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) and in 1958 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 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.
- 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
- Microdosimetry for research applications including implantable dosimeters for biological studies

**Radiation Hardened Electronic Systems**

- Methods for hardening pre-existing technologies
- 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
• 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
• 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
• 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
• 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, in space technology. The newest, the fastest, 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 in 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 regular daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered as 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,
- Modeling, identification, simulation, and control of aerospace vehicles in-flight test, 4/ flight sensors, sensor arrays and airborne instruments for flight research, and 5/ 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 system and to develop the optimal plan for transitioning to the future system. 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 influence 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 dynamical subsystems with an emphasis towards 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 require a demonstration in an actual flight environment to fully characterize or validate.
Glenn Research Center Topic T3

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. Our world-class research and technology development is focused on space power, space flight, electric and nuclear space propulsion, space and aeronautical communications, advanced materials research, biological and physical microgravity science, and aerospace propulsion systems for safe and environmentally friendly skies. One-third of our 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 large, 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 PhD degrees.

Sub Topics:

T3.01 Aeropropulsion and Power

Lead Center: GRC

The research sponsored by the Propulsion and Power Project focuses on ensuring the long-term environmental compatibility and efficiency of aircraft propulsion and power systems. The project addresses critical propulsion and power technology needs across a broad range of investment areas including revolutionary advances in combustion-based aeropropulsion systems and technologies and unconventional propulsion and power systems and technologies. High-risk, high-potential research investments include fuel-cell based propulsion systems, high-temperature nanotechnology, and pulse detonation engine components and subsystems. Ultimately, the Propulsion and Power Project seeks to demonstrate (in a laboratory environment) key component technologies to enable nonconventional combustion-based propulsion systems and electric and hybrid propulsion and power systems. The Propulsion and Power Project directly supports the NASA objectives of: "Protect the Environment: local environmental quality and the global climate by reducing aircraft noise and emissions" and "Explore New Aerospace Missions: Pioneer novel aerospace concepts to support Earth and space science missions."

Innovations sought include:

- Alternative fuels and/or alternative propulsion systems, i.e., aeronautical propulsion technology concepts with horizons of 20-40 years from today with potential for two times the payload-range performance. Such high-payoff propulsion systems would set new, revolutionary directions well beyond the evolutionary approaches. These alternative fuel and/or alternative propulsion systems may include, but are not limited to the following areas.

  - Revolutionary engine design (technologies beyond the conventional Brayton cycle gas turbine engine). For example, micromachined SiC microengines which may have potential for use in a distributed propulsion architecture.
Nano- and autonomous systems. For example: nanotechnology fibers, tubes, spheres, and high temperature shape memory alloys and piezoelectric materials for their unique role in tribology, structures and composite reinforcements, and control systems for autonomous, adaptive engine control and sealing.

- Non-combustion (electric) propulsion and power systems, e.g., hydrogen-based and electric aeropropulsion (propulsion systems capable of flight while producing zero CO₂ emissions), and new missions enabled by quiet, clean, electric propulsion. Key technologies to enable design of an alternatively fueled, fuel cell or hybrid propulsion system. These technologies may include, but are not limited to:
  - Hydrogen tankage;
  - Fuel cell systems, components, and subcomponents; and
  - Power management and distribution materials, components, and configurations.

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*

The mission of the Earth Science Enterprise is 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 from terrestrial applications, as well as the vantage point of space, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

This STTR solicitation is to help provide advanced remote sensing technologies to enable future Earth and Lunar Science measurements.

**Analytical Instrumentation for Planetary Atmospheres Research**

Innovations and the application of new technologies are sought for improving the operating characteristics of gas chromatograph-mass spectrometer systems in harsh environments. Reductions in volume, weight, power, and cost
while increases in performance, serviceability, and functionality of system components is highly desirable. The overall goal is to develop an instrument with increased performance in the areas of improved collection, detection, and measurement. Specific areas of interest include:

- Miniatrurized and ruggedized gas chromatograph columns
- Microvalves
- Improved stability and performance of secondary electron multipliers
- Performance increases in the areas of size and conversion efficiency of high voltage DC/DC converters
- Rigid miniature vacuum pumps

**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 systems must be compact upon launch, they must achieve high precision surface form factors, and they must include beam-scanning capabilities. The antenna compactness on launch can be achieved either through folding technologies or from some assemblage of small components into the larger final system in space. The microwave antenna surface characteristics must be accurate enough to produce microwave beam patterns with adequately small side lobes. 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. The beam widths must be small enough to resolve the few kilometer scales needed for many geophysical observations. The microwave wavelengths will be determined according to the geophysical measurement of interest. The antenna concepts may include large single apertures or apertures composed of multiple elements that are operated synergistically to produce the desired performance.

**Active Optical Systems and Technology for UAVs and Ballooncraft**

Lidar remote sensing systems are required to meet the demanding requirements for future Earth Science missions. It is envisioned that lidar systems will be used in the following application areas: high spatial and temporal resolution observations of the land surface and vegetation cover (biomass); profiling of clouds, aerosols, and atmospheric state variables including temperature, humidity, winds, and trace constituents including tropospheric and stratospheric ozone and CO$_2$ (profiling and total column); measurement of the air/sea interface and mixed layer. New systems and approaches are sought in these areas, which will:

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

Systems and approaches will be considered that demonstrate a capability which is scalable to space or can be mounted on a relevant platform (UAV, long duration balloon, or aircraft) for calibration and validation of a space-borne system.
Unmanned Aerial Vehicle (UAV) Technologies for Remote Sensing

Avionics, real-time telemetry acquisition and remote sensing spectral imaging devices to support Unmanned Aerial Vehicles’ (UAV) basic and applied science and application demonstrations (proposers need only to respond to a minimum of one of the below):

- Low cost avionics instrumentation for precise navigation and aircraft control, must have an attitude sampling rate greater than 25 Hz and an accuracy greater than 0.2° in roll and pitch.
- Real-time sensor fusion algorithms that combine low-cost inertial, GPS, magnetometer, and other sensor input to deliver aircraft state vectors at a rate greater than 50 Hz.
- Uncooled infrared and thermal spectral imager instrument to be less than 2 lbs and no larger than 0.05 m³ in volume. Must operate autonomously in coordination with the onboard flight plan. It must have a built-in data acquisition system. The 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. Quantization bit resolution should be 10-bit minimum.

Ballooncraft Trajectory Control and Station-Keeping

Trajectory Control and Station-Keeping are critical items for future Ultra-Long Duration Balloon remote sensing concepts.

- Trajectory control would allow for some authority of the path of the system that may be required or desired for several reasons such as science mission, geopolitical, or improved recovery options. Activities include concept studies for alternative systems, propeller design and fabrication, functional flight testing, airship design and analysis, material development, and performance modeling.

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 10⁻¹⁵ W/√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 (< 100 microwatts per channel)
- 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>Energy Range</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>0.05–150;15 keV</td>
<td>100–150;400 nm</td>
<td>400–700 nm</td>
<td>355–2050 nm</td>
<td>0.7–150;4 mm</td>
<td>20–800 mm</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>1–4 m</td>
<td>1–2 m</td>
<td>6–10+ m</td>
<td>3–4 m</td>
<td>10–25 m</td>
<td></td>
</tr>
<tr>
<td>Areal Density</td>
<td>&lt; 0.5 kg/m^2</td>
<td>&lt; 10 kg/m^2</td>
<td>&lt; 10 kg/m^2</td>
<td>&lt; 5 kg/m^2</td>
<td>&lt; 5 kg/m^2</td>
<td></td>
</tr>
<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>
</table>

* 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.
- 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
- High spatial resolution x-ray detectors, for producing ~50 meter 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)
- 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
- Trajectory simulation tools and software

**Johnson Space Center Topic T5**

The Johnson Space Center’s chief mission is the expansion of a human presence in space through exploration and the utilization of space for the benefit of mankind. The Center is also the lead center for curation and research of astromaterials (including Lunar rocks and other specimens), the International Space Station, the Space Shuttle, home to the Mission Control Center and to the NASA astronaut corps, and leads the development, testing, production and delivery of U.S. human spacecraft.

Sub Topics:

**T5.01 Understanding and Utilizing Gravitational Effects on Molecular Biology and for Medical Applications**

**Lead Center: JSC**

The microgravity environment enables scientists to perform unique studies on metabolic and functional changes in cells, and modified growth of multiple cells for artificial tissue development and behavior. NASA has developed novel rotating bioreactor technologies to model microgravity effects on cultures of suspended and anchorage-dependent cells and tissues. The spin-off from the NASA research has been the use of these novel culture methods for Earth-based research into mechanisms of enhancing cytokine and hormone secretions, production of 3-D tissue spheroids, interactions of cancer cells and normal cells in co-culture, and molecular mechanisms of altered immune cell functions, bone formation, and special uses of stem cells. The current focus is on development of new methods for enhancing production of commercial products from cultured cells for medicine and biotechnology applications. NASA cell science research includes development of space bioreactors for culture of fragile human cells; mechanisms for enhancing production of IFNs and cytokines from human white blood cells, near-infrared light mechanisms that stimulate wound healing and bone formation, and also for photodynamic therapy for local treatment of solid tumors; and tissue engineering systems which grow 3-D tissue constructs. New systems have been developed for microencapsulation of drugs and cells for transplantation in concert with the new culture systems for in vitro testing of the effectiveness of new drug combinations and biomodulators, and methods for measuring metastatic potential of tumor biopsies, and new tests for changes in specific cellular immune functions of persons under physiological stress. New fluorescent and bioluminescence imaging technologies are being developed to aid in the real-time assessment of these various effects on cultured cells in bioreactors and then applied to clinical tests especially for monitoring treatments for cancer.
Specific areas of interest are:

- New methods for culturing mammalian cells in bioreactors, including advanced bioreactor design and support systems; miniature sensors for measurement of pH, oxygen, carbon dioxide, glucose, glutamine, and metabolites; and microprocessor controllers. Neural fuzzy logic network systems for the control of mammalian cell culture systems. Methods to minimize biofilm formation on fluid-handling components, sensors, and bioreactors. Spectroscopic and biochemical analysis of biofilm formed in bioreactors. Microscale bioreactors for biomonitors of radiation and other external stressors.

- Technologies that allow automated biosampling and biospecimen collection, handling, preservation and fixation, and processing in cellular systems. Methods for separation and purification of living cells, proteins, and biomaterials, especially those using electrokinetic or magnetic fields that obviate thermal convection and sedimentation, enhance phase partitioning, or use laser light and other force fields to manipulate target cells or biomaterials.

- Techniques or apparatus for macro-molecular assembly of biological membranes, biopolymers, and molecular bioprocessing systems; biocompatible materials, devices, and sensors for implantable medical applications including molecular diagnostics, in vivo physiological monitoring and microprocessor control of prosthetic devices.

- Methods and apparatus that allow microscopic imaging including hyperspectral fluorescent, scattering and absorption imaging and biophysical measurements of cell functions, effects of electric or magnetic fields, photoactivation, and testing of drugs or biocompatible polymers on live tissues. Integrated instrumentation for separation and purification of RNA, DNA, and proteins from cells and tissues.

- Quantitative applications of molecular biology, fluorescence imaging and flow cytometry, and new methods for measurement of cell metabolism, cytogenetics, immune cell functions, DNA, RNA, oligonucleotides, intracellular proteins, secretory products, and cytokine or other cell surface receptors. Means to enhance and augment genomics and proteomics techniques, including molecular and nanoscale tools. Small-scale mass spectrometers. Development of novel fluorophores that tag proteins mediating cellular function, particularly those that can be excited using solid-state lasers.

- Micro-encapsulation of drugs, radiocontrast agents, crystals, and the development of novel drug delivery systems wherein immiscible liquid interactions, electrostatic coating methods, and drug release kinetics from microcapsules or liposomes can be altered under microgravity to better understand and improve manufacturing processes on Earth.

- Miniature bioprocessing systems, which allow for precise control of multiple environmental parameters such as low-level fluid shear, thermal, pH, conductivity, external electromagnetic fields, and narrow-band light for fluorescence or photoactivation of biological systems.

- Novel low temperature sample storage methods (-80°C and -180°C) and biological sample preservation methods. Methods to reduce launch/return mass of biological samples and support reagents.

- DNA template for molecular wiring that permits macro- to nanoscale connectivity. Nanoscale electronics based on self-assembling protein-based molecular structures.

- Computer models and software that better handle large numbers of coupled reactions in cell science systems.

- Tools and techniques to study mechanical properties of the cell: subcellular rheology, cell adhesion, affect of shear flow, affects of direct mechanical perturbation. Tools and techniques to facilitate multiple simultaneous probing and analyzing of a cell or subcellular region (examples include atomic force microscope coupled with microelectrode or micro-Raman, Optical trap).
Nanosensors for subcellular measurements: ultra-microelectrodes with less than 1micron diameter including cladding, nanoparticle reporters that provide spectroscopic information, and other novel intracellular sensor devices to provide spectroscopic data on intracellular processes.

Kennedy Space Center Topic T6

An entire chapter of U.S. history has been written at the John F. Kennedy Space Center (KSC). As the departure site for our first journey to the Moon, and hundreds of scientific, commercial, and applications spacecraft, and now as the base for Space Shuttle launch and landing operations, KSC plays a pivotal role in the nation's space program.

Sub Topics:
T6.01 Self-Healing Repair technologies

Lead Center: KSC

It is highly desirable to develop technologies for polymeric and composite materials that mimic the repair processes of biological systems. Much can be learned by relating the repair processes of biological systems to these inanimate materials, in particular, learning methods to initiate the self-healing processes. One example of inanimate 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. Another approach might be to combine animate and inanimate systems in such a way that the repair of the inanimate material is done by the animate system. Applications for self-healing processes of inanimate materials can be found in areas were failures could result in catastrophic consequences. Examples of these are failure of structural members in spacecraft or aircraft; failure of electrical wire insulation materials used in spacecraft, aircraft, or buildings; or failure of polymers membranes used in critical separations in the space exploration or medical devices.

Proposals are sought for innovative technologies and technology concepts in the areas of self-healing and repairing of electrical wiring insulation, which is an area under ASTRA's Advanced Technology Development (2.4.6). 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, Teflon, or vinyl-type 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 effect of the manufacturing process used to produce the insulated wire on the final product. These methods must produce a flexible water-tight seal over the damaged area. The physical and chemical properties of the final repair material should be similar to the initial insulating materials.
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 Vehicle (PAV) Research for Rural, Regional, and Intra-Urban On-Demand Transportation

Lead Center: LaRC

NASA is performing preliminary design studies of Personal Air Vehicle missions, concepts, and technologies for the purpose of augmenting on-demand personal transportation mobility and capacity. The intent of this research is to perform the analysis and demonstration 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.

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, providing improved comfort levels for passengers.

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.

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.
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.

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.

---

Marshall Space Flight Center Topic T8

High power levels needed for space exploration missions (including reactor powered electric propulsion, reactor powered surface systems, etc.) result in the need to reject large amounts of waste heat. Conventional radiator technologies, i.e., finned tube, heat pipe fed radiators, etc., are heavy, hard to package and deploy, and must be made quite redundant to assure long life operation. This solicitation seeks proposals for advanced heat rejection concepts that include belt and/or liquid droplet radiators, and other advanced radiator concepts that promise to lower mass by a factor of 3 to 10.

Sub Topics:

**T8.01 Aerospace Manufacturing Technology**

**Lead Center: MSFC**

NASA is interested in encouraging innovation in manufacturing through the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs. 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. 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 in 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; 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
development of the experimental approaches and data required to validate these tools. Transition of that
technology, however, from the 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 the
NASA's investments at the Nation's colleges and universities.

This subtopic solicits partnerships between academic institutions and small business 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 (3-D), time accurate analysis tools for modern rocket engine combustion
  chamber and turbomachinery environments and performance;
- Efficient, three-dimensional (3-D), time accurate analysis tools for predicting the environment and loads
  internal to valves, lines, and ducts in modern rocket engines;
- Practical 3-D steady and time-accurate multidisciplinary analysis (MDA) tools for design of space
  transportation 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 3-D flow
  simulations;
- Automated approaches for validating and assuring quality of application software;
- Practical unsteady 3-D 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.
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 institutions 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 4,500 employees, about 1,600 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, thus making 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/sec - 300 ft/s for LH2). Response time must be on the order of a few milliseconds to the 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 the 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 predicts 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, and 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:
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.

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

Sub Topics:
Space Radiation Dosimetry and Countermeasures Topic T1.02
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

• Microdosimetry for research applications including implantable dosimeters for biological studies

Radiation Hardened Electronic Systems

• Methods for hardening pre-existing technologies

• 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

• 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

• 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

• 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

• 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 in 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 regular daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered as 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,
- Modeling, identification, simulation, and control of aerospace vehicles in-flight test, 4/ flight sensors, sensor arrays and airborne instruments for flight research, and 5/ 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 system and to develop the optimal plan for transitioning to the future system. 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 influence 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 dynamical subsystems with an emphasis towards 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 require a demonstration in an actual flight environment to fully characterize or validate.

Sub Topics:
Aeropropulsion and Power Topic T3.01
The research sponsored by the Propulsion and Power Project focuses on ensuring the long-term environmental compatibility and efficiency of aircraft propulsion and power systems. The project addresses critical propulsion and power technology needs across a broad range of investment areas including revolutionary advances in combustion-based aeropropulsion systems and technologies and unconventional propulsion and power systems and technologies. High-risk, high-potential research investments include fuel-cell based propulsion systems, high-temperature nanotechnology, and pulse detonation engine components and subsystems. Ultimately, the Propulsion and Power Project seeks to demonstrate (in a laboratory environment) key component technologies to enable nonconventional combustion-based propulsion systems and electric and hybrid propulsion and power systems. The Propulsion and Power Project directly supports the NASA objectives of: "Protect the Environment"; "Protect local environmental quality and the global climate by reducing aircraft noise and emissions" and "Explore New Aerospace Missions"; Pioneer novel aerospace concepts to support Earth and space science missions."

Innovations sought include:

- Alternative fuels and/or alternative propulsion systems, i.e., aeronautical propulsion technology concepts with horizons of 20–40 years from today with potential for two times the payload-range performance. Such high-payoff propulsion systems would set new, revolutionary directions well beyond the evolutionary approaches. These alternative fuel and/or alternative propulsion systems may include, but are not limited to the following areas.

  - Revolutionary engine design (technologies beyond the conventional Brayton cycle gas turbine engine). For example, micromachined SiC microengines which may have potential for use in a distributed propulsion architecture.
Nano- and autonomous systems. For example: nanotechnology fibers, tubes, spheres, and high
temperature shape memory alloys and piezoelectric materials for their unique role in tribology,
structures and composite reinforcements, and control systems for autonomous, adaptive engine
control and sealing.

- Non-combustion (electric) propulsion and power systems, e.g., hydrogen-based and electric
aeropropulsion (propulsion systems capable of flight while producing zero CO\textsubscript{2} emissions), and new
missions enabled by quiet, clean, electric propulsion. Key technologies to enable design of an alternatively
fueled, fuel cell or hybrid propulsion system. These technologies may include, but are not limited to:

  - Hydrogen tankage;
  - Fuel cell systems, components, and subcomponents; and
  - Power management and distribution materials, components, and configurations.

Sub Topics:
Earth Science Sensors and Instruments Topic T4.01
The mission of the Earth Science Enterprise is 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 from terrestrial applications, as
well as the vantage point of space, we seek to observe, analyze, and model the Earth system to discover how it is
changing and the consequences for life on Earth.

This STTR solicitation is to help provide advanced remote sensing technologies to enable future Earth and Lunar
Science measurements.

Analytical Instrumentation for Planetary Atmospheres Research

Innovations and the application of new technologies are sought for improving the operating characteristics of gas
chromatograph-mass spectrometer systems in harsh environments. Reductions in volume, weight, power, and cost
while increases in performance, serviceability, and functionality of system components is highly desirable. The
overall goal is to develop an instrument with increased performance in the areas of improved collection, detection,
and measurement. Specific areas of interest include:

- Miniaturized and ruggedized gas chromatograph columns
- Microvalves
- Improved stability and performance of secondary electron multipliers
- Performance increases in the areas of size and conversion efficiency of high voltage DC/DC converters
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 systems must be compact upon launch, they must achieve high precision surface form factors, and they must include beam-scanning capabilities. The antenna compactness on launch can be achieved either through folding technologies or from some assemblage of small components into the larger final system in space. The microwave antenna surface characteristics must be accurate enough to produce microwave beam patterns with adequately small side lobes. 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. The beam widths must be small enough to resolve the few kilometer scales needed for many geophysical observations. The microwave wavelengths will be determined according to the geophysical measurement of interest. The antenna concepts may include large single apertures or apertures composed of multiple elements that are operated synergistically to produce the desired performance.

Active Optical Systems and Technology for UAVs and Ballooncraft

Lidar remote sensing systems are required to meet the demanding requirements for future Earth Science missions. It is envisioned that lidar systems will be used in the following application areas: high spatial and temporal resolution observations of the land surface and vegetation cover (biomass); profiling of clouds, aerosols, and atmospheric state variables including temperature, humidity, winds, and trace constituents including tropospheric and stratospheric ozone and CO$_2$ (profiling and total column); measurement of the air/sea interface and mixed layer. New systems and approaches are sought in these areas, which will:

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

Systems and approaches will be considered that demonstrate a capability which is scalable to space or can be mounted on a relevant platform (UAV, long duration balloon, or aircraft) for calibration and validation of a space-borne system.

Unmanned Aerial Vehicle (UAV) Technologies for Remote Sensing

Avionics, real-time telemetry acquisition and remote sensing spectral imaging devices to support Unmanned Aerial Vehicles’ (UAV) basic and applied science and application demonstrations (proposers need only to respond to a minimum of one of the below):

- Low cost avionics instrumentation for precise navigation and aircraft control, must have an attitude sampling rate greater than 25 Hz and an accuracy greater than 0.2° in roll and pitch.
- Real-time sensor fusion algorithms that combine low-cost inertial, GPS, magnetometer, and other sensor input to deliver aircraft state vectors at a rate greater than 50 Hz.
• Uncooled infrared and thermal spectral imager instrument to be less than 2 lbs and no larger than 0.05 m³ in volume. Must operate autonomously in coordination with the onboard flight plan. It must have a built-in data acquisition system. The 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. Quantization bit resolution should be 10-bit minimum.

**Ballooncraft Trajectory Control and Station-Keeping**

Trajectory Control and Station-Keeping are critical items for future Ultra-Long Duration Balloon remote sensing concepts.

• Trajectory control would allow for some authority of the path of the system that may be required or desired for several reasons such as science mission, geopolitical, or improved recovery options. Activities include concept studies for alternative systems, propeller design and fabrication, functional flight testing, airship design and analysis, material development, and performance modeling.

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 10⁻¹⁵ 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 (< 100 microwatts per channel)
  • 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>Energy Range</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>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>
<td></td>
</tr>
</tbody>
</table>
**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
- High spatial resolution x-ray detectors, for producing ~50 meter 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 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)
- 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
Trajectory simulation tools and software

Sub Topics:
Self-Healing Repair technologies Topic T6.01
It is highly desirable to develop technologies for polymeric and composite materials that mimic the repair processes of biological systems. Much can be learned by relating the repair processes of biological systems to these inanimate materials, in particular, learning methods to initiate the self-healing processes. One example of inanimate 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. Another approach might be to combine animate and inanimate systems in such a way that the repair of the inanimate material is done by the animate system. Applications for self-healing processes of inanimate materials can be found in areas where failures could result in catastrophic consequences. Examples of these are failure of structural members in spacecraft or aircraft; failure of electrical wire insulation materials used in spacecraft, aircraft, or buildings; or failure of polymers membranes used in critical separations in the space exploration or medical devices.

Proposals are sought for innovative technologies and technology concepts in the areas of self-healing and repairing of electrical wiring insulation, which is an area under ASTRA’s Advanced Technology Development (2.4.6). 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, Teflon, or vinyl-type 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 effect of the manufacturing process used to produce the insulated wire on the final product. These methods must produce a flexible water-tight seal over the damaged area. The physical and chemical properties of the final repair material should be similar to the initial insulating materials.

Sub Topics:
Personal Air Vehicle (PAV) Research for Rural, Regional, and Intra-Urban On-Demand Transportation Topic T7.01
NASA is performing preliminary design studies of Personal Air Vehicle missions, concepts, and technologies for the purpose of augmenting on-demand personal transportation mobility and capacity. The intent of this research is to perform the analysis and demonstration 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.

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, providing improved comfort levels for passengers.

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.

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.

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.

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:
- Aerospace Manufacturing Technology Topic T8.01

NASA is interested in encouraging innovation in manufacturing through the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs. 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. 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 in 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; 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
development of the experimental approaches and data required to validate these tools. Transition of that
technology, however, from the 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 the
NASA’s investments at the Nation’s colleges and universities.

This subtopic solicits partnerships between academic institutions and small business 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 (3-D), time accurate analysis tools for modern rocket engine combustion
  chamber and turbomachinery environments and performance;
- Efficient, three-dimensional (3-D), time accurate analysis tools for predicting the environment and loads
  internal to valves, lines, and ducts in modern rocket engines;
- Practical 3-D steady and time-accurate multidisciplinary analysis (MDA) tools for design of space
  transportation 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 3-D flow
  simulations;
- Automated approaches for validating and assuring quality of application software;
- Practical unsteady 3-D 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
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 the 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 the 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 predicts 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, and this must be quantified.
Techniques and models to determine these parameters for active test facilities are required.
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
- A comprehensive portal for Earth and lunar mapping data, both image- and vector-based.