The Small Probe Entry Descent and Landing System topic seeks proposals in relevant technology areas that will enable low cost approaches to obtaining flight data and qualify thermal protection systems in mid TRL levels and/or using small probe as a way to conduct bio, space and materials science experiments in space and bring back samples for laboratory analysis. The Information Technologies for Intelligent Planetary Robotics subtopic seeks proposals to develop information technologies that enable planetary robots to better support human exploration, with robotic support for human tasks such as advance scouting, site surveys, and site prep and documentation tasks that will enable long-duration missions.

Sub Topics:

**T1.01 Small Probe Entry Descent and Landing Systems**

Lead Center: ARC

The Entry, Descent and Landing (EDL) system of a spacecraft allows the payload to enter the atmosphere, survive the heating pulse, and touch down in a manner that doesn't harm the payload. The system generally consists initially of a spacecraft bus and an entry probe. The entry probe contains the payload.

During the initial entry portion of the mission the spacecraft bus provides power, avionics and maneuvering that governs the entry angle and a small de-orbit burn that sets the payload on the desired trajectory. This portion of the spacecraft is generally jettisoned before entry and is burned up in the atmosphere.

The Thermal Protection System (TPS) protects the payload from the severe heating encountered during hypersonic flight through a planetary atmosphere. In general, there are two classes of TPS: reusable and ablative. Typically, reusable TPS applications are limited to relatively mild entry environments like that of Space Shuttle. No change in the mass or properties of the TPS material results from entry with a significant amount of energy being re-radiated from the heated surface and the remainder conducted into the TPS material. Typically, a surface coating with high emissivity (to maximize the amount of energy re-radiated) and with low surface catalycity (to minimize convective heating by suppressing surface recombination of dissociated boundary layer species) is employed. The primary insulation has low thermal conductivity to minimize the mass of material required to insulate the primary structure. Ablative TPS materials, in contrast, accommodate high heating rates and heat loads through phase change and mass loss. All NASA planetary entry probes to date have used ablative TPS.

The payload contained in the thermal protection system may have special system constraints that will govern the design of the probe, such as peak deceleration loads and thermal control. For example a biological sample returning from space station may be limited to a few g's and max temperature rise on the order of 25 deg C.
The final portion of the entry is the landing system, typically defined as occurring during the supersonic and subsonic portions of the entry. The final touchdown can be via parachute or by direct impact of the probe with the planetary surface. While the parachute system adds mass and complexity to the mission it provides a final touchdown velocity small enough not to damage the probe. If the goal of the mission is to recover the probe without any impact damage the parachute and probe system can be snatched by aircraft during the terminal descent phase. Direct impact probes avoid the complexity of the parachute system and generally protect the payload with a crushable core to protect the payload from the high terminal velocity. The payload must be able to withstand the high deceleration loads in this type of a system.

NASA has successfully tackled the complexity of thermal protection systems for numerous missions to inner and outer planets in our solar system in the past; the knowledge gained has been invaluable but incomplete. In particular, ground test to flight traceability issues are incompletely understood.

An upcoming application of EDL technology is the desire to return small probes (i.e. cubesats and nanosats with payloads on the order of 1 kg) from low earth orbit. These missions will generally be launched as secondary payloads on much larger mass missions, or may be used to return biological samples from the International Space Station (ISS).

We are interested in building an integrated approach of probes or small platforms of probes with a spacecraft and a de-orbit system for multiple purposes: (1) As a TPS testbed wherein different TPS materials may be characterized during an actual re-entry, (2) Space/Bio Science mission including space station sample return, (3) materials in space testing such as exposure to space radiation and (4) Instrumentation packaging and demo (earth demo for planetary entry) and this may include such things as TPS instrumentation.

Areas of expertise are sought in all aspects of EDL design for these small entry probes as well as spacecraft integration with small probes that includes novel ideas for de-orbiting small probes. Advances in Multidisciplinary Design Optimization (MDO) are sought specifically in application to address combined aerothermal environments, material response, vehicle thermal-structural performance, payload thermal control, vehicle shape, vehicle size, aerodynamic stability, mass, vehicle entry trajectory/GN&C, and landing systems, characterizing the entry vehicle design problem.

The expected Technology readiness level is 4.

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**T1.02 Information Technologies for Intelligent Planetary Robotics**

**Lead Center:** ARC

The objective of this subtopic is to develop information technologies that enable planetary robots to better support human exploration. Since February 2004, NASA has been actively engaged in a long-term program to explore the
Moon, Mars, and other destinations. Several NASA studies have concluded that extensive and pervasive use of intelligent robots can significantly enhance human exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

Robots can do a variety of work to increase the productivity of human explorers on planetary surfaces. Robots can perform tasks that are highly repetitive, long-duration, or tedious. Robots can perform tasks that help prepare for subsequent crew activity. Robots can perform "follow-up" work, completing tasks started by humans. Example tasks include: robotic recon (advance scouting), systematic site surveys, documenting sites or samples, and unskilled labor (initial site prep, site clean-up, etc.).

Proposals are sought which address the following technology needs:

- Advanced user interfaces for remote robotic exploration, which include Web-based collaboration methods, panoramic and time-lapse imagery, support for public outreach/citizen science, social networking and/or visualization of geospatial information. The primary objectives are to enable more efficient interaction with robots, to facilitate situational awareness, and to enable a broad range of users to participate in robotic exploration.

- Ground control data systems for robotic exploration. Proposals should focus on software tools for planning variable-duration and adjustable autonomy command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing; and/or for automating ground control functions.

- Mobile robot navigation (localization, hazard avoidance, etc.) for multi-km traverses in unstructured environments. Novel "infrastructure free" techniques that utilize passive computer vision (real-time dense stereo, optical flow, etc.), active illumination (e.g., line striping), repurposed flight vehicle sensors (low light imager, star trackers, etc.), and/or wide-area simultaneous localization and mapping (SLAM) are of particular interest.

- Robot software architecture that radically reduces operator workload for remotely operating planetary rovers. This may include: on-board health management and prognostics, on-board automated data triage (to prioritize information for downlink to ground), and learning algorithms to improve hazard detection and selection of locomotion control modes.
Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts Flight Research separates "the real from the imagined" and makes known the "overlooked and the unexpected." NASA's flight research mission is to prove unique and novel concepts through discoveries in flight. The chief areas of research interests encompass aerospace flight research and technology integration; validation of space exploration concepts; and airborne sensing and science. This topic solicits innovative proposals that would advance aerospace technologies for the nation in all flight regimes.

Sub Topics:

**T2.01 Foundational Research for Aeronautics Experimental Capabilities**

**Lead Center:** AFRC

This subtopic is intended to solicit innovative technologies that enhance flight research competences at Dryden by advancing capabilities for in-flight experimentation and for the supporting test facilities in the following areas:

- Methods and associated technologies for conducting flight research and acquiring test information from experiments in flight.
- Numerical techniques for the planning, analysis and validation of flight-test experimentation conditions through simulation, modeling, control, or test information assessment.

The emphasis of this subtopic is proving feasibility, developing, and maturation technologies for advanced flight research experimentation that demonstrate new methodologies, technologies, and concepts (or new applications of existing approaches). It seeks advancements that promise significant gains in Dryden's flight research capabilities or addresses barriers to measurements, operations, safety, and cost. Proposals that demonstrate and confirm reliable application of concepts and technologies suitable for flight research and the test environment are a high priority. Proposals in any of these areas will be considered:

- Measurement techniques are needed to acquire aerodynamic, structural, flight control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. 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. Sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.
- 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 to increase understanding of the complex interactions between the vehicle dynamics and subsystems.
- 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, aero-elastic maneuver performance and load control (including smart actuation and active aero-structural concepts), autonomous health monitoring for improved stability, safety, performance, and drag minimization for high efficiency and extended range capability.

Proposals are encouraged that advocate technologies or methodologies that enable real-time location independent collaboration from experimenters from both domestic and international organizations. This approach holds the promise of increasing effectiveness, reducing cost, and adding significant value to the experimental results. This topic solicits proposals for improvements in all flight regimes - subsonic, transonic, supersonic, and hypersonic.

**Glenn Research Center Topic T3**

This topic seeks to solicit advanced innovative technologies and systems in space power and propulsion to fulfill our Nation's goal of space exploration. The anticipated technologies should advance the state-of-the-art or feature
enabling technologies to allow NASA to meet future exploration goals.

Sub Topics:

**T3.01 Technologies for Space Power and Propulsion**

**Lead Center: GRC**

Development of innovative technologies are sought that will result in durable, long-life, lightweight, high performance space power and in-space propulsion systems to substantially enhance or enable future missions.

Innovations for space power systems are sought that will offer significant improvements in efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, design flexibility/reconfigurability, autonomy, and affordability. In the area of power generation, advances are needed in photovoltaic cell technology (e.g., materials, structures, and incorporation of nanomaterials); solar array module/panel integration (e.g., advanced coatings, advanced structural materials, monolithic interconnects, and high-voltage operational capability); and solar array designs (e.g., ultra-lightweight deployment techniques for planar and concentrator arrays, restorable/redeploy able designs, high power arrays, and planetary surface concepts). For energy storage technology, advances are needed in primary and rechargeable batteries, fuel cells, flywheels, regenerative fuel cell systems, and innovative design methods. Advances are also needed in power management and distribution systems, power system control, energy conversion technology (such as Stirling and Brayton systems) and integrated health management. Advanced nuclear power concepts are also sought.

Innovations, advanced concepts and processes are sought for in-space propulsion, including electric propulsion, chemical propulsion, advanced rocket propellants/alternative fuels, nuclear propulsion, and tether technology. In electric propulsion, concepts for subcomponent improvements are needed for ion and Hall thruster systems, including cathodes, neutralizers, electrode-less plasma production, low-erosion materials, high-temperature permanent magnets, and power processing systems. Innovations are also needed for xenon and krypton fuel distribution systems. In small chemical thruster propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

**Goddard Space Flight Center Topic T4**

As part of its mission, NASA needs advanced remote sensing measurements to improve the scientific understanding of the Earth, its responses to natural and human-induced changes, and to improve model predictions of climate, weather, and natural hazards. By using improved technologies in terrestrial, airborne, and spaceborne instruments, NASA seeks to better observe, analyze, and model the Earth system to aid in the scientific understanding and the possible consequences for life on Earth.

This STTR solicitation is to help provide advanced remote sensing technologies to enable future measurements. Components are sought that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (Unmanned Aircraft Systems (UAS) or aircraft). New approaches, instruments, and components are sought that will:

- Enable new Earth Science measurements;
- 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.
Sub Topics:

**T4.01 Lidar, Radar, and Passive Microwave**

**Lead Center:** GSFC

**Lidar Remote Sensing Instruments and Components**

Lidar instruments and components are required to furnish remote sensing measurements for future Earth Science missions. NASA particularly needs advanced components for direct-detection lidar that can be used on new UAS platforms available to NASA, on the ground as test beds, and eventually in space. Important aspects for components are electro-optic performance, mass, power efficiency and lifetimes. Key components for direct-detection lidar techniques (particularly efficient lasers and sensitive detectors) are solicited that enable or support the following Earth Science measurements:

- Profiling of cloud and aerosol backscatter, with emphasis on multiple wavelength as relevant to the Aerosol-Clouds-Ecosystems (ACE) mission. A particular interest is development of novel scanning telescopes capable of scanning over 360 degrees in azimuth with nadir angle fixed in the range of 30 to 45 degrees, scalable to spaceborne operation without imposing requirements for momentum compensation.
- Wind measurements (using direct-detection techniques). A particular interest is photon-counting detectors (either single element or array) with high quantum efficiency (>70%) and low noise (< 100 counts/second) to improve direct-detection wind profiling at 355 nm.
- Trace gas measurements. Specifically, novel (preferably wave-guided) reference gas cells with fixed long path-lengths of ~20 m up to 100 m for laser wavelength locking and calibration in fiber optic C-band and L-band for flight missions. The gas cells must be compact, lightweight, insensitive to vibration and deformation, low in excess insertion loss (<10dB preferred), free of multi-pass interference (MPI) and other spectral fringes that upset wavelength locking and calibration.

**Radar Remote Sensing Instruments and Components**

Active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and UASs. New systems, approaches, and technologies are sought that will enable or significantly enhance the capability for: (1) tropospheric wind measurements within precipitation and clouds at X- through W-band, and (2) precipitation and cloud measurements. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (UAS or aircraft). Specific technologies include:

- High-speed digital transceivers for cloud/precipitation radar remote sensing.
- Scanning Ka or W-band Doppler radar technologies with high sensitivity for clouds.
- High power, high-speed, low loss W- and Ka-band radar receiver protection.
- Ultra-low sidelobe pulse compression technologies for cloud/precipitation applications.
- Frequency selective surface for W-and Ka-band radar front ends.

Jet Propulsion Laboratory Topic T5

This topic addresses the need for low mass, low power technologies that support in situ compositional analysis and mapping. Two areas are of particular interest: micro-scale analysis and mapping of the mineralogy, organic compounds, chemistry and elemental composition of planetary materials, related to rock fabrics and textures; and remote mapping of geologic outcrops and features. Such technologies are particularly relevant for the planned Mars 2018 rover mission, but may also be proposed to future landed missions to the moon, comets, asteroids, Europa, Titan, and other planetary bodies.

Sub Topics:

**T5.01 Technologies for In Situ Compositional Analysis and Mapping**
This subtopic is focused on developing and demonstrating technologies for in situ compositional analysis and mapping that can be proposed to future planetary missions, including the Mars 2018 Rover.

Possible areas of interest include:

- Improved sources such as lasers, LEDs, X-ray tubes, etc. for in situ imaging and spectroscopy instruments (including Laser Induced Breakdown Spectroscopy, Raman Spectroscopy, Deep UV Raman and Fluorescence spectroscopy, Hyperspectral Imaging Spectroscopy, and X-ray Fluorescence Spectroscopy);
- Improved detectors for in situ imaging and spectroscopy instruments (e.g. flight-compatible ICCDS and other time-gated detectors that provide gain, robot arm compatible PMT arrays and other detectors requiring high voltage operation, detectors with improved UV and near-to-mid IR performance, near-to-mid IR detectors with reduced cooling requirements);
- Technologies for 1-D and 2-D raster scanning from a robot arm;
- Novel approaches that could help enable in situ organic compound analysis from a robot arm (e.g. ultra-miniaturized Matrix Assisted Laser Desorption-Ionization Mass Spectrometry);
- "Smart software" for evaluating imaging spectroscopy data sets in real-time on a planetary surface to guide rover targeting, sample selection (for missions involving sample return), and science optimization of data returned to earth;
- Other technologies and approaches (e.g. improved cooling methods) that could lead to lower mass, lower power, and/or improved science return from in situ instruments used to study the elemental, chemical, and mineralogical composition of planetary materials.

Projects selected under this subtopic should address at least one of the above areas of interest. Multiple-area proposals are encouraged. Proposers should specifically address:

- The suitability of the technology for flight applications, e.g. mass, power, compatibility with expected shock and vibration loads, radiation environment, interplanetary vacuum, etc.;
- Advantages of the proposed technology compared to the competition;
- Relevance of the technology to NASA’s planetary exploration science goals.

**Johnson Space Center Topic T6**

To accomplish the Agency's goals and objectives for a robust space exploration program, innovative technologies and approaches are needed to meet these major challenges for human space explorers. This topic solicits technologies to support inflatable modules and advanced portable sensor technologies for high-purity oxygen determination. These technology innovations could help minimize launch mass, size and costs. The anticipated proposed technologies shall have a dramatic impact on achieving NASA's goals.

**Sub Topics:**

**T6.01 Inflatable Modules**

This subtopic solicits innovative structural concepts that support the development of lightweight structures technologies that could be applicable to space applications. The targeted innovative lightweight structures are for primary pressurized volumes. Innovations in technology are needed to minimize launch mass, size and costs, while increasing operational volume and maintaining the required structural performance for loads and environments.

Of particular interest are inflatable structures, which are viable solutions for increasing the volume in habitats, airlocks, and potentially other crewed vessels. To build confidence in the use of these structures; design, analysis
and manufacturing methods that produce optimal structure on a consistent basis need development above the current state of the art.

The development, analysis, and testing of dual purpose materials that show significant benefits in more than one area such as structural, thermal protection, micrometeoroid/orbital debris protection, radiation protection, atomic oxygen protection, and such are of particular interest.

The folding, packaging and deployment of multi-layer systems especially those with an integrated window or hatch penetration and particularly those of a torus shape surrounding a cylindrical body are also an area of interest.

Also of interest are low permeable bladder materials and the development and testing of a low permeable interface between a gas barrier and a structural core or hatch penetration that is durable over time and does not degrade due to effects such as cold flow. Development of low permeability bladder materials that can tolerate flexure at cold temperatures are of particular interest.

Developments can include material development and testing, conceptual design and demonstration, analysis methods and verification, and/or manufacturing techniques. Technological improvements focus on risk reduction/mitigation, and development of reliable yet robust designs under this announcement. Research demonstrates the technical feasibility during Phase I and shows a path toward a Phase II hardware demonstration, and when possible, delivers a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

T6.02 Advanced Portable Sensor Technology for High-Purity Oxygen Determination

Lead Center: JSC

Determining the purity of oxygen near 100% is problematic using portable electrochemical sensor-based devices. Accurate laboratory analysis is based on techniques such as separation (e.g., gas chromatography, GC) followed by peak integration or mass-spectral analysis. Though accurate, these devices are not readily portable, usually delicate and often require a carrier or calibration gas. While not specifically excluded, a carrier gas is strongly discouraged and calibration should require a minimum of consumables.

This solicitation seeks a reliable technique that can be applied to accurately assess oxygen purity in the range of 99.0% to 99.7% (see an example below)*. The technique or technology should be able to determine oxygen purity with a variety of simple diluents such as nitrogen, argon, hydrogen, water vapor and trace amounts of low molecular weight organics, CO and/or CO₂. It is not important that the technique specifically identify or quantify the diluents(s). The target accuracy for oxygen purity in the range is 0.05%.
Proposed technologies should be easily calibrated in remote locations, should be highly resistant to drift (i.e., long time between calibration cycles) and have potential to be adapted to a size and portability suitable to space missions. Potential applications include on-orbit determination of high-purity oxygen or other remote applications. A minimum of support equipment, maintenance, power and consumables is a key characteristic sought.

The first phase should address potential approaches with anticipated ranges of accuracy and precision along with known or potential limitations and interferences. Subsequent phase will be to develop and demonstrate a working prototype.

Example: The proposed technology should be able to reliably determine and differentiate the oxygen concentration between the following two example gas streams:

- 99.7% Oxygen, 0.2% Argon, 0.1% Nitrogen with a dew point of -60°C;
- 99.4% Oxygen, 0.4% Argon, 0.2% Nitrogen with a dew point of -40°C.

Kennedy Space Center Topic T7

The Kennedy Space Center has been supporting the development of wireless SAW sensor arrays through prior research activities. A new communication system has been demonstrated, namely Orthogonal Frequency Coding, that allows access to an array of SAW sensors, each with its own unique identifier to measure temperature, cryogenic levels, humidity, and hydrogen. However, further development in other types of wireless monitoring is desired such as: pressure, strain, near-by impacts/structural acoustic events, acceleration, proximity detection, magnetic/electric field, current, and hypergols (monomethyl-hydrazine or nitrogen tetroxide). The goal is to maximize the ability to acquire information on these and other parameters while minimizing the need for cabling and preventative maintenance requirements. Wireless SAW sensor arrays appear to promote this goal.

Sub Topics:

**T7.01 Wireless SAW Sensor Arrays**

**Lead Center: KSC**

Wireless surface acoustic wave (SAW) sensor arrays may have significant application in the ground processing of future spacecraft. These sensors do not require an embedded power source; instead they are powered by an RF interrogation pulse. Consequently, they have the promise of being essentially maintenance free, allowing them to be installed in normally inaccessible areas and provide environmental information for many years. In addition, as opposed to microprocessor-based transponders, SAW devices can be designed to operate from cryogenic temperatures up to about 1000 degrees C. These characteristics have resulted in interest in this technology, not only for ground processing, but recently from both the NASA research and flight centers.

The Kennedy Space Center has been supporting the development of wireless SAW sensor arrays through prior
STTR activities. A new communication system has been demonstrated, namely Orthogonal Frequency Coding, that allows access to an array of SAW sensors, each with its own unique identifier. Also specific sensors have been developed to measure temperature, cryogenic level, humidity, and hydrogen under prior year funding. These are all of interest, but further development in other types of wireless SAW sensors is desired. This call requests proposals for wireless SAW sensors that can monitor, for example, pressure, strain, near-by impacts/structural acoustic events, acceleration, proximity, magnetic field, current, electric field, and hypergols (monomethyl-hydrazine or nitrogen tetroxide). This list is not exclusive and other sensors may also be of interest as well. In addition, alternative communication or multiplexing concepts are of interest, and enabling technologies, such as antenna design for SAW sensors, are welcome.

Applications for these sensors are diverse. When a vehicle is moved to the pad on a mobile launch platform strain sensors and accelerometers monitor the vehicle's sway, pressure sensors could be placed under sprayed on foam insulation to ensure bonding integrity up to launch, moisture sensors could be used to determine if water has migrated into inaccessible areas. Electric field sensors might help with lightening warnings, chemical sensors can improve safety, and magnetic field or current sensors can monitor valve performance. The goal is to maximize the ability to acquire information on these and other parameters while minimizing the need for cabling, maintenance, and operator labor. Wireless SAW sensor arrays appear to promote this goal.

Langley Research Center Topic T8

For Space Environment Resistant Materials there are opportunities to improve the performance of engineering materials that support spacecraft performance, lifetime, and mission assurance. Areas of opportunity to improve material performance for low earth orbiting satellites are reflective coatings and emissive coatings that maintain properties for extended periods with resistance to high-energy radiation and atomic oxygen. Other areas of interests include materials that resist internal electrostatic discharge in highly charged radiation belt environments. The outer planet environments, such as Jupiter, have predominantly highly charged trapped electrons, which pose challenges for protecting critical spacecraft components inside the bus from internal electrostatic discharge. Charged environments can be on Earth at geosynchronous and medium orbits where interactions with trapped radiation belts that are charged by solar space weather are prevalent. Polymeric and composite materials that can assist in reducing adverse affects of spacecraft charging and internal electrostatic discharge are sought without the loss of coating, electrical, adhesive, thermal, and mechanical properties. Research and development of space environment resistant materials support the mission assurance of NASA earth science, exploration, and space science spacecraft missions outlined in the decadal survey.

Sub Topics:

T8.01 Flexible Charge Dissipation Coatings for Spacecraft Electronics

Lead Center: LaRC

Participating Center(s): JPL

Many NASA spacecraft and satellites operate in radiation environments: geostationary and medium earth orbits, radiation belts in the outer planets, solar wind, and Lagrangian points near the sun. With highly charged particles that penetrate spacecraft, internal electrostatic discharge risks mission assurance. The Jovian environment has radiation levels 7 times greater that Earth's geostationary orbit, which is the NASA Europa Jupiter System Mission environment. In order to reduce the risk of internal electrostatic discharge on sensitive spacecraft electronic components, NASA seeks a conformal conductive coating that dissipates charge on the surface of electronic boards. It is highly desired for the coating to be applied to electronic boards using a standard industry method such as painting or other brush technique in a cleanroom environment. The coating must dissipate charge, have low outgassing, and have low water absorption. The coating is highly desired to be optically clear for visual inspection of components. The coating is also highly preferred to be thermoplastic for removal if needed. The minimum maximum service temperature for the coating is 70 deg C. Charge dissipation testing can be done using electron gun, which can be screened using a scanning electron microscope (SEM). At the macroscopic level, the volume resistivity of the conductive coating must be in the range of $1 \times 10^8$-$10^{12}$ ohm cm. The paint or coating must be able to adhesively bond to conventional electronic epoxy and polyimide circuit boards without damaging metal circuits, resistors, capacitors, and semiconductor surfaces. Improved charge dissipation supports the mission assurance of NASA satellites and spacecraft that operate in charging environments.
T8.02 Spacecraft Internal Electrostatic Discharge (IESD) Resistant Circuit Board Materials

Lead Center: LaRC

Participating Center(s): JPL

The improvement in the performance of spacecraft circuit board materials with resistance to IESD will enhance performance, lifetime, and mission assurance. Circuit boards are sought from composite materials, such as graphite fibers and epoxy or polyimide resins that dissipate electron charge. It is important for the circuit board materials to be compared for circuit board physical properties (dielectric constant, temperature range, breakdown voltage, coefficient of thermal expansion, and etc.) with the current commercial state of the art materials, such as FR4 and others. A typical volume resistivity of $10^{12}$ ohm cm is needed for the circuit board material and the ability to leak electron charge at the microscopic level. Charge dissipation studies can be initially performed by electron gun or scanning electron microscope (SEM) for initial screening. The outer planet environments, such as Jupiter, have predominantly highly charged trapped electrons, which pose challenges for protecting critical spacecraft components inside the bus from internal electrostatic discharge. Charged environments can be found at geosynchronous and medium Earth orbits where interactions with trapped radiation belts that are charged by solar space weather are prevalent. Polymeric and composite circuit board materials that can assist in reducing adverse affects of internal electrostatic discharge are sought without the loss of electrical, thermal, and mechanical properties. Research and development of spacecraft IESD resistant circuit board materials support the mission assurance of NASA earth science, exploration, and space science missions outlined in the decadal survey.

T8.03 Innovative Green Technologies for Renewable Energy Sources

Lead Center: LaRC

NASA is interested in advancing green technology research for achieving sustainable and environmental friendly energy sources for terrestrial and space applications. Dependence on fossil fuels has to be balanced with other potential sources of energy for minimizing deleterious effects of their byproducts. In the case of Lunar, Mars and other planetary explorations including development of human habitats, use of clean and renewable energy sources would help advance mission objectives to a greater extent besides reducing waste products.

Proposals are sought to develop innovative renewable sources of energy that generate minimal emissions, environmentally safe and are sustainable over extended periods of time. Proposed technologies should advance the state-of-the art systems and/or components by focusing on techniques that either reduce or replace the use of fossil fuels in a cost effective manner.
Clean energy source technologies and methodologies including but are not limited to those based on solar, wind, hydro, biomass, geothermal, and atmospheric constituents such as hydrogen, carbon dioxide are solicited. Innovative space based solar power generation and effective transport to benefit terrestrial and space applications are desired. Proposals related to efficient operation over wide temperature ranges under harsh environmental conditions are also sought. Energy sources that enable future missions which otherwise would be difficult with conventional resources are desired.

Marshall Space Flight Center Topic T9

Achieving NASA’s exploration goals will hinge on continued development of improved capabilities in propulsion system design and manufacturing techniques. NASA is interested in innovative design and manufacturing technologies that enable sustained and affordable human and robotic exploration of the solar system. The development of and operation of these propulsion systems will benefit greatly from improvements in design and analysis tools and from improvements in manufacturing capabilities.

Sub Topics:

T9.01 Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing

Lead Center: MSFC

This subtopic solicits partnerships between academic institutions and small businesses in the following specific areas of interest: Innovative design and analysis techniques, manufacturing, materials, and processes relevant to propulsion systems launch vehicles, crew exploration vehicles, orbiters, and landers. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components.

- Polymer Matrix Composites (PMCs) Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant, repairable, and self-healing technologies; advanced materials and manufacturing processes for both cryogenic and high-temperature applications.
- 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.
- Solid-state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites, and high strength and high temperature or functionally graded materials.
- New advanced super alloys 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.

- Advanced NDE Methods Portable and lightweight NDE tools provide 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.
- Improvement in techniques for predicting the self-generated dynamics of space propulsion system when operated at off-design conditions.
- Improvement in techniques for predicting the acoustic field produced by the operation of a space propulsion system in near ground operation.
- Predictive capability of the performance and internal environment for systems, solid or liquid propellants, undergoing multi-phase combustion. Of special interest are systems utilizing nano-energetics solid fuels.
- Predictive capability improvements for the coupled fluid-structural problem with focus on accurate prediction of heat-transfer that occurs in the chamber of a nuclear thermal rocket.
- Design and analysis tools that accurately model small valves and turbopumps.
- Development of databases and instrumentation advances required for validation of previously mentioned predictive capabilities.

Stennis Space Center Topic T10

NASA’s Stennis Space Center (SSC) seeks advanced technologies to support its testing rocket engines including innovative approaches for measurement of propellant tank volume, new tools for prediction operational life of critical components, and health monitoring and management of test facilities infrastructure. Technologies are also sought to improve the Center’s energy conservation and Sustainability

Sub Topics:

**T10.01 Test Area Technologies**

**Innovative Approaches to Tank Volume Measurement**

Develop new innovative non-contact methods to measure liquid propellant tank volume and tank fluid level with improved accuracy, repeatability and minimal tank entries for maintenance and calibration. Currently, differential pressure measurements or multiple float switched are typically used. Differential pressure measurements do not provide sufficient accuracy for low density fluids such as liquid hydrogen, and multiple float switch gages only offer readings at discrete tank liquid levels, and are subject to mechanical failure and expensive maintenance. Accuracies of 0.5% or better are desired. Need for improved technology is mid-term, and highly desirable.

Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

**Robust Components Technologies**

Develop new innovative tools to predict operational capability and life for key facility components (e.g., valves, valve seals and seats, actuators, flowmeters, tanks, etc.) for ultra high (>8000 psi) pressure, high flow rates, and cryogenic environments. Tools would be used for the design, procurement, and modification of facility components and ideally also incorporated in system models for simulation of test stand operation. Current TRL is 3 for modeling valves and flowmeters. Need for improved technologies are mid-term, and are highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 5.

**Infrastructure Health Monitoring**

Infrastructure health monitoring and management for test facilities and for widely distributed sup-port systems (WDSS) such as gas distribution and cooling water. Capabilities being sought for WDSS include remote monitoring of vacuum lines, gas leaks, and fire; using wireless technologies in order to eliminate running miles of power and data wires. Proposed innovative systems must lead to improved safety and reduced test costs by use of
technologies for automated anomaly detection; diagnosis; determination of faults and their effects; prediction of future anomalies; capture and analysis of usage information; tools for rapid and effective analysis of data, information, and knowledge; and efficient user interfaces to enable integrated awareness of the system condition by users. Effectiveness of technologies in addressing the stated needed capabilities: robustness of wireless monitoring systems, effectiveness of anomaly detection (percent of anomalies captured, percent of false alarms), improvements in safety, and reduction in costs. Need for improved technologies is mid-term, and highly desirable. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

Cost-Saving Vacuum System Technologies

The objective here is to prototype and field test vacuum monitoring devices that minimize "touch maintenance" thereby reducing costs and preclude cabling by working wireless. Current state of the art for vacuum jacketed liquid hydrogen (LH) lines is walking the lines and manually performing the required periodic checks and sensor maintenance. The new altitude test stand will produce high vacuum inside a large rocket engine test chamber with ambient pressure outside. Some locations will be difficult or impossible to reach. Due to the unique and harsh environmental nature of this test facility, new technologies and vacuum measurement techniques are needed to monitor this environment. Performance metrics include high accuracy and sensitivity in the 0.1 to 1 psia, insensitivity to high levels of noise and vibration, and ruggedness. Need for improved technologies is short term, and highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

T10.02 Energy Conservation and Sustainability

Lead Center: SSC

John C Stennis Space Center (SSC) is a large rocket propulsion test facility located in southern Mississippi close to the Louisiana state line. Due to the size of the test facilities, energy consumption is very large. In an effort to conserve on energy, there is an interest in pursuing innovation in the following areas:

Innovative Geothermal Technology

SSC is interested in innovative geothermal technology in an effort to reduce energy consumption, reducing the Center's carbon footprint. The feasibility and application of geothermal technology has not been investigated for use at SSC. SSC is looking for geothermal technology that is cost effective to implement and maintain. There are potential commercial and residential applications. The feasibility of geothermal technology will require an assessment of the local topography, underground soil composition, location of water "sinks", and determination of the area's ground "constant" temperature. Concepts will be evaluated based on their potential efficiency, ease of implementation and maintenance, and flexibility of applications (including, but not limited to, HVAC, preheating hot water heaters, and other means of extracting energy), as well as, applicability to the Center's mission. Proposals will also be evaluated based on the maturity level to which the technology will be developed and innovative techniques.

Innovative Lighting Technology
Stennis Space Center is interested in developing innovative technologies, systems, or methodologies that will reduce the energy consumption and heat generation from facility lighting while maintaining the desired level of illumination for safety and effective work environments. SSC is interested in innovative lighting technologies for the test area and parking lots. These lighting technologies will need to reduce energy consumption while maintaining a comfortable and safe working environment. SSC is particularly interested in replacing costly lighting in the test area (test stands, hydrogen/oxygen environments, hazardous and potentially corrosive environments). The lighting should be in compliance with IESNA RP 7-01, Practice for Industrial Lighting. Proposals will be evaluated based on the maturity level to which the technology will be developed and innovative techniques that will provide a reasonable life expectancy. Proposals will also be evaluated on implementation strategy and ease of maintenance.

Innovative Solar Technology

Reduction in energy consumption and subsequent energy cost is a high priority at SSC. SSC is interested in developing new technologies for the efficient and effective use of photovoltaic/solar cell to reduce energy costs. Major issues in the development and use of solar panel include efficient system design and installation as well as effective maintenance. Innovative approaches and tools to facilitate the design of efficient solar cell systems, effective application of solar cells systems for building rooftops or a separate field area of solar cells are desired as well as innovative approaches to the monitor the health of the system and maintenance methods to insure the most effective and efficient operations of the system in an environment with high humidity, extensive rain showers, high pollen counts, rapid mold and fungal growth, etc.

Technologies for Propellant Conservation

Objective is to minimize usage of costly gases (helium and hydrogen) through devices that can recover/recycle efflux from cryogenic test facilities (currently no recovery is done). This could include technologies such as real time gas sampling/contamination monitoring system for propellant and purge systems that could also help minimize use of non renewable resources such as Helium, or Helium reclamation carts for recapture of inert/purges.

Small Probe Entry Descent and Landing Systems Topic T1.01
The Entry, Descent and Landing (EDL) system of a spacecraft allows the payload to enter the atmosphere, survive the heating pulse, and touch down in a manner that doesn't harm the payload. The system generally consists initially of a spacecraft bus and an entry probe. The entry probe contains the payload. During the initial entry portion of the mission the spacecraft bus provides power, avionics and maneuvering that governs the entry angle and a small de-orbit burn that sets the payload on the desired trajectory. This portion of the spacecraft is generally jettisoned before entry and is burned up in the atmosphere.

The Thermal Protection System (TPS) protects the payload from the severe heating encountered during hypersonic
flight through a planetary atmosphere. In general, there are two classes of TPS: reusable and ablative. Typically, reusable TPS applications are limited to relatively mild entry environments like that of Space Shuttle. No change in the mass or properties of the TPS material results from entry with a significant amount of energy being re-radiated from the heated surface and the remainder conducted into the TPS material. Typically, a surface coating with high emissivity (to maximize the amount of energy re-radiated) and with low surface catalycity (to minimize convective heating by suppressing surface recombination of dissociated boundary layer species) is employed. The primary insulation has low thermal conductivity to minimize the mass of material required to insulate the primary structure. Ablative TPS materials, in contrast, accommodate high heating rates and heat loads through phase change and mass loss. All NASA planetary entry probes to date have used ablative TPS.

The payload contained in the thermal protection system may have special system constraints that will govern the design of the probe, such as peak deceleration loads and thermal control. For example a biological sample returning from space station may be limited to a few g's and max temperature rise on the order of 25 deg C.

The final portion of the entry is the landing system, typically defined as occurring during the supersonic and subsonic portions of the entry. The final touchdown can be via parachute or by direct impact of the probe with the planetary surface. While the parachute system adds mass and complexity to the mission it provides a final touchdown velocity small enough not to damage the probe. If the goal of the mission is to recover the probe without any impact damage the parachute and probe system can be snatched by aircraft during the terminal descent phase. Direct impact probes avoid the complexity of the parachute system and generally protect the payload with a crushable core to protect the payload from the high terminal velocity. The payload must be able to withstand the high deceleration loads in this type of a system.

NASA has successfully tackled the complexity of thermal protection systems for numerous missions to inner and outer planets in our solar system in the past; the knowledge gained has been invaluable but incomplete. In particular, ground test to flight traceability issues are incompletely understood.

An upcoming application of EDL technology is the desire to return small probes (i.e. cubesats and nanosats with payloads on the order of 1 kg) from low earth orbit. These missions will generally be launched as secondary payloads on much larger mass missions, or may be used to return biological samples from the International Space Station (ISS).

We are interested in building an integrated approach of probes or small platforms of probes with a spacecraft and a de-orbit system for multiple purposes: (1) As a TPS testbed wherein different TPS materials may be characterized during an actual re-entry, (2) Space/Bio Science mission including space station sample return, (3) materials in space testing such as exposure to space radiation and (4) Instrumentation packaging and demo (earth demo for planetary entry) and this may include such things as TPS instrumentation.

Areas of expertise are sought in all aspects of EDL design for these small entry probes as well as spacecraft integration with small probes that includes novel ideas for de-orbiting small probes. Advances in Multidisciplinary Design Optimization (MDO) are sought specifically in application to address combined aerothermal environments, material response, vehicle thermal-structural performance, payload thermal control, vehicle shape, vehicle size, aerodynamic stability, mass, vehicle entry trajectory/GN&C, and landing systems, characterizing the entry vehicle design problem.
The expected Technology readiness level is 4.

Sub Topics:
Information Technologies for Intelligent Planetary Robotics Topic T1.02
The objective of this subtopic is to develop information technologies that enable planetary robots to better support human exploration. Since February 2004, NASA has been actively engaged in a long-term program to explore the Moon, Mars, and other destinations. Several NASA studies have concluded that extensive and pervasive use of intelligent robots can significantly enhance human exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

Robots can do a variety of work to increase the productivity of human explorers on planetary surfaces. Robots can perform tasks that are highly repetitive, long-duration, or tedious. Robots can perform tasks that help prepare for subsequent crew activity. Robots can perform "follow-up" work, completing tasks started by humans. Example tasks include: robotic recon (advance scouting), systematic site surveys, documenting sites or samples, and unskilled labor (initial site prep, site clean-up, etc.).

Proposals are sought which address the following technology needs:

- Advanced user interfaces for remote robotic exploration, which include Web-based collaboration methods, panoramic and time-lapse imagery, support for public outreach/citizen science, social networking and/or visualization of geospatial information. The primary objectives are to enable more efficient interaction with robots, to facilitate situational awareness, and to enable a broad range of users to participate in robotic exploration.

- Ground control data systems for robotic exploration. Proposals should focus on software tools for planning variable-duration and adjustable autonomy command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing; and/or for automating ground control functions.

- Mobile robot navigation (localization, hazard avoidance, etc.) for multi-km traverses in unstructured environments. Novel "infrastructure free" techniques that utilize passive computer vision (real-time dense stereo, optical flow, etc.), active illumination (e.g., line striping), repurposed flight vehicle sensors (low light imager, star trackers, etc.), and/or wide-area simultaneous localization and mapping (SLAM) are of particular interest.

- Robot software architecture that radically reduces operator workload for remotely operating planetary rovers. This may include: on-board health management and prognostics, on-board automated data triage (to prioritize information for downlink to ground), and learning algorithms to improve hazard detection and selection of locomotion control modes.
Sub Topics: Foundational Research for Aeronautics Experimental Capabilities Topic T2.01
This subtopic is intended to solicit innovative technologies that enhance flight research competences at Dryden by advancing capabilities for in-flight experimentation and for the supporting test facilities in the following areas:

- Methods and associated technologies for conducting flight research and acquiring test information from experiments in flight.
- Numerical techniques for the planning, analysis and validation of flight-test experimentation conditions through simulation, modeling, control, or test information assessment.

The emphasis of this subtopic is proving feasibility, developing, and maturation technologies for advanced flight research experimentation that demonstrate new methodologies, technologies, and concepts (or new applications of existing approaches). It seeks advancements that promise significant gains in Dryden's flight research capabilities or addresses barriers to measurements, operations, safety, and cost. Proposals that demonstrate and confirm reliable application of concepts and technologies suitable for flight research and the test environment are a high priority. Proposals in any of these areas will be considered:

- Measurement techniques are needed to acquire aerodynamic, structural, flight control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. 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. Sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.
- 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 to increase understanding of the complex interactions between the vehicle dynamics and subsystems.
- 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, aero-elastic maneuver performance and load control (including smart actuation and active aero-structural concepts), autonomous health monitoring for improved stability, safety, performance, and drag minimization for high efficiency and extended range capability.

Proposals are encouraged that advocate technologies or methodologies that enable real-time location independent collaboration from experimenters from both domestic and international organizations. This approach holds the promise of increasing effectiveness, reducing cost, and adding significant value to the experimental results. This topic solicits proposals for improvements in all flight regimes - subsonic, transonic, supersonic, and hypersonic.

Sub Topics: Technologies for Space Power and Propulsion Topic T3.01
Development of innovative technologies are sought that will result in durable, long-life, lightweight, high performance space power and in-space propulsion systems to substantially enhance or enable future missions.

Innovations for space power systems are sought that will offer significant improvements in efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, design flexibility/reconfigurability, autonomy, and affordability. In the area of power generation, advances are needed in photovoltaic cell technology (e.g., materials, structures, and incorporation of nanomaterials); solar array module/panel integration (e.g.,
advanced coatings, advanced structural materials, monolithic interconnects, and high-voltage operational capability; and solar array designs (e.g., ultra-lightweight deployment techniques for planar and concentrator arrays, restorable/redeployable designs, high power arrays, and planetary surface concepts). For energy storage technology, advances are needed in primary and rechargeable batteries, fuel cells, flywheels, regenerative fuel cell systems, and innovative design methods. Advances are also needed in power management and distribution systems, power system control, energy conversion technology (such as Stirling and Brayton systems) and integrated health management. Advanced nuclear power concepts are also sought.

Innovations, advanced concepts and processes are sought for in-space propulsion, including electric propulsion, chemical propulsion, advanced rocket propellants/alternative fuels, nuclear propulsion, and tether technology. In electric propulsion, concepts for subcomponent improvements are needed for ion and Hall thruster systems, including cathodes, neutralizers, electrode-less plasma production, low-erosion materials, high-temperature permanent magnets, and power processing systems. Innovations are also needed for xenon and krypton fuel distribution systems. In small chemical thruster propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

Sub Topics:
Lidar, Radar, and Passive Microwave Topic T4.01

Lidar Remote Sensing Instruments and Components
Lidar instruments and components are required to furnish remote sensing measurements for future Earth Science missions. NASA particularly needs advanced components for direct-detection lidar that can be used on new UAS platforms available to NASA, on the ground as test beds, and eventually in space. Important aspects for components are electro-optic performance, mass, power efficiency and lifetimes. Key components for direct-detection lidar techniques (particularly efficient lasers and sensitive detectors) are solicited that enable or support the following Earth Science measurements:

- Profiling of cloud and aerosol backscatter, with emphasis on multiple wavelength as relevant to the Aerosol-Clouds-Ecosystems (ACE) mission. A particular interest is development of novel scanning telescopes capable of scanning over 360 degrees in azimuth with nadir angle fixed in the range of 30 to 45 degrees, scalable to spaceborne operation without imposing requirements for momentum compensation.
- Wind measurements (using direct-detection techniques). A particular interest is photon-counting detectors (either single element or array) with high quantum efficiency (>70%) and low noise (< 100 counts/second) to improve direct-detection wind profiling at 355 nm.
- Trace gas measurements. Specifically, novel (preferably wave-guided) reference gas cells with fixed long path-lengths of ~20 m up to 100 m for laser wavelength locking and calibration in fiber optic C-band and L-band for flight missions. The gas cells must be compact, lightweight, insensitive to vibration and deformation, low in excess insertion loss (<10dB preferred), free of multi-pass interference (MPI) and other spectral fringes that upset wavelength locking and calibration.

Radar Remote Sensing Instruments and Components
Active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and UASs. New systems, approaches, and technologies are sought that will enable or significantly enhance the capability for: (1) tropospheric wind measurements within precipitation and clouds at X- through W-band, and (2) precipitation and cloud measurements. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (UAS or aircraft). Specific technologies include:

- High-speed digital transceivers for cloud/precipitation radar remote sensing.
- Scanning Ka or W-band Doppler radar technologies with high sensitivity for clouds.
- High power, high-speed, low loss W- and Ka-band radar receiver protection.
- Ultra-low sidelobe pulse compression technologies for cloud/precipitation applications.
- Frequency selective surface for W and Ka-band radar front ends.

Sub Topics:
Technologies for In Situ Compositional Analysis and Mapping Topic T5.01
This subtopic is focused on developing and demonstrating technologies for in situ compositional analysis and mapping that can be proposed to
Possible areas of interest include:

- Improved sources such as lasers, LEDs, X-ray tubes, etc. for in situ imaging and spectroscopy instruments (including Laser Induced Breakdown Spectroscopy, Raman Spectroscopy, Deep UV Raman and Fluorescence spectroscopy, Hyperspectral Imaging Spectroscopy, and X-ray Fluorescence Spectroscopy);
- Improved detectors for in situ imaging and spectroscopy instruments (e.g. flight-compatible iCCDS and other time-gated detectors that provide gain, robot arm compatible PMT arrays and other detectors requiring high voltage operation, detectors with improved UV and near-to-mid IR performance, near-to-mid IR detectors with reduced cooling requirements);
- Technologies for 1-D and 2-D raster scanning from a robot arm;
- Novel approaches that could help enable in situ organic compound analysis from a robot arm (e.g. ultra-miniaturized Matrix Assisted Laser Desorption-Ionization Mass Spectrometry);
- "Smart software" for evaluating imaging spectroscopy data sets in real-time on a planetary surface to guide rover targeting, sample selection (for missions involving sample return), and science optimization of data returned to earth;
- Other technologies and approaches (e.g. improved cooling methods) that could lead to lower mass, lower power, and/or improved science return from in situ instruments used to study the elemental, chemical, and mineralogical composition of planetary materials.

Projects selected under this subtopic should address at least one of the above areas of interest. Multiple-area proposals are encouraged. Proposers should specifically address:

- The suitability of the technology for flight applications, e.g. mass, power, compatibility with expected shock and vibration loads, radiation environment, interplanetary vacuum, etc.;
- Advantages of the proposed technology compared to the competition;
- Relevance of the technology to NASA's planetary exploration science goals.

Sub Topics:

Inflatable Modules Topic T6.01
This subtopic solicits innovative structural concepts that support the development of lightweight structures technologies that could be applicable to space applications. The targeted innovative lightweight structures are for primary pressurized volumes. Innovations in technology are needed to minimize launch mass, size and costs, while increasing operational volume and maintaining the required structural performance for loads and environments.

Of particular interest are inflatable structures, which are viable solutions for increasing the volume in habitats, airlocks, and potentially other crewed vessels. To build confidence in the use of these structures; design, analysis and manufacturing methods that produce optimal structure on a consistent basis need development above the current state of the art.

The development, analysis, and testing of dual purpose materials that show significant benefits in more than one area such as structural, thermal protection, micrometeoroid/ orbital debris protection, radiation protection, atomic oxygen protection, and such are of particular interest.

The folding, packaging and deployment of multi-layer systems especially those with an integrated window or hatch penetration and particularly those of a torus shape surrounding a cylindrical body are also an area of interest.
Also of interest are low permeable bladder materials and the development and testing of a low permeable interface between a gas barrier and a structural core or hatch penetration that is durable over time and does not degrade due to effects such as cold flow. Development of low permeability bladder materials that can tolerate flexure at cold temperatures are of particular interest.

Developments can include material development and testing, conceptual design and demonstration, analysis methods and verification, and/or manufacturing techniques. Technological improvements focus on risk reduction/mitigation, and development of reliable yet robust designs under this announcement. Research demonstrates the technical feasibility during Phase I and shows a path toward a Phase II hardware demonstration, and when possible, delivers a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

Sub Topics:  
Advanced Portable Sensor Technology for High-Purity Oxygen Determination Topic T6.02  
Determining the purity of oxygen near 100% is problematic using portable electrochemical sensor-based devices. Accurate laboratory analysis is based on techniques such as separation (e.g., gas chromatography, GC) followed by peak integration or mass-spectral analysis. Though accurate, these devices are not readily portable, usually delicate and often require a carrier or calibration gas. While not specifically excluded, a carrier gas is strongly discouraged and calibration should require a minimum of consumables. 

This solicitation seeks a reliable technique that can be applied to accurately assess oxygen purity in the range of 99.0% to 99.7% (see an example below). The technique or technology should be able to determine oxygen purity with a variety of simple diluents such as nitrogen, argon, hydrogen, water vapor and trace amounts of low molecular weight organics, CO and/or CO$_2$. It is not important that the technique specifically identify or quantify the diluents(s). The target accuracy for oxygen purity in the range is 0.05%.

Proposed technologies should be easily calibrated in remote locations, should be highly resistant to drift (i.e., long time between calibration cycles) and have potential to be adapted to a size and portability suitable to space missions. Potential applications include on-orbit determination of high-purity oxygen or other remote applications. A minimum of support equipment, maintenance, power and consumables is a key characteristic sought.

The first phase should address potential approaches with anticipated ranges of accuracy and precision along with known or potential limitations and interferences. Subsequent phase will be to develop and demonstrate a working prototype.

Example: The proposed technology should be able to reliably determine and differentiate the oxygen concentration between the following two example gas streams:
• 99.7% Oxygen, 0.2% Argon, 0.1% Nitrogen with a dew point of -60°C;
• 99.4% Oxygen, 0.4% Argon, 0.2% Nitrogen with a dew point of -40°C.

Sub Topics:
Wireless SAW Sensor Arrays Topic T7.01
Wireless surface acoustic wave (SAW) sensor arrays may have significant application in the ground processing of future spacecraft. These sensors do not require an embedded power source; instead they are powered by an RF interrogation pulse. Consequently, they have the promise of being essentially maintenance free, allowing them to be installed in normally inaccessible areas and provide environmental information for many years. In addition, as opposed to microprocessor-based transponders, SAW devices can be designed to operate from cryogenic temperatures up to about 1000 degrees C. These characteristics have resulted in interest in this technology, not only for ground processing, but recently from both the NASA research and flight centers.

The Kennedy Space Center has been supporting the development of wireless SAW sensor arrays through prior STTR activities. A new communication system has been demonstrated, namely Orthogonal Frequency Coding, that allows access to an array of SAW sensors, each with its own unique identifier. Also specific sensors have been developed to measure temperature, cryogenic level, humidity, and hydrogen under prior year funding. These are all of interest, but further development in other types of wireless SAW sensors is desired. This call requests proposals for wireless SAW sensors that can monitor, for example, pressure, strain, near-by impacts/structural acoustic events, acceleration, proximity, magnetic field, current, electric field, and hypergols (monomethyl-hydrazine or nitrogen tetroxide). This list is not exclusive and other sensors may also be of interest as well. In addition, alternative communication or multiplexing concepts are of interest, and enabling technologies, such as antenna design for SAW sensors, are welcome.

Applications for these sensors are diverse. When a vehicle is moved to the pad on a mobile launch platform strain sensors and accelerometers monitor the vehicle’s sway, pressure sensors could be placed under sprayed on foam insulation to ensure bonding integrity up to launch, moisture sensors could be used to determine if water has migrated into inaccessible areas. Electric field sensors might help with lightning warnings, chemical sensors can improve safety, and magnetic field or current sensors can monitor valve performance. The goal is to maximize the ability to acquire information on these and other parameters while minimizing the need for cabling, maintenance, and operator labor. Wireless SAW sensor arrays appear to promote this goal.

Sub Topics:
Flexible Charge Dissipation Coatings for Spacecraft Electronics Topic T8.01
Many NASA spacecraft and satellites operate in radiation environments: geostationary and medium earth orbits, radiation belts in the outer planets, solar wind, and Lagrangian points near the sun. With highly charged particles that penetrate spacecraft, internal electrostatic discharge risks mission assurance. The Jovian environment has radiation levels 7 times greater that Earth’s geostationary orbit, which is the NASA Europa Jupiter System Mission environment. In order to reduce the risk of internal electrostatic discharge on sensitive spacecraft electronic components, NASA seeks a conformal conductive coating that dissipates charge on the surface of electronic boards. It is highly desired for the coating to be applied to electronic boards using a standard industry method such as painting or other brush technique in a cleanroom environment. The coating must dissipate charge, have low outgassing, and have low water absorption. The coating is highly desired to be optically clear for visual inspection of components. The coating is also highly preferred to be thermoplastic for removal if needed. The minimum maximum service temperature for the coating is 70 deg C. Charge dissipation testing can be done using electron gun, which can be screened using a scanning electron microscope (SEM). At the macroscopic level, the volume resistivity of the conductive coating must be in the range of $1 \times 10^{-8}-10^{-12}$ ohm cm. The paint or coating must be able to adhesively bond to conventional electronic epoxy and polyimide circuit boards without damaging metal circuits, resistors, capacitors, and semiconductor surfaces. Improved charge dissipation supports the mission assurance of NASA satellites and spacecraft that operate in charging environments.
The improvement in the performance of spacecraft circuit board materials with resistance to IESD will enhance performance, lifetime, and mission assurance. Circuit boards are sought from composite materials, such as graphite fibers and epoxy or polyimide resins that dissipate electron charge. It is important for the circuit board materials to be compared for circuit board physical properties (dielectric constant, temperature range, breakdown voltage, coefficient of thermal expansion, and etc.) with the current commercial state of the art materials, such as FR4 and others. A typical volume resistivity of $10^{12}$ ohm cm is needed for the circuit board material and the ability to leak electron charge at the microscopic level. Charge dissipation studies can be initially performed by electron gun or scanning electron microscope (SEM) for initial screening. The outer planet environments, such as Jupiter, have predominantly highly charged trapped electrons, which pose challenges for protecting critical spacecraft components inside the bus from internal electrostatic discharge. Charged environments can be found at geosynchronous and medium Earth orbits where interactions with trapped radiation belts that are charged by solar space weather are prevalent. Polymeric and composite circuit board materials that can assist in reducing adverse affects of internal electrostatic discharge are sought without the loss of electrical, thermal, and mechanical properties. Research and development of spacecraft IESD resistant circuit board materials support the mission assurance of NASA earth science, exploration, and space science missions outlined in the decadal survey.

Innovative Green Technologies for Renewable Energy Sources Topic T8.03

NASA is interested in advancing green technology research for achieving sustainable and environmental friendly energy sources for terrestrial and space applications. Dependence on fossil fuels has to be balanced with other potential sources of energy for minimizing deleterious effects of their byproducts. In the case of Lunar, Mars and other planetary explorations including development of human habitats, use of clean and renewable energy sources would help advance mission objectives to a greater extent besides reducing waste products.

Proposals are sought to develop innovative renewable sources of energy that generate minimal emissions, environmentally safe and are sustainable over extended periods of time. Proposed technologies should advance the state-of-the art systems and/or components by focusing on techniques that either reduce or replace the use of fossil fuels in a cost effective manner.

Clean energy source technologies and methodologies including but are not limited to those based on solar, wind, hydro, biomass, geothermal, and atmospheric constituents such as hydrogen, carbon dioxide are solicited. Innovative space based solar power generation and effective transport to benefit terrestrial and space applications are desired. Proposals related to efficient operation over wide temperature ranges under harsh environmental conditions are also sought. Energy sources that enable future missions which otherwise would be difficult with conventional resources are desired.
Sub Topics:
Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing Topic T9.01

This subtopic solicits partnerships between academic institutions and small businesses in the following specific areas of interest: Innovative design and analysis techniques, manufacturing, materials, and processes relevant to propulsion systems launch vehicles, crew exploration vehicles, orbiters, and landers. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components.

- Polymer Matrix Composites (PMCs) Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant, repairable, and self-healing technologies; advanced materials and manufacturing processes for both cryogenic and high-temperature applications.
- 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.
- New advanced super alloys 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.
- Advanced NDE Methods Portable and lightweight NDE tools provide 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.
- Improvement in techniques for predicting the self-generated dynamics of space propulsion system when operated at off-design conditions.
- Improvement in techniques for predicting the acoustic field produced by the operation of a space propulsion system in near ground operation.
- Predictive capability of the performance and internal environment for systems, solid or liquid propellants, undergoing multi-phase combustion. Of special interest are systems utilizing nano-energetics solid fuels.
- Predictive capability improvements for the coupled fluid-structural problem with focus on accurate prediction of heat-transfer that occurs in the chamber of a nuclear thermal rocket.
- Design and analysis tools that accurately model small valves and turbopumps.
- Development of databases and instrumentation advances required for validation of previously mentioned predictive capabilities.

Sub Topics:
Test Area Technologies Topic T10.01

Innovative Approaches to Tank Volume Measurement

Develop new innovative non-contact methods to measure liquid propellant tank volume and tank fluid level with improved accuracy, repeatability and minimal tank entries for maintenance and calibration. Currently, differential pressure measurements or multiple float switched are typically used. Differential pressure measurements do not provide sufficient accuracy for low density fluids such as liquid hydrogen, and multiple float switch gages only offer readings at discrete tank liquid levels, and are subject to mechanical failure and expensive maintenance. Accuracies of 0.5% or better are desired. Need for improved technology is mid-term, and highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.
Develop new innovative tools to predict operational capability and life for key facility components (e.g., valves, valve seals and seats, actuators, flowmeters, tanks, etc.) for ultra high (>8000 psi) pressure, high flow rates, and cryogenic environments. Tools would be used for the design, procurement, and modification of facility components and ideally also incorporated in system models for simulation of test stand operation. Current TRL is 3 for modeling valves and flowmeters. Need for improved technologies are mid-term, and are highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 5.

Infrastructure Health Monitoring

Infrastructure health monitoring and management for test facilities and for widely distributed sup-port systems (WDSS) such as gas distribution and cooling water. Capabilities being sought for WDSS include remote monitoring of vacuum lines, gas leaks, and fire; using wireless technologies in order to eliminate running miles of power and data wires. Proposed innovative systems must lead to improved safety and reduced test costs by use of technologies for automated anomaly detection; diagnosis; determination of faults and their effects; prediction of future anomalies; capture and analysis of usage information; tools for rapid and effective analysis of data, information, and knowledge; and efficient user interfaces to enable integrated awareness of the system condition by users. Effectiveness of technologies in addressing the stated needed capabilities: robustness of wireless monitoring systems, effectiveness of anomaly detection (percent of anomalies captured, percent of false alarms), improvements in safety, and reduction in costs. Need for improved technologies is mid-term, and highly desirable. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

Cost-Saving Vacuum System Technologies

The objective here is to prototype and field test vacuum monitoring devices that minimize "touch maintenance" thereby reducing costs and preclude cabling by working wireless. Current state of the art for vacuum jacketed liquid hydrogen (LH) lines is walking the lines and manually performing the required periodic checks and sensor maintenance. The new altitude test stand will produce high vacuum inside a large rocket engine test chamber with ambient pressure outside. Some locations will be difficult or impossible to reach. Due to the unique and harsh environmental nature of this test facility, new technologies and vacuum measurement techniques are needed to monitor this environment. Performance metrics include high accuracy and sensitivity in the 0.1 to 1 psia, insensitivity to high levels of noise and vibration, and ruggedness. Need for improved technologies is short term, and highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Sub Topics:
Energy Conservation and Sustainability Topic T10.02
John C Stennis Space Center (SSC) is a large rocket propulsion test facility located in southern Mississippi close to the Louisiana state line. Due to the size of the test facilities, energy consumption is very large. In an effort to conserve on energy, there is an interest in pursuing innovation in the following areas:

Innovative Geothermal Technology

SSC is interested in innovative geothermal technology in an effort to reduce energy consumption, reducing the Center's carbon footprint. The feasibility and application of geothermal technology has not been investigated for use at SSC. SSC is looking for geothermal technology that is cost effective to implement and maintain. There are
potential commercial and residential applications. The feasibility of geothermal technology will require an assessment of the local topography, underground soil composition, location of water "sinks", and determination of the area's ground "constant" temperature. Concepts will be evaluated based on their potential efficiency, ease of implementation and maintenance, and flexibility of applications (including, but not limited to, HVAC, preheating hot water heaters, and other means of extracting energy), as well as, applicability to the Center's mission. Proposals will also be evaluated based on the maturity level to which the technology will be developed and innovative techniques.

**Innovative Lighting Technology**

Stennis Space Center is interested in developing innovative technologies, systems, or methodologies that will reduce the energy consumption and heat generation from facility lighting while maintaining the desired level of illumination for safety and effective work environments. SSC is interested in innovative lighting technologies for the test area and parking lots. These lighting technologies will need to reduce energy consumption while maintaining a comfortable and safe working environment. SSC is particularly interested in replacing costly lighting in the test area (test stands, hydrogen/oxygen environments, hazardous and potentially corrosive environments). The lighting should be in compliance with IESNA RP 7-01, Practice for Industrial Lighting. Proposals will be evaluated based on the maturity level to which the technology will be developed and innovative techniques that will provide a reasonable life expectancy. Proposals will also be evaluated on implementation strategy and ease of maintenance.

**Innovative Solar Technology**

Reduction in energy consumption and subsequent energy cost is a high priority at SSC. SSC is interested in developing new technologies for the efficient and effective use of photovoltaic/solar cell to reduce energy costs. Major issues in the development and use of solar panel include efficient system design and installation as well as effective maintenance. Innovative approaches and tools to facilitate the design of efficient solar cell systems, effective application of solar cell systems for building rooftops or a separate field area of solar cells are desired as well as innovative approaches to monitor the health of the system and maintenance methods to ensure the most effective and efficient operations of the system in an environment with high humidity, extensive rain showers, high pollen counts, rapid mold and fungal growth, etc.

**Technologies for Propellant Conservation**

Objective is to minimize usage of costly gases (helium and hydrogen) through devices that can recover/recycle efflux from cryogenic test facilities (currently no recovery is done). This could include technologies such as real time gas sampling/contamination monitoring system for propellant and purge systems that could also help minimize use of non renewable resources such as Helium, or Helium reclamation carts for recapture of inert/purges.