NASA STTR 2009 Phase I Solicitation

Small Business Technology Transfer

Information Technologies for System Health Management and the Study of Space Radiation Environments and Associated Health Risks Topic T1

This topic seeks advances in the design, development, and operation of complex aerospace systems to enable safe operation in the event of system failures, innovative technologies for robotic exploration of planetary surfaces, and emerging technologies that will enable the optimization of limited resources and management of sustainable systems for space operations and Earth-based development.

Sub Topics:

T1.01 Information Technologies for System Health Management and Sustainability

Lead Center: ARC

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

- Enabling technologies for sustainable systems such as life-cycle cost analysis, including production impact of system maintenance and upgrades, testing methodologies to maximize the efficiency of energy systems, optimization of limited resources, and smart energy systems that self-monitor and adjust accordingly to changing conditions;

- Health management systems that perform quickly enough to monitor a flight control system in a highly dynamic environment and respond to anomalies with suggested recovery or mitigation actions;

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

- Techniques for analyzing and reasoning from development and operational data sets to identify degradation of components and predict remaining useful life;

- 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.
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 solar system and beyond, beginning with robotic missions to the Moon and leading eventually to human exploration of Mars. 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 the Moon or Mars. Robots can perform tasks that are tedious, highly-repetitive or long-duration. Robots can perform tasks that help prepare (or help optimize planning) for future 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:

- Intelligent subsystems (algorithms, software and hardware) to improve the mobility or manipulation performance of planetary rovers. Mobility subsystems, such as traction control or active suspension, that enable MER- to MSL- scale rovers to drive at 3 m/s over lunar-relevant terrain while carrying a 100 kg payload are of particular interest. Manipulation subsystems, such as modular end-effectors for deploying instruments or placing markers, are also sought.

- Ground control user interfaces and data management systems for robotic exploration. Proposals should focus on software tools for planning variable-duration and variable-complexity command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing geospatial information; and for automating ground control functions.

- Autonomous surface navigation (localization and hazard avoidance) over long-distances and in permanently shadowed regions. 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 wide-area simultaneous localization and mapping (SLAM) are of particular interest.

- Physics-based simulation to develop and test planetary rover algorithms and systems. Existing mobile robot simulators (e.g., Player-Stage) lack the fidelity required to test high (and varying) levels of rover autonomy in non-terrestrial environments. Proposals are sought that provide robot simulation frameworks with models for planetary illumination, surface composition, specialized sensor and scientific instruments, communication, and rover resources.

- Robot software architecture that radically reduces ground control requirements for remote operations of 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 manage locomotion control modes switching.
Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts Topic T2

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.

Technologies for Space Exploration 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, light-weight, high performance space power and in-space propulsion systems to substantially enhance or enable future missions.

In space power systems, innovations 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, restowable/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.
In space propulsion, innovations are sought that will improve electric propulsion technology. 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. Alternative fuels for space propulsion are also sought.

Innovative Sensors, Detectors and Instruments for Science Applications Topic T4

This topic solicits innovative sensors, detectors and instruments that support the research in Earth and its environment, the solar system, and the universe through observations from space. To assure that our Nation maintains leadership in this endeavor, we are committed to excellence in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies.

Sub Topics:

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

*Lead Center: GSFC*

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.

**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 (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 beam systems to provide horizontal coverage of relevance to the Aerosol-Clouds-Ecosystems (ACE) mission;
- Wind measurements (using direct-detection techniques).

**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 efficiency solid state power amplifiers (>5W at W-band, >20W at Ka-band and >50W at Ku-band);
- High duty cycle (~10%) power supplies and modulators for high-power Klystrons at Ka and W-band (~2 kW peak) for high-altitude (65,000 ft) operation;
- Cross track scanning Ka or W-band Doppler radar technologies with high sensitivity for clouds;
- Low sidelobe (better than -30 dB), high power phased array antennas (X, Ku, or Ka) for high-altitude operation (65,000 ft);
- High speed (output center frequency > 500 MHz), wide bandwidth (>200 MHz) adaptive versatile waveform generator for FM chirp (with amplitude modulation for ultra-low sidelobe pulse compression) generation;
- High power (>5W at W-band, >20W at Ka-band), high-speed, low loss T/R switches;
- Ultra-low sidelobe pulse compression technologies for cloud/precipitation applications.

**Combined Radar and Radiometer Instruments and Components**

Combined passive and active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and, in particular, on UASs. Next-generation radar-radiometer packaging concepts are to fit into an active and passive module (1.5 -5 lb. mass allocation) at X-band, Ku-band, and Ka-band for measuring snow water equivalent to support calibration/validation
activities for the Snow and Cold Land Processes (SCLP) mission. Packaging concepts are similar for L-band and C-band for measuring sea surface salinity and soil moisture in support of the Soil Moisture Active and Passive (SMAP) mission. L-band also measures sea surface temperature/roughness and thus supports "coastal" Aquarius calibration. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (in particular, UASs). Specific technologies include:

- Solid State Power Amplifier (SSPA) technology that can demonstrate ultra-high (70%) efficiency, thus enabling both low power operation for radars and thermal stability for radiometers. Design efforts should include on-wafer load-pull measurements for all frequency bands; analysis of thermal performance and comparison with present commercially available amplifiers; and design for packaged amplifiers (including efficiency, system noise parameters, and weight constraint). Each module should deliver 2W at frequency. This technology enables higher level packaging concepts for snow water equivalent (X-, Ku-, Ka-band), and soil moisture (L-, C-band). Four modules can be combined into a 2 X 2 package on a UAS experiment.

Modeling and Simulation Topic T5

This topic addresses the ability to measure the predictive capability of integrated spacecraft system models. Future spacecraft mission concepts are being considered that will be difficult or impossible to fully test on the ground. Such mission concepts may include large space telescopes, planet-finding coronagraphs, large microwave sensors for Earth science, and long duration robotic planetary missions, as examples. It is expected that models and simulations will play a central role in the flight qualification of these systems. Doing so will require substantial advancement in modeling and simulation technology.

Sub Topics:

T5.01 Quantification of Margins and Uncertainties in Integrated Spacecraft System Models

Lead Center: JPL

This subtopic is focused on modeling and simulation technologies for the quantification of margins and uncertainties (QMU) in integrated spacecraft system models. The goal is to develop generic capabilities in QMU either from analysis or from test. The outcomes of the research projects selected under this subtopic may include software packages, benchmark databases, or test methods that support QMU of complex, integrated models.

Possible areas of interest include:
- Reduced order modeling (ROM) for QMU of large scale simulations;
- Methods for efficient QMU for models that couple multiple, large scale commercial or proprietary simulation codes;
- Methods for the roll-up of lower level benchmark or component level tests to subsystem and system uncertainties;
- Methods for early life cycle (simple) system models that evolve into complex, coupled system models;
- Development of "open source" databases with unit tests or benchmark tests that support model verification and validation for integrated models;
- Effective methods for treating epistemic uncertainty in large scale simulations;
- User interfaces for preparation and execution of large scale QMU analyses, on either commercial or proprietary codes;
- Methods for inverse statistical modeling or inverse epistemic modeling from test data;
- Methods for extrapolation of margins and uncertainties outside the domain of model validation tests.

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

- Scalability to problems with hundreds or thousands of uncertain parameters;
- Competition against traditional, sampling based methods (e.g., Monte Carlo);
- Application of the methods or techniques throughout the project life cycle, from concept development to flight operations.

Innovative Technologies and Approaches for Space 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 outposts, habitats, science packages, and state-of-the-art materials that will be safe as well as provide specific energy for primary or secondary batteries in excess of 300 mAh/g. The high specific energy will greatly help to reduce the mass of batteries that will have to be launched for the various applications for long duration Lunar as well as Mars Exploration Missions. The anticipated proposed technologies shall have a dramatic impact on achieving the goals of the Space Exploration Vision.
Sub Topics:

**T6.01 Safe High Energy Density Batteries and Ultracapacitors**

**Lead Center: JSC**

Commercial batteries have been used extensively by NASA to provide portable power for space applications for more than four decades. The cells range in capacity from 0.75 Ah to about 100 Ah, with a wider range of capacities and voltages at the battery level. Due to the high energy densities and the nature of the cell components, most battery chemistries are not inherently safe and have a tendency to be hazardous under off-nominal conditions. The top level requirement for crewed space vehicles and environments is two-fault tolerance to catastrophic failures.

With the future long duration manned missions to Moon and Mars in mind, NASA seeks to develop high specific energy (reduced mass) primary and secondary batteries that are safe and capable of performing under a wide temperature range and/or vacuum environments.

This solicitation seeks state-of-the-art materials that will be safe as well as provide specific energy for primary or secondary batteries in excess of 300 mAh/g. The high specific energy will greatly help reduce the mass of batteries that will have to be launched for the various applications for long duration Lunar as well as Mars Exploration Missions.

A second area that requires improvement is in the area of safe performance under the wide temperature ranges seen on Moon or Mars. The goals at this time are to obtain materials that will provide operation and be safe in a temperature range of -40 to +60°C. At least 50% performance should be obtained at the quoted extreme temperatures as compared to that at ambient (23°C).

A third area that would benefit from improvements is with respect to safe performance of pouch cells under vacuum conditions. Both primary and rechargeable batteries may be expected to perform in unpressurized environments for long periods on Lunar as well as Mars surfaces. Pouch cells provide a very high advantage in mass as well as design flexibility over hard case containers, but they do not provide stable performance under vacuum conditions. This solicitation seeks pouch cell designs for primary or secondary battery chemistries that are capable of safely providing greater than 95% of the capacity obtained at ambient pressures at the beginning of life and greater than 80% capacity after 500 cycles.

A fourth area of interest is in the field of ultracapacitors. Ultracapacitors with a voltage range of 2.0 to 4.0 V (single unit), low self discharge (\(\times\))

For the above-mentioned areas of interest, Phase 1 will require demonstration of feasibility of concept at the lab scale and Phase 2 will require demonstration of concept in prototype or small capacity completed cells.

**T6.02 Planetary Surface Analog Support Technologies**
Lead Center: JSC

Current testing of Lunar Surface System elements (such as rovers, habitats, space suits, etc.) is performed either piecemeal in laboratory testing facilities or in an integrated fashion at remote site field exercises. Large-scale controlled facilities in which lunar surface outpost elements and operations can be tested in integrated scenarios are needed to reduce the risk of future human lunar missions and eventually Mars missions. Development of such facilities provides many advantages to planetary exploration programs but also poses many technological challenges. Such technology development challenges include non-hazardous lunar/Mars soil/regolith simulants, lunar/Mars lighting systems, lunar/Mars gravity off-load systems, etc.

Launch Site Technologies Topic T7

With the advent of the Constellation program new inspection requirements will be required at the launch site and one area of specific interest is the examination of non-metallic materials, such as foam, cork, Avcoat, and others. When these materials are applied to the spacecraft there is a possibility that voids will be created, either due to missing material or to missing adhesive. Also, some materials may be applied in a non-uniform manner or become non-uniform after exposure to the environment, for example from water absorption. A capability that can be used at the launch site to examine these materials and produce a 3D image highlighting non-uniformities will be beneficial to the new program. In addition, access is usually limited to one side of the material since it is being applied to a spacecraft or fuel tank, so the imaging technique will need to operate in a reflective rather than a transmissive manner.

Sub Topics:

T7.01 One-Sided 3D Imaging of Non-Uniformities in Non-Metallic Space Flight Materials

Lead Center: KSC

In the Space Shuttle program as well as the Constellation program, limited assembly occurs at the launch site. For example, most of the insulation on the Space Shuttle’s External Tank is applied during construction, but a few access areas are left bare and must be coated after the External Tank is attached to the Solid Rocket Boosters and Orbiter. Since this insulation is often applied in layers it is possible that voids may be formed, necessitating an evaluation method to ensure integrity. One approach, a backscatter x-ray technique, was recently demonstrated that allows one-sided 2D imaging of defects and voids in the Space Shuttle External Tank’s sprayed on foam insulation (SOFI) [1]. This method works well for large thin acreage sheets, but for smaller, more complicated volumes a 3D imaging method would improve the location and subsequent repair of the foam.

Recently x-ray backscatter was also demonstrated as a technique for locating voids in the adhesive used to attach sections of a Phenolic Impregnated Carbon Ablator (PICA) heat-shield to each other and to a capsule. The concern was in examining the workmanship of this assembly after completion to ensure that adequate adhesive had been used. The x-ray backscatter technique worked well for this application, but required imaging at relatively steep angles in order to see the various planes of adhesive. A 3-D capability would improve the performance of this technique and help determine where voids or imperfections were located. NASA has now selected Avcoat as the...
heat-shield material for the Orion Spacecraft and similar inspections will be required for it.

These two examples highlight the need for a system that can generate 3D images of non-metallic materials when access is limited to one side of the material. In many cases contact with the material is allowed opening the range of possible solutions to include ultrasonic and capacitive, in addition to the noncontact x-ray approach mentioned above and TeraHertz or Millimeter Wave (MMW) systems, as well as others. The primary technical advance being sought here is to extend methods that normally supply a 2D projected image through a sheet of material, to a 3D image of a more complicated volume, such as foam sprayed over a strut. It would be advantageous if the proposed method were potentially portable, allowing it to be brought to the spacecraft; rugged, allowing it to be handled in the field; and inexpensive, allowing several to be available for multiple applications.

Computational Fluid Dynamics (CFD) Mesh Creation Topic T8

NASA's work in advanced aeronautics and space vehicle development relies on Computational Fluid Dynamics (CFD) codes such as FUN3D, which numerically solve equations of fluid motion over a discrete mesh of points in three dimensions. Extensive CFD modeling is required for a wide range of NASA missions, which include subsonic commercial aircraft, rotorcraft, supersonic and hypersonic vehicles, and planetary exploration vehicles.

Sub Topics:

T8.01 Computational Fluid Dynamics Mesh Creation

Lead Center: LaRC

A critical step in CFD modeling is mesh creation. A judicious placement of mesh points is required to optimize computing efficiency while maintaining a specified level of discretization accuracy. This placement is further constrained by the need to capture disparate characteristic length scales and flow feature orientations. A result of these constraints is that many mesh elements formed by connecting points can have very high aspect ratio -- O(10,000:1) or more. Rapid generation of such a mesh and its subsequent adaptation to better resolve the problem physics and reduce discretization errors are critical to the application of CFD to complex real world problems of interest. While current meshing methods, those using advancing front/layer, and/or Delaunay algorithms, have been successfully applied to complex problems, additional research and development is needed in the area of mesh generation to reduce human involvement and increase robustness.

Proposals are sought, resulting in the development and improvement of software packages for high-aspect ratio, three-dimensional meshing and re-meshing. The mesher must accommodate cell aspect ratio requests of at least 10,000:1 even in the presence of a curved metric tensor field to enable high Reynolds number finite-volume Computational Fluid Dynamics applications. In regions of high anisotropy, mesh cells should be layers of semi-structured hexahedra or triangular prisms to allow non-dissipative capture of bow shocks, boundary layers, free shear layers, wakes, contact surfaces, and so forth. Furthermore, to provide uncertainty estimates for the computational results, the mesher should enable mesh adaptation, whereby an existing mesh is adapted to
improve the solution based on the problem physics and/or a solution error estimate.

Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing Topic T9

Achieving the Space Exploration Goals that NASA has defined 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 Moon, Mars, and solar system. Implementing certain aspects of the NASA Vision for Space Exploration will require versatile, reliable space propulsion engines that can operate over a wide range of thrust levels, high specific impulse, and have multiple restart capability. 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, and lunar 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; 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 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.
• 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 environment for systems, solid or liquid propellants, undergoing multi-phase combustion.

• Improvements in prediction of stability and stability margins for liquid, gaseous, and solid propulsion systems.

• Zero net positive suction pressure pump design and analysis techniques.

• Design and analysis tools that accurately model small valves and turbopumps.

• Data bases and instrumentation advances required for validation of previously mentioned predictive capabilities.

Rocket Propulsion Testing Systems Topic T10

NASA's Stennis Space Center (SSC) seeks advanced vacuum technologies to support its new test stand for testing rocket engines in a vacuum. Also needed are technologies for reclamation of the large amounts of helium and hydrogen gases used during engine testing.

Sub Topics:

T10.01 Test Area Technologies

Lead Center: SSC

Vacuum System Technologies

John C Stennis Space Center is embarking on a very ambitious era in its rocket engine propulsion test history. The construction of the new A3 test stand is in progress which is designed to test a very large (294,000 lbf thrust) cryogenic rocket engine at a simulated altitude of 100,000 feet. When the air in the engine test chamber is evacuated, the simulated altitude pressures inside the test chamber will be less than 0.20 PSIA. This will result in a very unique environment with extremely low pressures inside a very large chamber and ambient pressures outside this chamber. Due to the unique nature of this test facility, new technologies and measurement techniques will need to be developed which includes but is not limited to:

• Instrument closeouts at vacuum pressures for hundreds of channels of instrumentation entering the chamber;

• New sealing technologies for large cryogenic piping entering this very large test cell wall to seal against this unique environment;
- Methods of generating vacuum for test, measurement and calibration of test stand systems and instrumentation;

- Fatigue life prediction techniques for the thousands of square feet of sheet metal used in the construction of the test chamber and diffuser ducting which will be cycling between ambient and vacuum pressures;

- Inspection techniques for the vacuum chamber structures and diffuser ducting.

**GHe Reclamation**

Due to the size of the cryogenic rocket engines and the test facilities required to test the engines, extremely large quantities of helium are used during testing each year. This requirement makes Stennis one of the world's largest users of gaseous helium which is a non-renewable natural resource. Cost of helium is increasing as the supply diminishes. The cost and shortage of helium are beginning to impact testing of the rocket engines for the space propulsion systems.

Innovative solutions are needed for efficient, cost effective, in-situ methods to recapture helium used during the engine purging and testing processes, to reclean the captured helium, to repressurize it, and then to reintroduce it for reuse. Research into technologies in these areas, demonstration of the technology capability, and conceptual design for the technology installation at Stennis are desired to assist in the helium reuse.

Helium used in rocket engine purge must meet very specific cleanliness standards. One of the challenges will be to develop and in-situ, on-site helium re-utilization system capable of recycling the helium to the cleanliness standards requirements.

The technologies developed to recapture and clean the helium must be cost effective and able to perform the recycling process in an in-situ rocket engine test area environment. It will be required to comply with all safety and quality standards required in this environment.

**Hydrogen Reclamation**

Due the testing of cryogenic rocket engines, SSC is one of the world's largest users of hydrogen. Currently, the LH2 is brought to SSC by trucks. During transfers and test operations, there huge amounts of LH2 lost due to boiloff as the heat in the systems causes the LH2 to phase into gaseous hydrogen. Conservatively, approximately one half of the hydrogen bought for use in test programs is lost or wasted during these operations.

The vast majority of this hydrogen boiloff is burned in the facility flare stacks as a safety precaution. The capability to reclaim and reutilize this hydrogen boiloff could offer potential savings of millions of dollars annually. The emerging hydrogen economy has developed systems and technologies that could potentially make use of this wasted hydrogen if methods were developed to recover at least a portion of the boiloff for reuse. A potential utilization would need to capture, reclean, repressurize and store this boiloff for reuse by the test facility. Options for the reuse of this reclaimed hydrogen could be as GH2 in the test facility or potentially even other alternate energy uses. Another possible option would be to reliquify and reuse the boiloff as propellant if this were economically efficient.

Innovative solutions are needed for efficient, cost effective, in-situ methods to recapture the hydrogen boiloff, to
reclean and repressurize it, and then to store it for reuse. Research into technologies in these areas, demonstration of the technology capability, and conceptual design for the technology installation at Stennis are desired to assist in the hydrogen recovery and reuse.

The primary challenge will be to safely capture, process and store the large amounts of gaseous hydrogen released during test operations. Gaseous hydrogen used in rocket engine test operations must meet very specific cleanliness standards. Another challenge will be to develop an in-situ, on-site system capable of recycling the captured hydrogen to the cleanliness standards requirements. An additional challenge will be to determine the appropriate utilization of the recaptured hydrogen for test operations or alternative energy uses.

The technologies developed to capture and clean the hydrogen must be cost effective and able to perform the recycling process in an in-situ rocket engine test area environment. It will be required to comply with all safety and quality standards required in this environment.

**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). 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.

Assessment of Best Practices to Determine Test Programs Carbon Footprint and Environmental Impact

SSC is interested in technologies, systems, or methodologies for measuring and analyzing the carbon footprints of rocket engine testing activities. Due to the variety of rocket engine propulsion systems testing and the nature of the facilities required for testing, it would be useful to have ways to measure and understanding the carbon footprint generated by these test activities to effectively control and mitigate them as much as possible. A relatively generic methodology that can be suited for different test programs is desirable. Proposals will be evaluated based on the feasibility and applicability of Life Cycle Assessment on test programs or other applicable carbon assessment tools. Tools developed should be in compliance with ISO 14044 and ISO 14040.

Information Technologies for System Health Management and Sustainability Topic T1.01

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

- Enabling technologies for sustainable systems such as life-cycle cost analysis, including production impact of system maintenance and upgrades, testing methodologies to maximize the efficiency of energy systems, optimization of limited resources, and smart energy systems that self-monitor and adjust accordingly to changing conditions;

- Health management systems that perform quickly enough to monitor a flight control system in a highly dynamic environment and respond to anomalies with suggested recovery or mitigation actions;

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

- Techniques for analyzing and reasoning from development and operational data sets to identify degradation of components and predict remaining useful life;

- 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.
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 solar system and beyond, beginning with robotic missions to the Moon and leading eventually to human exploration of Mars. 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 the Moon or Mars. Robots can perform tasks that are tedious, highly-repetitive or long-duration. Robots can perform tasks that help prepare (or help optimize planning) for future 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:

- Intelligent subsystems (algorithms, software and hardware) to improve the mobility or manipulation performance of planetary rovers. Mobility subsystems, such as traction control or active suspension, that enable MER- to MSL-scale rovers to drive at 3 m/s over lunar-relevant terrain while carrying a 100 kg payload are of particular interest. Manipulation subsystems, such as modular end-effectors for deploying instruments or placing markers, are also sought.

- Ground control user interfaces and data management systems for robotic exploration. Proposals should focus on software tools for planning variable-duration and variable-complexity command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing geospatial information; and for automating ground control functions.

- Autonomous surface navigation (localization and hazard avoidance) over long-distances and in permanently shadowed regions. 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 wide-area simultaneous localization and mapping (SLAM) are of particular interest.

- Physics-based simulation to develop and test planetary rover algorithms and systems. Existing mobile robot simulators (e.g., Player-Stage) lack the fidelity required to test high (and varying) levels of rover autonomy in non-terrestrial environments. Proposals are sought that provide robot simulation frameworks with models for planetary illumination, surface composition, specialized sensor and scientific instruments, communication, and rover resources.

- Robot software architecture that radically reduces ground control requirements for remote operations of 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 manage locomotion control modes switching.
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, light-weight, high-performance space power and in-space propulsion systems to substantially enhance or enable future missions.

In space power systems, innovations 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, restowable/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.

In space propulsion, innovations are sought that will improve electric propulsion technology. 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. Alternative fuels for space propulsion are also sought.

Sub Topics:

Lidar, Radar and Passive Microwave Topic T4.01
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.

**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 (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 beam systems to provide horizontal coverage of relevance to the Aerosol-Clouds-Ecosystems (ACE) mission;
- Wind measurements (using direct-detection techniques).

**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 efficiency solid state power amplifiers (>5W at W-band, >20W at Ka-band and >50W at Ku-band);
- High duty cycle (~10%) power supplies and modulators for high-power Klystrons at Ka and W-band (~2 kW
peak) for high-altitude (65,000 ft) operation;

- Cross track scanning Ka or W-band Doppler radar technologies with high sensitivity for clouds;
- Low sidelobe (better than -30 dB), high power phased array antennas (X, Ku, or Ka) for high-altitude operation (65,000 ft);
- High speed (output center frequency > 500 MHz), wide bandwidth (>200 MHz) adaptive versatile waveform generator for FM chirp (with amplitude modulation for ultra-low sidelobe pulse compression) generation;
- High power (>5W at W-band, >20W at Ka-band), high-speed, low loss T/R switches;
- Ultra-low sidelobe pulse compression technologies for cloud/precipitation applications.

Combined Radar and Radiometer Instruments and Components

Combined passive and active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and, in particular, on UASs. Next-generation radar-radiometer packaging concepts are to fit into an active and passive module (1.5 -5 lb. mass allocation) at X-band, Ku-band, and Ka-band for measuring snow water equivalent to support calibration/validation activities for the Snow and Cold Land Processes (SCLP) mission. Packaging concepts are similar for L-band and C-band for measuring sea surface salinity and soil moisture in support of the Soil Moisture Active and Passive (SMAP) mission. L-band also measures sea surface temperature/roughness and thus supports "coastal" Aquarius calibration. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (in particular, UASs). Specific technologies include:

- Solid State Power Amplifier (SSPA) technology that can demonstrate ultra-high (70%) efficiency, thus enabling both low power operation for radars and thermal stability for radiometers. Design efforts should include on-wafer load-pull measurements for all frequency bands; analysis of thermal performance and comparison with present commercially available amplifiers; and design for packaged amplifiers (including efficiency, system noise parameters, and weight constraint). Each module should deliver 2W at frequency. This technology enables higher level packaging concepts for snow water equivalent (X-, Ku-, Ka-band), and soil moisture (L-, C-band). Four modules can be combined into a 2 X 2 package on a UAS experiment.

Sub Topics:

Quantification of Margins and Uncertainties in Integrated Spacecraft System Models Topic T5.01

This subtopic is focused on modeling and simulation technologies for the quantification of margins and uncertainties (QMU) in integrated spacecraft system models. The goal is to develop generic capabilities in QMU either from analysis or from test. The outcomes of the research projects selected under this subtopic may include software packages, benchmark databases, or test methods that support QMU of complex, integrated models.

Possible areas of interest include:
Reduced order modeling (ROM) for QMU of large scale simulations;

Methods for efficient QMU for models that couple multiple, large scale commercial or proprietary simulation codes;

Methods for the roll-up of lower level benchmark or component level tests to subsystem and system uncertainties;

Methods for early life cycle (simple) system models that evolve into complex, coupled system models;

Development of "open source" databases with unit tests or benchmark tests that support model verification and validation for integrated models;

Effective methods for treating epistemic uncertainty in large scale simulations;

User interfaces for preparation and execution of large scale QMU analyses, on either commercial or proprietary codes;

Methods for inverse statistical modeling or inverse epistemic modeling from test data;

Methods for extrapolation of margins and uncertainties outside the domain of model validation tests.

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

- Scalability to problems with hundreds or thousands of uncertain parameters;
- Competition against traditional, sampling based methods (e.g., Monte Carlo);
- Application of the methods or techniques throughout the project life cycle, from concept development to flight operations.

Sub Topics:

Safe High Energy Density Batteries and Ultracapacitors Topic T6.01

Commercial batteries have been used extensively by NASA to provide portable power for space applications for more than four decades. The cells range in capacity from 0.75 Ah to about 100 Ah, with a wider range of capacities and voltages at the battery level. Due to the high energy densities and the nature of the cell components, most battery chemistries are not inherently safe and have a tendency to be hazardous under off-nominal conditions. The top level requirement for crewed space vehicles and environments is two-fault tolerance to catastrophic failures.
With the future long duration manned missions to Moon and Mars in mind, NASA seeks to develop high specific energy (reduced mass) primary and secondary batteries that are safe and capable of performing under a wide temperature range and/or vacuum environments.

This solicitation seeks state-of-the-art materials that will be safe as well as provide specific energy for primary or secondary batteries in excess of 300 mAh/g. The high specific energy will greatly help reduce the mass of batteries that will have to be launched for the various applications for long duration Lunar as well as Mars Exploration Missions.

A second area that requires improvement is in the area of safe performance under the wide temperature ranges seen on Moon or Mars. The goals at this time are to obtain materials that will provide operation and be safe in a temperature range of -40 to +60°C. At least 50% performance should be obtained at the quoted extreme temperatures as compared to that at ambient (23°C).

A third area that would benefit from improvements is with respect to safe performance of pouch cells under vacuum conditions. Both primary and rechargeable batteries may be expected to perform in unpressurized environments for long periods on Lunar as well as Mars surfaces. Pouch cells provide a very high advantage in mass as well as design flexibility over hard case containers, but they do not provide stable performance under vacuum conditions. This solicitation seeks pouch cell designs for primary or secondary battery chemistries that are capable of safely providing greater than 95% of the capacity obtained at ambient pressures at the beginning of life and greater than 80% capacity after 500 cycles.

A fourth area of interest is in the field of ultracapacitors. Ultracapacitors with a voltage range of 2.0 to 4.0 V (single unit), low self discharge.

For the above-mentioned areas of interest, Phase 1 will require demonstration of feasibility of concept at the lab scale and Phase 2 will require demonstration of concept in prototype or small capacity completed cells.

Sub Topics:
  Planetary Surface Analog Support Technologies Topic T6.02
Current testing of Lunar Surface System elements (such as rovers, habitats, space suits, etc.) is performed either piecemeal in laboratory testing facilities or in an integrated fashion at remote site field exercises. Large-scale controlled facilities in which lunar surface outpost elements and operations can be tested in integrated scenarios are needed to reduce the risk of future human lunar missions and eventually Mars missions. Development of such facilities provides many advantages to planetary exploration programs but also poses many technological challenges. Such technology development challenges include non-hazardous lunar/Mars soil/regolith simulants, lunar/Mars lighting systems, lunar/Mars gravity off-load systems, etc.
In the Space Shuttle program as well as the Constellation program, limited assembly occurs at the launch site. For example, most of the insulation on the Space Shuttle's External Tank is applied during construction, but a few access areas are left bare and must be coated after the External Tank is attached to the Solid Rocket Boosters and Orbiter. Since this insulation is often applied in layers it is possible that voids may be formed, necessitating an evaluation method to ensure integrity. One approach, a backscatter x-ray technique, was recently demonstrated that allows one-sided 2D imaging of defects and voids in the Space Shuttle External Tank's sprayed on foam insulation (SOFI) [1]. This method works well for large thin acreage sheets, but for smaller, more complicated volumes a 3D imaging method would improve the location and subsequent repair of the foam.

Recently x-ray backscatter was also demonstrated as a technique for locating voids in the adhesive used to attach sections of a Phenolic Impregnated Carbon Ablator (PICA) heat-shield to each other and to a capsule. The concern was in examining the workmanship of this assembly after completion to ensure that adequate adhesive had been used. The x-ray backscatter technique worked well for this application, but required imaging at relatively steep angles in order to see the various planes of adhesive. A 3-D capability would improve the performance of this technique and help determine where voids or imperfections were located. NASA has now selected Avcoat as the heat-shield material for the Orion Spacecraft and similar inspections will be required for it.

These two examples highlight the need for a system that can generate 3D images of non-metallic materials when access is limited to one side of the material. In many cases contact with the material is allowed opening the range of possible solutions to include ultrasonic and capacitive, in addition to the noncontact x-ray approach mentioned above and TeraHertz or Millimeter Wave (MMW) systems, as well as others. The primary technical advance being sought here is to extend methods that normally supply a 2D projected image through a sheet of material, to a 3D image of a more complicated volume, such as foam sprayed over a strut. It would be advantageous if the proposed method were potentially portable, allowing it to be brought to the spacecraft; rugged, allowing it to be handled in the field; and inexpensive, allowing several to be available for multiple applications.

A critical step in CFD modeling is mesh creation. A judicious placement of mesh points is required to optimize computing efficiency while maintaining a specified level of discretization accuracy. This placement is further constrained by the need to capture disparate characteristic length scales and flow feature orientations. A result of these constraints is that many mesh elements formed by connecting points can have very high aspect ratio --
O(10,000:1) or more. Rapid generation of such a mesh and its subsequent adaptation to better resolve the problem physics and reduce discretization errors are critical to the application of CFD to complex real world problems of interest. While current meshing methods, those using advancing front/layer, and/or Delaunay algorithms, have been successfully applied to complex problems, additional research and development is needed in the area of mesh generation to reduce human involvement and increase robustness.

Proposals are sought, resulting in the development and improvement of software packages for high-aspect ratio, three-dimensional meshing and re-meshing. The mesher must accommodate cell aspect ratio requests of at least 10,000:1 even in the presence of a curved metric tensor field to enable high Reynolds number finite-volume Computational Fluid Dynamics applications. In regions of high anisotropy, mesh cells should be layers of semi-structured hexahedra or triangular prisms to allow non-dissipative capture of bow shocks, boundary layers, free shear layers, wakes, contact surfaces, and so forth. Furthermore, to provide uncertainty estimates for the computational results, the mesher should enable mesh adaptation, whereby an existing mesh is adapted to improve the solution based on the problem physics and/or a solution error estimate.

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, and lunar 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; 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 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.

- 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 environment for systems, solid or liquid propellants, undergoing multi-phase combustion.

- Improvements in prediction of stability and stability margins for liquid, gaseous, and solid propulsion systems.

- Zero net positive suction pressure pump design and analysis techniques.

- Design and analysis tools that accurately model small valves and turbopumps.

- Data bases and instrumentation advances required for validation of previously mentioned predictive capabilities.

Sub Topics:
Test Area Technologies Topic T10.01
Vacuum System Technologies

John C Stennis Space Center is embarking on a very ambitious era in its rocket engine propulsion test history. The construction of the new A3 test stand is in progress which is designed to test a very large (294,000 lbf thrust) cryogenic rocket engine at a simulated altitude of 100,000 feet. When the air in the engine test chamber is evacuated, the simulated altitude pressures inside the test chamber will be less than 0.20 PSIA. This will result in a very unique environment with extremely low pressures inside a very large chamber and ambient pressures outside this chamber. Due to the unique nature of this test facility, new technologies and measurement techniques will need to be developed which includes but is not limited to:

- Instrument closeouts at vacuum pressures for hundreds of channels of instrumentation entering the chamber;

- New sealing technologies for large cryogenic piping entering this very large test cell wall to seal against this unique environment;

- Methods of generating vacuum for test, measurement and calibration of test stand systems and instrumentation;

- Fatigue life prediction techniques for the thousands of square feet of sheet metal used in the construction of the test chamber and diffuser ducting which will be cycling between ambient and vacuum pressures;

- Inspection techniques for the vacuum chamber structures and diffuser ducting.

**GHe Reclamation**

Due to the size of the cryogenic rocket engines and the test facilities required to test the engines, extremely large
quantities of helium are used during testing each year. This requirement makes Stennis one of the world's largest users of gaseous helium which is a non-renewable natural resource. Cost of helium is increasing as the supply diminishes. The cost and shortage of helium are beginning to impact testing of the rocket engines for the space propulsion systems.

Innovative solutions are needed for efficient, cost effective, in-situ methods to recapture helium used during the engine purging and testing processes, to reclean the captured helium, to repressurize it, and then to reintroduce it for reuse. Research into technologies in these areas, demonstration of the technology capability, and conceptual design for the technology installation at Stennis are desired to assist in the helium reuse.

Helium used in rocket engine purge must meet very specific cleanliness standards. One of the challenges will be to develop and in-situ, on-site helium re-utilization system capable of recycling the helium to the cleanliness standards requirements.

The technologies developed to recapture and clean the helium must be cost effective and able to perform the recycling process in an in-situ rocket engine test area environment. It will be required to comply with all safety and quality standards required in this environment.

**Hydrogen Reclamation**

Due to the testing of cryogenic rocket engines, SSC is one of the world's largest users of hydrogen. Currently, the LH2 is brought to SSC by trucks. During transfers and test operations, there huge amounts of LH2 lost due to boiloff as the heat in the systems causes the LH2 to phase into gaseous hydrogen. Conservatively, approximately one half of the hydrogen bought for use in test programs is lost or wasted during these operations.

The vast majority of this hydrogen boiloff is burned in the facility flare stacks as a safety precaution. The capability to reclaim and reutilize this hydrogen boiloff could offer potential savings of millions of dollars annually. The emerging hydrogen economy has developed systems and technologies that could potentially make use of this wasted hydrogen if methods were developed to recover at least a portion of the boiloff for reuse. A potential utilization would need to capture, reclean, repressurize and store this boiloff for reuse by the test facility. Options for the reuse of this reclaimed hydrogen could be as GH2 in the test facility or potentially even other alternate energy uses. Another possible option would be to reliquify and reuse the boiloff as propellant if this were economically efficient.

Innovative solutions are needed for efficient, cost effective, in-situ methods to recapture the hydrogen boiloff, to reclean and repressurize it, and then to store it for reuse. Research into technologies in these areas, demonstration of the technology capability, and conceptual design for the technology installation at Stennis are desired to assist in the hydrogen recovery and reuse.

The primary challenge will be to safely capture, process and store the large amounts of gaseous hydrogen released during test operations. Gaseous hydrogen used in rocket engine test operations must meet very specific cleanliness standards. Another challenge will be to develop an in-situ, on-site system capable of recycling the captured hydrogen to the cleanliness standards requirements. An additional challenge will be to determine the appropriate utilization of the recaptured hydrogen for test operations or alternative energy uses.
The technologies developed to capture and clean the hydrogen must be cost effective and able to perform the recycling process in an in-situ rocket engine test area environment. It will be required to comply with all safety and quality standards required in this environment.

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). Proposals will also be evaluated based on the maturity level to which the technology will be developed and innovative techniques.

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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.

Assessment of Best Practices to Determine Test Programs Carbon Footprint and Environmental Impact

SSC is interested in technologies, systems, or methodologies for measuring and analyzing the carbon footprints of rocket engine testing activities. Due to the variety of rocket engine propulsion systems testing and the nature of the facilities required for testing, it would be useful to have ways to measure and understanding the carbon footprint generated by these test activities to effectively control and mitigate them as much as possible. A relatively generic methodology that can be suited for different test programs is desirable. Proposals will be evaluated based on the feasibility and applicability of Life Cycle Assessment on test programs or other applicable carbon assessment tools. Tools developed should be in compliance with ISO 14044 and ISO 14040.
Sub Topics: