/75 at l = 1 mm</td>
<td>l/14 at l = 20 mm</td>
</tr>
</tbody>
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* Near-infrared

• Large-area, lightweight (2) focusing optics, including inflatable or deployable structures;
• Novel laser devices (e.g., for lidars) that are tunable, compact, lower power and appropriate for mapping planetary (and lunar) surfaces. Future lidar systems may require up to ~1.5 m optics and novel designs; and
• Fresnel-zone X-ray focusing optics to form large X-ray telescopes with small apertures but high angular resolution—better than 1 milli-arc-second. Besides newly developed optics, these missions will require formation flying of spacecraft to an unprecedented level.

Mars and Lunar Initiative Technologies
The new Exploration Initiative (Code T) will embark upon an ambitious plan of robotic and human exploration of Mars with intermediate work to be done on the Moon. A broad program of analysis and resource identification is being planned, including X-ray and Gamma-ray spectroscopy. Exploiting the existing resources will be an important part of these initiatives rather than moving resources from place to place. These resource investigations will be conducted from orbit and from landers, both of which have differing requirements. On missions to Mars and other planets, instruments are typically limited to ~5-10 kg maximum.

• Low-weight, high throughput X-ray diffraction systems at 60 keV so that sample spectra can be accumulated in minutes or hours, not days;
• Laser-based X-ray generators (up to 60 keV), both compact and lightweight;
• Improved scintillator resolution for Gamma-rays up to 10 MeV; and
• High spatial resolution X-ray detectors, for producing ~50 meters or less maps from orbiting spacecraft, also with high throughput.

Computing
Massively parallel computer clusters for ever more complicated problems (in General Relativity, electrodynamics and "space weather," for example) are becoming more important. Ways to increase performance and reliability and lower cost are called for.

• Novel computing techniques for simulations (including hydrodynamics, stellar evolution, general relativity calculations, etc.);
• New high-performance, low-cost, reliable massively-parallel computers (i.e., Beowulf clusters); and
• Validation tools and software for space weather simulations and modeling.

UAV and Balloon-craft Technologies
Both remotely piloted (unmanned airborne vehicles) and balloon instrumentation technologies are sought. New techniques and materials for forming "super-pressure" balloons and ways of formation flying or station-keeping with balloons would enable new science from this inexpensive platform, especially in the unmanned exploration of other planets.

• Super-pressure balloon manufacturing technologies;
• Station-keeping and trajectory control devices for balloons;
• New architectures and technologies for remote sensing applications; and
• Trajectory simulation tools and software.

Sub Topics:
Advanced Crew Support Technology Topic T5.01
Advanced Crew Support Technologies will be essential to provide capabilities to enable humans to live and work safely, effectively, and efficiently in space during long-duration missions away from Earth as outlined by the Vision for Human Exploration of Space. Special emphasis is placed on development of technologies that will have a dramatic impact on reduction of mass, power, volume and crew time, and increased safety and reliability. Areas being solicited include Advanced Life Support and Extravehicular Activity including development of direct energy conversion, energy storage, and applications utilizing nanotechnologies relevant to these areas. Research and technology development with dual uses pertinent to Earth-based applications to improve environmental sustainability are of interest.

Life Support and Habitation (LSH)
Closed-loop life support systems were identified by the President's Commission on Implementation of United States Space Exploration Policy as an enabling technology critical to attainment of exploration objectives within reasonable schedules and affordable costs. Subsystems are needed to fully recycle air and water, recover resources from solid wastes, and produce food from plants. Requirements include: safe operability in micro-and partial-gravity, high reliability, minimal use of expendables, ease of maintenance, and low system volume, mass, and power. Specific areas of interest include:

• Waste Management: Technologies to safely and effectively manage dry and wet solid wastes expected on near-term missions (plastics, food scraps, clothing, paper, tape, hygiene materials, and/or feces) performing the following functions: compaction, stabilization, dewatering, storage, and control of odor release;
• Water Recovery: technologies in two specific areas are solicited: 1) low-temperature catalysts for
destruction of organic carbon and nitrogen residuals in processed wastewater that operate at temperatures below 100º C; 2) technologies for recovery of water from brines generated from primary and secondary water processors including distillation and reverse osmosis systems that do not require use of consumable media;

- Filtration of Air and Water: techniques and technologies for separation and removal of particulates from water and gas streams, including air, potable water, and wastewater, that are regenerable, do not require consumable materials, have low pressure drop, and are suitable for use in micro- and hypo-gravity including consideration for collection and disposal of the solid phase;

- Food Provisioning and Galley: proposals are being sought in two areas: 1) Development of a non-metallic, high barrier packaging material with less mass and volume and/or is biodegradable, recyclable, or reusable, to minimize a potentially significant trash management problem. All packaging materials must have adequate oxygen and water barrier properties to maintain the food's 3- to 5-year shelf life. 2) Development of efficient and reliable food preparation or food processing equipment that can be used in hypogravity and reduced atmospheric pressure;

- Habitation Systems: Clothing Management Systems for reuse of clothing during long duration spaceflight, including clothes washing and drying technologies and which consider new advances in fabrics and materials;

- Crop Systems: new or more efficient technologies for lighting systems for crop growth, for use for fresh vegetable production within spacecraft or crop production systems on planetary surfaces. Lighting technologies must provide high irradiance and meet the spectral requirements for crops. These may include development of highly efficient electric light sources, highly efficient systems for collection, distribution, and re-emission of solar radiation or selectively transparent materials for direct solar lighting;

- Nanomaterials Applications: proposals are also solicited for development of advanced life support technologies that utilize unique properties of nanomaterials that are not possible with conventional materials, with emphasis on applications using single wall carbon nanotubes; and

- Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety and maintainability commensurate with in-cabin applications in crewed vehicles.

Advanced Extravehicular Activity (AEVA)

Complex missions require innovative approaches for maximizing human productivity and for providing the capability to perform useful work tasks. Requirements include reduction of system hardware weight and volume; increased hardware reliability, durability, operating lifetime, and increased human comfort. Specific areas of interest are as follows:

- Lightweight Structural and Protective Materials: proposals are sought for development of lightweight structural and protective materials for use in space suits to provide integral shell structure strength, impact, and puncture protection from shape edges, micrometeoroids and orbital debris, radiation protection, and prevention of abrasion, adhesion, and mitigation from Lunar and Martian dust;

- Protective Suits for Hazardous Environments: proposals are sought for development of a protective suit based on EVA technologies and concepts for Homeland Security and hazmat applications including hazardous materials handling and minimizing exposures to chemical and biological agents;

- Airlocks with minimum gas loss and volume: proposals are sought for development of both in-space and surface vehicle airlocks that minimize gas loss during depressurization and repressurization operations and also require minimum volume for airlock hatch and EVA crewmembers.
Nanomaterials Applications: proposals are also solicited for development of technologies for Advanced Extravehicular Activity that utilize unique properties of nanomaterials that are not possible with conventional materials with special emphasis on applications using single wall carbon nanotubes; and

Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in operating temperature range, in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety commensurate with in-cabin and exterior applications in crewed vehicles.

Sub Topics:
Robotics and Virtual Digital Human Technologies Topic T5.02
An Integrated Approach with Digital Virtual Humans(DVH) and Robotic Simulations

NASA is targeting a new level in space exploration operations. Critical advancements in crew and ground support technologies will be needed as NASA develops new operational capabilities to support multiple-manned, robotic, and long-duration/distance missions. Two potential areas for research are the ever-evolving Robotics and 3D DVH training procedures and simulation technologies providing operational robustness and intelligence. Furthermore, advanced capabilities for information integration and real-time interaction provide foundation for more simulation interaction between the two technologies. More advanced inter-system support capabilities (performance, maintenance, etc.) coordinated with a reliable knowledge base will be needed.

Proposals that improve operator efficiency via advanced displays, controls, and telepresence interfaces and improve the ability of humans and computers to seamlessly control robotic systems are sought. Specific technology requirements include the following hardware:

- Thermal feedback device for protecting the Robotic End-Of-Effector from grasping a hot/cold object that will damage its hand;
- Tactile feedback interface for collision awareness between workspace and avatar objects and robotic structure;
- Force feedback device for operator awareness of manipulator and payload inertia, gripping/slipping force, and forces and moments due to contact with external objects;
- Stereographic/autostereoscopic display systems for high-fidelity depth perception, field of view, and high resolution; and
- Spatial tracking for user appendages (i.e., head, arms, legs, fingers, and eyes) and avatar/robotic motion.

Based on the new Mission Control Center System (MCCS) Architecture framework, integrated support for Digital Virtual Human (DVH) in the loop and teleoperational interfaces are also the focus of this solicitation. Proposals offering innovation in the form of 3D visualization and simulation capabilities of robotic systems (direct manipulation, telerobotics, telepresence, etc.) with relation to the 3D DVH in the loop concept are being sought. The application targets would be flight and ground operations development, analyses, planning, training, and support. The main result desired is an interactive system that enhances operator and IVA/EVA procedure tasks efficiency via the teleoperational technologies and distributed collaborative virtual environments. The introduction of the DVH in a Virtual Reality (VR) robotic scenario is necessary for task and robotic device design, development, testing, planning, training, and operations functioning as integrated systems.
The core element of this project is the implementation of the Digital Virtual Human (DVH). This innovative human modeling technology comprises a combination of anatomical, biomechanical, and anthropometric functionality to fully simulate the somatic components and systems of the human body. Based on the tenets of the Visible Human Project, this DVH technology provides the opportunity to simulate real-world problems on the DVH in a simulated, virtual environment (VE) interfacing with virtual objects. The main objective is to apply a high-fidelity DVH in a scenario that "re-creates" a real world. Scenes involving the DVH imply rich, complex problems to solve, visualize, and predict outcomes. The DVHs will have a key role in Shared VEs and truly interactive scenarios based on real-time data/information. More complex DVH embodiment increases natural interaction within the environment. The users' more natural perception of each other (and of autonomous actors/avatars) increases their sense of being together and thus the overall sense of shared presence in the environment.

Immersive technologies such as Virtual Reality (VR), Digital Virtual Human (DVH), and 3D DVH training procedure and simulation modeling have become a significant vehicle for NASA's effort to generate and communicate knowledge/understanding to K-12 levels through university/academic institutions to continuing education modalities. The ability to share aerospace-related operation simulations such as International Space Station and Space Shuttle/Space Transport System (STS) operations, robotics, intravehicular/extravehicular activities, Mission Control Center Systems (MCCS) conduct, interplanetary space flight, and microgravity simulation provides opportunity for educational and commercial growth for NASA and its research and development partners.

**Human/Robotic Operations in Space**

- Small, low power machine advanced vision systems for tracking a moving, articulated object;
- Machine vision techniques including the construction of image mosaics, for detection of unspecified changes in objects being inspected under diverse or changing lighting and viewing conditions;
- Small, lower power, range/range-rate sensors;
- Control interfaces that allow for seamless human/robot operations;
- 3D path planning systems and intelligent trajectory assessment feedback during teleoperations;
- Miniaturized motor control and drive electronics;
- Miniaturized sensing systems for manipulator position, rate, acceleration, force and torque; and
- Reduced-part-count miniaturized propulsion hardware (e.g., compressed gas storage with output pressure regulation via valve control only).

**Sub Topics:**

**Self-Healing Repair Technologies Topic T6.01**

It is highly desirable to develop technologies for polymeric materials used in electrical wire insulation that have the ability to self-heal. One example of self-healing is the repair process for composite materials, which uses the stress induced by a microfissure to rupture microcapsules of repair materials. In this system, a monomer is
microencapsulated and then dispersed along with a catalyst. Once the microcapsules rupture, the monomer is polymerized by the dispersed catalyst and the microfissure is filled. Applications for self-healing processes for materials can be found in areas where failures could result in catastrophic consequences. For example, failure of structural members in spacecraft or aircraft; failure of electrical wire insulation materials used in spacecraft, aircraft, or buildings; or failure of polymer membranes used in critical separations in space exploration or medical devices. The key to any self-healing process is to use the change that occurs during the onset of the failure to initiate the repair process. This change could be the result of an impact to the insulation or the beginning of the electrical breakdown of the insulation. What is required would be an action that provided sufficient energy to start a second reaction or process that ultimately produced and/or bonded the repair material to the damaged insulation.

Wire insulation failure is considered a major problem on spacecraft and proposals should support concepts to develop self-healing technologies that have the ability to repair damaged Kapton or Teflon wire insulation. Of particular importance will be the methods needed to induce the self-repair process in wire insulation that has been manufactured. It is important to recognize the impact of the manufacturing process used to produce the insulated wire on the final product. These methods must produce a flexible, watertight seal over the damaged area. The physical and chemical properties of the final repair material should be similar to the initial insulating materials.

Proposals are also sought for innovative technologies and technology concepts in combining or bonding self-healing materials to conductor materials for an integrated, advanced, next-generation wiring system. Technologies for advancing conductor materials to allow for this integrated system should be considered since this is a topic area of concern in the Human and Robotic Technology Program.

Sub Topics:

Batteryless, Wireless Remote Sensors Topic T6.02
Recently, an innovative communication scheme was demonstrated that increases the attractiveness of using Surface Acoustic Wave (SAW) sensors as the basis for wireless, passive, sensor networks. It now appears feasible that a moderate number of sensors could be distributed throughout a volume of space and interrogated remotely and individually. Such a capability is of interest to the space program in that it may provide a lightweight (no wires and small sensors), low maintenance (no batteries), sensing network that can be used in harsh environments (predicted temperature ranges are from cryogenic through 900° C). NASA is currently funding work on a distributed temperature-sensing network but seeks other advances in this area.

At the recent 2004 IEEE International Ultrasonics, Ferroelectrics, and Frequency Control 50th Anniversary Joint Conference, two papers on Orthogonal Frequency Coding for SAW Sensors were presented. This new communication scheme for SAW devices and sensors appears to offer the capability to develop sensing networks where individual sensors can be interrogated from among a distributed array of devices. It also appears to provide scaling of the system in both number and range while suffering minimal degradation in the time resolution of the echoed signals. Consequently, NASA has recently decided to fund the development of a demonstration system using this concept and using a selected sensor (most likely temperature).

But, further advances are sought in this area, particularly, but not limited to, the area of novel sensors. Both the Space Shuttle as well as future vehicles could benefit from distributed strain sensors allowing high resolution monitoring of airframe stress. Embedded sensors within high pressure dewars might indicate fracturing before destructive failure occurs. Sensors that can operate within a cryogenic environment without the heat loss associated with wires could offer level, pressure, or temperature monitoring capabilities that are difficult or impossible to achieve with current technology. Embedded corrosion sensors or other process monitors could
provide useful data. For example, it might be advantageous to locate moisture sensors under the Shuttle’s thermal protection system materials. Also, there is interest in distributed leak detection systems, where, for example, hydrogen could be detected before it accumulates to the 4% explosive level in air. In addition to sensor development, improvements to the overall system are sought. For example, improvements are desirable in antenna design or system architecture that increase range or sensitivity.

The goal is to provide new sensors and capabilities that are compatible with the Orthogonal Frequency Coding scheme recently demonstrated under NASA funding in order to increase the range of applicability of this concept.

Sub Topics:
Personal Air Transportation Technologies for Flight Demonstration Topic T7.01
NASA is performing technology research for future, on-demand, personal air transportation that is more robust and consumer focused than current commercial airline operations. The current studies involve the investigation of missions, concepts, and technologies for the purpose of augmenting on-demand personal transportation mobility and capacity over the next 20 years. The intent of this research is to perform the analyses and demonstrations required to provide radical improvements to the key metrics that currently inhibit market growth of these small, personal-use vehicles. Initial markets would build on the near-term, existing general aviation infrastructure with takeoff and landing field lengths of approximately 2500 feet. Next-generation general aviation markets will encompass a class of vehicles that have utility, comfort, public acceptance, efficiencies, cost, and ease of use which can be more closely associated with automobile-like characteristics. Long-term markets would involve mission concepts that are capable of much closer proximity operations and the ability to perform near door-to-door transportation service, but with significantly greater speed and reach.

This PAV research will include focused technology efforts leading towards the following goals and objectives:

1) Reducing small aircraft certified flyover community noise by 24 dbA from the state-of-the-art values of approximately 84 dbA while still achieving reasonable cost and efficiency with integrated vehicle concepts capable of 200-mph performance. This noise reduction equates to a tenfold reduction in the perceived noise so that these aircraft are no noisier than current motorcycle regulations. The intent of this effort is to demonstrate that significant increases in small aircraft operations can be acceptable to communities, as these vehicles are designed with technologies that permit them to be good neighbors. These community noise reductions should also provide a significant reduction in cabin noise which will provide improved comfort levels for passengers.

2) Reducing the aircraft acquisition cost on the order of 60% from current price levels while still at relatively modest production volumes of approximately 2000 units/year. This effort will include investigation of advanced quality assurance certification processes and procedures instead of the current quality control methods. Significant industry investment has not occurred because a sizable market is not envisioned at cost levels where only a small fraction of the population can enter the market. Future production of such vehicles could be on the scale of limited
production luxury cars, however the demonstration of affordable vehicles at relatively low volume is a critical step for market growth that would provide the capital for rapid expansion.

3) Simplify the operation of small aircraft such that the specialized skills, knowledge, and associated training are reduced to levels comparable to operating an automobile or boat. This reduction must be achieved during near-all-weather operations and with a level of safety that is superior to comparable operations today.

4) Additional mid-term and long-term technology investigations could also include efforts that provide improved performance, efficiency, and short field length takeoff and landing capability. Implicit to all these investigations will be enhancing the vehicle safety, versatility, ease of entry, interior environment, visibility, and maintenance and operations cost.

Research that can be demonstrated, through flight or ground experiment, will be especially helpful in establishing a credible foundation from which personal mobility technologies can proceed in the private marketplace. Information is desired on current research efforts in these focused areas for respondents interested in partnering with NASA on collaborative investigation. It is anticipated that subsystem design and testing will be performed on selected technologies or concepts.

Sub Topics:

Non-destructive Evaluation and Structural Health Monitoring Topic T7.02

Innovative concepts are being solicited for the development of non-destructive evaluation (NDE) and health-monitoring technologies for vehicles and structures involved in exploration missions. The highest priority is structural health monitoring systems that provide real time in situ diagnostics and evaluation of structural integrity. Emphasis is focused on highly miniaturized, lightweight, compact systems that deliver accurate assessment of structural health. The sensors, data acquisition and analysis systems and associated electronics must perform in high stress and hostile conditions expected on launch vehicles and space environments. Diagnostic systems intended for external inspection of space vehicles and structures will be highly autonomous, remotely operated and preferably non-contacting.

Evaluation sciences include ultrasonics, laser ultrasonics, optics and fiber optics, video optics and laser metrology, thermography, electromagnetics, acoustic emission, X-ray and terahertz radiation. Innovative and novel evaluation approaches are sought for the following materials and structural systems:

- Adhesives and bonded joints, sealants, bearings, coatings, glasses, alloys, laminates, monolithics, material blends, wire insulating materials, and weldments;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.
Proposals should address the following performance metrics as appropriate:

- Characterization of material properties;
- Assessment of effects of defects in materials and structures;
- Evaluation of mass-loss in materials;
- Detection of cracks, porosity, foreign material, inclusions, and corrosion;
- Dis-bonded adhesive joints;
- Detection of cracks around fasteners such as bolts and rivets;
- Real-time and in situ monitoring, reporting, and damage characterization for structural durability and life prediction;
- Repair certification;
- Environmental sensing;
- Planetary entry aero-shell validation;
- Micro-meteor and orbital debris impact location and damage assessment;
- Electronic system/wiring integrity assessment; wire insulation integrity and condition (useful life) and arc location for failed insulation;
- Characterization of load environment on a variety of structural materials and geometries including thermal protection systems and bonded configurations;
- Identification of loads exceeding design;
- Monitoring loads for fatigue and preventing overloads;
- Suppression of acoustic loads;
- Early detection of damage; and
- In situ monitoring and control of materials processing.

Measurement and analysis innovations will be characterized by:

- Advanced integrated multi-functional sensor systems;
- Autonomous inspection approaches;
- Distributed/embedded sensors;
- Roaming inspectors;
• Shape adaptive sensors;
• Concepts in computational models for signal processing and data interpretation to establish quantitative characterization;
• Advanced techniques for management and analysis of digital NDE data for health assessment and lifetime prediction; and
• Biomimetic, and nano-scale sensing approaches for structural health monitoring that meet size and weight limitations for long duration space flight.

Sub Topics:
Aerospace Manufacturing Technology Topic T8.01
Continued technological innovation is critical to a strong manufacturing sector in the United States economy. NASA is interested in innovated manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system. Specific areas of interest in this solicitation include innovative manufacturing, materials, and processes relevant to propulsion systems and airframe structures for next-generation launch vehicles, crew exploration vehicles, lunar orbiters and landers, and supporting space systems. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components. Only processes that are environmentally friendly and worker-health oriented will be considered.

Proposals are sought, but are not limited to, the following areas:

**Polymer Matrix Composites (PMCs)**
Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing (e.g., e-beam, ultrasonic); damage tolerant and repairable structures; advanced materials and manufacturing processes for both cryogenic and high-temperature applications; and improved thermal protection systems (e.g., integrated structures, integral cryogenic tanks and insulations).

**Ceramic Matrix Composite (CMCs)**
Materials and processes that are projected to significantly increase safety and reduce costs simultaneously while decreasing weight for space transportation propulsion. Innovative material and process technology advancements that are required to enable long-life, reliable, and environmentally-durable materials.

**Metals and Metal Matrix Composites (MMCs)**
Advanced manufacturing processes such as pressure infiltration casting (for MMCs); laser engineered near-net shaping; electron-beam physical vapor deposition; *in situ* MMC formation; solid state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites; advanced materials such as metallic matrix alloys compositions, which optimize high
ductility and good joinability; functionally graded materials for high- or low-temperature application; alloys and nanophase materials to achieve more than 120 ksi tensile strength at room temperature and 60 ksi at elevated temperature above 500° F; new advanced superalloys that resist hydrogen embrittlement and are compatible with high-pressure oxygen; innovative thermal-spray or cold-spray coating processes that substantially improve material properties, combine dissimilar materials, application of dense deposits of refractory metals and metal carbides, and coating on nonmetallic composite materials.

Manufacturing Nanotechnology

Innovations that use nanotechnology processes to achieve highly reliable or low-cost manufacturing of high-quality materials for engineered structures.

Sub Topics:
Advanced High Fidelity Design and Analysis Tools For Space Propulsion Topic T8.02
The pace at which the United States, through NASA, explores space will largely be driven by the cost of developing the systems required to make future explorations practical. The nation's ability to decrease the cost and schedule required to develop new space transportation systems that are required to support NASA's exploration missions is hampered by inadequacies in our design tools and databases. Space Transportation systems operate at the extremes of our materials capabilities, therefore, any shortcomings in our ability to predict the internal operating environments during the design process will almost always lead to redesigns during the development of the system. These redesigns are costly and always compromise the project's schedule. One way to address this issue is to increase the fidelity and accuracy of the tools used to predict the internal operating environments during design.

Universities are at the leading edge of development of new, "first principles" physical models of development of new high-fidelity numerical approaches for simulating operation of space transportation systems and of developing experimental approaches and data required to validate these tools. Transition of these technologies, however, from an academic setting to a production, applications-centered environment, where it can be applied to the design of NASA's space transportation systems, requires focused effort. Efficient and timely transfer of these capabilities from the university setting to the operational (production) setting is required to reduce the developmental risks associated with NASA's space transportation systems and to maximize the return on NASA's investments at the nation's colleges and universities.

This subtopic solicits partnerships between academic institutions and small businesses for the purpose of developing novel design and analysis approaches and the methods by which to validate them into useful production tools that can be used to develop NASA's space transportation systems. Examples of specific areas where innovations are sought follow:

- Efficient, three-dimensional (3D), time-accurate analysis tools for modern rocket engine combustion chamber and turbomachinery environments and performance;
- Efficient, three-dimensional (3D), time-accurate analysis tools for predicting the environment and loads internal to valves, lines, and ducts in modern rocket engines;
- Practical 3D, steady and time-accurate, multidisciplinary analysis (MDA) tools for design of space transportations systems components and subsystems;

- Practical approaches for predicting the time-varying, 3D flow field in cases involving relative motion between objects;

- Practical Large Eddy Simulation (LES) tools for the analysis of high pressure reacting flows;

- Automated hybrid grid generation tools and grid adaptation tools;

- Efficient and accurate fluid properties routines for the range of conditions applicable to rocket engines;

- Automated approaches for extracting key engineering information and flow features from 3D flow simulations;

- Automated approaches for validating and assuring quality of application software;

- Practical, unsteady, 3D cavitation models for implementation into Reynolds-Averaged Navier-Stokes (RANS) analysis codes;

- Advanced instrumentation and diagnostic techniques necessary for acquisition of steady and unsteady code validation data; and

- Validation data for all of the tool types mentioned above.

Sub Topics:
Rocket Propulsion Testing Systems Topic T9.01
Proposals are sought for innovative technologies and technology concepts in the area of propulsion test operations. Proposals should support the reduction of overall propulsion test operations costs (recurring costs) and/or increase reliability and performance of propulsion ground test facilities and operations methodologies. As a minor element in a proposal for this topic, the offeror may include specific educational related research, technology advances, or other deliverables that address and support the Agency's education mission such as the enhancement of science, technology, engineering, and mathematics instruction with unique teaching tools and experiences. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies
Innovative, nonintrusive sensors for measuring flow rate, temperature, pressure, rocket engine plume constituents, and effluent gas detection. Sensors must not physically intrude at all into the measurement space. Low-millisecond to sub-millisecond response time is required. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH2) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH2). Flow rate sensors must have a range of up to 2000 lb/s (82 ft/sec) for LOX and 500 lb/sec (300 ft/s) for LH2. Pressure sensors must have a range up to 15,000 psi. Rocket plume sensors must determine gas species, temperature, and velocity for H2, O2, hydrocarbons (kerosene), and hybrid fuels.

Rugged, high accuracy (0.2%), fast response, temperature measuring sensors and instrumentation for very high
pressure, high flow rate cryogenic piping systems. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH2) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/sec 300 ft/s for LH2). Response time must be on the order of a few milliseconds to sub-milliseconds.

Phenomenology, modeling, sensors, and instrumentation for prediction, characterization, and measurement of rocket engine combustion instability. Sensor systems should have bandwidth capabilities in excess of 100 kHz. Emphasis is on development of optical-based sensor systems that will be nonintrusive in the test article hardware or plume.

**Improvement in Ground-Test Operation, Safety, Cost-effectiveness, and Reliability**

Smart system components (control valves, regulators, and relief valves) that provide real-time, closed-loop control, component configuration, automated operation, and component health. Components must be able to operate in cryogenic temperatures (as low as 160R for LOX and 34R for LH2) under high pressure (up to 15,000 psi) high flow rate conditions (2000 lb/s - 82 ft/s for LOX; 500 lb/sec - 300 ft/s for LH2). Components must be able to operate in the elevated temperatures associated with a rocket engine testing environment. Response time must be on the order of a few milliseconds to sub-milliseconds.

Improved, long-life, liquid oxygen compatible seal technology. Materials and designs suitable for oxygen service at pressures up to 10,000 psi. Both cryogenic and elevated temperature candidate materials and designs are of interest. Typical temperature ranges will be either -320°F to 100°F, or -40°F to 300°F. Seal designs may include both dynamic and static use. Plastic, metal, or electrometric materials, or combinations thereof are of particular interest.

Miniature front-end electronics to support embedding of intelligent functions on sensors. Requirements include: computational power comparable to a 200 MHz PC with approximately 32 MB of RAM and similar non-volatile storage; analog input/output (I/O) (at least two of each with programmable amplification and anti-aliasing filters plus automatic calibration); digital I/O (at least eight) communication port for Ethernet bus protocol (one high speed and one low speed); support for C programming (or other high level language); and a development kit for a PC. The package should occupy a space no larger than 4" x 4" x 2". The system should include an embedded temperature sensor, an embedded stable voltage calibration source, and programmable switching to connect calibration source input and output.

New and innovative acoustic measurement techniques and sensors for use in a rocket plume environment. Current methods of predicting far-field and near-field acoustic levels produced by rocket engines rely on empirical models and require numerous physical measurements. New and innovative acoustic prediction methods are required which can accurately predict the acoustic levels a priori or using fewer measurements. New, innovative techniques based on energy density measurements rather than pressure measurements show promise as replacements for the older models.

Development of tools that integrate simple operator interfaces with detailed design and/or analysis software for modeling and enhancing the flow performance of flow system components such as valves, check valves, pressure regulators, flow meters, cavitating venturis, and propellant run tanks.
New and improved methods to accurately model the transient interaction between cryogenic fluid flow and immersed sensors that predict the dynamic load on the sensors, frequency spectrum, heat transfer, and effect on the flow field, are needed.

Modeling of atmospheric transmission attenuation effects on test spectroscopic measurements. Atmospheric transmission losses can be significant in certain wavelength regions for radiometric detectors located far from the rocket engine exhaust plume. Consequently, atmospheric losses can result in over-prediction of the incident radiant flux generated by the plume. Accurate atmospheric transmission modeling is needed for high-temperature rocket engine plume environments. The capabilities should address both the losses from ambient atmosphere and localized environments such as condensation clouds generated by cryogenic propellants.

Application of System Modeling to Ground Test Operations in a Resource Constrained Environment

New innovative approaches to incorporating knowledge and information processing techniques (prepositional logic, fuzzy logic, neural nets, etc.) to support test system decision making and operations. A requirement exists to develop, apply, and train intelligent agents, behavioral networks, and logic streams for rocket engine testing modes of operations and practice. Applications must operate statistically well on small and disparate data sources. The resulting products are inferential, representative, and they capture tacit and explicit knowledge. Statistical analysis must be supported.

Techniques to reduce required sample size to maintain acceptable levels of confidence in cost data. In order to use appropriate models and to manage the cost of data acquisition and maintenance, the minimization of required data sample sizes is critical.

Measurements and data are the product of ground testing. High accuracy, precision, uncertainty bands, and error bands are important elements of the data that is generated; this must be quantified. Techniques and models to determine these parameters for active test facilities are required.

Sub Topics:
Integrated Life-Cycle Asset Mapping, Management, and Tracking Topic T9.02
To support NASA's need for reliable and low-cost asset management in all of its programs including Earth-based activities, robotic and human lunar exploration, and planning for later expeditions to Mars and beyond, the Earth Science Applications Directorate at Stennis Space Center seeks proposals supporting NASA's requirements for asset management. With proper physical infrastructure and information systems, identification tags should allow any item to be tracked throughout its life cycle. When combined with Earth and lunar GIS, and related supporting documentation, any significant asset should be located, through time and space, as well as organization. Starting with programmatic requirements and design data, assets would be tracked through manufacture, testing, possible launch, use, maintenance, and eventual disposal. Innovative technology and information architectures should integrate and visually map infrastructure, assets, and associated documentation with the ability to link to program structure, budget, and workflow. Innovative solutions will facilitate information flow between the various NASA Centers and Programs. The system must maintain signature authority and restrict unauthorized moves. Ideally, if fully implemented, any remote item could be actively located throughout the NASA system with minimal delay. Any tagged item should be able to be queried at its location to retrieve associated records, e.g., maintenance, inspection, configuration management, chain-of-custody, engineering specifications, etc. A simple operator interface would provide "finger-tip knowledge" about the asset. It should be possible to provide secure access to this information for both domestic and international partners. The proposed solution will minimize capital cost and human work effort required for inventory and tracking of nonconsumable assets while exceeding the performance of current systems. Note that tagged assets may be subject to extreme environments in space and on Earth.
The innovation may eventually interoperate with a holistic information system, and may not preclude other uses for a terrestrial and lunar GIS such as:

- Operational infrastructure support AM/FM (automated mapping / facilities management);
- Asset and resource management, including waste disposal;
- Lunar landing and facility site selection, and optimization;
- Conceptual site infrastructure and layout design;
- Surface navigation;
- Emergency response information; and
- A comprehensive portal for Earth and lunar mapping data, both image- and vector-based.

Sub Topics: