NASA STTR 2006 Phase I Solicitation

Small Business Technology Transfer

Ames Research Center Topic T1

Ames Research Center stands at the epicenter of the most prolific and prosperous cluster of high technology businesses, universities, and research laboratories in the world. Ames is internationally recognized as a pre-eminent research institution with an enduring research culture. Innovative design concepts and breakthrough technologies developed here over the last 60 years are legendary. They include the blunt body concept, the first manmade object to leave the Solar System (Pioneer), the supersonic area rule, hypersonic ranges, arc jets, the chemical origins of life, computational fluid dynamics, massively parallel computing, air traffic management, airborne science, exploration of the outer planets, infrared astronomy, and the discovery of water on the moon. Ames today seeks innovative breakthroughs in a 21st Century arena. Ames’ pioneering research in information technology, biotechnology, and nanotechnology will enable development of innovative sensors to probe Earth, other planets, and other solar systems, and dramatically increase the ability to communicate large volumes of information across space. It could also lead to stronger materials, ultra-small electronic devices, and new space missions with lower-weight components requiring less power and fuel. With leading-edge capabilities in high-end computing, Ames can fully exploit these emerging technologies and interdisciplinary research, which many see as the most likely source of breakthrough technologies in the coming decades.

Sub Topics:

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

Lead Center: ARC

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. Proposals should focus on data analysis and interpretation rather than development of new sensors;

- 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;

- 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

Center: ARC

As NASA embarks on its Exploration agenda the study of the Cosmic, Solar, Lunar, and Van Allen Belt space radiation environments will continue to guide new biologically related innovation and mitigation needs at NASA. Understanding Space Radiation induced effects on biological organisms is a vital component for future manned spaceflight mission success. Development of support technologies to protect astronaut crew health will be essential for successful long-term mission operations. Our current understanding of the space radiation environment interaction with humans, space rated materials, and technological systems is limited. Specifically, information on radiation events with high atomic number, high energy particles (HZE particles), and energetic protons is lacking 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. NASA also supports a facility at Loma Linda University Medical Center capable of generating energetic protons to enable research studies and technology development. NASA is seeking innovative technologies in the areas described below.

**Advanced Space Radiation Dosimeters**

NASA seeks the development of a small, low power suite of dosimeters to measure the biologically significant range of space radiation on board manned spacecraft, planetary habitats, or on astronaut extravehicular activity (EVA) suits. The devices must be able to measure the absorbed dose/linear energy transfer (LET) based dose equivalent from electrons, photons (X-rays and gamma rays), protons, heavy ions (HZE's) and secondary neutrons. Both real-time dose/dose equivalent rate and cumulative dose/dose equivalent over selected time intervals, e.g. a day or a mission, are required, along with an alarm system based on fluence rate, dose rate, or cumulative dose (e.g. during Solar Particle Events). The suite of dosimeters should provide time resolved LET data or a suitable surrogate (e.g. lineal energy (y) as measured by a gas filled microdosimeter) and have embedded linear energy transfer-based quality factor algorithms for determining dose equivalent. The devices should be sensitive down to 0.05 milliGray/0.1 mSv and should be able to measure a maximum dose of 1 Gy/3 Sv. The LET of charged particles of interest ranges from 0.2 keV/µm to 1000 keV/µm. The National Council on Radiation Protection and Measurements Report 142 includes a detailed description of the radiation field to be assessed for radiation protection of astronauts. NASA acknowledges the difficulty in measuring secondary neutrons from interactions of protons and heavy ions with spacecraft structures and has particular interest in this area. If possible, the response
of candidate dosimeters to protons, heavy ions, and neutrons should be characterized. For absorbed dose calibrations, the devices should be calibrated to National Institute of Standards and Technology (NIST) traceable absorbed dose standards. Prototype hardware or technology developed must be capable of being converted to robust and reliable space flight hardware in the future. This means that all hardware and software must be capable of being fully documented in the future, and that interface software must be compatible with current operating systems.

**High Throughput Genomic Analysis Techniques**

Following low dose irradiation of cells by protons and heavy ions, damage is localized to only a very few cells. The ability to separate cells with or without genetic changes in an automated manner is of interest. Current technologies are inefficient in identifying smaller-scale genetic changes (less than a million base-pairs (Mbp)) under these conditions. Technologies of interest are:

- Technologies to rapidly score small-scale genetic changes (1 Mbp) genetic changes to chromosomes following low dose irradiation;
- Imaging techniques to rapidly identify with high accuracy undamaged cells from a cell population irradiated at low doses.

**High Throughput Countermeasure Evaluation Techniques**

NASA seeks the development of high throughput techniques for the evaluation of countermeasures that can be used by astronauts to ameliorate the effects of ionizing radiation in space, including Solar Particle Events, secondary radiation particle events, and continuous low dose radiation exposure. Techniques to evaluate currently available pharmaceuticals to counteract radiation effects are of interest.

Dryden Flight Research Center Topic T2

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

Sub Topics:

**T2.01 Flight Dynamic Systems Characterization**

**Lead Center:** AFRC  
**Center:** DFRC

This subtopic 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: Emphasis is placed on the development and application of state-of-the-art,
novel, and computationally efficient solution schemes that enable effective simulation of complex practical
problems such as modern flight vehicles, like X-43 and F-18-AAW, as well as more routine problems encountered
in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance
computing equipment and computer graphics development is also considered an important part of this topic.

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

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

**Lead Center:** AFRC  
**Center:** DFRC

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

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

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

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

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

Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this subtopic 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 subtopic 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 subtopic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and that
require a demonstration in an actual-flight environment to fully characterize or validate advances.

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. NASA Glenn's world-class research and technology development is focused on space power, space flight, electric and nuclear space propulsion, space and aeronautic communications, advanced materials research, biological and physical microgravity science, and aerospace propulsion systems for safe and environmentally friendly skies. NASA Glenn has two sites in northern Ohio. Situated on 350 acres of land adjacent to the Cleveland Hopkins International Airport, the Cleveland site in northeast Ohio comprises more than 140 buildings including 24 major research facilities and over 500 specialized research and test facilities. Plum Brook Station is 50 miles west of Cleveland and has four major world-class facilities for space research available for Government and industry programs. The staff consists of over 2000 civil service and support service contractor employees. Scientists and engineers comprise more than half of our workforce with technical specialists, skilled workers, and administrative staff supporting them. Over 60 percent of our scientists and engineers have advanced degrees, and 25 percent have earned Ph.D. degrees.

Sub Topics:

**T3.01 Space Power and Propulsion**

**Lead Center:** GRC

**Center:** GRC

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

Innovations are sought that will significantly improve the efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, flexibility/reconfigurability, and autonomy of space power systems. In power generation, advances are needed in photovoltaic cell structure including the incorporation of nanomaterials; module integration including monolithic interconnections and high-voltage operation; and array technologies including ultra-lightweight deployment techniques for flexible, thin-film modules, and concentrator techniques as well as dynamic power generation systems for nuclear power conversion. In energy storage systems, advances are needed in batteries-primary and rechargeable-regenerative fuel cells, and flywheels. Advances are also needed in power management and distribution systems, power system control, and integrated health management.
Innovations are sought that will improve the capability of spacecraft propulsion systems. In solar electric propulsion technology, advances are needed for ion, Hall, and advanced plasma thrusters including cathodes, neutralizers, electrode-less plasma production, low-erosion materials, high-temperature permanent magnets, and power processing. Innovations are needed for xenon, krypton, and metal propellant storage and distribution systems. In small chemical propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Also, advances are sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems and nano- and autonomous systems that include nanomaterials, high temperature shape memory alloys, and piezoelectric materials as well as control systems for autonomous, adaptive engine control and sealing.

**T3.02 Bio-Technology and Life Support**

**Lead Center:** GRC

**Center:** GRC

The new Vision for Space Exploration (VSE) entails the eventual presence of humans on the planetary surfaces of both the Moon and Mars. The physiological effects of prolonged space exposure (to both the microgravity environment of interplanetary space as well as the reduced gravity environments of the moon and Mars) need to be quantified in order to minimize mission risk, as well as insure the general health of astronauts both in space and upon their return to earth. Biomedical sensors to monitor astronaut health that maximize diagnostic capability while reducing up-mass and power requirements are of significant interest for exploration missions. For longer duration missions on the Moon and the journey to Mars, the astronaut's continued health maintenance and fitness evaluation for mission critical activities will need to be performed routinely. Similarly, medical diagnostics are required to evaluate acute events like fatigue fractures. As a result, there is an acknowledged need for compact, robust, multi-function diagnostic biomedical sensors to reduce levels of risk in exploration class missions. To fully quantify space-normal physiology, these biomedical sensors must be supplemented by advanced analytical tools, such as high-resolution microscopy and lab-on-a-chip instrumentation (for blood or urine analysis). In addition, computational models (incorporating the direct physiological data) are needed that allow comparison to 1G values and determination of secondary physiological quantities (e.g., cardiac dysrhythmia and renal stone formation, as related to measured calcium levels). These computational models will also enable physicians to predict, diagnose and treat pathologies that are either not present in a 1G environment or are induced by synergies with spaceflight stressors. Specific innovations required for this task include:

- Noninvasive or minimally invasive sensors to detect health parameters such as: metabolic rate, heart rate, ECG, oxygen consumption rate, CO₂ generation rate, core and/or skin temperature, radiation monitoring, oxygen saturation level, intra-cranial pressure, and ocular blood flow rates;

- Novel analytical capabilities such as high resolution microscopy and lab-on-a-chip analysis of blood and urine;

- Technologies for IV fluid mixing and medical grade water generation from the onboard potable water supply;
Novel approaches to noninvasive measurement of cephalad fluid shift and bone density measurements on astronauts in space is desired to understand and mitigate adverse effects of space environment on astronaut health and performance.

Although the Moon and Mars differ vastly in their origins and near-surface environments, common to both is the ubiquitous presence of fine particulates in the surface regolith. The objectives of the VSE specify missions of unprecedented duration and complexity, posing new classes of technical and operational challenges. One such challenge is managing the effects arising from the finest particulate fractions, commonly referred to as dust. The detailed experiences afforded by the series of Apollo missions provide valuable insights into the problems attributable to Lunar dust. Both anecdotal descriptions provided in situ by the crew members and analysis after the fact provide a lengthy testimony to the numerous technical issues associated with dust. Innovative technologies are needed to monitor the presence of dust, separation of dust from the cabin environment, removal of dust from EVA suit and mitigation of any adverse effects on astronaut health. Specific innovations required include:

- Novel approaches (and instrumentation) for detecting the presence of fine particulates in the cabin and airlock environments and effective regenerative technologies for removing them are required;
- Technologies to effectively and safely remove dust particles from EVA suits and from the surface of any equipment that needs to be transported from the Lunar surface into the cabin environment are needed;
- Technologies and novel approaches to mitigate any adverse effects of dust on the performance of life support equipment and processes are also needed.

Low mass, high reliability, robustness, low power consumption, long life, ease of usage and easy interface with the onboard data acquisition and control system are highly desirable attributes for all candidate technologies.
As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

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

**Active Remote Sensing Instruments (Lidar)**

Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth Science missions. Instruments are solicited that enable or support the following Earth Science measurements:

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

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

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

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

Spectral imaging devices for remote sensing onboard UAVs are also desired. In particular, uncooled infrared and thermal spectral imager instruments with the following specifications are solicited:
Instrument must be less than 2 lbs and no larger than 0.05 m³ in volume;

Must operate autonomously in coordination with the onboard flight plan;

Must have a built-in data acquisition system;

Spectral bands must all be coregistered and the data must be GPS time tagged;

Spectral bands should be centered at 3.75, 3.96, and 11 microns as well as a band in the visible at 0.6 microns; and

Quantization bit resolution should be 10-bit minimum.

Active Remote Sensing Instruments (Radar) for Aircraft and Unmanned Aerial Vehicles (UAVs)

Active microwave remote sensing instruments are required for future Earth Science missions with initial system concept development and science measurements on aircraft and UAVs. New systems, approaches, and technologies are sought that will enable or significantly advance the capability for:

- Tropospheric wind measurements within precipitation and clouds (X- through W-band);
- Large Ground Penetrating Radars (GPR) (P-band and lower);
- Rain measurements using differential or dual-frequency approaches (X- through Ka-band).

Data Compression

New approaches to data compression, also known as source coding, are needed to assist in transporting science instrument data within constrained communication channels, and/or to reduce the requirements for onboard data storage. Additional benefits of data compression include more science data return and facilitating the direct broadcast of science data to ground stations. To target multiple missions, implementations should conform to the Consultative Committee for Space Data Systems (CCSDS, www.ccsds.org [1]) recommendation CCDDS 121.0-B 1. This solicitation seeks development of new data compression processors that:

- Can process science instrument data at over 50 Msamples/sec and take science data input from 1-bit/sample and preferably up to 32 bits/sample;
- Can demonstrate radiation tolerance required for both near-Earth and deep space missions; and
- Consume less than 2 watts of electrical power at 50 Msamples/sec.
T4.02 Space Science Sensors and Instruments

Lead Center: GSFC
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 with sensitivities better than 10-16 W per root Hz;
- Cryogenic devices, such as SQUID amplifiers and SQUID multiplexers, superconducting transition-edge temperature sensors, and miniature, self-contained low-temperature He refrigerators;
- Analog application-specific integrated circuits (ASICs) with large dynamic range (> 10^5) and low power (< 100 microwatts per channel); and
- 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**

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<tr>
<th>wartości</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>
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<tbody>
<tr>
<td>Energy Range</td>
<td>0.05 - 15 keV</td>
<td>100 - 400 nm</td>
<td>400 - 700 nm</td>
<td>355 - 2050 nm</td>
<td>0.7 - 4 mm</td>
<td>20 - 800 mm</td>
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<tr>
<td>Size</td>
<td>1 - 4 m</td>
<td>1 - 2 m</td>
<td>6 - 10+ m</td>
<td>0.7 - 1.5 m</td>
<td>3m - 4 m</td>
<td>10 - 25 m</td>
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<tr>
<td>Areal Density</td>
<td>&lt; 0.5 kg/m^2/grazing incidence</td>
<td>&lt; 10 kg/m^2</td>
<td>&lt; 5 kg/m^2</td>
<td>&lt; 10 kg/m^2</td>
<td>&lt; 5 kg/m^2</td>
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<tr>
<td>Surface Figure</td>
<td>I/150 at I = 633 nm</td>
<td>Diffraction Limited at I = 300 nm</td>
<td>I/150 at I = 500 nm</td>
<td>I/10 at I = 633 nm</td>
<td>I/75 at I = 1 mm</td>
<td>I/14 at I = 20 mm</td>
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* Near-infrared
• Large-area, lightweight (< 15 kg/m$^2$) focusing optics, including inflatable or deployable structures;
• Novel laser devices (e.g., for lidars) that are tunable, compact, lower power and appropriate for mapping planetary (and lunar) surfaces. Future lidar systems may require up to ~1.5 m optics and novel designs; and
• Fresnel-zone X-ray focusing optics to form large X-ray telescopes with small apertures but high angular resolution—better than 1 milli-arc-second. Besides newly developed optics, these missions will require formation flying of spacecraft to an unprecedented level.

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

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

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

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

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

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

Johnson Space Center Topic T5

Innovative technologies and approaches are needed to support human surface exploration on the Lunar/Martian surfaces, and means to better understand and reduce the risk to manned missions from ascent, orbital and interplanetary debris sources. The new technologies being solicited include means to improve operational
capabilities; increase human productivity; develop advanced extravehicular activity hardware; provide better debris impact structural modeling and damage prediction; new techniques or solutions for detecting, locating and quantifying potential for damage; better and improved repair techniques; and abilities to enhance the success of future human exploration missions. The anticipated proposed technologies shall have a dramatic impact on achieving the agency goals of the Space Exploration Vision.

Sub Topics:

**T5.01 Advanced Extravehicular Activity (AEVA)**

**Lead Center: JSC**

**Center: JSC**

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

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

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

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

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

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

- **Space suit mounted monocular displays for use inside a space suit with a small screen of view similar to that of a mobile computer screen and a binocular display with a panoramic field of view similar to that of immersive VR display systems.** The monocular must display text, graphics, imagery and video with multiple windows and overlays as well as support all mission profiles with a multi-function display that enables situational awareness. The binocular must display wide field imagery with overlays, enable 3D or stereoscopic visualization, and provide vision enhancement as a low light navigational aid when combined with image intensification sensors.

- **Dust and abrasion mitigating materials, seals, bearings, techniques, and mechanisms for space suits and EVA equipment are solicited. This includes materials and systems that prevent lunar dust from adhering to the outer layer of the suit or removes the dust prior to entry into an airlock. Seals, bearings, and mechanisms that preclude the migration of dust particles into bearings and the space suit life support system and pressure garment are also sought.**
T5.02 Impact Detection and Evaluation for Man-Rated Space Vehicles

Lead Center: JSC
Center: JSC

There is significant risk to manned missions from ascent, orbital and interplanetary debris sources. Various NASA programs have chosen to treat the ascent debris and Micro-meteoroid and Orbital Debris (MMOD) impact risk with different intensity and concern. Since the STS-107 accident, NASA has become more concerned about understanding and compensating for this threat. This requires (1) predicting and correlating impacts with structural damage levels; (2) predicting and correlating impact damage levels with structural-dynamic/shock wave responses; (3) efficient systems for detecting, locating and quantifying impacts; (4) inspecting, repairing and performing Non-Destructive Evaluation (NDE) on damaged areas; and (5) efficient systems for detecting, locating and quantifying leaks to vacuum. The scope includes direct application of technology and techniques to Space Shuttle, International Space Station Modules, Inflatable-rigidizable habitats and structures, and Constellation Program man-rated vehicles. Critical areas, such as thermal protection systems and pressurized modules are of primary concern. Awareness of current, state-of-the-art methods and technologies available to and/or applied by NASA is important. Technology development areas are as follows:

Debris impact structural modeling and damage prediction: The developer will use impact test data and design/materials properties to develop models that predict under what conditions impacts will cause damage and what is the extent of the damage. Certain existing flight and ground test data and current analytical techniques can be made available.

- Space Shuttle and International Space Station - develop modeling improvements to critical areas of Orbiter thermal protection system which can more accurately predict failure modes and levels of damage for various ascent debris and MMOD in low Earth orbit.(Orbiter - ascent and on-orbit, ISS on-orbit only).

- Inflatable-rigidizable habitats and structures - develop methods to model potential damage from ascent vibration, earth orbit MMOD and/or lunar surface applications for various candidate inflatable structural material configurations and suggest improvements which reduce risk of damage, more observable damage signatures, incorporate weight savings or other benefits, such as thermal insulation, radiation protection, or longer life. Impact modeling for lunar surface applications will include analysis of free-standing, shielded (separately deployed "umbrella") and covered (layers of regolith for protection).

- Constellation Program vehicles - develop and evaluate structural models of various candidate and actual vehicle concepts as they evolve for their susceptibility to damage from ascent and Earth orbit MMOD impacts as well as trans-lunar, lunar surface, and trans-Martian impacts.

Debris impact structural-dynamic/shock wave modeling for detection, location and quantification potential for damage: Analytical routines and techniques to optimize prediction accuracy and decrease uncertainties using impact test data, actual flight data, existing and proposed sensor systems and modeling will be developed. Each type of structure in item is a candidate for either improvements in existing structural-dynamic and shock wave prediction models (Space Shuttle Orbiter and International Space Station) or development of these models.
Debris impact sensors/sensing systems for critical areas: The developer will recommend practical sensor system solutions for future installations to not only provide impact detection, location and quantification of damage, but also to validate structural models. The sensor/system solutions must account for optimizing the typical factors for space missions: system cost, weight, performance, power, integration, operations time, complexity/reliability, reconfigurability/maintainability, autonomy from Earth-based support, etc. Sensing systems should reduce the vehicle and communication architecture overhead needed for functional redundancy and reliability by considering methods to store and process impact data such that answers are the primary information needed to be transferred within the vehicle but raw data is available on request. No-power Radio Frequency Identification (RFID)-like sensors, very low power standalone sensor systems with scavenge or very long-life power sources, remote sensors and various embedded sensors with a minimum of wired interfaces are examples of what is desired. Other non-contact systems, such as visible or IR flash detection or higher frequency radio frequency (RF) pulse detection may be investigated.

Debris impact structural damage NDE evaluation away from Earth (internal or external environments): Systems and techniques will be developed and tested that can be readily used by astronauts or mobile/robotic systems to evaluate impact-damaged areas and subsequent repairs. Tools and equipment that can provide adequate inspection in hard-to-access areas internally and externally will be especially helpful if it can provide position-awareness of the sensor with respect to the vehicle. Simple human operator interfaces and remote access to data should be considered. NDE systems such as high frequency 3-d imaging, infra-red imagers, eddy current and ultrasound systems will need to evaluated for their effectiveness on new structural composites, inflatable and rigidizable structures - practically applied in both internal and external evaluations. Certain structural health monitoring needs may require remotely operated NDE systems for periods when the vehicles listed above are not man-tended.

Debris impact structural leaks to vacuum detection, location, quantification and repair: The systems must monitor the pressurized vehicle integrity such that catastrophic leaks can be immediately dealt with to provide crew safety and, for smaller leaks, be sensitive enough to avoid loss of precious air resources to vacuum. Low weight, self-sealing structural concepts will be developed that minimize the air lost, but still are able to be located after the sealing has been accomplished for NDE evaluation. Test-validated models of both structural and airborne ultrasonic propagation of sound in the above pressurized modules, as well as sensing above typical background levels will be important to resolving these issues. Systems should be responsive to some or all levels of impact and leak indications through the rate of pressure loss detected requiring:

- Immediate location and isolation with limited access to the evacuated module afterward;
- Limited time to locate and plug the leak; and
Extended period to locate, inspect, plan and effect repair and perform NDE afterward.

Kennedy Space Center Topic T6

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

Sub Topics:

T6.01 Predictive Modeling Techniques for the Mechanical Behaviors of Powders, Granular Materials, and Soils

Lead Center: KSC

Center: KSC

Developing software models to predict the mechanical behavior of granular materials and powders is an area of ongoing and active research and development. NASA has a need for advances in software modeling techniques to support a number of on-going initiatives. One such area is the prediction of stress/strain shearing and compaction response of powder insulation materials located inside the annular space of very large cryogenic dewars (e.g., 80 feet in diameter with a 3 - 4 foot radius in the annular space). This is an area of high interest to KSC due to the use of large cryogenic tanks at the launch pads and the problems associated with the insulation in them. Another area of interest is the mechanical behavior of lunar soil during drilling and digging, during construction and compaction (of berms), or during beneficiation and chemical processing of the soil (e.g., to remove water ice). This area is of interest to KSC due to the need for launch-site facilities to enable the assembly, flight qualification, and final checkout of spacecraft and payloads including the re-testing of last-minute modifications. Modeling the behavior of lunar soil in such facilities and comparing to the expected behavior in the lunar environment is a critical ability for developing launch-site facilities and procedures.

In both areas of interest, it is impossible to perform full-scale testing of the material in the relevant environment, and therefore extrapolation is necessary to compare small-scale or terrestrial experiments against what is expected in the full-scale or lunar environment. Extrapolation from one scale (or one environment) to another is very difficult and currently has a low probability of producing high-fidelity predictions. Unfortunately, without such extrapolation it is impossible to use an affordable small-scale (or terrestrial) test as a means to validate the design of hardware or to validate the expected behavior of the powder or soil in the full-scale (or lunar) case.
The best, presently-known method to do an extrapolation from one scale (or environment) to another is to produce a computer model to realistically simulate the physics of the granular material. The simulation can then be parameterized to make predictions in either scale or in either environment. The simulation can be benchmarked using the accessible scale (or environment), and then the parameterization can be adjusted to the inaccessible scale (or environment) to make the predictive extrapolation. Additional confidence in the extrapolation can be obtained by studying the model's sensitivity upon its various parameters within some experimentally-accessible range. Furthermore, the model can be used long-term as an engineering tool, iteratively refining it as new data become available from the full-scale application (or from the lunar environment). Thus, the model becomes a method to organize and compare new data as they become available across multiple scales and environments.

Innovations are sought in the area of multi-scale granular material modeling with true extrapolatory, predictive power across scales and environments. These innovations could be in the form of software techniques that integrate Discrete Element Models with Finite Element Models (or other software innovations), benchmarking techniques that integrate experimental methods with modeling methods in new ways, innovative analysis techniques, or any combination of the above. Other innovations will also be considered. The key point to the innovation is that it must extend the state-of-the-art in predicting granular/powder mechanical behavior. Innovations are particularly desired in the ability to model and predict powder shearing and compaction and to model lunar soil geotechnics.

T6.02 Predictive Numerical Simulation of Rocket Exhaust Interactions with Lunar Soil

Lead Center: KSC
Center: KSC

One of the major challenges routinely faced at the Kennedy Space Center's launch and landing sites is to prevent hardware damage from the blasts associated with launching spacecraft. This includes the prediction of the aerodynamics and vibro-acoustics of rocket plumes in the launch environment, the reduction of high velocity ejection of materials by the rocket plume, and protection of the surrounding hardware from these effects. This will be a greater challenge at extraterrestrial spaceports. When a spacecraft lands on the Moon, surrounding hardware may be damaged and contaminated by the high velocity spray of eroded soil particles, and the landing spacecraft may be affected by an upward spray along the reflection planes between multiple engines. On lunar spaceports, the blast protection infrastructure must be constructed (in part) using in-situ materials, such as a berm made with lunar soil. There are a number of mission scenarios that will be different than the Apollo experience and that cause the erosion problem to be more significant. Thus, this needs to be assessed in hardware and architecture design.

The lunar soil erosion theory developed during the 1940's and 50's did not include some of the relevant physics and as such it does not allow us to quantitatively predict the blast effects (with sufficient confidence) for missions that include multiple spacecraft landing in close vicinity to one another on the Moon. Without these predictions, it is currently not possible to develop adequate blast mitigation and protection technologies. To obtain better predictions, the Kennedy Space Center desires the development of a software tool that numerically predicts the plume interactions with the soil for rockets landing or launching on the Moon, including the erosion rates and trajectories of ejected particulate matter.
Innovations are sought, resulting in the development of a software package to improve the prediction of lunar blast dynamics. The difficulties in developing a flow code to predict these effects include the unique lunar environment, the difficulty in solving flow physics from first principles around discrete particle assemblages, the large spatial scale of the flow features compared to the vast number of lunar soil particles within that region, and the need to parameterize the erosion of soil to produce realistic predictions (although realistic benchmarking experiments of lunar erosion are difficult to perform terrestrially). In recent years, researchers have been making significant progress in understanding the interactions of particle assemblages with fluids. Emphasis shall therefore be placed on the research effort extending this progress toward correctly describing the physics of the gas/soil interactions.

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 Non-Destructive Evaluation and Structural Health Monitoring

Lead Center: LaRC
Center: LaRC

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

Evaluation sciences include ultrasonics, laser ultrasonics, optics and fiber optics, video optics and laser metrology, thermography, electromagnetics, acoustic emission, X-ray and terahertz radiation. Innovative and novel evaluation approaches are sought for the following materials and structural systems:
- Adhesives and bonded joints, sealants, bearings, coatings, glasses, alloys, laminates, monolithics, material blends, wire insulating materials, and weldments;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.

Proposals should address the following performance metrics as appropriate:

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

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

T7.02 Remote Sensors for Entry, Descent and Landing Applications

Lead Center: LaRC

Center: LaRC

The NASA Langley Research Center, located in Hampton VA, maintains core competencies in laser/lidar technology development and entry/landing/descent (EDL) applications. Innovative or improved concepts are solicited for the development of sensors supporting human and robotic exploration missions to planetary surfaces. Of immediate interest are technologies enhancing or enabling sensors used in precision guidance and navigation related to surface landings and hazard avoidance. The sensors would be employed from orbit, through descent, and during final approach. The deployed system may require multiple sensors of different fundamental types. Specific sensors/components currently of interest include those associated with:

- 3D lidar systems, including flash lidars and scanning lidars;
- High resolution radars;
- 2D optical imaging devices.
Examples of components desired would include:

- New, highly accurate and robust wide angle scanning systems;
- Moderate power high efficiency lasers;
- Fast detector arrays suitable for use in coherent lidar systems;
- High efficiency long range flash lamps.

Proposals should describe the expected improvements and advantages of proposed deliverables over existing technologies, and should estimate the effects of these improvements on the state-of-the-art EDL guidance, control and hazard avoidance capabilities. Technologies likely to be ready for flight demonstration within the next 2 or 3 years are preferred, but highly innovative longer-term concepts will also be considered.
and components. Only processes that are environmentally friendly and worker-health oriented will be considered. Proposals are sought, but are not limited to, the following areas:

**Polymer Matrix Composites (PMCs)**

Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing (e.g., e-beam, ultrasonic); damage tolerant and repairable structures and self-healing technologies; 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) and Ablatives**

CMC materials and processes are projected to significantly increase safety and reduce costs simultaneously while decreasing system weight for space transportation propulsion. Advanced CMC, ablative, and insulation materials and processing technologies are of interest which have low volume at low cost and are repeatable and scalable to large sizes. Applications of interest include, but not limited to: solid propulsion nozzles and throats, liquid propulsion nozzles and thrust cells with integral injectors, and ancillary hardware components necessary for earth-to-orbit and in-space transportation.

**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.

**Fiber-Based and Inflatable Systems**

Fabrics and films may be appropriate materials for some space structures, but significant research is required to investigate the benefits, challenges and failure modes of such systems. Where fiber-based or inflatable structures have been demonstrated as potentially valuable to NASA, quality-controlled manufacture of these structures will be a strong focus and interaction between designers, manufacturing specialists and performance analysts can lead to better products; innovative procedures for manufacturing improvements and concepts are of interest.

**Advanced NDE Methods**
Portable and lightweight NDE tools that take advantage of nanotechnology for noninvasive, noncontact area inspection and characterization of polymer, ceramic and metal matrix composites. Areas include but are not limited to microwaves, millimeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.

T8.02 Component Development for Deep Throttling Space Propulsion Engines

Lead Center: MSFC
Participating Center(s): MSFC
Center: MSFC

Implementing certain aspects of the NASA Vision for Space Exploration will require versatile space propulsion engines that can operate over a wide range of thrust levels, a capability known as throttling. The ability of a rocket engine to reliably produce a small fraction of the maximum thrust on command during flight is referred to as deep throttling. High specific impulse deep-throttling space propulsion engines may be required for controlled spacecraft descent to planetary surfaces, and a significant degree of throttling may also be required for ascent and in-space transfer maneuvers.

This subtopic solicits partnerships between academic institutions and small businesses in the development of components, design tools, and performance databases for engines in the 5,000-15,000 pound thrust range that use liquid hydrogen and liquid oxygen as propellants and which can be throttled to as little as 7% of the maximum thrust value. Examples of specific areas where innovations are sought include:

- High-throttle-response engine concepts;
- Low-cost regeneratively cooled chamber designs and demonstrations of such;
- Injectors that can provide stable engine performance with two-phase (gas/liquid) flow of propellants, especially during start-up transients;
- Ignition systems that can operate reliably over a wide fuel/oxidizer mixture ratio;
- Propulsion system or component technologies that do not require thermal conditioning prior to ignition;
- Zero net positive suction pressure pump design concepts, and demonstrations of such;
- Performance databases for small turbopumps and turbomachinery components;
- Design and analysis tools that accurately model small valves and turbopumps, and data required for code validation;
- Alternatives to the use of turbopumps for achieving chamber pressures of 1000 pounds per square inch; and
Stennis Space Center Topic T9

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

T9.01 Rocket Propulsion Testing Systems

Lead Center: SSC
Center: SSC

Proposals are sought for innovative technologies 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. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies

Innovative, non-intrusive sensors for measuring gas velocity, temperature, pressure, molecular and metallic plume constituents, and environmentally sensitive effluent gas detection. 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 should be capable of measuring gas species, temperature, and velocity for H₂, O₂, hydrocarbon and hybrid fuels.

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

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 non-intrusive optical-based sensors.

**Test Facility Modeling Tools and Methods**

Developing and verifying test facilities is complex and expensive. The wide range of pressures, flow rates, and temperatures necessary for engine testing result in complex relationships and dynamics. It is not realistic to physically test each component and the component-to-component interaction in all states before designing a system. Currently, systems must be tuned after fabrication, requiring extensive testing and verification.

Tools using computational methods to accurately model and predict system performance are required that integrate simple interfaces with detailed design and/or analysis software. SSC is interested in improving capabilities and methods to accurately predict and model the transient fluid structure interaction between cryogenic fluids and immersed components to predict the dynamic loads, frequency response of facilities.

Component Design, Prediction and Modeling - Improved capabilities to predict and model the behavior of components (valves, check valves, chokes etc.) during the facility design process. This capability is required for modeling components in high pressure 12,000 psi, high flow 100 lb/sec cryogenic environments and must address two-phase flows.

Process System Design, Prediction and Modeling - Improved capabilities to predict and model process systems. The capability should incorporate the previous two areas to accurately model the process systems and test articles.

**T9.02 Field Sensors, Instruments, and Related Technologies**

Lead Center: SSC
Coastal environments and their natural resources are vital to our Nation's economy, security, commerce and recreation. These environments are strongly impacted by severe weather and other natural hazards. Because most of the world's population lives in coastal regions, these important and dynamic environments are also significantly impacted by human-induced events. Moreover, they are also especially sensitive to the initial effects of global climate change.

This subtopic solicits innovative field measurement technologies and analytical tools to support NASA's remote sensing technologies used in coastal research and applications. Specific interests at SSC include the following:

- Coupling of land and ocean processes (run-off, air quality, material flux);
- Coral reef mapping and health;
- Algal blooms (detection and monitoring);
- Sea level rise (measuring and forecasting effects);
- Sediment and contaminant transport (measuring and monitoring);
- Natural disasters such as tropical systems, tsunamis, and floods (planning, impact assessment, mitigation, and recovery).

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. Proposals should focus on data analysis and interpretation rather than development of new sensors;

- 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;

- 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
- Center: ARC

As NASA embarks on its Exploration agenda the study of the Cosmic, Solar, Lunar, and Van Allen Belt space radiation environments will continue to guide new biologically related innovation and mitigation needs at NASA. Understanding Space Radiation induced effects on biological organisms is a vital component for future manned spaceflight mission success. Development of support technologies to protect astronaut crew health will be essential for successful long-term mission operations. Our current understanding of the space radiation environment interaction with humans, space rated materials, and technological systems is limited. Specifically, information on radiation events with high atomic number, high energy particles (HZE particles), and energetic protons is lacking 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. NASA also supports a facility at Loma Linda University Medical Center capable of generating energetic protons to enable research studies and technology development. NASA is seeking innovative technologies in the areas described below.

**Advanced Space Radiation Dosimeters**

NASA seeks the development of a small, low power suite of dosimeters to measure the biologically significant range of space radiation on board manned spacecraft, planetary habitats, or on astronaut extravehicular activity (EVA) suits. The devices must be able to measure the absorbed dose/linear energy transfer (LET) based dose equivalent from electrons, photons (X-rays and gamma rays), protons, heavy ions (HZE) and secondary neutrons. Both real-time dose/dose equivalent rate and cumulative dose/dose equivalent over selected time intervals, e.g. a day or a mission, are required, along with an alarm system based on fluence rate, dose rate, or cumulative dose (e.g. during Solar Particle Events). The suite of dosimeters should provide time resolved LET data or a suitable surrogate (e.g. lineal energy (y) as measured by a gas filled microdosimeter) and have embedded linear energy transfer-based quality factor algorithms for determining dose equivalent. The devices should be sensitive down to 0.05 milliGray/0.1 mSv and should be able to measure a maximum dose of 1 Gy/3 Sv. The LET of charged
particles of interest ranges from 0.2 keV/µm to 1000 keV/µm. The National Council on Radiation Protection and Measurements Report 142 includes a detailed description of the radiation field to be assessed for radiation protection of astronauts. NASA acknowledges the difficulty in measuring secondary neutrons from interactions of protons and heavy ions with spacecraft structures and has particular interest in this area. If possible, the response of candidate dosimeters to protons, heavy ions, and neutrons should be characterized. For absorbed dose calibrations, the devices should be calibrated to National Institute of Standards and Technology (NIST) traceable absorbed dose standards. Prototype hardware or technology developed must be capable of being converted to robust and reliable space flight hardware in the future. This means that all hardware and software must be capable of being fully documented in the future, and that interface software must be compatible with current operating systems.

High Throughput Genomic Analysis Techniques

Following low dose irradiation of cells by protons and heavy ions, damage is localized to only a very few cells. The ability to separate cells with or without genetic changes in an automated manner is of interest. Current technologies are inefficient in identifying smaller-scale genetic changes (less than a million base-pairs (Mbp)) under these conditions. Technologies of interest are:

- Technologies to rapidly score small-scale genetic changes (1 Mbp) genetic changes to chromosomes following low dose irradiation;
- Imaging techniques to rapidly identify with high accuracy undamaged cells from a cell population irradiated at low doses.

High Throughput Countermeasure Evaluation Techniques

NASA seeks the development of high throughput techniques for the evaluation of countermeasures that can be used by astronauts to ameliorate the effects of ionizing radiation in space, including Solar Particle Events, secondary radiation particle events, and continuous low dose radiation exposure. Techniques to evaluate currently available pharmaceuticals to counteract radiation effects are of interest.

Sub Topics:
Flight Dynamic Systems Characterization Topic T2.01
Center: DFRC

This subtopic 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: Emphasis is placed on the development and application of state-of-the-art, novel, and computationally efficient solution schemes that enable effective simulation of complex practical problems such as modern flight vehicles, like X-43 and F-18-AAW, as well as more routine problems encountered in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered an important part of this topic.

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

Sub Topics:
Advanced Concepts for Flight Research Topic T2.02
Center: DFRC

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

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

Proposals in any of these areas will be considered.

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

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

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

Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this subtopic 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 subtopic 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 subtopic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and that require a demonstration in an actual-flight environment to fully characterize or validate advances.
Development of innovative technologies and systems are sought that will result in robust, lightweight, ultra-high efficiency, lower cost, power and in-space propulsion systems that are long-lived in the relevant mission environment and that enable future missions. The technology developments being sought would, through highly-efficient generation and utilization of power and in-space propulsion, significantly increase the system performance.

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

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

The new Vision for Space Exploration (VSE) entails the eventual presence of humans on the planetary surfaces of both the Moon and Mars. The physiological effects of prolonged space exposure (to both the microgravity environment of interplanetary space as well as the reduced gravity environments of the moon and mars) need to be quantified in order minimize mission risk, as well as insure the general health of astronauts both in space and upon their return to earth. Biomedical sensors to monitor astronaut health that maximize diagnostic capability while reducing up-mass and power requirements are of significant interest for exploration missions. For longer duration missions on the Moon and the journey to Mars, the astronaut's continued health maintenance and fitness evaluation for mission critical activities will need to be performed routinely. Similarly, medical diagnostics are required to evaluate acute events like fatigue fractures. As a result, there is an acknowledged need for compact, robust, multi-function diagnostic biomedical sensors to reduce levels of risk in exploration class missions. To fully quantify space-normal physiology, these biomedical sensors must be supplemented by advanced analytical tools, such as high-resolution microscopy and lab-on-a-chip instrumentation (for blood or urine analysis). In addition, computational models (incorporating the direct physiological data) are needed that allow comparison to 1G values and determination of secondary physiological quantities (e.g., cardiac dysrhythmia and renal stone formation, as related to measured calcium levels). These computational models will also enable physicians to predict, diagnose and treat pathologies that are either not present in a 1G environment or are induced by synergies with spaceflight.
stressors. Specific innovations required for this task include:

- Noninvasive or minimally invasive sensors to detect health parameters such as: metabolic rate, heart rate, ECG, oxygen consumption rate, CO₂ generation rate, core and/or skin temperature, radiation monitoring, oxygen saturation level, intra-cranial pressure, and ocular blood flow rates;

- Novel analytical capabilities such as high resolution microscopy and lab-on-a-chip analysis of blood and urine;

- Technologies for IV fluid mixing and medical grade water generation from the onboard potable water supply;

- Novel approaches to noninvasive measurement of cephalad fluid shift and bone density measurements on astronauts in space is desired to understand and mitigate adverse effects of space environment on astronaut health and performance.

Although the Moon and Mars differ vastly in their origins and near-surface environments, common to both is the ubiquitous presence of fine particulates in the surface regolith. The objectives of the VSE specify missions of unprecedented duration and complexity, posing new classes of technical and operational challenges. One such challenge is managing the effects arising from the finest particulate fractions, commonly referred to as dust. The detailed experiences afforded by the series of Apollo missions provide valuable insights into the problems attributable to Lunar dust. Both anecdotal descriptions provided in situ by the crew members and analysis after the fact provide a lengthy testimony to the numerous technical issues associated with dust. Innovative technologies are needed to monitor the presence of dust, separation of dust from the cabin environment, removal of dust from EVA suit and mitigation of any adverse effects on astronaut health. Specific innovations required include:

- Novel approaches (and instrumentation) for detecting the presence of fine particulates in the cabin and airlock environments and effective regenerative technologies for removing them are required;

- Technologies to effectively and safely remove dust particles from EVA suits and from the surface of any equipment that needs to be transported from the Lunar surface into the cabin environment are needed;

- Technologies and novel approaches to mitigate any adverse effects of dust on the performance of life support equipment and processes are also needed.

Low mass, high reliability, robustness, low power consumption, long life, ease of usage and easy interface with the onboard data acquisition and control system are highly desirable attributes for all candidate technologies.
As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

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

**Active Remote Sensing Instruments (Lidar)**

Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth Science missions. Instruments are solicited that enable or support the following Earth Science measurements:

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

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

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

**Passive Remote Sensing Instruments for Unmanned Aerial Vehicles (UAVs)**
Spectral imaging devices for remote sensing onboard UAVs are also desired. In particular, uncooled infrared and thermal spectral imager instruments with the following specifications are solicited:

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

**Active Remote Sensing Instruments (Radar) for Aircraft and Unmanned Aerial Vehicles (UAVs)**

Active microwave remote sensing instruments are required for future Earth Science missions with initial system concept development and science measurements on aircraft and UAVs. New systems, approaches, and technologies are sought that will enable or significantly advance the capability for:

- Tropospheric wind measurements within precipitation and clouds (X- through W-band);
- Large Ground Penetrating Radars (GPR) (P-band and lower);
- Rain measurements using differential or dual-frequency approaches (X- through Ka-band).

**Data Compression**

New approaches to data compression, also known as source coding, are needed to assist in transporting science instrument data within constrained communication channels, and/or to reduce the requirements for onboard data storage. Additional benefits of data compression include more science data return and facilitating the direct broadcast of science data to ground stations. To target multiple missions, implementations should conform to the Consultative Committee for Space Data Systems (CCSDS, [www.ccsds.org](http://www.ccsds.org)) recommendation CCDDS 121.0-B. This solicitation seeks development of new data compression processors that:

- Can process science instrument data at over 50 Msamples/sec and take science data input from 1-bit/sample and preferably up to 32 bits/sample;
- Can demonstrate radiation tolerance required for both near-Earth and deep space missions; and
- Consume less than 2 watts of electrical power at 50 Msamples/sec.
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 with sensitivities better than 10-16 W per root Hz;
- Cryogenic devices, such as SQUID amplifiers and SQUID multiplexers, superconducting transition-edge temperature sensors, and miniature, self-contained low-temperature He refrigerators;
- Analog application-specific integrated circuits (ASICs) with large dynamic range (> 105) and low power (< 100 microwatts per channel); and
- Novel packaging techniques and interconnection techniques for analog and digital electronics.

**Optics**

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

**Goals for Future NASA Optical Systems**

<table>
<thead>
<tr>
<th></th>
<th>X-ray Mirrors</th>
<th>UV Mirrors</th>
<th>Visible Scanning</th>
<th>Lidar Telescope</th>
<th>NIR* Earth Science Systems</th>
<th>Far Infrared to submillimeter Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Range</strong></td>
<td>0.05 - 15 keV</td>
<td>100 - 400 nm</td>
<td>400 - 700 nm</td>
<td>355 - 2050 nm</td>
<td>0.7 - 4 mm</td>
<td>20 - 800 mm</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>1 - 4 m</td>
<td>1 - 2 m</td>
<td>6 - 10+ m</td>
<td>0.7 - 1.5 m</td>
<td>3m - 4 m</td>
<td>10 - 25 m</td>
</tr>
<tr>
<td><strong>Areal Density</strong></td>
<td>&lt; 0.5 kg/m²/ grazing incidence</td>
<td>&lt; 10 kg/m²</td>
<td>&lt; 5 kg/m²</td>
<td>&lt; 10 kg/m²</td>
<td>&lt; 5 kg/m²</td>
<td>&lt; 5 kg/m²</td>
</tr>
<tr>
<td><strong>Surface Figure</strong></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 (< 15 kg/m²) focusing optics, including inflatable or deployable structures;
- Novel laser devices (e.g., for lidars) that are tunable, compact, lower power and appropriate for mapping
planetary (and lunar) surfaces. Future lidar systems may require up to ~1.5 m optics and novel designs; and
- Fresnel-zone X-ray focusing optics to form large X-ray telescopes with small apertures but high angular resolution-better than 1 milli-arc-second. Besides newly developed optics, these missions will require formation flying of spacecraft to an unprecedented level.

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

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

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

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

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

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

Sub Topics:
- Advanced Extravehicular Activity (AEVA) Topic T5.01
- Center: JSC

Complex missions require innovative approaches for maximizing human productivity and for providing the capability to perform useful work tasks. Requirements include reduction of system hardware weight and volume; increased hardware reliability, durability, operating lifetime, and increased human comfort. Specific areas of interest are as follows:
• Lightweight Structural and Protective Materials: proposals are sought for development of lightweight structural and protective materials for use in space suits to provide integral shell structure strength, impact, and puncture protection from shape edges, micrometeoroids and orbital debris, radiation protection, and prevention of abrasion, adhesion, and mitigation from Lunar and Martian dust;

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

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

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

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

• Space suit mounted monocular displays for use inside a space suit with a small screen of view similar to that of a mobile computer screen and a binocular display with a panoramic field of view similar to that of immersive VR display systems. The monocular must display text, graphics, imagery and video with multiple windows and overlays as well as support all mission profiles with a multi-function display that enables situational awareness. The binocular must display wide field imagery with overlays, enable 3D or stereoscopic visualization, and provide vision enhancement as a low light navigational aid when combined with image intensification sensors.

• Dust and abrasion mitigating materials, seals, bearings, techniques, and mechanisms for space suits and EVA equipment are solicited. This includes materials and systems that prevent lunar dust from adhering to the outer layer of the suit or removes the dust prior to entry into an airlock. Seals, bearings, and mechanisms that preclude the migration of dust particles into bearings and the space suit life support system and pressure garment are also sought.

Sub Topics:
Impact Detection and Evaluation for Man-Rated Space Vehicles Topic T5.02
Center: JSC

There is significant risk to manned missions from ascent, orbital and interplanetary debris sources. Various NASA programs have chosen to treat the ascent debris and Micro-meteoroid and Orbital Debris (MMOD) impact risk with different intensity and concern. Since the STS-107 accident, NASA has become more concerned about understanding and compensating for this threat. This requires (1) predicting and correlating impacts with structural damage levels; (2) predicting and correlating impact damage levels with structural-dynamic/shock wave responses; (3) efficient systems for detecting, locating and quantifying impacts; (4) inspecting, repairing and performing Non-Destructive Evaluation (NDE) on damaged areas; and (5) efficient systems for detecting, locating and quantifying leaks to vacuum. The scope includes direct application of technology and techniques to Space Shuttle, International Space Station Modules, Inflatable-rigidizable habitats and structures, and Constellation Program man-
rated vehicles. Critical areas, such as thermal protection systems and pressurized modules are of primary concern. Awareness of current, state-of-the-art methods and technologies available to and/or applied by NASA is important. Technology development areas are as follows:

Debris impact structural modeling and damage prediction: The developer will use impact test data and design/materials properties to develop models that predict under what conditions impacts will cause damage and what is the extent of the damage. Certain existing flight and ground test data and current analytical techniques can be made available.

- Space Shuttle and International Space Station - develop modeling improvements to critical areas of Orbiter thermal protection system which can more accurately predict failure modes and levels of damage for various ascent debris and MMOD in low Earth orbit.(Orbiter - ascent and on-orbit, ISS on-orbit only).
- Inflatable-rigidizable habitats and structures - develop methods to model potential damage from ascent vibration, earth orbit MMOD and/or lunar surface applications for various candidate inflatable structural material configurations and suggest improvements which reduce risk of damage, more observable damage signatures, incorporate weight savings or other benefits, such as thermal insulation, radiation protection, or longer life. Impact modeling for lunar surface applications will include analysis of free-standing, shielded (separately deployed "umbrella") and covered (layers of regolith for protection).
- Constellation Program vehicles - develop and evaluate structural models of various candidate and actual vehicle concepts as they evolve for their susceptibility to damage from ascent and Earth orbit MMOD impacts as well as trans-lunar, lunar surface, and trans-Martian impacts.

Debris impact structural-dynamic/shock wave modeling for detection, location and quantification potential for damage: Analytical routines and techniques to optimize prediction accuracy and decrease uncertainties using impact test data, actual flight data, existing and proposed sensor systems and modeling will be developed. Each type of structure in item is a candidate for either improvements in existing structural-dynamic and shock wave prediction models (Space Shuttle Orbiter and International Space Station) or development of these models (inflatable habitats/structures and Constellation vehicles).Limited ground test and flight data can be made available for some structures, but proposals that include instrumented impact testing are encouraged which validate proposed modeling techniques.

Debris impact sensors/sensing systems for critical areas: The developer will recommend practical sensor system solutions for future installations to not only provide impact detection, location and quantification of damage, but also to validate structural models. The sensor/system solutions must account for optimizing the typical factors for space missions: system cost, weight, performance, power, integration, operations time, complexity/reliability, reconfigurability/maintainability, autonomy from Earth-based support, etc. Sensing systems should reduce the vehicle and communication architecture overhead needed for functional redundancy and reliability by considering methods to store and process impact data such that answers are the primary information needed to be transferred within the vehicle but raw data is available on request. No-power Radio Frequency Identification (RFID)-like sensors, very low power standalone sensor systems with scavenge or very long-life power sources, remote sensors and various embedded sensors with a minimum of wired interfaces are examples of what is desired. Other non-contact systems, such as visible or IR flash detection or higher frequency radio frequency (RF) pulse detection may be investigated.
Debris impact structural damage NDE evaluation away from Earth (internal or external environments): Systems and techniques will be developed and tested that can be readily used by astronauts or mobile/robotic systems to evaluate impact-damaged areas and subsequent repairs. Tools and equipment that can provide adequate inspection in hard-to-access areas internally and externally will be especially helpful if it can provide position-awareness of the sensor with respect to the vehicle. Simple human operator interfaces and remote access to data should be considered. NDE systems such as high frequency 3-d imaging, infra-red imagers, eddy current and ultrasound systems will need to evaluated for their effectiveness on new structural composites, inflatable and rigidizable structures - practically applied in both internal and external evaluations. Certain structural health monitoring needs may require remotely operated NDE systems for periods when the vehicles listed above are not man-tended.

Debris impact structural leaks to vacuum detection, location, quantification and repair: The systems must monitor the pressurized vehicle integrity such that catastrophic leaks can be immediately dealt with to provide crew safety and, for smaller leaks, be sensitive enough to avoid loss of precious air resources to vacuum. Low weight, self-sealing structural concepts will be developed that minimize the air lost, but still are able to be located after the sealing has been accomplished for NDE evaluation. Test-validated models of both structural and airborne ultrasonic propagation of sound in the above pressurized modules, as well as sensing above typical background levels will be important to resolving these issues. Systems should be responsive to some or all levels of impact and leak indications through the rate of pressure loss detected requiring:

- Immediate location and isolation with limited access to the evacuated module afterward;
- Limited time to locate and plug the leak; and
- Extended period to locate, inspect, plan and effect repair and perform NDE afterward.

Sub Topics:
Predictive Modeling Techniques for the Mechanical Behaviors of Powders, Granular Materials, and Soils Topic T6.01
Center: KSC

Developing software models to predict the mechanical behavior of granular materials and powders is an area of ongoing and active research and development. NASA has a need for advances in software modeling techniques to support a number of on-going initiatives. One such area is the prediction of stress/strain shearing and compaction response of powder insulation materials located inside the annular space of very large cryogenic dewars (e.g., 80 feet in diameter with a 3 - 4 foot radius in the annular space). This is an area of high interest to KSC due to the use of large cryogenic tanks at the launch pads and the problems associated with the insulation in them. Another area
of interest is the mechanical behavior of lunar soil during drilling and digging, during construction and compaction (of berms), or during beneficiation and chemical processing of the soil (e.g., to remove water ice). This area is of interest to KSC due to the need for launch-site facilities to enable the assembly, flight qualification, and final checkout of spacecraft and payloads including the re-testing of last-minute modifications. Modeling the behavior of lunar soil in such facilities and comparing to the expected behavior in the lunar environment is a critical ability for developing launch-site facilities and procedures.

In both areas of interest, it is impossible to perform full-scale testing of the material in the relevant environment, and therefore extrapolation is necessary to compare small-scale or terrestrial experiments against what is expected in the full-scale or lunar environment. Extrapolation from one scale (or one environment) to another is very difficult and currently has a low probability of producing high-fidelity predictions. Unfortunately, without such extrapolation it is impossible to use an affordable small-scale (or terrestrial) test as a means to validate the design of hardware or to validate the expected behavior of the powder or soil in the full-scale (or lunar) case.

The best, presently-known method to do an extrapolation from one scale (or environment) to another is to produce a computer model to realistically simulate the physics of the granular material. The simulation can then be parameterized to make predictions in either scale or in either environment. The simulation can be benchmarked using the accessible scale (or environment), and then the parameterization can be adjusted to the inaccessible scale (or environment) to make the predictive extrapolation. Additional confidence in the extrapolation can be obtained by studying the model's sensitivity upon its various parameters within some experimentally-accessible range. Furthermore, the model can be used long-term as an engineering tool, iteratively refining it as new data become available from the full-scale application (or from the lunar environment). Thus, the model becomes a method to organize and compare new data as they become available across multiple scales and environments.

Innovations are sought in the area of multi-scale granular material modeling with true extrapolatory, predictive power across scales and environments. These innovations could be in the form of software techniques that integrate Discrete Element Models with Finite Element Models (or other software innovations), benchmarking techniques that integrate experimental methods with modeling methods in new ways, innovative analysis techniques, or any combination of the above. Other innovations will also be considered. The key point to the innovation is that it must extend the state-of-the-art in predicting granular/powder mechanical behavior. Innovations are particularly desired in the ability to model and predict powder shearing and compaction and to model lunar soil geotechnics.

Sub Topics:
- Predictive Numerical Simulation of Rocket Exhaust Interactions with Lunar Soil Topic T6.02
  - Center: KSC

One of the major challenges routinely faced at the Kennedy Space Center's launch and landing sites is to prevent hardware damage from the blasts associated with launching spacecraft. This includes the prediction of the aerodynamics and vibro-acoustics of rocket plumes in the launch environment, the reduction of high velocity ejection of materials by the rocket plume, and protection of the surrounding hardware from these effects. This will be a greater challenge at extraterrestrial spaceports. When a spacecraft lands on the Moon, surrounding hardware may be damaged and contaminated by the high velocity spray of eroded soil particles, and the landing spacecraft may be affected by an upward spray along the reflection planes between multiple engines. On lunar spaceports, the blast protection infrastructure must be constructed (in part) using in-situ materials, such as a berm made with lunar soil. There are a number of mission scenarios that will be different than the Apollo experience and that cause
the erosion problem to be more significant. Thus, this needs to be assessed in hardware and architecture design.

The lunar soil erosion theory developed during the 1940's and 50's did not include some of the relevant physics and as such it does not allow us to quantitatively predict the blast effects (with sufficient confidence) for missions that include multiple spacecraft landing in close vicinity to one another on the Moon. Without these predictions, it is currently not possible to develop adequate blast mitigation and protection technologies. To obtain better predictions, the Kennedy Space Center desires the development of a software tool that numerically predicts the plume interactions with the soil for rockets landing or launching on the Moon, including the erosion rates and trajectories of ejected particulate matter.

Innovations are sought, resulting in the development of a software package to improve the prediction of lunar blast dynamics. The difficulties in developing a flow code to predict these effects include the unique lunar environment, the difficulty in solving flow physics from first principles around discrete particle assemblages, the large spatial scale of the flow features compared to the vast number of lunar soil particles within that region, and the need to parameterize the erosion of soil to produce realistic predictions (although realistic benchmarking experiments of lunar erosion are difficult to perform terrestrially). In recent years, researchers have been making significant progress in understanding the interactions of particle assemblages with fluids. Emphasis shall therefore be placed on the research effort extending this progress toward correctly describing the physics of the gas/soil interactions.

Sub Topics:

Non-Destructive Evaluation and Structural Health Monitoring Topic T7.01
Center: LaRC

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

Evaluation sciences include ultrasonics, laser ultrasonics, optics and fiber optics, video optics and laser metrology, thermography, electromagnetics, acoustic emission, X-ray and terahertz radiation. Innovative and novel evaluation approaches are sought for the following materials and structural systems:
- Adhesives and bonded joints, sealants, bearings, coatings, glasses, alloys, laminates, monolithics, material blends, wire insulating materials, and weldments;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.

Proposals should address the following performance metrics as appropriate:

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

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

Sub Topics:
Remote Sensors for Entry, Descent and Landing Applications Topic T7.02
Center: LaRC

The NASA Langley Research Center, located in Hampton VA, maintains core competencies in laser/lidar technology development and entry/landing/descent (EDL) applications. Innovative or improved concepts are solicited for the development of sensors supporting human and robotic exploration missions to planetary surfaces. Of immediate interest are technologies enhancing or enabling sensors used in precision guidance and navigation related to surface landings and hazard avoidance. The sensors would be employed from orbit, through descent, and during final approach. The deployed system may require multiple sensors of different fundamental types. Specific sensors/components currently of interest include those associated with:

- 3D lidar systems, including flash lidars and scanning lidars;
- High resolution radars;
- 2D optical imaging devices.

Examples of components desired would include:
New, highly accurate and robust wide angle scanning systems;
Moderate power high efficiency lasers;
Fast detector arrays suitable for use in coherent lidar systems;
High efficiency long range flash lamps.

Proposals should describe the expected improvements and advantages of proposed deliverables over existing technologies, and should estimate the effects of these improvements on the state-of-the-art EDL guidance, control and hazard avoidance capabilities. Technologies likely to be ready for flight demonstration within the next 2 or 3 years are preferred, but highly innovative longer-term concepts will also be considered.

Sub Topics:
Manufacturing Technologies for Human and Robotic Space Exploration Topic T8.01
Center: MSFC

Continued technological innovation is critically linked to a strong manufacturing sector in the United States economy. 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, 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 and self-healing technologies; 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) and Ablatives**
CMC materials and processes are projected to significantly increase safety and reduce costs simultaneously while decreasing system weight for space transportation propulsion. Advanced CMC, ablative, and insulation materials and processing technologies are of interest which have low volume at low cost and are repeatable and scalable to large sizes. Applications of interest include, but not limited to: solid propulsion nozzles and throats, liquid propulsion
nozzles and thrust cells with integral injectors, and ancillary hardware components necessary for earth-to-orbit and in-space transportation.

**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.

**Fiber-Based and Inflatable Systems**

Fabrics and films may be appropriate materials for some space structures, but significant research is required to investigate the benefits, challenges and failure modes of such systems. Where fiber-based or inflatable structures have been demonstrated as potentially valuable to NASA, quality-controlled manufacture of these structures will be a strong focus and interaction between designers, manufacturing specialists and performance analysts can lead to better products; innovative procedures for manufacturing improvements and concepts are of interest.

**Advanced NDE Methods**

Portable and lightweight NDE tools that take advantage of nanotechnology for noninvasive, noncontact area inspection and characterization of polymer, ceramic and metal matrix composites. Areas include but are not limited to microwaves, millimeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.

Sub Topics:

Component Development for Deep Throttling Space Propulsion Engines Topic T8.02

Center: MSFC

Implementing certain aspects of the NASA Vision for Space Exploration will require versatile space propulsion engines that can operate over a wide range of thrust levels, a capability known as throttling. The ability of a rocket engine to reliably produce a small fraction of the maximum thrust on command during flight is referred to as deep throttling. High specific impulse deep-throttling space propulsion engines may be required for controlled spacecraft descent to planetary surfaces, and a significant degree of throttling may also be required for ascent and in-space
transfer maneuvers.

This subtopic solicits partnerships between academic institutions and small businesses in the development of components, design tools, and performance databases for engines in the 5,000-15,000 pound thrust range that use liquid hydrogen and liquid oxygen as propellants and which can be throttled to as little as 7% of the maximum thrust value. Examples of specific areas where innovations are sought include:

- High-throttle-response engine concepts;
- Low-cost regeneratively cooled chamber designs and demonstrations of such;
- Injectors that can provide stable engine performance with two-phase (gas/liquid) flow of propellants, especially during start-up transients;
- Ignition systems that can operate reliably over a wide fuel/oxidizer mixture ratio;
- Propulsion system or component technologies that do not require thermal conditioning prior to ignition;
- Zero net positive suction pressure pump design concepts, and demonstrations of such;
- Performance databases for small turbopumps and turbomachinery components;
- Design and analysis tools that accurately model small valves and turbopumps, and data required for code validation;
- Alternatives to the use of turbopumps for achieving chamber pressures of 1000 pounds per square inch; and
- Instrumentation for integrated vehicle health management.

Sub Topics:
Rocket Propulsion Testing Systems Topic T9.01
Center: SSC

Proposals are sought for innovative technologies 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. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies
Innovative, non-intrusive sensors for measuring gas velocity, temperature, pressure, molecular and metallic plume constituents, and environmentally sensitive effluent gas detection. 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/sec 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 should be capable of measuring gas species, temperature, and velocity for H₂, O₂, hydrocarbon 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 times must be on the order of a few milliseconds to sub-milliseconds.

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 non-intrusive optical-based sensors.

Test Facility Modeling Tools and Methods

Developing and verifying test facilities is complex and expensive. The wide range of pressures, flow rates, and temperatures necessary for engine testing result in complex relationships and dynamics. It is not realistic to physically test each component and the component-to-component interaction in all states before designing a system. Currently, systems must be tuned after fabrication, requiring extensive testing and verification.

Tools using computational methods to accurately model and predict system performance are required that integrate simple interfaces with detailed design and/or analysis software. SSC is interested in improving capabilities and methods to accurately predict and model the transient fluid structure interaction between cryogenic fluids and immersed components to predict the dynamic loads, frequency response of facilities.

Component Design, Prediction and Modeling - Improved capabilities to predict and model the behavior of components (valves, check valves, chokes etc.) during the facility design process. This capability is required for modeling components in high pressure 12,000 psi, high flow 100 lb/sec cryogenic environments and must address two-phase flows.

Process System Design, Prediction and Modeling - Improved capabilities to predict and model process systems. The capability should incorporate the previous two areas to accurately model the process systems and test articles.

Sub Topics:
Field Sensors, Instruments, and Related Technologies Topic T9.02
Center: SSC
Coastal environments and their natural resources are vital to our Nation's economy, security, commerce and recreation. These environments are strongly impacted by severe weather and other natural hazards. Because most of the world's population lives in coastal regions, these important and dynamic environments are also significantly impacted by human-induced events. Moreover, they are also especially sensitive to the initial effects of global climate change.

This subtopic solicits innovative field measurement technologies and analytical tools to support NASA's remote sensing technologies used in coastal research and applications. Specific interests at SSC include the following:

- Coupling of land and ocean processes (run-off, air quality, material flux);
- Coral reef mapping and health;
- Algal blooms (detection and monitoring);
- Sea level rise (measuring and forecasting effects);
- Sediment and contaminant transport (measuring and monitoring);
- Natural disasters such as tropical systems, tsunamis, and floods (planning, impact assessment, mitigation, and recovery).