NASA STTR 2007 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 radiation detection and measurement, and emerging technologies that will enable the determination and management of the health of advanced aircraft and space exploration crews and vehicles.

Sub Topics:

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

Lead Center: ARC

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

- Onboard methods that monitor system health and then automatically reconfigure to respond to failures and sustain progress toward high-level goals. Special emphasis will be on computational techniques that enable lifecycle consistency in system characterization during design through operations with engineering and data models. Proposals should focus on data analysis and interpretation rather than development of new sensors.

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

- Data fusion, data mining, and automated reasoning technologies that can improve risk assessments, 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 Space Radiation Dosimetry and Countermeasures

Lead Center: ARC

As NASA embarks on its exploration agenda, the study of space radiation environments and associated health risks to astronauts will continue to guide radiation detection technology development and mitigation strategies. The development of suitable radiation detection technologies (both physical and biological) is vital to the success of long-term manned spaceflight. As NASA returns to the Moon and then on to Mars, a series of small, unmanned missions are anticipated followed by manned missions, including long-term (6 months) stays on the surface of the Moon. It is anticipated that the unmanned missions (e.g., small satellites that may even land on the Moon) will provide test beds for new and emerging miniaturized technologies that can be further evaluated on manned missions including on the lunar base. Prior to testing in space, the technologies must be tested using simulated space radiations available at the National Space Radiation Laboratory (NSRL), a NASA funded facility at the Brookhaven National Laboratory in New York. The NSRL is capable of generating high-energy particle radiation from protons to 56Fe nuclei. NASA also supports a facility at Loma Linda University Medical Center capable of generating energetic protons. These facilities enable research studies and technology development in support of NASA funded research. NASA is seeking innovative technologies in the areas described below.

Radiation Measurement Technologies for Small Spacecraft

NASA Ames is interested in flying small spacecraft payloads that measure radiation levels alone as well as in combination with biological payloads. In support of this objective, NASA Ames is seeking:

- Small radiation detectors that measure total dose equivalent;
- Miniaturized, radiation-hardened electronics;
- Technologies for combined radiation and biology payloads.

These technologies must minimize the use of power, volume, and mass, and provide what is needed to interface to a spacecraft bus. In the case of biological payloads, a pressurized environment, and environmental control including consideration of gas, thermal control, and humidity needed to support the biology experiment, must be provided. Biological experiments ranging from cells to small organisms are of interest.

Radiation Health Monitoring Techniques

Technologies are needed to monitor the adverse effects of spaceflight radiation on human health. The following are
• Methods that are minimally invasive to the crew and provide monitoring of the biological effects of radiation;
• Application of high throughput analyses and genomic, proteomic, and metabolomic approaches used for other biological problems to space radiation effects;
• Concept and technology development of miniaturized spaceflight devices from existing laboratory-based devices to support the analyses described above.

Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts Topic T2

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; airborne sensing and science; and mission support for the Shuttle and International Space Station. This topic solicits innovative proposals that would advance aerospace technologies for the nation in all flight regimes.

Sub Topics:

T2.01 Aerospace Vehicles Flight Dynamic Modeling and Simulation

Lead Center: AFRC

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

Research and development in simulation algorithms for revolutionary aerospace flight projects involving computational fluid dynamics (CFD), structures, heat transfer, and propulsion disciplines: Emphasis is placed on the development and application of state-of-the-art, novel, and computationally efficient solution schemes that enable effective simulation of complex modern flight vehicles, like the Space Shuttle, the Constellation (Aries and Orion), light-weight highly flexible structures, as well as more routine problems encountered in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered an important part of this topic.
Aeroelasticity and aeroservoelasticity, linear and non-linear: Vehicle design and stability analysis are an important aspect of this topic. Primary concern is with the development and application of novel, multi-disciplinary, simulation software using finite element and other associated techniques.

**T2.02 Foundational Research for Aeronautics Experimental Capabilities**

**Lead Center: AFRC**

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

- Automated online health management and data analysis;
- 21st Century air-traffic management;
- Modeling, identification, simulation, and control of aerospace vehicles in-flight test, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts.

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

Proposals in any of these areas will be considered.

Online health monitoring is a critical technology for improving aviation safety. Safe, affordable, and more efficient operation of aerospace vehicles requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local and wide area networks. Online health monitoring is a general concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of online emphasizes algorithms that minimize the time between data acquisition and decision-making.
The challenges in Air Traffic Management (ATM) are to create the next generation systems and to develop the optimal plan for transitioning to future systems. This system should be one that seamlessly supports the operation of ROAs. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.

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

Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this subtopic is the development of sensors, sensor systems, sensor arrays, or instrumentation systems for improving the state-of-the-art in aircraft ground or flight-testing. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight testing by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This topic solicits proposals for improving airborne sensors and sensor-instrumentation systems in all flight regimes - particularly transonic and hypersonic. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.
Technologies for Space Exploration and Human Research 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. Space exploration will require the presence of humans on the planets and NASA will need to insure the general health of the astronauts through development of advanced biomedical sensors that will diagnose and monitor astronaut health. The above 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 Space Power and Propulsion**

Lead Center: GRC

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

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

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

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

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

- Noninvasive or minimally invasive sensors to detect health parameters such as: metabolic rate, heart rate, ECG, oxygen consumption rate, CO$_2$ generation rate, core and/or skin temperature, radiation monitoring, oxygen saturation level, intra-cranial pressure, and ocular blood flow rates;
- Novel analytical capabilities such as high resolution microscopy and lab-on-a-chip analysis of blood and urine;
- Technologies for IV fluid mixing and medical grade water generation from the onboard potable water supply;
- Novel approaches to noninvasive measurement of cephalad fluid shift and bone density measurements on astronauts in space is desired to understand and mitigate adverse effects of space environment on astronaut health and performance.

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

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

Low mass, high reliability, robustness, low power consumption, long life, ease of usage and easy interface with the onboard data acquisition and control system are highly desirable attributes for all candidate technologies.

Technologies for Space Exploration and Human Research Topic T3

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Sub Topics:
Innovative Sensors, Detectors and Instruments Technology Needs for Earth Science, Space Science and Exploration 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 Earth Science Sensors and Instruments

Lead Center: GSFC

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

This STTR subtopic seeks to help provide advanced remote sensing technologies to enable future Earth Science
measurements. Systems and approaches will be considered that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV or aircraft). New systems and approaches are sought that will

- Enable 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**

Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth Science missions. A particular emphasis is placed on instruments that can be used on UAV platforms such as the NASA Ikhana or Altair platforms. Instruments are solicited that enable or support the following Earth Science measurements:

- High spatial and temporal resolution observations of the land surface and vegetation cover (biomass);
- Profiling of clouds and aerosols, with emphasis on multiple beam systems to provide horizontal coverage;
- Wind measurements (direct-detection technology only);
- Tropospheric and stratospheric ozone and CO$_2$ (profiling and total column).

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

Active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and UAVs. 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, (2) precipitation and cloud measurements, and (3) large aperture ground penetrating radars (GPR) at P-band and lower. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (UAV or aircraft). Specific technologies include:

- High efficiency, solid state power amplifiers (>10W at Ka-band and >30W at Ku-band);
- High performance, low power, compact, real-time radar processors, FPGA-based digital receivers, data processing algorithms and data reduction techniques;
• Implementation of radar transmitters/receivers using digital signal synthesis;

• High power, low sidelobe (better than -30 dB) scanning phased array antennas (X, Ku, Ka or W-band) for high-altitude operation (65,000 feet);

• Wide-bandwidth (>=400 MHz), high efficiency FM chirp/linear pulse signal generator with amplitude modulation; and

• High power (30W at Ka-band, 5W at W-band), high speed (=250µs), high isolation (=40 dB) and low insertion (1.5 dB at Ka and 2 dB at W-band) switch.

Data Compression

To complement data compression, data decompression processors are needed to decode compressed data streams. To target multiple missions, implementations should conform to the Consultative Committee for Space Data Systems (CCSDS, www.ccsds.org [1]) recommendation CCDDS 122.0-B.1. This solicitation seeks development of new data decompression processors that can:

• Process instrument data at over 20 Mpixels/sec decoding rate for instruments that employ compression for either direct broadcast or during nearly real-time ground processing after telemetering the data to ground stations;

• Decode up to 16-bit of science data; and

• Decode embedded compression bit stream following the format described in CCSDS 122.0-B.1 (www.ccsds.org [1]).

T4.02 Space Science and Exploration Sensors and Instruments

Lead Center: GSFC

This subtopic focuses on key component and subsystem technologies for space science and exploration sensors and instruments. The focus is on innovative, lower TRL technologies which may have a longer term development time. The technology focus in this solicitation is for cryogenic cooling technologies, in situ sensors for miniaturized planetary instruments, optical subsystems and wavefront sensing and control, and detectors for the IR, far IR, submillimeter, and millimeter wave regions.

Cryogenic Cooling Technologies for Space Science and Space Exploration
Cryogenics systems are enabling technologies for cutting edge space science including infrared imaging and spectroscopy and x-ray spectroscopy. Cryogenic cooling is also needed to enable the long term storage of the cryo-propellants needed for space exploration missions. Improvements in cryogenic technologies enable space science and exploration missions at lower cost with reduced mass, reduced volume and reduced risk.

New concepts that would provide cooling with improved thermodynamic efficiency for the following applications are sought.

- Coolers for long term cryo-propellant storage with cooling power in the range of 50 to 100 Watts at 100 K and 20 Watts at 25 K to 30 K;
- Low vibration coolers for space science instruments with approximately 0.1 Watt of cooling power at 4 K;
- Highly efficient sub-Kelvin cooling technologies capable of cooling detectors to 50 milliKelvin.

In Situ Sensors for Planetary Science

Instruments for in situ investigations are required for NASA’s planned and potential planetary science missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface landers and rovers, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses. A focus is on developing components and subsystems for miniaturized instruments.

- Enabling instrument component and support technologies for a miniaturized mass spectrometry/gas chromatography instrument with improved capabilities over the SAM instrument on the Mars Science Laboratory. These include miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and microfluidic technologies for sample preparation.

Optical Subsystems and Wavefront Sensing and Control

This subtopic solicits technology for collecting and controlling star light with advanced optical telescopes and telescope arrays. This topic includes innovative optical subsystems, devices and components that directly collect and process optical signals and images for all regions of the electromagnetic spectrum from X-ray to UV to Visible to Far-IR/Sub-MM. Pre-detection technologies of interest include capabilities to preprocess or analyze an optical wave front or signal to extract time-dependent, spectral, polarization and spatial information from scenes or signals prior to detection. Specific technology areas of interest include: high reflectance UV coatings and uniform polarization coatings for all wavelengths; high angular resolution imaging enabled via large-baseline segmented-aperture telescopes and sparse aperture telescopes/interferometers. Component-level technology needed to enable the characterization and combination of wavefronts from multiple apertures. Innovative technology needed to integrate, assemble, align and control test large aperture segmented mirrors for x-ray, ambient and cryogenic
Proposals in the following areas are specifically solicited:

- Optical coatings: broad-band polarization preserving and polarizing for UV to Far-IR/Sub-MM; high-reflectivity EUV; large area, high acceptance angle narrow-band optical filters; broad-band wide-acceptance angle UV anti-reflection on PMMA substrates; environmentally stable protected silver.

- Innovative mounting/support and metrology/control technologies to integrate, assemble, align and control large aperture lightweight low-cost segmented mirrors for x-ray, ambient and cryogenic normal incidence applications - also, systems with extreme alignment tolerances such as PIAA.

- Techniques to mitigate optical surface errors includes phase retrieval and wavefront sensing and control techniques and instrumentation, optical systems with high-precision controls, active and/or adaptive mirrors, shape control of deformable telescope mirrors, and image stabilization systems; techniques to sense/control segmented primary mirrors.

**Detector Technology for IR, far IR, Submillimeter, and Millimeter**

Advances in detectors, readout electronics, and other technologies enabling polarimetry and large format imaging arrays for the IR, far submillimeter and millimeter and spectroscopy with unprecedented sensitivity are sought.

Innovations are sought in detector capability for the following wavelength ranges:

- 1-30 microns: Increased sensitivity and larger array size; Large format cryogenic readout multiplexers; large format (>1000 x 1000) array hybridization techniques. Technologies for assembly of large format focal plane arrays. Photon counting detector arrays with fast readout electronics.

- 100 microns - 3 mm: Noise equivalent power (NEP) of $10 \times 10^{20}$ W/Hz$^{1/2}$ in a 1,000 pixel spectroscopic array with low-power readout electronics, and NEP $10 \times 10^{18}$ W/Hz$^{1/2}$ in a 10,000 pixel photometric imaging array. Capabilities for photon counting, polarimetry, and energy resolving detection.

- RF (GHz to THz) MEMS switches with low insertion loss.

- (18 dB), capable of switching with speeds of >100 Hz at cryogenic temperatures (below 10 K) for $10^8$ or more cycles.
Proximity Glare Suppression for Astronomical Coronagraphy

This subtopic section addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources and innovative advanced wavefront sensing and control for cost-effective space telescopes. Examples include: planetary systems beyond our own, the detailed inner structure of galaxies with very bright nuclei, binary star formation, and stellar evolution. Contrast ratios of one million to ten billion over an angular spatial scale of 0.05-1.5 arcsec are typical of these objects. Achieving a very low background requires control of both scattered and diffracted light. The failure to control either amplitude or phase fluctuations in the optical train severely reduces the effectiveness of starlight cancellation schemes.

This innovative research focuses on advances in coronagraphic instruments, starlight cancellation instruments, and potential occulting technologies that operate at visible and infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission. Much of the scientific instrumentation used in future NASA observatories for the astrophysical sciences will require control of unwanted radiation (thermal and scattered) across a modest field of view. The performance and observing efficiency of astrophysics instruments, however, must be greatly enhanced. The instrument components are expected to offer much higher optical throughput, larger fields of view, and better detector performance. The wavelengths of primary interest extend from the visible to the thermal infrared. Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development, and innovative instrument design, as well as in the fabrication of subsystem devices to include, but are not limited to, the following areas:

**Starlight Suppression Technologies**

- Advanced starlight canceling coronagraphic instrument concepts;
- Advanced aperture apodization and aperture shaping techniques;
- Pupil plane masks for interferometry;
- Advanced apodization mask or occulting spot fabrication technology controlling smooth density gradients to 10-4 with spatial resolutions ~1 µm, low dispersion, and low dependence of phase on optical density;
- Metrology for detailed evaluation of compact, deep density apodizing masks, Lyot stops, and other types of graded and binary mask elements. Development of a system to measure spatial optical density, phase inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of masks and stops is needed;
- Interferometric starlight cancellation instruments and techniques to include aperture synthesis and single
input beam combination strategies;

- Single mode fiber filtering from visible to 20 µm wavelength;
- Methods of polarization control and polarization apodization; and
- Components and methods to insure amplitude uniformity in both coronagraphs and interferometers, specifically materials, processes, and metrology to insure coating uniformity.

**Wavefront Control Technologies**

- Development of small stroke, high precision, deformable mirrors (DM) and associated driving electronics scalable to $10^4$ or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple DM technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices;
- Development of instruments to perform broad-band sensing of wavefronts and distinguish amplitude and phase in the wavefront.
- Adaptive optics actuators, integrated mirror/actuator programmable deformable mirror;
- Reliability and qualification of actuators and structures in deformable mirrors to eliminate or mitigate single actuator failures;
- Multiplexer development for electrical connection to deformable mirrors that has ultra-low power dissipation.
- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance; and
- Highly reflecting broadband coatings.

**Precision Deployable Optical Structures and Metrology**

Planned future NASA Missions in astrophysics, (such as the Single Aperture Far-IR (SAFIR) telescope, Life Finder, and Submillimeter Probe of the Evolution of Cosmic Structure (SPECS), and the UV Optical Imager (UVOIR) require 10 - 30 m class cost effective telescopes that are diffraction limited at wavelengths from the visible to the far IR, and operate at temperatures from 4 - 300 K. The desired areal density is 1 - 10 kg/m². Static and dynamic wavefront error tolerances may be achieved through passive means (e.g., via a high stiffness system) or through active control. Potential architecture implementations must package into an existing launch volume, deploy and be self-aligning to the micron level. The target space environment is expected to be L2.

This subtopic section solicits proposals to develop enabling, cost effective component and subsystem technology for these telescopes. Research areas of particular interest include: precision deployable structures and metrology, i.e., innovative active or passive deployable primary or secondary support structures; innovative concepts for packaging fully integrated (i.e., including power distribution, sensing, and control components), distributed and localized actuation systems; deployment packaging and mechanisms; active control distributed on or within the structure (downstream corrective and adaptive optics are not included in this topic area); actuator systems for alignment of reflector panels (order of cm stroke actuators, lightweight, submicron dynamic range, nanometer
stability); mechanical, inflatable, or other deployable technologies; new thermally-stable materials (CTE

Also of interest are innovative metrology systems for direct measurement of the optical elements or their supporting structure. Requirements for micron level absolute and subnanometer relative metrology for tens of points on the primary mirror. Also measurement of the metering truss. Innovative systems which minimize complexity, mass, power and cost are sought.

The goal for this effort is to mature technologies that can be used to fabricate 20 m class, lightweight, ambient or cryogenic flight-qualified telescope primary mirror systems. Proposals to fabricate demonstration components and subsystems with direct scalability to flight systems (concept described in the proposal) will be given preference. The target launch volume and expected disturbances, along with the estimate of system performance, should be included in the discussion. A successful proposal shows a path toward a Phase 2 delivery of demonstration hardware on the scale of 3 m for characterization.

T4.04 JPL - Communications

Lead Center: JPL

**Long Range Optical Telecommunications**

The adaptation of current standard laboratory techniques for deployment on planetary missions is a focus. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

Instruments for in situ investigations are required for NASA's planned and potential solar system exploration missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface landers and rovers, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses.

This subtopic seeks advances in instruments and critical components in the following areas:
• X-Ray Diffraction and X-Ray Fluorescence (XRD/XRF) instruments, with capabilities beyond those currently planned for the CHEMIN instrument on the Mars Science Laboratory (MSL - 2009), with a focus on elemental and mineralogical analysis in the Venus surface environment (90 bars CO₂, 450°C);

• Scanning electron microscopy with chemical analysis capability;

• Mass spectrometry/Gas chromatography with improved capabilities over the SAM instrument on MSL or applicability to in situ atmospheric measurements on Venus or Titan;

• Geochronology, with a focus on isotopic dating of planetary surfaces in the 100 Ma to 4.5 Ga timeframe with better than 10% accuracy;

• Gamma-Ray Spectroscopy, with a focus in short duration;

• X-Ray Photoelectron Spectroscopy (XPS) and Auger Electron Spectroscopy (AES).

Astrobiology includes the study of the origin, evolution, and distribution of life in the universe. New technologies are required to enable the search for extant or extinct life elsewhere in the solar system, to obtain an organic history of planetary bodies, to discover and explore water sources elsewhere in the solar system, and to detect microorganisms and biologically important molecular structures within complex chemical mixtures.

Astrobiology solicits new measurement concepts, advances in existing instrument concepts, and advances in critical components in the following areas:

• Instrumentation focused on assessments of the identification and characterization of biomarkers of extinct or extant life, such as prebiotic molecules, complex organic molecules, biomolecules, or biominerals. At this time we are not soliciting DNA and RNA analysis techniques.

• High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures.

In addition, enabling instrument component and support technologies for the above, such as miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and fluidic technologies for sample preparation, are also solicited. These must be presented in the context of a complete instrument system.

Long Range Space RF Telecommunications

This subtopic seeks innovative technologies for long-range RF telecommunications supporting the needs of space missions. Proposals are sought in the following areas:
• Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders and components, incorporating MMT. The adaptation of current standard laboratory techniques for deployment on planetary missions is a focus. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

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• Scanning electron microscopy with chemical analysis capability;

• Mass spectrometry/Gas chromatography with improved capabilities over the SAM instrument on MSL or applicability to in situ atmospheric measurements on Venus or Titan;

• Geochronology, with a focus on isotopic dating of planetary surfaces in the 100 Ma to 4.5 Ga timeframe with better than 10% accuracy;

• Gamma-Ray Spectroscopy, with a focus in short duration (X-Ray Photoelectron Spectroscopy (XPS) and Auger Electron Spectroscopy (AES).

Astrobiology includes the study of the origin, evolution, and distribution of life in the universe. New technologies are required to enable the search for extant or extinct life elsewhere in the solar system, to obtain an organic history of planetary bodies, to discover and explore water sources elsewhere in the solar system, and to detect microorganisms and biologically important molecular structures within complex chemical mixtures.

Astrobiology solicits new measurement concepts, advances in existing instrument concepts, and advances in critical components in the following areas:
• Instrumentation focused on assessments of the identification and characterization of biomarkers of extinct or extant life, such as prebiotic molecules, complex organic molecules, biomolecules, or biominerals. At this time we are not soliciting DNA and RNA analysis techniques.

• High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures;

In addition, enabling instrument component and support technologies for the above, such as miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and fluidic technologies for sample preparation, are also solicited. These must be presented in the context of a complete instrument system. ICs and Bi-CMOS circuits;

• MMIC modulators with drivers to provide large linear phase modulation (above 2.5 rad), high-data rate (10 - 200 Mbps), BPSK/QPSK modulation at X-band (8.4 GHz), and Ka-band (26 GHz, 32 GHz and 38 GHz);

• High-efficiency (> 60%) Solid-State Power Amplifiers (SSPAs), of both medium output power (10 W - 50 W) and high-output power (150 W - 1 KW), using power combining techniques and/or wide-bandgap semiconductor devices at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz);

• Epitaxial GaN films with threading dislocations less than 1e6 per cm2 for use in wide band-gap semiconductor devices at X- and Ka-Band;

• Utilization of nanomaterials and/or other novel materials and techniques for improving the power efficiency or reducing the cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons);

• Long lifetime, radiation hard SSPAs, modulators and MMICs for 26 GHz Ka-band (lunar communication);

• TWTAs operating at higher millimeter wave frequencies (e.g., W-Band) and at data rates of 10 Gbps or higher;

• Ultra low-noise amplifiers (MMICs or hybrid) for RF front-ends (MEMS-based RF switches and photonic control devices needed for use in reconfigurable antennas, phase shifters, amplifiers, oscillators, and in-flight reconfigurable filters. Frequencies of interest include VHF, UHF, L-, S-, X-, Ka-, V-band (60 GHz) and W-band (94 GHz). Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.
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:
Innovative Technologies and Approaches for Space Topic T5

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 advancing the technologies in communication systems' filters and antennas; new dynamic radiation sensors; better and longer range no-power radio frequency (RF) sensors-tag for identification, position and sensor data; and highly effective algorithms for autonomous robotic handling to increase the flexibility and efficacy of robots deployed to the surface of the Moon and Mars missions. The new technologies being solicited include means to improve operational capabilities; improve crew safety; increase human productivity; reduce the size, weight and power; reduce the Extravehicular Activity (EVA) time required to setup and deploy outposts, habitats, science packages, and others; and abilities to enhance the success of future human exploration missions. The anticipated proposed technologies shall have a dramatic impact on achieving these goals of the Space Exploration Vision.

Sub Topics:

T5.01 MEMS-Enabled Filters, Antennas, and Sensors

Lead Center: JSC

Given the great demands placed upon communication transceivers to assure crew safety and robustness in mobile environments, NASA seeks to develop novel techniques to reduce the size, weight, and power (SWAP) for long duration manned missions. Such high analog-to-digital conversion power consumption, large form factor, and expensive components pose challenges for power and weight constrained in software defined radios. Thus, significant technical advances are needed in the area of high performance channel select filter banks, tunable filters with low-loss and high-rejection, and reconfigurable and multi-band antennas.

First, this solicitation seeks substantial improvements over state-of-the-art technologies and aims at the development of banks of low loss and high rejection filters in the UHF (401 - 402 MHz, 25 kHz bandwidth), S-band (2.4 - 2.483 GHz), and Ka-bands (25.25 - 27.5 GHz). Closely spaced (in frequency) narrow band ( 50 dB) and low insertion loss (%

Second, to complement an existing software programmable radio, NASA needs to develop a compact, lightweight, multi-band (UHF, S-band, and Ka-band - see above frequencies) antenna solution that enables robust surface-to-surface communications among mobile and fixed nodes (rovers, astronauts, lander, habitat) at operational range 10 km.

Assume audio, telemetry, and high-rate video delivery transmission, bi-directional link, and 20 Mbps data rate. Assume omnidirectional and multi-band RF communications and simultaneously links to suit/vehicle and RF contingency voice on UHF - half-duplex. MEMS-enabled reconfigurable, multi-band antennas promise significant reductions in form factor, lower power consumption, and enhanced reliability. This new class of miniaturized antennas should provide high antenna gains with small aperture sizes. Smart antenna technologies with self-monitor and calibration capability are also of interest for adapting to harsh environmental threats including dust storms.

Third, this solicitation seeks to develop robust radiation sensors capable of omni-directional micro-dosimeter measurements and discriminating both charged particles and neutrons that simulate tissue volumes spanning a few
10nm to monitor crew radiation exposure in space. While current Tissue Equivalent Proportional Counters (TEPCs) are limited to measuring integral radiation effects at the cell nucleus scale (~10 µm), or at chromosome level (~1 µm), contemporary radiobiological concepts elicit differential measurements at the sub-micron scale of chromatin fiber (~25 nm) or even DNA molecule (2 nm).

Fourth, NASA needs to demonstrate robust no-power RF sensor-tag systems capable of providing identification, position and sensor data in and on aerospace vehicles through wireless interrogation and receivers up to several meters away. Systems must provide additional vehicle capability and modularity, increasing redundancy while decreasing cost and schedule as they minimize cabled connectivity to sensors. Projects must demonstrate and compare standard instrumentation approaches to no-power RF sensor-tag approaches over a vehicle life-cycle for the following: ground and flight test instrumentation, operational health and status monitoring, and control of systems.

Below are expected outcomes corresponding to the four tasks:

Phase 1:

1. Propose a reconfigurable multi-band MEMS tunable filter solution for the above frequency bands. Develop notional architecture, conceptual approach, and implementation strategy, anticipating insertion into a future frequency-agile EVA software defined radio. Compared with traditional approaches, assess MEMS RF tunable filter trade-offs with mass, power, size, flexibility, and complexity. Offer solutions to vibration, temperature, and gravitational changes commonly associated with MEMS devices for long-duration missions.

2. Delineate through a combination of analysis and demonstrated prototypes that the multi-band compact, lightweight, and flexible multi-band antenna solutions can achieve robust, high performance operation in a mobile environment. Conduct antenna trades on power consumption, sensitivity, form factor, weight, and reliability for a EVA UHF, S-band, and Ka- multi-band helmet-mounted option.

3. Validate through a combination of analysis and demonstrated prototypes that the proposed TEPC detection solution can achieve robust, high performance omni-directional operation in radiation environment. Assess detectors performance and compare it with traditional approaches. Develop feasible concepts and assess technical pitfalls/challenges of infusing this technology into the Exploration radiation monitoring program.

4. Submit report and recommendations for follow-on applications based on test results and life-cycle cost analyses that compare the application of various no-power RF sensor-tag technologies against standard wired approaches for at least one relevant vehicle/vehicle test in NASA's Exploration Program.

Phase 2:

Leverage results in Phase 1 and demonstrate feasibility on actual hardware prototype units for space applications. To ensure robust operation and MEMS reliability, conduct testing across harsh temperature, vibration, shock, and
other conditions similar for space operations and survivability.

Commercial Potential:

Broad commercial applications for channel select filter banks span cellular and wireless LAN communication links, cognitive radios, and ultra-wide band ADCs.

TEPC detectors can be harnessed in nuclear facilities; no-power RF sensor tags in aerospace industry, replacing cables between data acquisition systems and sensors.

T5.02 Algorithms for Autonomous Robotic Materials Handling

Lead Center: JSC

The focus of this subtopic is to solicit new technologies that will increase the flexibility and efficacy of robots deployed to the surface of the Moon and Mars. Robots are expected to make an important contribution to future Moon and Mars missions by decreasing the EVA time required to set up and deploy outposts, habitats, science packages, etc. An important part of this robot activity will be autonomously or semi-autonomously handling a variety of materials such as cables, connectors, solar arrays, inflatable modules, samples, payloads, and trusses. Semi-autonomous robot handling will allow these activities to be controlled from Earth so that they can take place before astronauts arrive and to continue after they leave.

Based on the above planetary applications, proposals are solicited for the development of algorithms that address one of the following:

- Autonomous robotic grasping, manipulation, and dexterity;
- Tool use; or
- Combining mobility and manipulation.

Emphasis should be placed on techniques that can be effective in unmodeled or unplanned for situations. Some important issues related to autonomous robotic grasping, manipulation, and dexterity include: positioning of the manipulator and grasp contacts relative to the object, determining good manipulator configurations for grasping, adhering to grasp and task constraints on action sequencing during grasping and manipulation, using whole-arm/body contact surfaces, sensing relevant data, simultaneous sensing and action, and the control of forces during manipulation. Some important issues relating to tool use are: representing and utilizing the affordances of tools, representing the task constraints on grasp, modeling the interactions between the tool and the environment,
representing the function of the tool in a larger (planetary repair) task, and using tools to adapt to contingencies imposed by the task or environment. Some important issues related to combining mobility and manipulation are: coordinating the use of mobility and manipulator DOFs to achieve a common manipulation purpose, coordinating multiple mobile manipulators so as to achieve a common goal, grasping or manipulating an object so that it can be transported.

Some areas of research and development that are expected to be relevant to the above problems are:

- Continuous or discrete control;
- Machine vision or tactile sensing; and
- Machine learning and robot development.

The proposal should target advancements in aspects of the above areas of research and development that are relevant to robotic materials handling. The proposed approach should take advantage of the specific constraints and simplifications that result from the materials handling problem.

Proposals should identify the specific problem(s) that are to be addressed and a brief outline of the proposed approach. In addition, proposals should outline a plan for testing key aspects of the approach on robotic hardware. Preference will be given to approaches that appear to be practical given realistic sensor and hardware limitations.

Launch Site Technologies Topic T6

The purpose of this Topic is to develop technologies and concepts that will improve launch processing safety, make launch operations more cost- and time-efficient, and improve reliability of ground equipment. Improvements in launch site operations can enable airport-like efficiencies at reduced cost and shortened processing turnaround time, thereby contributing significantly to the goal of a sustained and affordable space exploration program. Topic areas that will be emphasized for improvements in launch site operations include:
Wireless surface acoustic wave (SAW) sensors that can monitor, for example, pressure, strain, near-by impacts/structural acoustic events, acceleration, proximity, magnetic field sensors, current, electric field, hypergols (monomethyl-hydrazine or nitrogen tetroxide), and moisture;

Active vibration isolation system effective in protecting ground processing equipment from launch environment effects to significantly reduce life cycle costs and enhance equipment reliability.

Sub Topics:

T6.01 Wireless Surface Acoustic Wave (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 1000ºC. 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, temperature sensors, cryogenic level sensors, and hydrogen sensors have been demonstrated under prior year funding. These are all of interest to the ground processing community, 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 sensors, current, electric field, hypergols (monomethyl-hydrazine or nitrogen tetroxide), and moisture. 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.
T6.02 Active Vibration Control for Ground Support Equipment

Lead Center: KSC

Equipment located near a major rocket launch is exposed to extreme environments including heat, unsteady rocket plume impingement, acoustics and vibration. NASA’s experience shows that considerable attention to the protection of critical electronic ground support equipment housed in a mobile launch platform or on adjacent tower structures is required.

The effect of high acoustic and exhaust blast loading on the launch structures results in large amplitude motions of the structural panels, including floors supporting racks of electronics. Measured acceleration spectra vary considerably from area to area but a general characterization is that the peak frequencies lie in the range below 100 Hz and amplitudes of several g's rms or higher. Typically, electronic systems are housed in a rack structure, for example a 19-inch rack, which might be 2 meters tall and weigh in the vicinity of 500 kg. Passive vibration isolator systems required to support this weight often have natural resonance within the broad excitation spectrum of the floor, resulting in less than desirable equipment protection. One consequence is the need for extensive check out of systems after each launch and often repairs. Another consequence is the need for extensive design and qualification testing to ensure the survivability of this equipment. Development of an effective vibration isolation system will significantly reduce life cycle costs and enhance equipment reliability.

The relatively short duration of the high vibration environment suggests that an active vibration control system using locally stored energy could provide a significant improvement in suppressing vibration effects. This call requests proposals for vibration control systems that would be highly reliable and capable of sensing and reducing vibration effects in ground support electronic racks. This technology is envisioned to consist of some type of platform with actuators, passive elements (springs, dampers), sensors, and a local energy source (if required). Alternately, active isolator kits could be developed that attach to the corners of a larger platform to allow designers to support a row of racks but a method of integration to allow the control of all 6 degrees-of-freedom of the complex assembly must be provided.

Applications of this technology go beyond launch equipment to any environment requiring vibration isolation of critical equipment from episodic and intense events. These range from earthquake protection and transportation to military applications. The goal is to have a platform system that can be applied to expensive equipment where the specific vibration excitation is intense and somewhat poorly defined so that a designer can specify the system with confidence and without detailed analysis, and without requiring extensive testing of the components being protected.
Aerospace and Atmospheric Research for Improving Quality of Life Topic T7

To accomplish the Agency’s goals and objectives in atmospheric research new innovations are required in the areas of optical detectors arrays for lidar and passive remote sensing and fabrication techniques for high temperature composites. This STTR Topic will deliver validated technology, scientific knowledge, and understanding of the Earth’s atmosphere.

Sub Topics:

**T7.01 Optical Detector Arrays with Unusual Geometrical Shapes for Lidar and Passive Remote Sensing Applications**

**Lead Center: LaRC**

Innovative or improved concepts are solicited for the development of detectors and detector arrays formed into unusual shapes. Of immediate interest are detector formats with cylindrical symmetry, where the detecting surface is on the curved portion of a cylinder and extends entirely (or nearly entirely) around the circumference of the cylinder. The detecting element need not be continuous, but could be a series of discrete elements. The ultimate goal of this solicitation is the development and production of a stacked array of cylindrical detecting elements.

NASA has interest in developing PV or PC IR detector arrays, but is especially interested in the development of visible/NIR photon-counting detectors constructed in a stacked cylindrical format. The stacked arrays should be sensitive across a broad spectral range. If cooling is required, the contact point to the cooler must be at one end of the array stack.

Arrays eventually employed will have a small size (cylindrical diameter ~ 1 centimeter or less, total length ~ 2-5 centimeters) and a moderately large number of axial elements (~ 32-128.) Fill factor of the array should be optimized to have as little non-detector surface area as possible. Electronics required to read the devices should also be developed as part of the project unless these are readily obtainable elsewhere.

Ultimately these detectors will be used as part of novel lidar systems and passive IR/visible spectrometers.

Proposals should describe the expected sensitivities/efficiencies of the proposed devices in terms of signal levels and wavelength dependencies. Limitations on the eventual size and power requirements of fully developed devices should be indicated in the proposal along with a discussion of any potential environmental constraints on their operation.
Innovative concepts are being solicited for the development of fabrication techniques for high temperature composites capable of operating within the range of 350°F for at least 50,000 hours to 600°F for 1000 hours. The highest priority is structural materials that are capable of being used at the above temperature regimes for aerospace applications. Emphasis is focused on cost effective and highly automated high temperature composite manufacturing concepts. Composite processing techniques that do not require autoclave processing are of key importance. Fabrication techniques include resin infusion (VARTM, RTM), tow/tape placement, e-beam curing and other non-autoclave processing techniques. Innovative and novel composite fabrication approaches are sought for the following materials and structural systems:

- Polymer matrix composites;
- Fiber metal laminates;
- Hybrid composites;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.

Proposals should address the following performance metrics as appropriate:

- Processing techniques of lightweight, high temperature composites;
- Resin development;
- Reinforcement development;
- Out of Autoclave fabrication technologies;
- Aerospace quality structural application;
- Characterization of material properties;
- Elevated use temperature capability;
- Damage tolerance;
- Solvent resistance;
- Long term durability;
- Scalability.

Aerospace and Atmospheric Research for Improving Quality of Life Topic T7

To accomplish the Agency's goals and objectives in atmospheric research new innovations are required in the areas of optical detectors arrays for lidar and passive remote sensing and fabrication techniques for high temperature composites. This STTR Topic will deliver validated technology, scientific knowledge, and understanding of the Earth's atmosphere.

Sub Topics:
- Space Exploration and Transportation Topic T8

Implementing the NASA Vision for Space Exploration will require improving materials and engine throttling capabilities. NASA is interested in innovative manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system to reduce cost and weight of systems and components while increasing safety. Versatile space propulsion engines that can operate over a wide range of thrust levels (throttling) are needed for space transportation. High specific impulse deep-throttling space propulsion engines may be required for controlled spacecraft descent to planetary surfaces, and a significant degree of throttling may also be required for ascent and in-space transfer maneuvers.

Sub Topics:

T8.01 Manufacturing Technologies for Human and Robotic Space Exploration

Lead Center: MSFC
Participating Center(s): MSFC

Continued technological innovation is critically linked to a strong manufacturing sector in the United States economy. NASA is interested in innovative manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system. Specific areas of interest in this solicitation include innovative manufacturing, materials, and processes relevant to propulsion systems and airframe structures for next-generation launch vehicles, crew exploration vehicles, lunar orbiters and landers, and supporting space systems. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components. Only processes that are environmentally friendly and worker-health oriented will be considered. Proposals are sought, but are not limited to, the following areas:
Polymer Matrix Composites (PMCs)

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

Ceramic Matrix Composite (CMCs) and Ablatives

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

Metals and Metal Matrix Composites (MMCs)

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

Manufacturing Nanotechnology

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

Fiber-Based and Inflatable Systems

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

**Advanced NDE Methods**

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

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

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

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

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

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

Rocket Propulsion Testing Systems Topic T9

In support of NASA’s plans and visions for current space activities and future exploration goals, ground and simulated altitude testing of all large rocket propulsion systems are conducted at the John C. Stennis Space Center (SSC). Current testing includes the Space Shuttle Main Engine and the Rocketdyne RS68 engine. Existing test facilities are being modified and a new test stand is being built to test the Rocketdyne J-2X engine for the Constellation program.

This topic solicits advanced technologies: that support an Integrated Health Management (ISHM) capability for rocket engine testing and ground operations; for innovative non-intrusive sensors for measuring combustion instability, fluid properties under extreme conditions of pressure, temperature, and velocity; rocket plume sensors capable of measuring gas species, temperature, and velocity for hydrogen and hydrocarbon fuels. Specifically, sensors capable of measuring hot gas velocity up to Mach 5 in a vacuum and the heat flux impinging on the inside surface of a pipe during altitude simulation are needed to support J-2X engine testing. Computational tools to accurately model and predict rocket engine test stand components and system performance are also desired. Sub Topics:

T9.01 Rocket Propulsion Testing Systems

Lead Center: SSC
Center: SSC

Proposals are sought for innovative technologies in the area of propulsion test operations. Proposals should support the reduction of overall propulsion test operations costs (recurring costs) and/or increase reliability and
performance of propulsion ground test facilities and operations methodologies. Specific areas of interest in this subtopic include the following:

**Facility and Test Article Health-Monitoring Technologies**

Innovative, non-intrusive sensors for measuring gas velocity, temperature, pressure, molecular and metallic plume constituents, and environmentally sensitive effluent gas detection. Low-millisecond to sub-millisecond response time is required. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH₂) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH₂). Flow rate sensors must have a range of up to 2000 lb/s (82 ft/sec) for LOX and 500 lb/sec (300 ft/s) for LH₂. Pressure sensors must have a range up to 15,000 psi. Rocket plume sensors should be capable of measuring gas species, temperature, and velocity for H₂, O₂, hydrocarbon and hybrid fuels.

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

Modeling, sensors, and instrumentation for prediction, characterization, and measurement of rocket engine combustion instability. Sensor systems should have bandwidth capabilities in excess of 100 kHz. Emphasis is on development of non-intrusive optical-based sensors.

**Test Facility Modeling Tools and Methods**

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

Tools using computational methods to accurately model and predict system performance are required that integrate simple interfaces with detailed design and/or analysis software. SSC is interested in improving capabilities and methods to accurately predict and model the transient fluid structure interaction between cryogenic fluids and immersed components to predict the dynamic loads, frequency response of facilities.
Component Design, Prediction and Modeling - Improved capabilities to predict and model the behavior of components (valves, check valves, chokes etc.) during the facility design process. This capability is required for modeling components in high pressure 12,000 psi, high flow 100 lb/sec cryogenic environments and must address two-phase flows.

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

T9.02 Field Sensors, Instruments, and Related Technologies

Lead Center: SSC

Center: SSC

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

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

- Coupling of land and ocean processes (run-off, air quality, material flux);
- Coral reef mapping and health;
- Algal blooms (detection and monitoring);
- Sea level rise (measuring and forecasting effects);
• Sediment and contaminant transport (measuring and monitoring);

• Natural disasters such as tropical systems, tsunamis, and floods (planning, impact assessment, mitigation, and recovery).

Rocket Propulsion Testing Systems Topic T9

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

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

• Onboard methods that monitor system health and then automatically reconfigure to respond to failures and sustain progress toward high-level goals. Special emphasis will be on computational techniques that enable lifecycle consistency in system characterization during design through operations with engineering and data models. Proposals should focus on data analysis and interpretation rather than development of new sensors.

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

• Data fusion, data mining, and automated reasoning technologies that can improve risk assessments,
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:
Space Radiation Dosimetry and Countermeasures Topic T1.02
As NASA embarks on its exploration agenda, the study of space radiation environments and associated health risks to astronauts will continue to guide radiation detection technology development and mitigation strategies. The development of suitable radiation detection technologies (both physical and biological) is vital to the success of long-term manned spaceflight. As NASA returns to the Moon and then on to Mars, a series of small, unmanned missions are anticipated followed by manned missions, including long-term (6 months) stays on the surface of the Moon. It is anticipated that the unmanned missions (e.g., small satellites that may even land on the Moon) will provide test beds for new and emerging miniaturized technologies that can be further evaluated on manned missions including on the lunar base. Prior to testing in space, the technologies must be tested using simulated space radiations available at the National Space Radiation Laboratory (NSRL), a NASA funded facility at the Brookhaven National Laboratory in New York. The NSRL is capable of generating high-energy particle radiation from protons to 56Fe nuclei. NASA also supports a facility at Loma Linda University Medical Center capable of generating energetic protons. These facilities enable research studies and technology development in support of NASA funded research. NASA is seeking innovative technologies in the areas described below.

Radiation Measurement Technologies for Small Spacecraft

NASA Ames is interested in flying small spacecraft payloads that measure radiation levels alone as well as in combination with biological payloads. In support of this objective, NASA Ames is seeking:

- Small radiation detectors that measure total dose equivalent;
- Miniaturized, radiation-hardened electronics;
- Technologies for combined radiation and biology payloads.

These technologies must minimize the use of power, volume, and mass, and provide what is needed to interface to a spacecraft bus. In the case of biological payloads, a pressurized environment, and environmental control including consideration of gas, thermal control, and humidity needed to support the biology experiment, must be provided. Biological experiments ranging from cells to small organisms are of interest.
Radiation Health Monitoring Techniques

Technologies are needed to monitor the adverse effects of spaceflight radiation on human health. The following are of interest:

- Methods that are minimally invasive to the crew and provide monitoring of the biological effects of radiation;
- Application of high throughput analyses and genomic, proteomic, and metabolomic approaches used for other biological problems to space radiation effects;
- Concept and technology development of miniaturized spaceflight devices from existing laboratory-based devices to support the analyses described above.

Sub Topics:
- Aerospace Vehicles Flight Dynamic Modeling and Simulation Topic T2.01
  This subtopic solicits proposals for innovative, linear or non-linear, aerospace vehicles dynamic systems modeling and simulation techniques. In particular:

  Research and development in simulation algorithms for revolutionary aerospace flight projects involving computational fluid dynamics (CFD), structures, heat transfer, and propulsion disciplines: Emphasis is placed on the development and application of state-of-the-art, novel, and computationally efficient solution schemes that enable effective simulation of complex modern flight vehicles, like the Space Shuttle, the Constellation (Aries and Orion), light-weight highly flexible structures, as well as more routine problems encountered in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered an important part of this topic.

  Aeroelasticity and aeroservoelasticity, linear and non-linear: Vehicle design and stability analysis are an important aspect of this topic. Primary concern is with the development and application of novel, multi-disciplinary, simulation software using finite element and other associated techniques.
Sub Topics:
Foundational Research for Aeronautics Experimental Capabilities Topic T2.02
This subtopic is intended to be broad and to solicit and promote technologies for the following:

- Automated online health management and data analysis;
- 21st Century air-traffic management;
- Modeling, identification, simulation, and control of aerospace vehicles in-flight test, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts.

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

Proposals in any of these areas will be considered.

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

The challenges in Air Traffic Management (ATM) are to create the next generation systems and to develop the optimal plan for transitioning to future systems. This system should be one that seamlessly supports the operation of ROAs. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.
Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influences of structural dynamics, thermal dynamics, steady and unsteady aerodynamics, and the control system. The benefit of this effort will ultimately be an increased understanding of the complex interactions between the vehicle dynamics subsystems with an emphasis on flight test validation methods for control-oriented applications. Proposals for novel multidisciplinary nonlinear dynamic systems modeling, identification, and simulation for control objectives are encouraged. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance and load control (including smart actuation and active aerostructural concepts), autonomous health monitoring for stability and performance, and drag minimization for high efficiency and range performance. Methodologies should pertain to any of a variety of types of vehicles ranging from low-speed, high-altitude, long-endurance to hypersonic and access-to-space aerospace vehicles.

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

Sub Topics:

Space Power and Propulsion Topic T3.01
Development of innovative technologies and systems are sought that will result in robust, lightweight, ultra-high efficiency, lower cost, power and in-space propulsion systems that are long-lived in the relevant mission environment and that enable future missions. The technology developments being sought would, through highly-efficient generation and utilization of power and in-space propulsion, significantly increase the system performance.

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

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

Sub Topics:

Bio-Technology and Life Support Topic T3.02
The new Vision for Space Exploration (VSE) entails the eventual presence of humans on the planetary surfaces of both the Moon and Mars. The physiological effects of prolonged space exposure (to both the microgravity environment of interplanetary space as well as the reduced gravity environments of the Moon and Mars) need to be quantified in order minimize mission risk, as well as insure the general health of astronauts both in space and upon their return to Earth. Biomedical sensors to monitor astronaut health that maximize diagnostic capability while reducing up-mass and power requirements are of significant interest for exploration missions. For longer duration missions on the Moon and the journey to Mars, the astronauts' continued health maintenance and fitness evaluation for mission critical activities will need to be performed routinely. Similarly, medical diagnostics are required to evaluate acute events like fatigue fractures. As a result, there is an acknowledged need for compact, robust, multi-function diagnostic biomedical sensors to reduce levels of risk in exploration class missions. To fully quantify space-normal physiology, these biomedical sensors must be supplemented by advanced analytical tools, such as high-resolution microscopy and lab-on-a-chip instrumentation (for blood or urine analysis). In addition, computational models (incorporating the direct physiological data) are needed that allow comparison to 1G values and determination of secondary physiological quantities (e.g., cardiac dysrhythmia and renal stone formation, as related to measured calcium levels). These computational models will also enable physicians to predict, diagnose and treat pathologies that are either not present in a 1G environment or are induced by synergies with spaceflight stressors. Specific innovations required for this task include:

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

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

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

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

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

Low mass, high reliability, robustness, low power consumption, long life, ease of usage and easy interface with the onboard data acquisition and control system are highly desirable attributes for all candidate technologies.

Sub Topics:
Earth Science Sensors and Instruments Topic T4.01
As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.
This STTR subtopic seeks to help provide advanced remote sensing technologies to enable future Earth Science measurements. Systems and approaches will be considered that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV or aircraft). New systems and approaches are sought that will enable 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**

Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth Science missions. A particular emphasis is placed on instruments that can be used on UAV platforms such as the NASA Ikhana or Altair platforms. Instruments are solicited that enable or support the following Earth Science measurements:

- High spatial and temporal resolution observations of the land surface and vegetation cover (biomass);
- Profiling of clouds and aerosols, with emphasis on multiple beam systems to provide horizontal coverage;
- Wind measurements (direct-detection technology only);
- Tropospheric and stratospheric ozone and CO$_2$ (profiling and total column).

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

Active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and UAVs. 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, (2) precipitation and cloud measurements, and (3) large aperture ground penetrating radars (GPR) at P-band and lower. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (UAV or aircraft). Specific technologies include:

- High efficiency, solid state power amplifiers (>10W at Ka-band and >30W at Ku-band);
- High performance, low power, compact, real-time radar processors, FPGA-based digital receivers, data
processing algorithms and data reduction techniques;

- Implementation of radar transmitters/receivers using digital signal synthesis;
- High power, low sidelobe (better than -30 dB) scanning phased array antennas (X, Ku, Ka or W-band) for high-altitude operation (65,000 feet);
- Wide-bandwidth (>=400 MHz), high efficiency FM chirp/linear pulse signal generator with amplitude modulation; and
- High power (30W at Ka-band, 5W at W-band), high speed (=250µs), high isolation (=40 dB) and low insertion (1.5 dB at Ka and 2 dB at W-band) switch.

**Data Compression**

To complement data compression, data decompression processors are needed to decode compressed data streams. To target multiple missions, implementations should conform to the Consultative Committee for Space Data Systems (CCSDS, [www.ccsds.org](http://www.ccsds.org)) recommendation CCDDS 122.0-B.1. This solicitation seeks development of new data decompression processors that can:

- Process instrument data at over 20 Mpixels/sec decoding rate for instruments that employ compression for either direct broadcast or during nearly real-time ground processing after telemetering the data to ground stations;
- Decode up to 16-bit of science data; and
- Decode embedded compression bit stream following the format described in CCSDS 122.0-B.1 ([www.ccsds.org](http://www.ccsds.org) [1]).

**Sub Topics:**

**Space Science and Exploration Sensors and Instruments Topic T4.02**

This subtopic focuses on key component and subsystem technologies for space science and exploration sensors and instruments. The focus is on innovative, lower TRL technologies which may have a longer term development time. The technology focus in this solicitation is for cryogenic cooling technologies, in situ sensors for miniaturized planetary instruments, optical subsystems and wavefront sensing and control, and detectors for the IR, far IR, submillimeter, and millimeter wave regions.

**Cryogenic Cooling Technologies for Space Science and Space Exploration**

Cryogenics systems are enabling technologies for cutting edge space science including infrared imaging and spectroscopy and x-ray spectroscopy. Cryogenic cooling is also needed to enable the long term storage of the cryo-propellants needed for space exploration missions. Improvements in cryogenic technologies enable space science and exploration missions at lower cost with reduced mass, reduced volume and reduced risk.
New concepts that would provide cooling with improved thermodynamic efficiency for the following applications are sought.

- Coolers for long term cryo-propellant storage with cooling power in the range of 50 to 100 Watts at 100 K and 20 Watts at 25 K to 30 K;
- Low vibration coolers for space science instruments with approximately 0.1 Watt of cooling power at 4 K;
- Highly efficient sub-Kelvin cooling technologies capable of cooling detectors to 50 milliKelvin.

**In Situ Sensors for Planetary Science**

Instruments for in situ investigations are required for NASA’s planned and potential planetary science missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface landers and rovers, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses. A focus is on developing components and subsystems for miniaturized instruments.

- Enabling instrument component and support technologies for a miniaturized mass spectrometry/gas chromatography instrument with improved capabilities over the SAM instrument on the Mars Science Laboratory. These include miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and microfluidic technologies for sample preparation.

**Optical Subsystems and Wavefront Sensing and Control**

This subtopic solicits technology for collecting and controlling star light with advanced optical telescopes and telescope arrays. This topic includes innovative optical subsystems, devices and components that directly collect and process optical signals and images for all regions of the electromagnetic spectrum from X-ray to UV to Visible to Far-IR/Sub-MM. Pre-detection technologies of interest include capabilities to preprocess or analyze an optical wave front or signal to extract time-dependent, spectral, polarization and spatial information from scenes or signals prior to detection. Specific technology areas of interest include: high reflectance UV coatings and uniform polarization coatings for all wavelengths; high angular resolution imaging enabled via large-baseline segmented-aperture telescopes and sparse aperture telescopes/interferometers. Component-level technology needed to enable the characterization and combination of wavefronts from multiple apertures. Innovative technology needed to integrate, assemble, align and control test large aperture segmented mirrors for x-ray, ambient and cryogenic applications.
Proposals in the following areas are specifically solicited:

- Optical coatings: broad-band polarization preserving and polarizing for UV to Far-IR/Sub-MM; high-reflectivity EUV; large area, high acceptance angle narrow-band optical filters; broad-band wide-acceptance angle UV anti-reflection on PMMA substrates; environmentally stable protected silver.

- Innovative mounting/support and metrology/control technologies to integrate, assemble, align and control large aperture lightweight low-cost segmented mirrors for x-ray, ambient and cryogenic normal incidence applications - also, systems with extreme alignment tolerances such as PIAA.

- Techniques to mitigate optical surface errors includes phase retrieval and wavefront sensing and control techniques and instrumentation, optical systems with high-precision controls, active and/or adaptive mirrors, shape control of deformable telescope mirrors, and image stabilization systems; techniques to sense/control segmented primary mirrors.

**Detector Technology for IR, far IR, Submillimeter, and Millimeter**

Advances in detectors, readout electronics, and other technologies enabling polarimetry and large format imaging arrays for the IR, far submillimeter and millimeter and spectroscopy with unprecedented sensitivity are sought.

Innovations are sought in detector capability for the following wavelength ranges:

- 1-30 microns: Increased sensitivity and larger array size; Large format cryogenic readout multiplexers; large format (>1000 x 1000) array hybridization techniques. Technologies for assembly of large format focal plane arrays. Photon counting detector arrays with fast readout electronics.

- 100 microns - 3 mm: Noise equivalent power (NEP) of $10^{-20}$ W/Hze-1/2 in a 1,000 pixel spectroscopic array with low-power readout electronics, and NEP $10^{-18}$ W/Hze-1/2 in a 10,000 pixel photometric imaging array. Capabilities for photon counting, polarimetry, and energy resolving detection.

- RF (GHz to THz) MEMS switches with low insertion loss.

- (18 dB), capable of switching with speeds of >100 Hz at cryogenic temperatures (below 10 K) for $10^8$ or more cycles.

Sub Topics:

JPL - Large Telescopes Topic T4.03
Proximity Glare Suppression for Astronomical Coronagraphy

This subtopic section addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources and innovative advanced wavefront sensing and control for cost-effective space telescopes. Examples include: planetary systems beyond our own, the detailed inner structure of galaxies with very bright nuclei, binary star formation, and stellar evolution. Contrast ratios of one million to ten billion over an angular spatial scale of 0.05-1.5 arcsec are typical of these objects. Achieving a very low background requires control of both scattered and diffracted light. The failure to control either amplitude or phase fluctuations in the optical train severely reduces the effectiveness of starlight cancellation schemes.

This innovative research focuses on advances in coronagraphic instruments, starlight cancellation instruments, and potential occulting technologies that operate at visible and infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission. Much of the scientific instrumentation used in future NASA observatories for the astrophysical sciences will require control of unwanted radiation (thermal and scattered) across a modest field of view. The performance and observing efficiency of astrophysics instruments, however, must be greatly enhanced. The instrument components are expected to offer much higher optical throughput, larger fields of view, and better detector performance. The wavelengths of primary interest extend from the visible to the thermal infrared. Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development, and innovative instrument design, as well as in the fabrication of subsystem devices to include, but are not limited to, the following areas:

Starlight Suppression Technologies

- Advanced starlight canceling coronagraphic instrument concepts;
- Advanced aperture apodization and aperture shaping techniques;
- Pupil plane masks for interferometry;
- Advanced apodization mask or occulting spot fabrication technology controlling smooth density gradients to 10-4 with spatial resolutions ~1 µm, low dispersion, and low dependence of phase on optical density;
- Metrology for detailed evaluation of compact, deep density apodizing masks, Lyot stops, and other types of graded and binary mask elements. Development of a system to measure spatial optical density, phase inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of masks and stops is needed;
- Interferometric starlight cancellation instruments and techniques to include aperture synthesis and single input beam combination strategies;
- Single mode fiber filtering from visible to 20 µm wavelength;
- Methods of polarization control and polarization apodization; and
- Components and methods to insure amplitude uniformity in both coronagraphs and interferometers, specifically materials, processes, and metrology to insure coating uniformity.
Wavefront Control Technologies

- Development of small stroke, high precision, deformable mirrors (DM) and associated driving electronics scalable to $10^4$ or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple DM technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices;

- Development of instruments to perform broad-band sensing of wavefronts and distinguish amplitude and phase in the wavefront.

- Adaptive optics actuators, integrated mirror/actuator programmable deformable mirror;

- Reliability and qualification of actuators and structures in deformable mirrors to eliminate or mitigate single actuator failures;

- Multiplexer development for electrical connection to deformable mirrors that has ultra-low power dissipation.

- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance; and

- Highly reflecting broadband coatings.

Precision Deployable Optical Structures and Metrology

Planned future NASA Missions in astrophysics, (such as the Single Aperture Far-IR (SAFIR) telescope, Life Finder, and Submillimeter Probe of the Evolution of Cosmic Structure (SPECS), and the UV Optical Imager (UVOIR) require 10 - 30 m class cost effective telescopes that are diffraction limited at wavelengths from the visible to the far IR, and operate at temperatures from 4 - 300 K. The desired areal density is 1 - 10 kg/m$^2$. Static and dynamic wavefront error tolerances may be achieved through passive means (e.g., via a high stiffness system) or through active control. Potential architecture implementations must package into an existing launch volume, deploy and be self-aligning to the micron level. The target space environment is expected to be L2.

This subtopic section solicits proposals to develop enabling, cost effective component and subsystem technology for these telescopes. Research areas of particular interest include: precision deployable structures and metrology, i.e., innovative active or passive deployable primary or secondary support structures; innovative concepts for packaging fully integrated (i.e., including power distribution, sensing, and control components), distributed and localized actuation systems; deployment packaging and mechanisms; active control distributed on or within the structure (downstream corrective and adaptive optics are not included in this topic area); actuator systems for alignment of reflector panels (order of cm stroke actuators, lightweight, submicron dynamic range, nanometer stability); mechanical, inflatable, or other deployable technologies; new thermally-stable materials (CTE

Also of interest are innovative metrology systems for direct measurement of the optical elements or their supporting structure. Requirements for micron level absolute and subnanometer relative metrology for tens of points on the primary mirror. Also measurement of the metering truss. Innovative systems which minimize complexity, mass, power and cost are sought.
The goal for this effort is to mature technologies that can be used to fabricate 20 m class, lightweight, ambient or cryogenic flight-qualified telescope primary mirror systems. Proposals to fabricate demonstration components and subsystems with direct scalability to flight systems (concept described in the proposal) will be given preference. The target launch volume and expected disturbances, along with the estimate of system performance, should be included in the discussion. A successful proposal shows a path toward a Phase 2 delivery of demonstration hardware on the scale of 3 m for characterization.

Sub Topics:

JPL - Communications Topic T4.04
Long Range Optical Telecommunications

The adaptation of current standard laboratory techniques for deployment on planetary missions is a focus. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

Instruments for in situ investigations are required for NASA’s planned and potential solar system exploration missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface landers and rovers, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses.

This subtopic seeks advances in instruments and critical components in the following areas:

- X-Ray Diffraction and X-Ray Fluorescence (XRD/XRF) instruments, with capabilities beyond those currently planned for the CHEMIN instrument on the Mars Science Laboratory (MSL - 2009), with a focus on elemental and mineralogical analysis in the Venus surface environment (90 bars CO₂, 450°C);
- Scanning electron microscopy with chemical analysis capability;
- Mass spectrometry/Gas chromatography with improved capabilities over the SAM instrument on MSL or applicability to in situ atmospheric measurements on Venus or Titan;
- Geochronology, with a focus on isotopic dating of planetary surfaces in the 100 Ma to 4.5 Ga timeframe with better than 10% accuracy;
• Gamma-Ray Spectroscopy, with a focus in short duration (X-Ray Photoelectron Spectroscopy (XPS) and Auger Electron Spectroscopy (AES)).

Astrobiology includes the study of the origin, evolution, and distribution of life in the universe. New technologies are required to enable the search for extant or extinct life elsewhere in the solar system, to obtain an organic history of planetary bodies, to discover and explore water sources elsewhere in the solar system, and to detect microorganisms and biologically important molecular structures within complex chemical mixtures.

Astrobiology solicits new measurement concepts, advances in existing instrument concepts, and advances in critical components in the following areas:

• Instrumentation focused on assessments of the identification and characterization of biomarkers of extinct or extant life, such as prebiotic molecules, complex organic molecules, biomolecules, or biominerals. At this time we are not soliciting DNA and RNA analysis techniques.

• High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures.

In addition, enabling instrument component and support technologies for the above, such as miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and fluidic technologies for sample preparation, are also solicited. These must be presented in the context of a complete instrument system.

**Long Range Space RF Telecommunications**

This subtopic seeks innovative technologies for long-range RF telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

• Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders and components, incorporating MMThe adaptation of current standard laboratory techniques for deployment on planetary missions is a focus. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

Instruments for in situ investigations are required for NASA’s planned and potential solar system exploration missions. Instruments are required for the characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for in situ measurements on surface
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- High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures;

In addition, enabling instrument component and support technologies for the above, such as miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and fluidic technologies for sample preparation, are also solicited. These must be presented in the context of a complete instrument system. ICs and Bi-CMOS circuits;
- MMIC modulators with drivers to provide large linear phase modulation (above 2.5 rad), high-data rate (10 - 200 Mbps), BPSK/QPSK modulation at X-band (8.4 GHz), and Ka-band (26 GHz, 32 GHz and 38 GHz);

- High-efficiency (> 60%) Solid-State Power Amplifiers (SSPAs), of both medium output power (10 W - 50 W) and high-output power (150 W - 1 KW), using power combining techniques and/or wide-bandgap semiconductor devices at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz);

- Epitaxial GaN films with threading dislocations less than 1e6 per cm² for use in wide band-gap semiconductor devices at X- and Ka-Band;

- Utilization of nanomaterials and/or other novel materials and techniques for improving the power efficiency or reducing the cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons);

- Long lifetime, radiation hard SSPAs, modulators and MMICs for 26 GHz Ka-band (lunar communication);

- TWTAs operating at higher millimeter wave frequencies (e.g., W-Band) and at data rates of 10 Gbps or higher;

- Ultra low-noise amplifiers (MMICs or hybrid) for RF front-ends (MEMS-based RF switches and photonic control devices needed for use in reconfigurable antennas, phase shifters, amplifiers, oscillators, and in-flight reconfigurable filters. Frequencies of interest include VHF, UHF, L-, S-, X-, Ka-, V-band (60 GHz) and W-band (94 GHz). Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.

Sub Topics:
MEMS-Enabled Filters, Antennas, and Sensors Topic T5.01

Given the great demands placed upon communication transceivers to assure crew safety and robustness in mobile environments, NASA seeks to develop novel techniques to reduce the size, weight, and power (SWAP) for long duration manned missions. Such high analog-to-digital conversion power consumption, large form factor, and expensive components pose challenges for power and weight constrained in software defined radios. Thus, significant technical advances are needed in the area of high performance channel select filter banks, tunable filters with low-loss and high-rejection, and reconfigurable and multi-band antennas.

First, this solicitation seeks substantial improvements over state-of-the-art technologies and aims at the development of banks of low loss and high rejection filters in the UHF (401 - 402 MHz, 25 kHz bandwidth), S-band (2.4 - 2.483 GHz), and Ka-bands (25.25 - 27.5 GHz). Closely spaced (in frequency) narrow band (50 dB) and low insertion loss.

Second, to complement an existing software programmable radio, NASA needs to develop a compact, lightweight, multi-band (UHF, S-band, and Ka-band - see above frequencies) antenna solution that enables robust surface-to-surface communications among mobile and fixed nodes (rovers, astronauts, lander, habitat) at operational range 10 km.
Assume audio, telemetry, and high-rate video delivery transmission, bi-directional link, and 20 Mbps data rate. Assume omnidirectional and multi-band RF communications and simultaneously links to suit/vehicle and RF contingency voice on UHF - half-duplex. MEMS-enabled reconfigurable, multi-band antennas promise significant reductions in form factor, lower power consumption, and enhanced reliability. This new class of miniaturized antennas should provide high antenna gains with small aperture sizes. Smart antenna technologies with self-monitor and calibration capability are also of interest for adapting to harsh environmental threats including dust storms.

Third, this solicitation seeks to develop robust radiation sensors capable of omni-directional micro-dosimeter measurements and discriminating both charged particles and neutrons that simulate tissue volumes spanning a few 10nm to monitor crew radiation exposure in space. While current Tissue Equivalent Proportional Counters (TEPCs) are limited to measuring integral radiation effects at the cell nucleus scale (~10 µm), or at chromosome level (~1 µm), contemporary radiobiological concepts elicit differential measurements at the sub-micron scale of chromatin fiber (~25 nm) or even DNA molecule (2 nm).

Fourth, NASA needs to demonstrate robust no-power RF sensor-tag systems capable of providing identification, position and sensor data in and on aerospace vehicles through wireless interrogation and receivers up to several meters away. Systems must provide additional vehicle capability and modularity, increasing redundancy while decreasing cost and schedule as they minimize cabled connectivity to sensors. Projects must demonstrate and compare standard instrumentation approaches to no-power RF sensor-tag approaches over a vehicle life-cycle for the following; ground and flight test instrumentation, operational health and status monitoring, and control of systems.

Below are expected outcomes corresponding to the four tasks:

Phase 1:

(1) Propose a reconfigurable multi-band MEMS tunable filter solution for the above frequency bands. Develop notional architecture, conceptual approach, and implementation strategy, anticipating insertion into a future frequency-agile EVA software defined radio. Compared with traditional approaches, assess MEMS RF tunable filter trade-offs with mass, power, size, flexibility, and complexity. Offer solutions to vibration, temperature, and gravitational changes commonly associated with MEMS devices for long-duration missions.

(2) Delineate through a combination of analysis and demonstrated prototypes that the multi-band compact, lightweight, and flexible multi-band antenna solutions can achieve robust, high performance operation in a mobile environment. Conduct antenna trades on power consumption, sensitivity, form factor, weight, and reliability for a EVA UHF, S-band, and Ka- multi-band helmet-mounted option.

(3) Validate through a combination of analysis and demonstrated prototypes that the proposed TEPC detection solution can achieve robust, high performance omni-directional operation in radiation environment. Assess detectors performance and compare it with traditional approaches. Develop feasible concepts and assess technical pitfalls/challenges of infusing this technology into the Exploration radiation monitoring program.
(4) Submit report and recommendations for follow-on applications based on test results and life-cycle cost analyses that compare the application of various no-power RF sensor-tag technologies against standard wired approaches for at least one relevant vehicle/vehicle test in NASA’s Exploration Program.

Phase 2:

Leverage results in Phase 1 and demonstrate feasibility on actual hardware prototype units for space applications. To ensure robust operation and MEMS reliability, conduct testing across harsh temperature, vibration, shock, and other conditions similar for space operations and survivability.

Commercial Potential:

Broad commercial applications for channel select filter banks span cellular and wireless LAN communication links, cognitive radios, and ultra-wide band ADCs.

TEPC detectors can be harnessed in nuclear facilities; no-power RF sensor tags in aerospace industry, replacing cables between data acquisition systems and sensors.

Sub Topics:

Algorithms for Autonomous Robotic Materials Handling Topic T5.02
The focus of this subtopic is to solicit new technologies that will increase the flexibility and efficacy of robots deployed to the surface of the Moon and Mars. Robots are expected to make an important contribution to future Moon and Mars missions by decreasing the EVA time required to set up and deploy outposts, habitats, science packages, etc. An important part of this robot activity will be autonomously or semi-autonomously handling a variety of materials such as cables, connectors, solar arrays, inflatable modules, samples, payloads, and trusses. Semi-autonomous robot handling will allow these activities to be controlled from Earth so that they can take place before astronauts arrive and to continue after they leave.

Based on the above planetary applications, proposals are solicited for the development of algorithms that address one of the following:

- Autonomous robotic grasping, manipulation, and dexterity;
- Tool use; or
Combining mobility and manipulation.

Emphasis should be placed on techniques that can be effective in unmodeled or unplanned for situations. Some important issues related to autonomous robotic grasping, manipulation, and dexterity include: positioning of the manipulator and grasp contacts relative to the object, determining good manipulator configurations for grasping, adhering to grasp and task constraints on action sequencing during grasping and manipulation, using whole-arm/body contact surfaces, sensing relevant data, simultaneous sensing and action, and the control of forces during manipulation. Some important issues relating to tool use are: representing and utilizing the affordances of tools, representing the task constraints on grasp, modeling the interactions between the tool and the environment, representing the function of the tool in a larger (planetary repair) task, and using tools to adapt to contingencies imposed by the task or environment. Some important issues related to combining mobility and manipulation are: coordinating the use of mobility and manipulator DOFs to achieve a common manipulation purpose, coordinating multiple mobile manipulators so as to achieve a common goal, grasping or manipulating an object so that it can be transported.

Some areas of research and development that are expected to be relevant to the above problems are:

- Continuous or discrete control;
- Machine vision or tactile sensing; and
- Machine learning and robot development.

The proposal should target advancements in aspects of the above areas of research and development that are relevant to robotic materials handling. The proposed approach should take advantage of the specific constraints and simplifications that result from the materials handling problem.

Proposals should identify the specific problem(s) that are to be addressed and a brief outline of the proposed approach. In addition, proposals should outline a plan for testing key aspects of the approach on robotic hardware. Preference will be given to approaches that appear to be practical given realistic sensor and hardware limitations.

Sub Topics:

Wireless Surface Acoustic Wave (SAW) Sensor Arrays Topic T6.01

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 1000ºC. 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, temperature sensors, cryogenic level sensors, and hydrogen sensors have been demonstrated under prior year funding. These are all of interest to the ground processing community, 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 sensors, current, electric field, hypergols (monomethyl-hydrazine or nitrogen tetroxide), and moisture. 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:
Active Vibration Control for Ground Support Equipment Topic T6.02
Equipment located near a major rocket launch is exposed to extreme environments including heat, unsteady rocket plume impingement, acoustics and vibration. NASA's experience shows that considerable attention to the protection of critical electronic ground support equipment housed in a mobile launch platform or on adjacent tower structures is required.

The effect of high acoustic and exhaust blast loading on the launch structures results in large amplitude motions of the structural panels, including floors supporting racks of electronics. Measured acceleration spectra vary considerably from area to area but a general characterization is that the peak frequencies lie in the range below 100 Hz and amplitudes of several g's rms or higher. Typically, electronic systems are housed in a rack structure, for example a 19-inch rack, which might be 2 meters tall and weigh in the vicinity of 500 kg. Passive vibration isolator systems required to support this weight often have natural resonance within the broad excitation spectrum of the floor, resulting in less than desirable equipment protection. One consequence is the need for extensive check out of systems after each launch and often repairs. Another consequence is the need for extensive design and qualification testing to ensure the survivability of this equipment. Development of an effective vibration isolation system will significantly reduce life cycle costs and enhance equipment reliability.
The relatively short duration of the high vibration environment suggests that an active vibration control system using locally stored energy could provide a significant improvement in suppressing vibration effects. This call requests proposals for vibration control systems that would be highly reliable and capable of sensing and reducing vibration effects in ground support electronic racks. This technology is envisioned to consist of some type of platform with actuators, passive elements (springs, dampers), sensors, and a local energy source (if required). Alternately, active isolator kits could be developed that attach to the corners of a larger platform to allow designers to support a row of racks but a method of integration to allow the control of all 6 degrees-of-freedom of the complex assembly must be provided.

Applications of this technology go beyond launch equipment to any environment requiring vibration isolation of critical equipment from episodic and intense events. These range from earthquake protection and transportation to military applications. The goal is to have a platform system that can be applied to expensive equipment where the specific vibration excitation is intense and somewhat poorly defined so that a designer can specify the system with confidence and without detailed analysis, and without requiring extensive testing of the components being protected.

Sub Topics:

Optical Detector Arrays with Unusual Geometrical Shapes for Lidar and Passive Remote Sensing Applications

Innovative or improved concepts are solicited for the development of detectors and detector arrays formed into unusual shapes. Of immediate interest are detector formats with cylindrical symmetry, where the detecting surface is on the curved portion of a cylinder and extends entirely (or nearly entirely) around the circumference of the cylinder. The detecting element need not be continuous, but could be a series of discrete elements. The ultimate goal of this solicitation is the development and production of a stacked array of cylindrical detecting elements.

NASA has interest in developing PV or PC IR detector arrays, but is especially interested in the development of visible/NIR photon-counting detectors constructed in a stacked cylindrical format. The stacked arrays should be sensitive across a broad spectral range. If cooling is required, the contact point to the cooler must be at one end of the array stack.
Arrays eventually employed will have a small size (cylindrical diameter ~ 1 centimeter or less, total length ~ 2-5 centimeters) and a moderately large number of axial elements (~ 32-128.) Fill factor of the array should be optimized to have as little non-detector surface area as possible. Electronics required to read the devices should also be developed as part of the project unless these are readily obtainable elsewhere.

Ultimately these detectors will be used as part of novel lidar systems and passive IR/visible spectrometers.

Proposals should describe the expected sensitivities/efficiencies of the proposed devices in terms of signal levels and wavelength dependencies. Limitations on the eventual size and power requirements of fully developed devices should be indicated in the proposal along with a discussion of any potential environmental constraints on their operation.

Sub Topics:

Innovative Fabrication Techniques for High Temperature Composites Topic T7.02
Innovative concepts are being solicited for the development of fabrication techniques for high temperature composites capable of operating within the range of 350°F for at least 50,000 hours to 600°F for 1000 hours. The highest priority is structural materials that are capable of being used at the above temperature regimes for aerospace applications. Emphasis is focused on cost effective and highly automated high temperature composite manufacturing concepts. Composite processing techniques that do not require autoclave processing are of key importance. Fabrication techniques include resin infusion (VARTM, RTM), tow/tape placement, e-beam curing and other non-autoclave processing techniques. Innovative and novel composite fabrication approaches are sought for the following materials and structural systems:

- Polymer matrix composites;
- Fiber metal laminates;
- Hybrid composites;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.

Proposals should address the following performance metrics as appropriate:
Processing techniques of lightweight, high temperature composites;

Resin development;

Reinforcement development;

Out of Autoclave fabrication technologies;

Aerospace quality structural application;

Characterization of material properties;

Elevated use temperature capability;

Damage tolerance;

Solvent resistance;

Long term durability;

Scalability.

Sub Topics:

Manufacturing Technologies for Human and Robotic Space Exploration Topic T8.01

Continued technological innovation is critically linked to a strong manufacturing sector in the United States economy. NASA is interested in innovative manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system. Specific areas of interest in this solicitation include innovative manufacturing, materials, and processes relevant to propulsion systems and airframe structures for next-generation launch vehicles, crew exploration vehicles, lunar orbiters and landers, and supporting space systems. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components. Only processes that are environmentally friendly and worker-health oriented will be considered. Proposals are sought, but are not limited to, the following areas:

Polymer Matrix Composites (PMCs)

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

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

Metals and Metal Matrix Composites (MMCs)

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

Manufacturing Nanotechnology

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

Fiber-Based and Inflatable Systems

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

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

Sub Topics:
Component Development for Deep Throttling Space Propulsion Engines Topic T8.02
Implementing certain aspects of the NASA Vision for Space Exploration will require versatile space propulsion engines that can operate over a wide range of thrust levels, a capability known as throttling. The ability of a rocket engine to reliably produce a small fraction of the maximum thrust on command during flight is referred to as deep throttling. High specific impulse deep-throttling space propulsion engines may be required for controlled spacecraft descent to planetary surfaces, and a significant degree of throttling may also be required for ascent and in-space transfer maneuvers.

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

- High-throttle-response engine concepts;
- Low-cost regeneratively cooled chamber designs and demonstrations of such;
- Injectors that can provide stable engine performance with two-phase (gas/liquid) flow of propellants, especially during start-up transients;
- Ignition systems that can operate reliably over a wide fuel/oxidizer mixture ratio;
- Propulsion system or component technologies that do not require thermal conditioning prior to ignition;
- Zero net positive suction pressure pump design concepts and demonstrations of such;
- Performance databases for small turbopumps and turbomachinery components;
- Design and analysis tools that accurately model small valves and turbopumps, and data required for code validation;
- Alternatives to the use of turbopumps for achieving chamber pressures of 1000 pounds per square inch; and
- Instrumentation for integrated vehicle health management.
Sub Topics:
Rocket Propulsion Testing Systems Topic T9.01
Center: SSC

Proposals are sought for innovative technologies in the area of propulsion test operations. Proposals should support the reduction of overall propulsion test operations costs (recurring costs) and/or increase reliability and performance of propulsion ground test facilities and operations methodologies. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies

Innovative, non-intrusive sensors for measuring gas velocity, temperature, pressure, molecular and metallic plume constituents, and environmentally sensitive effluent gas detection. Low-millisecond to sub-millisecond response time is required. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH₂) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH₂). Flow rate sensors must have a range of up to 2000 lb/s (82 ft/sec) for LOX and 500 lb/sec (300 ft/s) for LH₂. Pressure sensors must have a range up to 15,000 psi. Rocket plume sensors should be capable of measuring gas species, temperature, and velocity for H₂, O₂, hydrocarbon and hybrid fuels.

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

Modeling, sensors, and instrumentation for prediction, characterization, and measurement of rocket engine combustion instability. Sensor systems should have bandwidth capabilities in excess of 100 kHz. Emphasis is on development of non-intrusive optical-based sensors.

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

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

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

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

Sub Topics:
Field Sensors, Instruments, and Related Technologies Topic T9.02
Center: SSC

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

This subtopic solicits innovative field measurement technologies and analytical tools to support NASA's remote sensing technologies used in coastal research and applications. Specific interests at SSC include the following:
• Coupling of land and ocean processes (run-off, air quality, material flux);
• Coral reef mapping and health;
• Algal blooms (detection and monitoring);
• Sea level rise (measuring and forecasting effects);
• Sediment and contaminant transport (measuring and monitoring);
• Natural disasters such as tropical systems, tsunamis, and floods (planning, impact assessment, mitigation, and recovery).

Sub Topics: