This year’s STTR topic hosted by NASA Ames Research Center spans three technology investment areas at the center. These interests include: Synthetic Biology for Space Exploration, Commodity Based Technologies, and Information Technologies for Intelligent Planetary Robotics. Please see the subtopic descriptions for what is sought under each of these solicitations.

Sub Topics:

**T1.01 Synthetic Biology for Space Exploration**

Lead Center: ARC

The field of Synthetic Biology is a rapidly growing area of study that encompasses research ranging from the introduction of incremental function or regulation into existing organisms to the creation of fully synthetic living structures and systems. NASA is interested in harnessing this emerging field to create technological advances for multiple mission focus areas. Topics include biological life support for air, water and waste management; local production of fuels, food and plastics; in situ resource utilization (ISRU) technologies such as biomining for metals and biocementation of regolith for building materials/radiation shielding; biomedical applications including in situ therapeutic production and radiation/gravity countermeasures; advanced chemical and life sensing; and fabrication of advanced materials. Overarching research concerns include using synthetic biology techniques for the development of life forms that have been specifically adapted to perform well in extraterrestrial environments, including increased resistance to radiation, desiccation and temperature extremes. Foundational and applied solutions are sought that provide game-changing capabilities that enable cost effective and sustainable spaceflight and habitation.

**T1.02 Commodity Based Technologies**

Lead Center: ARC

This subtopic seeks out-of-the-box, innovative, broad-based approaches to address space mission requirements.

Desired proposals would enable the commoditization of space mission requirements by utilizing existing commercial technology goods and services to reduce schedule and costs of implementation.
Examples:

Smart-phones today are able to perform many of the basic capabilities of the spacecraft, having a high speed processor with large memory capacity, a set of sensors such as an accelerometer, rate gyroscopes, magnetometer, global positioning system (GPS).

Another example would be using multiple COTS (commercial off the shelf) digital cameras with multiple color filter settings, and then combining the image as a hyper-spectral imager at low cost. Other consumer goods that may have high utility for small spacecraft include but are not limited to:

- PDA-based smart phones.
- High resolution digital cameras.
- Consumer robotics.
- Lego-like assemblies.
- Medical grade surgical adhesives.
- Pressure sensitive paint.
- In-situ bioanalytical diagnostics.
- Mining technologies.
- Biohybrid devices.
- Diagnostics.
- X10-based domonics.

Proposers are asked to build a conceptual system/spacecraft design/operational scenario that details the architecture, components and specifications. Supporting analysis including cost and feasibility should be included. Phase II contract efforts should be used to prototype the system(s) detailed in Phase I.

Proposals should focus on the following areas of research:

- Transformational Small Spacecraft, Subsystems, and Mission Architectures.
- Biological Technologies for Life Beyond Low Earth Orbit.
- GREEN Technologies (Technologies for Sustainability).
• Emerging Aeronautics Systems and Technologies.

• Autonomous Laboratories on Planetary Surfaces.

• Hybrid Systems Modeling and Analysis.

• Advanced Information, Robotics, and Autonomous Systems.

Proposals that focus on the above areas of research, and contribute to the NASA Space Technology Grand Challenges will have higher priority.

Reference Documents:

• Grand Challenges


• Roadmaps


T1.03 Information Technologies for Intelligent Planetary Robotics

**Lead Center: ARC**

The objective of this subtopic is to develop information technologies that enable robots to better support planetary exploration. Intelligent robots are already at work in all of NASA's Mission Directorates and will be critical to the success of future exploration missions. The 2010 NASA "Robotics, Tele-Robotics, and Autonomous Systems Roadmap" (RTA Roadmap) indicates that extensive and pervasive use of intelligent robots can significantly enhance exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

Robots can do a variety of work to increase the productivity of planetary exploration. Robots can perform tasks that are highly-repetitive, long-duration, or tedious. Robots can perform tasks that help prepare for subsequent human missions. Robots can perform "follow-up" work, completing tasks started by astronauts. Example tasks include: robotic recon (advance scouting), systematic site surveys, documenting sites or samples, and unskilled labor (site clean-up, close-out tasks, etc).
The RTA Roadmap identifies three key areas for improvements in robotics:

- Technology should aim to exceed human performance in sensing, piloting, driving, manipulating, rendezvous and docking.
- Technology should target cooperative and safe human interfaces to form human-robot teams.
- Autonomy should make human crews independent from Earth and robotic missions more capable.

Thus, proposals are sought which address the following topics:

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

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

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

- Robot software architecture that radically reduces operator workload for remotely operating planetary rovers. This may include: on-board health management and prognostics, on-board automated data triage (to prioritize information for downlink to ground), and learning algorithms to improve hazard detection and selection of locomotion control modes.

Atmospheric Flight Research and Technology Demonstration Topic T2

This topic solicits innovative aerospace concepts and techniques that would advance aerospace technologies in all flight regimes. NASA’s flight research mission is to demonstrate aeronautical and space technologies through flight
research and testing. NASA also seeks advance flight test techniques and analysis tools for efficient and timely flight research. The principle areas of interest encompass game-changing aerodynamic concepts; flight controls; multi-disciplinary flight system analysis and validation; miniaturized, low-power, light-weight sensors and systems for flight research data and processing; Airborne Science Platform instrument support capabilities to more effectively conduct NASA's scientific missions and investigations.

Sub Topics:

**T2.01 Technologies for Aeronautics Experimental Capabilities**

**Lead Center: AFRC**

The emphasis of this subtopic is proving feasibility, developing, and demonstrating technologies for advanced flight research experimentation that matures new methodologies, technologies, and concepts. It seeks advancements that promise significant gains in NASA's flight research capabilities or addresses barriers to measurements, operations, safety, and cost in all flight regimes from low sub-sonic to high supersonic. This subtopic solicits innovative technologies that enhance flight research competencies by advancing capabilities for in-flight experimentation. Proposals that demonstrate and confirm reliable application of concepts and technologies suitable for flight research and the test environment are a high priority.

Measurement techniques are needed to acquire aerodynamic, structural, flight control, and propulsion system performance characteristics to safely expand the flight envelope of aerospace vehicles. The goals are to improve the effectiveness of flight-testing by simplifying and minimizing sensor installation, measuring parameters in novel ways, improving the quality of measurements, and minimizing the disturbance to the measured parameter from the sensor presence. Sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.

Special areas of interest include:

- Methods and associated technologies for conducting flight research and acquiring test information in flight.
- Numerical methods for the planning, prediction, analysis and validation of flight-test experimentation.
- Sensors and data systems that have fast response, low volume, minimal intrusion, and increased accuracy and reliability.
- Innovative techniques that decrease turn-around time for inspections and assessments for safe operations of aircraft (e.g., non destructive examination of composites through ultrasonic techniques).
- Advanced design and manufacturing techniques for improved upper stage performance for nano- & small-satellite booster technologies (e.g., manufacturability, affordability, and performance of a small upper-stage booster rocket motors for small & nano-satellites).
- Novel dynamic modeling and simulation of aircraft flight and structural control are encouraged. Control objectives include aerodynamic boundary layer and laminar flow control, autonomous and adaptive systems for improved stability, safety, performance, and drag reduction.
This subtopic addresses advanced control-oriented techniques for aeroservoelastic (ASE) flight systems including distributed network sensor systems, modeling, simulation, optimization and stabilization methods of ASE systems to actively and/or adaptively control wing geometry, vibration, gust/turbulence response, static/dynamic loads, and other aeroelastic (AE) objectives for enhanced aeroservoelastic performance and stability characteristics.

Technical elements for these proposals may include:

- ASE enhancements for flight control while minimizing adverse AE interaction.
- Flexible aircraft stabilization and performance optimization.
- Modeling and system identification of distributed AE dynamics with aircraft flight dynamics.
- Sensor/actuator developments and modeling for ASE control.
- Uncertainty modeling of complex ASE system behavior and interactions.
- Distributed networked control schemes for wing shape, vibration, and load control.
- Boundary-layer, shock, and viscous flow sensing with AE control feedback.
- Mission/maneuver adaptivity with dissipative optimal energy-force distribution.
- Data-driven multi-objective ASE control with physics-based aeroelastic sensing.
- Compressive information-based sensing.

This subtopic also addresses capabilities enabling design solutions for performance and environmental challenges of future air vehicles. Research in revolutionary aircraft configurations include lighter and more flexible materials, improved propulsion systems, and advanced concepts for high lift and drag reduction. This subtopic targets efficiency and environmental compatibilities requiring performance challenges and novel control-oriented techniques for aeroservoelastic considerations which are gaining prevalence in advanced aerospace flight vehicles, atmospheric and extra-terrestrial.

Development of distributed sensory-driven control-oriented ASE systems is solicited to enable game-changing flight vehicle concepts and designs that manage aerostructural dynamic uncertainty on a vehicle’s overall performance. This subtopic will assist in revolutionizing improvements in performance to empower a new generation of air vehicles to meet the challenges of Next Generation Air Transportation System (NextGen) concerns, concepts and technology developments in systems analysis, integration and evaluation.

Higher performance measures include energy efficiency to reduce fuel burn and operability technologies that enable takeoff and landing on shorter runways. Distributed aeroelastic control allows for robust nonintrusive flush sensing for control near stall and ground effects, accounting for vehicle flexibility. Proposals should describe how
such improvements with distributed ASE systems promote new applications of flight with experimental methods to establish validation data in areas comparable to:

- Reduced take-off and landing field length requirements.
- Improved performance with lightweight structures and low drag aerodynamics.
- Multi-disciplinary design and analysis tools and processes to enable reliable, advanced aircraft configurations with control-oriented sensory-driven design concepts for flight near performance/stability limits.
- Transonic and supersonic shock/boundary-layer control in an aeroelastic environment.
- Sensory and control systems for the reduction of ASE uncertainty from hypersonic aerodynamic heat loads, resulting in lower vehicle weight from reduced design margins for thermal structures and thermal protection systems.
- Integration of interactions among the airframe, inlet, nozzle, and propulsion systems using physics-based ASE control-oriented design approach.

Technologies for Space Exploration Topic T3

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

Sub Topics:

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

*Lead Center: GRC*

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

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

Innovations, advanced concepts and processes are sought for in-space propulsion, including electric propulsion, chemical propulsion, advanced rocket propellants/alternative fuels, nuclear propulsion, and tether technology. In electric propulsion, concepts for subcomponent improvements are needed for electric propulsion systems, including cathode technologies, electrode-less plasma production, low-erosion materials, high-temperature magnetics, and lightweight simplified power processing systems. Innovations are also desired for low thrust trajectory analysis tools and new diagnostic techniques to quantify thruster performance and lifetime. In small chemical thruster propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

Innovative Sensors, Support Subsystems and Detectors for Small Satellite Applications Topic T4
This STTR topic solicits advanced technologies for satellites with masses less than approximately 20 kg and volumes less than approximately 10,000 cm3. Needed are components, subsystems, sensors, detectors and instruments that increase the capabilities of very small satellites while meeting the significant constraints imposed by the very limited size and mass of the observatory

Sub Topics:

T4.01 Innovative Sensors, Support Subsystems and Detectors for Small Satellite Applications

Lead Center: GSFC

As the launch opportunities of very small satellites increase, NASA needs advanced capabilities to be developed in order to increase the viability of world-class scientific and technological applications within smaller constraints. This will allow NASA to use every class of orbiting system to make measurements to improve the scientific understanding of the Earth, the Sun and the cosmos.

This STTR solicitation is to help provide advanced technologies for satellites with masses less than approximately 20 kg and volumes less than approximately 10,000 cm3. Components or subsystems are sought that demonstrate a capability that is applicable to orbital missions to 800 km and mission durations up to 2 years. New approaches,
instruments, and components are sought that will:

- Enable new Earth Science, Solar Science, or Astronomy measurements.
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal resolution, accuracy, range of regard).
- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same measurement capability.
- Provide satellite bus capabilities that increase the capabilities of very small satellites while meeting the significant constraints imposed by the very limited size and mass of the observatory.

**Small Satellite Subsystem Technologies**

Components and subsystems are required to furnish satellite bus capabilities for very small satellites. The subsystems are mass and volume constrained to a reasonable portion of satellites that must have total masses and volumes less than 20 kg and 10,000 cm³. In particular, NASA needs advanced component and/or subsystem designs for power, attitude control, telemetry, structures, propulsion, data and command processing, ground communication, and crosslink communication.

Components and subsystems must be those that consider the severe mass, volume, and power constraints imposed by these very small spacecraft.

**Small Satellite Sensors**

Sensors are required that support the assessment the state of spacecraft, and formations of spacecraft, needed to conduct sophisticated NASA science and technology missions. Sensors are required for spacecraft attitude, position, and velocity; relative attitude position and velocity; and accelerations. In addition, component temperatures, mechanism states, and magnetic field strength and direction are also needed.

**Small Satellite Science Detectors and Instruments**

Instruments or detectors are required that support Earth Science, Solar Physics, and Astrophysics experiments. Components and subsystems must be those that consider the severe mass, volume, and power constraints imposed by these very small spacecraft.
Technologies for Compositional Analysis and Mapping Topic T5

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

Sub Topics:

T5.01 Technologies for Planetary Compositional Analysis and Mapping

Lead Center: JPL

This subtopic is focused on developing and demonstrating technologies for both orbital and in situ compositional analysis and mapping that can be proposed to future planetary missions. Technologies that can increase instrument resolution, precision and sensitivity or achieve new & innovative scientific measurements are solicited. For example missions, see (http://science.hq.nasa.gov/missions [3]). For details of the specific requirements see the National Research Council's, Vision and Voyages for Planetary Science in the Decade 2013-2022 (http://solarsystem.nasa.gov/2013decadal/ [4]).

Possible areas of interest include:

- Improved sources such as lasers, LEDs, X-ray tubes, etc. for imaging and spectroscopy instruments (including Laser Induced Breakdown Spectroscopy, Raman Spectroscopy, Deep UV Raman and Fluorescence spectroscopy, Hyperspectral Imaging Spectroscopy, and X-ray Fluorescence Spectroscopy).

- Improved detectors for imaging and spectroscopy instruments (e.g., flight-compatible iCCDS and other time-gated detectors that provide gain, robot arm compatible PMT arrays and other detectors requiring high voltage operation, detectors with improved UV and near-to-mid IR performance, near-to-mid IR detectors with reduced cooling requirements).

- Technologies for 1-D and 2-D raster scanning from a robot arm.

- Novel approaches that could help enable in situ organic compound analysis from a robot arm (e.g., ultra-miniaturized Matrix Assisted Laser Desorption-Ionization Mass Spectrometry).

- "Smart software" for evaluating imaging spectroscopy data sets in real-time on a planetary surface to guide rover targeting, sample selection (for missions involving sample return), and science optimization of data returned to Earth.

- Other technologies and approaches (e.g., improved cooling methods) that could lead to lower mass, lower power, and/or improved science return from instruments used to study the elemental, chemical, and mineralogical composition of planetary materials.

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

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

Innovative Technologies and Approaches for Space Topic T6

This topic seeks research and technology development that can directly support the NASA Space Technology Roadmap (STR) and Space Technology Grand Challenges. The long-term goal is to advance the technologies that will be needed to achieve the NASA mission objectives as outlined in the National Space Policy. The efforts of this STTR topic in 2011 will focus on two specific areas:

- Affordable and Sustainable Crew Support and Protection.
- Active Debris Removal Technologies.

Sub Topics:

**T6.01 Affordable and Sustainable Crew Support and Protection**

*Lead Center: JSC*

This STTR sub-topic seeks to advance the state-of-the-art in spacecraft life support, thermal control, extra-vehicular activity and habitation systems, leading toward the ability to sustain a crew in space for years with minimal supplies launched from Earth. Atmosphere, water and waste all need to be regenerated with highly reliable systems to reduce or eliminate the need to launch parts and supplies to maintain the systems. The crew must also be protected from the dangers of the deep space environment. During extra-vehicular activity, this poses additional difficulties. Specific challenges areas where NASA is soliciting new ideas are described below.

**Wastewater Reuse**

Recycling of wastewater from gray and black water sources with minimal mass, power, volume and expendables is
needed. Source separation of hygiene wastewater and urine water may be assumed. A particular challenge is the stabilization of urine to prevent odor and fouling of systems without the use of hazardous chemicals. Any stabilization system should be compatible with the extraction of nearly 100% of the water from brine if concentrated wastewater is created by primary processors.

**Improved Thermal Control**

Long life (>1 year) active thermal control systems are needed that can operate over a wide range of heat loads in a wide range of thermal environments. Reduced freezing point (...)

Also, water/ice phase change heat exchangers are needed to accommodate thermal management in environments that vary from very cold to warmer than room temperature. A successful design will efficiently transfer heat into and out of the water while managing the location of the ice and void space. The heat exchanger should be capable of ten thousand freeze/thaw cycles without damage.

**Robust Extra-Vehicular Activity**

A state of the art Extra Vehicular Activity (EVA) space suit is made of multiple layers of fabrics with a hard upper torso and metal bearings. These fabric layers provide physical and mechanical protection for the astronaut, as well as thermal isolation and pressurization for EVA in vacuum. There are several materials development advances that could significantly revolutionize space suit design. These advances consist of combining some of the functions provided by the current suit layers into fewer layers or using new materials to improve suit sizing methods. There is a need not only to improve existing properties of the space suit such as flame retardancy or decreased mass but also add new properties such as microbial growth resistance, selective permeability, static build-up resistance, improved MMOD protection, and radiation shielding. These improvements would increase mission safety and the useful life of the space suit. Increased radiation protection could increase the number of hours crew members spend performing EVAs over their career. Materials that reduce charge build up or decrease shock hazards would alleviate risks associated with interfacing different vehicles or performing EVAs in a plasma environment. Materials that are self healing could improve astronaut protection by detecting punctures and small cuts and even repairing suit damage. In addition, there is a need for micrometeorite shielding technology of the crew during EVAs.

Vacuum Regenerable Trace Contamination Control for spacesuits is also sought. A spacesuit is a small, closed environment in which the atmosphere is continually recycled. Therefore, a means of removing air borne trace contaminants is needed to protect the health of the crew member during an Extravehicular Activity (EVA). The primary contaminants in question for space suit applications are thought to be ammonia and formaldehyde, and the Spacecraft Maximum Allowable Concentrations (SMAC) for these contaminants are 7 mg/m³ and 0.3 mg/m³, respectively. Expected generation rates for these two contaminants are approximated at ~80 mg of ammonia and ~0.3 mg of formaldehyde during an 8 hour EVA. The current Portable Life Support System (PLSS) concept uses a CO₂ and humidity control technology that regenerates with a 3 to 10 minute vacuum cycle. A trace contamination control technology that could regenerate with this same vacuum cycle, that minimizes mass, power, and system pressure drop is desired.

**T6.02 Active Debris Removal Technologies**

Lead Center: JSC
After more than 50 years of human space activities, orbital debris has become a problem in the near-Earth environment. The total mass of debris in orbit is close to 6000 tons at present. The U.S. Space Surveillance Network is currently tracking more than 22,000 objects larger than about 10 cm. Additional optical and radar data indicate that there are approximately 500,000 debris larger than 1 cm, and more than 100 million debris larger than 1 mm in the environment. Because of the high impact speed between orbiting objects in space, debris as small as 0.2 mm poses realistic threat to Human Space Flight (EVA suit penetration, Shuttle window replacement, etc.) and other critical national space assets.

Recent modeling studies indicate that debris mitigation measures commonly-adopted by the international community will be insufficient to stop the debris population growth in low Earth orbit (LEO, the region below 2000 km altitude). To better preserve the space environment for future generations, active debris removal (ADR) of large and massive upper stages and spacecraft must be considered. The need for ADR is also highlighted in the National Space Policy of the United States of America, released by the White House in June 2010. The Policy explicitly directs NASA and the Department of Defense to “pursue research and development of technology and techniques to mitigate and remove on-orbit debris.” Orbital debris is also one of the NASA Grand Challenges outlined by the Office of the Chief Technologist.

An end-to-end ADR operation includes, in general terms, launches; propulsion; guidance, navigation & control; proximity operations; precision tracking; rendezvous; stabilization (of the spinning/tumbling targets); capture/attachment; and deorbit/gravneyard maneuvers. Some of the technologies involved in the ADR process do exist, but the difficulty is to make them more cost effective. Other technologies, such as ways to stabilize a large and massive spinning/tumbling upper stage and the capture mechanisms, are new and will require major innovative research and development efforts. In addition, many of the potential ADR targets are upper stages with leftover propellants stored in pressurized containers. Any capture mechanisms of those upper stages will have to be carefully designed to reduce the possibility of explosion.

The focus of this subtopic is to support the development and advancement of cost-effective technologies and techniques to address any of the sub-components described above for active debris removal in LEO. The ultimate goal is to develop the full capability of an end-to-end ADR demonstration in LEO in 5 to 10 years.

Ground Effects of Launch Acoustics, Payload Integration, and Flexible Polymer Foam Systems Topic T7

Kennedy Space Center (KSC) is seeking innovative solutions to improve ground systems operations. This topic highlights three areas that KSC has a vested interest. These include: improved performance of materials for cryogenic insulation, fireproofing, energy absorption, and other aerospace applications; methodologies for verification and validation of software that simulates ground effects of launch acoustics; standardization of payload
integration and subsystem interfaces to enable low cost, reliable, and reusable standards and adapter systems for launch.

Sub Topics:

**T7.01 Ground Effects of Launch Acoustics**

**Lead Center:** KSC

The exhaust plume from a launch vehicle rocket engine generates severe acoustic waves, which cause acoustic loading on the ground structures and vehicle payload. Prediction and reduction of the acoustic levels in the near field of launch vehicle lift-off is an important factor that should be taken into consideration early in the design process of the space launch complex.

The Kennedy Space Center is dedicated for ground systems operation. It is crucial that ground support equipments (GSE) and launch pad structures are designed to withstand the launch-induced environments produced by the first-stage rocket exhaust plume.

High-fidelity prediction technique such as computational aeroacoustics (CAA) can be used to resolve the acoustic flow field in an accurate fashion. It is understood that CAA prediction can be computationally intensive and often prohibitive for a large domain as in the launch environment. However, recent advances in computational resources and methodology have allowed CAA to overcome these difficulties. In the past few years, researchers have employed CAA in the launch environment\(^1,2,3\). These results are promising, but they need to be validated against actual data. The economical way of getting acoustic data is from static firing in a subscale or full scale environment. The problem with static firing test is that they do not reveal the dynamic environment. Flight data from actual launch would yield much better data, but such data are limited and costly. The best alternative would be to collect data from a demonstration launch vehicle.

It is proposed that a capability be developed to perform launch acoustics research by launching a demonstration reusable vehicle from one of the launch pads at KSC or Cape Canaveral Air Force Station (CCAFS), with acoustic sensors installed on the vehicle and in the vicinity of the launch complex. The capability will allow raw data to be processed into one-third octave band sound pressure level and used for benchmarking results obtained from CAA analysis.

**References:**

T7.02 Payload Integration and Payload Launch Preparation Interface Standards

Lead Center: KSC

This STTR topic seeks commercial solutions that will allow and encourage standardization of key payload to launch vehicle, and subsystem interface standards to reduce the cost associated with analysis, integration, and preparation required to design and then configure space systems for launch. The goal is a set of launch vehicle adapters, processes, and avionics interface standards that can be collectively used to facilitate spacecraft and subsystem design while reducing testing duration and complexity, overall reducing mission risk and while enabling novel mission concepts.

These sets of systems will focus on new standards for payload in the following mass ranges:

- 1 to 10kg.
- 11 to 50kg.
- 51 to 100kg.
- 101 to 180kg.

These ranges have been identified as the regions where critical technologies demonstrations and new space technologies could be used to increase TRL level at a lower cost with reduced risk. Enabling these capabilities will allow spacecraft developers the ability to design to a specific mass range that will result in on orbit research.

This STTR will be used to evaluate each of the current and future launch vehicles in determining where cross cutting standards can be applied to the entire NASA launch vehicle fleet.

The STTR has been classified as highly desirable. This rating was determined because there are adapters in place that could support the missions. However, to have multiple systems across multiple launch vehicles will contribute to higher cost for integration of that mission. By having standards amongst the space craft and adapter community will reduce the per kilogram cost to orbit.

A significant fraction of mission costs are typically unique designs and approaches to perform relatively routine functions such as launch accommodations and subsystem-to-subsystem interface and communications. By standardizing many of these approaches, spacecraft and payload developers can design their systems with an expectation of a predictable, low-cost integration flow. Launch service providers can mitigate mission risk through the use of predictable and proven interfaces standardized to streamline analytical/physical integration processes and test flows.
Specific areas of interest:

- Launch adapters and systems and associated spacecraft standards.
- Standardized spacecraft and/or payload integration test flows, processes and qualification techniques.
- Standardized electrical interface standards, sometimes known as plug and play electrical power and data bus standards for streamlined subsystem integration.

Priority should be given to practical solutions that:

- Enable low-cost and reliable reusable standards and adapter systems.
- Demonstrate a higher likelihood of being incorporated into a wide number of commercial or government space access system, or systems.
- Can achieve flight or high-fidelity ground-based demonstrations within the next three years; longer-term development proposals will be accepted, but will be considered at a lower priority for funding.

**T7.03 Flexible Polymer Foams Systems for Fireproofing and Energy Absorption**

**Lead Center: KSC**

NASA has a growing need for flexible polymer foams for cryogenic insulation, fireproofing, energy absorption and other aerospace applications. NASA Chemists and Engineers at Langley Research Center and Kennedy Space Center have been developing high performance polyimide foams for the last 15 years or more for such applications with great success in varying densities, addressing cell content and effects on performance properties, and additionally producing composites of such foams with enhanced thermal conductivity. In addressing applications for these high performance foams, it has also been identified that increased flexibility with structural integrity foams are also needed in polyurethane foam systems. Advances in novel approaches to polyurethane foam systems are desired to address increased flexibility, good flame retardancy and acoustic attenuation properties for future vehicle and ground systems. The goal is explore new flexible foam systems that control cell content and offer “breathable” characteristics allowing for foam use in potential ice mitigation in such applications as umbilical systems. Delayed time to ignition, decreased peak heat release rates and smoke generation in non-halogen flame retardancy are also advantageous for response to this solicitation.
Autonomous Systems Topic T8

Autonomous and robotic systems are a critical capability in all of NASA’s mission areas including Aeronautics, Earth and Planetary Sciences, and Human Spaceflight and will be more pervasive in the future. Current systems are primarily automated, able to respond to a predicted set of conditions and require human interaction and control. The goal of this topic area is to develop technologies and capabilities that will lead fully autonomous systems that are able to learn and adapt to changes in their environment that were not predicted to accomplish the mission goals with minimal or no human involvement required, particularly if communication delays are significant or unavailable. Specific capabilities include perception, cognition, and mobility/manipulation to enable Multi-robotic systems, Atmospheric Flight and Remote Sensing and Navigation in GNSS-Denied Environments.

Sub Topics:

T8.01 Autonomous Multi-Robotic Systems

Lead Center: LaRC

Current NASA research/development and mission capabilities are primarily focused on single, automated robotic systems. For example, exploration of remote planetary surfaces has used single automated Telerobotic vehicles, dependent on human control, which limits the area covered, scope of mission and risk of a single point mission failure.

The goal of this topic area is to develop technologies and capabilities that will lead to fully autonomous systems that are able to learn and adapt to changes in their environment that were not predicted to accomplish the mission goals with minimal or no human involvement required. Of specific interest in this topic area is techniques for cooperation among multiple robotic vehicles to achieve complete mission objectives autonomously that cannot be accomplished by current robotic architectures. This would permit the exploration of larger spatial areas/volumes, increase system redundancy and enable distributed capability deployment, where vehicles can have varying sensor/manipulator capabilities to better achieve a broad range of objectives. The system would autonomously distribute required tasks amongst themselves based upon each vehicle’s capabilities/equipment package and adapt to changes in the environment, learned knowledge and failures on individual vehicles.

Three possible examples of multiple cooperating vehicles systems are described below, but other concepts will be considered:

- A “Parent” vehicle would provide transportation, control and logistical support for multiple “Child” vehicles, extending data gathering and mapping operations. For example, a Walker/Gecko could provide access to subterranean areas, the Walker navigating large rock fields, while the Gecko would be employed for exploring lava tubes and caves. The system requirements include: docking, deployment, recovery, and storage of the Child vehicles; re-fueling the Child vehicles; local navigation and communication, and adapting to potential failures, including the loss of communication.
A flying swarm of a large number of smaller vehicles, operating autonomously yet cooperatively, could extend the exploration range while maintaining direct surface contact as the swarm "hops" from point to point. Such a design has the added benefit that individual failure would not condemn the mission to fail (e.g., 80% of individuals could fail with 100% mission success). A swarm design presents new problems such as how the swarm will effectively fly in formation and how the swarm will determine course of action. Because much of the environment is unknown, the swarm must adapt to unforeseen situations. Centralized control and predetermined script execution is likely not practical. Without directions from a central controller, individual members of the swarm are limited to local observations and communication with neighboring members. From these observations, individuals must make autonomous decisions and take individual action. From these actions, a behavior emerges. Thus, the challenge is to design the swarm for desired emergent behavior beyond just formation flying, the swarm must demonstrate decisions on actions to complete an exploratory mission without a central controller, but rather the combined action of autonomous individuals.

A sensor network, a distribution of a large number of connected, capable devices distributed over a region, could extend the range of exploration without the requirement for mobility. Conventional sensor network design is limited to a sense and send scenario where individual devices periodically sense the environment and send information through a multi-hop network of others to the central controller. However, a much more complex mission could be accomplished by a "virtual swarm" over the distribution. While the individual devices remain fixed after initial deployment, the application could move around the network as required to complete the mission. To take full advantage of the architecture and achieve maximum success, the application must adapt to unforeseen circumstances presented by the environment. A successful demonstration will exhibit communication among a fixed set of devices that directs where and when observations are taken and what actions will be taken to complete a mission (i.e., virtual mobility). Devices must not be directed by a central controller or a predetermined script but must exhibit adaptive behavior to a non-deterministic scenario.

Phase I activities should include an assessment of current technology capabilities relative to future requirements, identify technology gaps and lay out a technology development roadmap for an integrated system. An integrated software simulation of the proposed concepts is desirable. Potential subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of an integrated prototype system of multiple cooperating autonomous vehicles.
reason, and adapt. Military applications have demonstrated the ability to do automated flight but their use in civil aviation requires additional research and development. The primary interest of this sub-topic is to advance the technologies for robotic and autonomous vehicle perception, cognition, as well as system integration. Proposals should be written around one of the following themes described below:

- Autonomous and robotic air-vehicles can enable new markets reduce operational cost, and improve safety. Autonomous systems can be applied far beyond remotely piloted aircraft. Maximum machine effectiveness can only be realized through vehicle autonomous systems ability to learn, reason and adapt. Current practice is to have a reliance on stored information, which is complemented by GPS position information. If there is an on-board, real-time means to sense and react to the local environment (including air and ground features and traffic), then autonomous and robotic air-vehicle can be fully utilized. But addressing how adaptive systems can still be ‘trusted’ in critical flight environments and achieve FAA certification is a technical issue that must be resolved. Proposals are sought to develop innovate approaches and enabling technologies for autonomous, robotic, and embodied intelligent air-vehicles. Example scenarios could include but are not limited to carrying passengers and cargo through the NAS, search, rescue, and surveillance operations, and sentries to patrol coastal waters, and land borders. Proposal should consider perception, cognition, as well as GPS enabled, GPS-denied, and cooperating and non-cooperating traffic environments.

- There are a broad range of technical subjects relevant to these new aviation markets and highly diverse aircraft operations include Machine and Operational Autonomy, Off-Nominal Autonomy, Future Consensus and Statistically Based Regulatory Processes, Safety Assurance, Software Certification, Electric and Redundant Propulsion Systems, Airspace Separation Assurance and Detection, Peer-to-Peer Deconfliction, Wireless Sensor Networks for Smart Aircraft Sub-Systems, Fault Tolerant Systems, and Multi-Spectral Sensing and Data Fusion. Proposals are also sought in the integration of these technologies in combination to achieve new societal capabilities across specific aircraft configurations. Therefore, emergent vehicle autonomy platforms that can showcase capabilities that were previously unable to be performed (without autonomy). One example would be the ability to follow complex flight paths such as dynamic soaring, where autonomy enables an entirely new ability through both predictive and optimal trajectory planning and execution. Likewise extreme Short and Vertical Takeoff and Landing aircraft have key gust response sensitivities that could be greatly enhanced through degrees of autonomy within the control loop to achieve much faster response, and therefore new flight capabilities. Of particular interest is the ability to showcase how spiral development and rapid experimentation in aerial robotics can provide early lessons learned and guidance for future larger-scale technology investment. Such efforts could leverage the ability of dynamically-scaled sub-scaled vehicle testing to push very low high risk technology readiness levels to higher levels that more easily justify research investment.

- Autonomous Remote Sensing Measurement Technologies required to support Advanced Flight Testing, Earth Science, and Intelligence, Surveillance and Reconnaissance (ISR) Applications. NASA's HYTHIRM project (AIAA-2010-241) has demonstrated an emerging capability to obtain quantitative global thermal surface temperatures associated with a hypersonic vehicle in flight. The available technology adequately measured the acreage surface temperature of the Shuttle lower surface during reentry. Future hypersonic cruise vehicles or advanced launcher configurations will challenge affordable human-in-the-loop remote imaging capability in terms of high speed tracking, spatial/spectral resolution and temperature sensitivity. A next generation system would entail a “smart payload” with a UAS optimally designed around it. The payload would ultimately permit autonomous long range target acquisition, tracking, image stabilization and enhancement, real-time sensor re-configuration and aircraft attitude/orientation to optimize the data collect thus significantly increasing mission flexibility while reducing operational costs. Phase I proposal should include an assessment of current imaging technology capabilities for spatially resolved thermal imagery along with requirements for a next generation autonomously controlled sensor/platform system. Proposals should consider Identification of technology gaps and lay out of a technology development roadmap. Software and hardware demonstrations are encouraged. Integration and autonomous control of the following technologies include: system simulation software; advanced high resolution focal plane array development including multi-color focal plane arrays; large apertures; miniaturization of high frame rate multi-waveband (i.e., visible, NIR, SWIR, MWIR, LWIR) including spectral/hyperspectral sensors; advanced
radiometric simulation software; real time imaging processing and post processing deconvolution algorithms; adaptive optics; target recognition and low latency tracking algorithms; active feedback for platform command and control functions and local navigation and communication. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable of integrating with a UAS.

T8.03 Autonomous Navigation in GNSS-Denied Environments

Lead Center: LaRC

Current NASA research/development and mission capabilities for exploration of remote planetary surfaces are primarily focused on automated telerobotic systems dependent on human control. More fully autonomous systems will be required for future missions, particularly where communications with Earth may be limited, unavailable for extended periods of time and have significant delays.

This subtopic is to investigate the autonomous navigation capabilities required for land and possibly aerial vehicle operation in areas lacking GNSS and/or magnetic compass to expanded exploration roles within planetary environments. A specific area of interest is to investigate biologically inspired algorithms and capabilities, such as techniques used by insects, such as Honey Bees, to accomplish this goal. Optical flow, image motion across the field of vision, offers unique capabilities for hazard detection and avoidance, landmark navigation, distance judgment, cave navigation, speed regulation, and visual odometry. Current technology is very computationally intensive. It is desired that with hardware support, high speed optic flow measurements can be obtained to speed up and simplify the extraction of motion information from the visual scene, which would both enhance obstacle and hazard detection and avoidance, as well as speed up the navigation process. This will be very critical if VTOL flight can be achieved, as a fuel-limited, in-motion VTOL vehicle is ill positioned to wait for a complicated and time consuming image analysis to be accomplished. Additionally, current laser scanner/imaging technology used for generating terrestrial 3D maps have mass and power requirements that are excessive for smaller planetary robotic exploration systems. Low mass, low power 3D mapping systems accommodated on planetary missions could be employed to support autonomous vehicle navigation and maneuvering operations. One example would be a parent vehicle that could launch multiple smaller vehicles that would autonomously explore larger regions and then navigate back to the parent vehicle to transmit data and refuel. In addition to navigation, these vehicles could gather detailed, photorealistic 3D maps that can be fused with associated science data and used by scientists, students, and the general public for "participatory exploration" activities.

Initial activities would include an assessment of current technology capabilities that could be compared to requirements to identify technology gaps, lay out a technology development roadmap, and develop a software simulation of proposed system and operation. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable autonomous navigation in environments that do not allow GNSS or magnetic compass navigation and have limited or no communication between vehicles.
Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing Topic T9

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

Sub Topics:

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

*Lead Center: MSFC*

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

- Polymer Matrix Composites (PMCs) Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant, repairable, and self-healing technologies; advanced materials and manufacturing processes for both cryogenic and high-temperature applications.

- Ceramic Matrix Composite (CMCs) and Ablatives CMC materials and processes are projected to significantly increase safety and reduce costs simultaneously while decreasing system weight for space transportation propulsion.

- Solid-state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites, and high strength and high temperature or functionally graded materials.

- New advanced super alloys that resist hydrogen embrittlement and are compatible with high-pressure oxygen; innovative thermal-spray or cold-spray coating processes that substantially improve material properties, combine dissimilar materials, application of dense deposits of refractory metals and metal carbides, and coating on nonmetallic composite materials.

- Advanced NDE Methods Portable and lightweight NDE tools provide characterization of polymer, ceramic and metal-matrix composites, areas include, but are not limited to, microwaves, millimeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.

- Improvement in techniques for predicting the self-generated dynamics of space propulsion system when operated at off-design conditions.
Improvement in techniques for predicting the acoustic field produced by the operation of a space propulsion system in near ground operation.

Predictive capability of the performance and internal environment for systems, solid or liquid propellants, undergoing multi-phase combustion. Of special interest are systems utilizing nano-energetics solid fuels.

Predictive capability improvements for the coupled fluid-structural problem with focus on accurate prediction of heat-transfer that occurs in the chamber of a nuclear thermal rocket.

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

Development of databases and instrumentation advances required for validation of previously mentioned predictive capabilities.

Rocket Propulsion/Energy Conservation Topic T10

NASA’s Stennis Space Center (SSC) seeks advanced technologies to support its testing of rocket engines including innovative approaches for component technologies, advanced rocket facility environment and health monitoring, new materials for rocket plume deflection and technologies for propellant conservation. Technologies are also sought to improve the Center's energy conservation and sustainability.

Sub Topics:

**T10.01 Test Area Technologies**

Lead Center: SSC

**Innovative Component Technologies**

The focus of this topic is the development of innovative rocket test facility components (e.g., valves, flowmeters, actuators, tanks, etc.) for ultra high pressure (>8000 psi), high flow rate (>100 lbm/sec), and cryogenic environments. Robust and reliable component designs which are oxygen compatible and can operate efficiently in high vibro-acoustic, transient environments are being sought. Components which can also provide coupled high-speed (kHz-MHz) measurement and control of rocket propellant feed systems with minimum induced system losses are desirable. Proposals of innovative valve design concepts which will provide true linear performance for installed configurations and/or provide dynamically adjustable valve trimming are encouraged. Expected TRL at end of Phase I is 2, and at the end of Phase II is 4.

**Advanced Rocket Facility Environment and Health Monitoring**

Development of practical, industrial-grade, advanced flow/thermal diagnostics and smart sensors to monitor the near field environment (thermal, acoustic, emission) that a rocket test facility is exposed to during an engine/stage testing is requested. Examples of advanced rocket test environment diagnostics would include high-speed robust scanning or visualization of rocket exhaust plumes for simultaneous heat flux, species/temperature and/or near-field acoustics. In addition to the rocket test induced environments, infrastructure health monitoring and management for test facilities and for widely distributed support systems (WDSS) such as gas distribution and cooling water is needed. Capabilities being sought for WDSS include remote monitoring of vacuum lines, gas leaks,
and fire, where the use of wireless technologies in order to eliminate running miles of power and data wires would be beneficial in this application. The proposed innovative systems must lead to improved safety and reduced test costs by allowing real-time analysis of data, information, and knowledge through efficient interfaces to enable integrated awareness of the system condition by users. Need for improved technologies are mid-term, and highly desirable. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

**Development of New Materials for Rocket Plume Deflection**

Refractory materials are commonly used to provide thermal protection of rocket plume deflectors on test facilities and launch pads. Advancement of refractory materials or development of new materials for the requirement of minimizing erosion (1500 BTU/ft²/sec) and shear/normal loads caused by the direct impingement of rocket exhausts is desired. Unlike launch facilities, test facilities are exposed to the plume environments for long durations (on the order of minutes) making the material requirements for minimum erosion even more stringent. The newly proposed material would need to be competitive to the material, installation and repair costs of current commercial grade high-temperature refractory materials. Also, the material development proposal should demonstrate the performance of the material in dynamically similar environments as would be present on the rocket test stand. Expected TRL at end of Phase I is 2, and at the end of Phase II is 4.

**Technologies for Propellant Conservation**

The objective is to minimize usage of costly gases (helium and hydrogen) through devices that can recover/recycle efflux from cryogenic test facilities (currently no recovery is done). This could include technologies such as real time gas sampling/contamination monitoring system for propellant and purge systems that could also help minimize use of non renewable resources such as Helium, or Helium reclamation carts for recapture of inert/purges. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

**T10.02 Energy Conservation and Sustainability**

**Lead Center: SSC**

John C Stennis Space Center (SSC) is a large rocket propulsion test facility located in southern Mississippi close to the Louisiana state line. Energy consumption is very large to sustain the static engine testing and supporting facilities. In an effort to conserve on energy and enhance the sustainability of these and other SSC facilities, interest exists in pursing innovative approaches to energy savings, water efficiency, CO₂ emission reductions, improved environmental quality. This includes the use of green technologies that support LEED certification. Technologies which have potential to support multiple centers or programs are highly desirable. The following listing includes some specific areas of interests for supporting SSC's energy conservation goals:

**Innovative Energy Conservation Technologies**

SSC is interested in innovative technologies for reducing energy consumption and improving building sustainability through the use of alternative energy sources including of geothermal, natural gas and solar. Those using renewable sources of energy are highly desired. The goal is to reduce overall energy consumption and the Center's carbon footprint. Energy conservation technologies must also be cost effective to implement and maintain. Concepts will be evaluated based on their potential efficiency, ease of implementation and maintenance, and flexibility of applications (including, but not limited to, HVAC, preheating hot water heaters, and other means of
extracting energy), as well as, applicability to the Center's mission. Proposals will also be evaluated based on the maturity level to which the technology will be developed and innovative techniques. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Facility Sustainability Technologies

SSC is interested in innovative technologies for enhancing building and facility sustainability. The goal is to reduce the life-cycle costs for sustainability facilities and testing through the use of green or renewable products. Specific areas of interest include technologies which help sustain a healthy workplace including mold spore filtration, self-decontamination and air purification. Concepts will be evaluated on the innovativeness, maturity level of the technology and long-term viability of the concept. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Lighting Technology

Stennis Space Center is interested in developing innovative technologies, systems, or methodologies that will reduce the energy consumption and heat generation from facility lighting while maintaining the desired level of illumination for safety and effective work environments. SSC is interested in innovative lighting technologies for the test areas, office areas and parking lots. Innovative approaches for bringing natural lighting through skylights or other receptors are also of interest. These lighting technologies will need to reduce energy consumption while maintaining a comfortable and safe working environment. Technologies can be for replacement a technology or optimization of current facility lighting system. SSC is particularly interested in replacing costly lighting in the test area (test stands, hydrogen/oxygen environments, hazardous and potentially corrosive environments). The lighting should be in compliance with IESNA RP 7-01, Practice for Industrial Lighting. Proposals will be evaluated based on the maturity level to which the technology will be developed and innovative techniques that will provide a reasonable life expectancy. Proposals will also be evaluated on implementation strategy and ease of maintenance. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Solar Technology

Reduction in energy consumption and subsequent energy cost is a high priority at SSC. SSC is interested in developing new technologies for the efficient and effective use of photovoltaic/solar cell to reduce energy costs. Major issues in the development and use of solar panel include efficient system design and installation as well as effective maintenance. Innovative approaches and tools to facilitate the design of efficient solar cell systems, effective application of solar cells systems for building rooftops or a separate field area of solar cells are desired as well as innovative approaches to the monitor the health of the system and maintenance methods to insure the most effective and efficient operations of the system in an environment with high humidity, extensive rain showers, high pollen counts, rapid mold and fungal growth, etc. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.
Synthetic Biology for Space Exploration Topic T1.01

The field of Synthetic Biology is a rapidly growing area of study that encompasses research ranging from the introduction of incremental function or regulation into existing organisms to the creation of fully synthetic living structures and systems. NASA is interested in harnessing this emerging field to create technological advances for multiple mission focus areas. Topics include biological life support for air, water and waste management; local production of fuels, food and plastics; in situ resource utilization (ISRU) technologies such as biomining for metals and biocementation of regolith for building materials/radiation shielding; biomedical applications including in situ therapeutic production and radiation/gravity countermeasures; advanced chemical and life sensing; and fabrication of advanced materials. Overarching research concerns include using synthetic biology techniques for the development of life forms that have been specifically adapted to perform well in extraterrestrial environments, including increased resistance to radiation, desiccation and temperature extremes. Foundational and applied solutions are sought that provide game-changing capabilities that enable cost effective and sustainable spaceflight and habitation.

Sub Topics:

Commodity Based Technologies Topic T1.02
This subtopic seeks out-of-the-box, innovative, broad-based approaches to address space mission requirements.

Desired proposals would enable the commoditization of space mission requirements by utilizing existing commercial technology goods and services to reduce schedule and costs of implementation.

Examples:

Smart-phones today are able to perform many of the basic capabilities of the spacecraft, having a high speed processor with large memory capacity, a set of sensors such as an accelerometer, rate gyroscopes, magnetometer, global positioning system (GPS).

Another example would be using multiple COTS (commercial off the shelf) digital cameras with multiple color filter settings, and then combining the image as a hyper-spectral imager at low cost. Other consumer goods that may have high utility for small spacecraft include but are not limited to:

- PDA-based smart phones.
- High resolution digital cameras.
- Consumer robotics.
- Lego-like assemblies.
• Medical grade surgical adhesives.
• Pressure sensitive paint.
• In-situ bioanalytical diagnostics.
• Mining technologies.
• Biohybrid devices.
• Diagnostics.
• X10-based domonics.

Proposers are asked to build a conceptual system/spacecraft design/operational scenario that details the architecture, components and specifications. Supporting analysis including cost and feasibility should be included. Phase II contract efforts should be used to prototype the system(s) detailed in Phase I.

Proposals should focus on the following areas of research:

• Transformational Small Spacecraft, Subsystems, and Mission Architectures.
• Biological Technologies for Life Beyond Low Earth Orbit.
• GREEN Technologies (Technologies for Sustainability).
• Emerging Aeronautics Systems and Technologies.
• Autonomous Laboratories on Planetary Surfaces.
• Hybrid Systems Modeling and Analysis.
• Advanced Information, Robotics, and Autonomous Systems.

Proposals that focus on the above areas of research, and contribute to the NASA Space Technology Grand Challenges will have higher priority.

Reference Documents:

• Grand Challenges
  • http://www.nasa.gov/pdf/503466main_space_tech_grand_challenges_12_02_10.pdf [1]
Sub Topics:
Information Technologies for Intelligent Planetary Robotics Topic T1.03

The objective of this subtopic is to develop information technologies that enable robots to better support planetary exploration. Intelligent robots are already at work in all of NASA's Mission Directorates and will be critical to the success of future exploration missions. The 2010 NASA "Robotics, Tele-Robotics, and Autonomous Systems Roadmap" (RTA Roadmap) indicates that extensive and pervasive use of intelligent robots can significantly enhance exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

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

The RTA Roadmap identifies three key areas for improvements in robotics:

- Technology should aim to exceed human performance in sensing, piloting, driving, manipulating, rendezvous and docking.
- Technology should target cooperative and safe human interfaces to form human-robot teams.
- Autonomy should make human crews independent from Earth and robotic missions more capable.

Thus, proposals are sought which address the following topics:

- Advanced user interfaces for remote robotic exploration, which include Web-based collaboration methods, panoramic and time-lapse imagery, support for public outreach/citizen science, social networking and/or visualization of geospatial information. The primary objectives are to enable more efficient interaction with robots, to facilitate situational awareness, and to enable a broad range of users to participate in robotic exploration missions.
- Ground control data systems for robotic exploration. Proposals should focus on software tools for planning
variable-duration and adjustable autonomy command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing; and/or for automating ground control functions.

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

- Robot software architecture that radically reduces operator workload for remotely operating planetary rovers. This may include: on-board health management and prognostics, on-board automated data triage (to prioritize information for downlink to ground), and learning algorithms to improve hazard detection and selection of locomotion control modes.

Sub Topics:
Technologies for Aeronautics Experimental Capabilities Topic T2.01

The emphasis of this subtopic is proving feasibility, developing, and demonstrating technologies for advanced flight research experimentation that matures new methodologies, technologies, and concepts. It seeks advancements that promise significant gains in NASA's flight research capabilities or addresses barriers to measurements, operations, safety, and cost in all flight regimes from low sub-sonic to high supersonic. This subtopic solicits innovative technologies that enhance flight research competencies by advancing capabilities for in-flight experimentation. Proposals that demonstrate and confirm reliable application of concepts and technologies suitable for flight research and the test environment are a high priority.

Measurement techniques are needed to acquire aerodynamic, structural, flight control, and propulsion system performance characteristics to safely expand the flight envelope of aerospace vehicles. The goals are to improve the effectiveness of flight-testing by simplifying and minimizing sensor installation, measuring parameters in novel ways, improving the quality of measurements, and minimizing the disturbance to the measured parameter from the sensor presence. Sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.

Special areas of interest include:

- Methods and associated technologies for conducting flight research and acquiring test information in flight.
- Numerical methods for the planning, prediction, analysis and validation of flight-test experimentation.
- Sensors and data systems that have fast response, low volume, minimal intrusion, and increased accuracy and reliability.
- Innovative techniques that decrease turn-around time for inspections and assessments for safe operations of aircraft (e.g., non destructive examination of composites through ultrasonic techniques).
- Advanced design and manufacturing techniques for improved upper stage performance for nano- & small-satellite booster technologies (e.g., manufacturability, affordability, and performance of a small upper-stage booster rocket motors for small & nano-satellites).

- Novel dynamic modeling and simulation of aircraft flight and structural control are encouraged. Control objectives include aerodynamic boundary layer and laminar flow control, autonomous and adaptive systems for improved stability, safety, performance, and drag reduction.

Sub Topics:
Aeroservoelastic (ASE) Control, Modeling, Simulation, and Optimization Topic T2.02

This subtopic addresses advanced control-oriented techniques for aeroservoelastic (ASE) flight systems including distributed network sensor systems, modeling, simulation, optimization and stabilization methods of ASE systems to actively and/or adaptively control wing geometry, vibration, gust/turbulence response, static/dynamic loads, and other aeroelastic (AE) objectives for enhanced aeroservoelastic performance and stability characteristics.

Technical elements for these proposals may include:

- ASE enhancements for flight control while minimizing adverse AE interaction.
- Flexible aircraft stabilization and performance optimization.
- Modeling and system identification of distributed AE dynamics with aircraft flight dynamics.
- Sensor/actuator developments and modeling for ASE control.
- Uncertainty modeling of complex ASE system behavior and interactions.
- Distributed networked control schemes for wing shape, vibration, and load control.
- Boundary-layer, shock, and viscous flow sensing with AE control feedback.
- Mission/maneuver adaptivity with dissipative optimal energy-force distribution.
- Data-driven multi-objective ASE control with physics-based aeroelastic sensing.
- Compressive information-based sensing.

This subtopic also addresses capabilities enabling design solutions for performance and environmental challenges of future air vehicles. Research in revolutionary aircraft configurations include lighter and more flexible materials, improved propulsion systems, and advanced concepts for high lift and drag reduction. This subtopic targets efficiency and environmental compatibilities requiring performance challenges and novel control-oriented techniques for aeroservoelastic considerations which are gaining prevalence in advanced aerospace flight vehicles, atmospheric and extra-terrestrial.
Development of distributed sensory-driven control-oriented ASE systems is solicited to enable game-changing flight vehicle concepts and designs that manage aerostructural dynamic uncertainty on a vehicle’s overall performance. This subtopic will assist in revolutionizing improvements in performance to empower a new generation of air vehicles to meet the challenges of Next Generation Air Transportation System (NextGen) concerns, concepts and technology developments in systems analysis, integration and evaluation.

Higher performance measures include energy efficiency to reduce fuel burn and operability technologies that enable takeoff and landing on shorter runways. Distributed aeroelastic control allows for robust nonintrusive flush sensing for control near stall and ground effects, accounting for vehicle flexibility. Proposals should describe how such improvements with distributed ASE systems promote new applications of flight with experimental methods to establish validation data in areas comparable to:

- Reduced take-off and landing field length requirements.
- Improved performance with lightweight structures and low drag aerodynamics.
- Multi-disciplinary design and analysis tools and processes to enable reliable, advanced aircraft configurations with control-oriented sensory-driven design concepts for flight near performance/stability limits.
- Transonic and supersonic shock/boundary-layer control in an aeroelastic environment.
- Sensory and control systems for the reduction of ASE uncertainty from hypersonic aerodynamic heat loads, resulting in lower vehicle weight from reduced design margins for thermal structures and thermal protection systems.
- Integration of interactions among the airframe, inlet, nozzle, and propulsion systems using physics-based ASE control-oriented design approach.

Sub Topics:
Technologies for Space Power and Propulsion Topic T3.01

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

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

Innovations, advanced concepts and processes are sought for in-space propulsion, including electric propulsion, chemical propulsion, advanced rocket propellants/alternative fuels, nuclear propulsion, and tether technology. In electric propulsion, concepts for subcomponent improvements are needed for electric propulsion systems, including cathode technologies, electrode-less plasma production, low-erosion materials, high-temperature magnetics, and lightweight simplified power processing systems. Innovations are also desired for low thrust trajectory analysis tools and new diagnostic techniques to quantify thruster performance and lifetime. In small chemical thruster propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

Sub Topics:
Innovative Sensors, Support Subsystems and Detectors for Small Satellite Applications Topic T4.01

As the launch opportunities of very small satellites increase, NASA needs advanced capabilities to be developed in order to increase the viability of world-class scientific and technological applications within smaller constraints. This will allow NASA to use every class of orbiting system to make measurements to improve the scientific understanding of the Earth, the Sun and the cosmos.

This STTR solicitation is to help provide advanced technologies for satellites with masses less than approximately 20 kg and volumes less than approximately 10,000 cm³. Components or subsystems are sought that demonstrate a capability that is applicable to orbital missions to 800 km and mission durations up to 2 years. New approaches, instruments, and components are sought that will:

- Enable new Earth Science, Solar Science, or Astronomy measurements.
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal
resolution, accuracy, range of regard).

- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same measurement capability.

- Provide satellite bus capabilities that increase the capabilities of very small satellites while meeting the significant constraints imposed by the very limited size and mass of the observatory.

**Small Satellite Subsystem Technologies**

Components and subsystems are required to furnish satellite bus capabilities for very small satellites. The subsystems are mass and volume constrained to a reasonable portion of satellites that must have total masses and volumes less than 20 kg and 10,000 cm$^3$. In particular, NASA needs advanced component and/or subsystems designs for power, attitude control, telemetry, structures, propulsion, data and command processing, ground communication, and crosslink communication.

Components and subsystems must be those that consider the severe mass, volume, and power constraints imposed by these very small spacecraft.

**Small Satellite Sensors**

Sensors are required that support the assessment the state of spacecraft, and formations of spacecraft, needed to conduct sophisticated NASA science and technology missions. Sensors are required for spacecraft attitude, position, and velocity; relative attitude position and velocity; and accelerations. In addition, component temperatures, mechanism states, and magnetic field strength and direction are also needed.

**Small Satellite Science Detectors and Instruments**

Instruments or detectors are required that support Earth Science, Solar Physics, and Astrophysics experiments. Components and subsystems must be those that consider the severe mass, volume, and power constraints imposed by these very small spacecraft.

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**Sub Topics:**  
Technologies for Planetary Compositional Analysis and Mapping Topic T5.01

This subtopic is focused on developing and demonstrating technologies for both orbital and in situ compositional analysis and mapping that can be proposed to future planetary missions. Technologies that can increase instrument resolution, precision and sensitivity or achieve new & innovative scientific measurements are solicited.
Possible areas of interest include:

- Improved sources such as lasers, LEDs, X-ray tubes, etc. for imaging and spectroscopy instruments (including Laser Induced Breakdown Spectroscopy, Raman Spectroscopy, Deep UV Raman and Fluorescence spectroscopy, Hyperspectral Imaging Spectroscopy, and X-ray Fluorescence Spectroscopy).

- Improved detectors for imaging and spectroscopy instruments (e.g., flight-compatible iCCDS and other time-gated detectors that provide gain, robot arm compatible PMT arrays and other detectors requiring high voltage operation, detectors with improved UV and near-to-mid IR performance, near-to-mid IR detectors with reduced cooling requirements).

- Technologies for 1-D and 2-D raster scanning from a robot arm.

- Novel approaches that could help enable in situ organic compound analysis from a robot arm (e.g., ultra-miniaturized Matrix Assisted Laser Desorption-Ionization Mass Spectrometry).

- "Smart software" for evaluating imaging spectroscopy data sets in real-time on a planetary surface to guide rover targeting, sample selection (for missions involving sample return), and science optimization of data returned to Earth.

- Other technologies and approaches (e.g., improved cooling methods) that could lead to lower mass, lower power, and/or improved science return from instruments used to study the elemental, chemical, and mineralogical composition of planetary materials.

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

- The suitability of the technology for flight applications, e.g., mass, power, compatibility with expected shock and vibration loads, radiation environment, interplanetary vacuum, etc.

- Advantages of the proposed technology compared to the competition.

- Relevance of the technology to NASA's planetary exploration science goals.
This STTR sub-topic seeks to advance the state-of-the-art in spacecraft life support, thermal control, extra-vehicular activity and habitation systems, leading toward the ability to sustain a crew in space for years with minimal supplies launched from Earth. Atmosphere, water and waste all need to be regenerated with highly reliable systems to reduce or eliminate the need to launch parts and supplies to maintain the systems. The crew must also be protected from the dangers of the deep space environment. During extra-vehicular activity, this poses additional difficulties. Specific challenges areas where NASA is soliciting new ideas are described below.

**Wastewater Reuse**

Recycling of wastewater from gray and black water sources with minimal mass, power, volume and expendables is needed. Source separation of hygiene wastewater and urine water may be assumed. A particular challenge is the stabilization of urine to prevent odor and fouling of systems without the use of hazardous chemicals. Any stabilization system should be compatible with the extraction of nearly 100% of the water from brine if concentrated wastewater is created by primary processors.

**Improved Thermal Control**

Long life (>1 year) active thermal control systems are needed that can operate over a wide range of heat loads in a wide range of thermal environments. Reduced freezing point (Also, water/ice phase change heat exchangers are needed to accommodate thermal management in environments that vary from very cold to warmer than room temperature. A successful design will efficiently transfer heat into and out of the water while managing the location of the ice and void space. The heat exchanger should be capable of ten thousand freeze/thaw cycles without damage.

**Robust Extra-Vehicular Activity**

A state of the art Extra Vehicular Activity (EVA) space suit is made of multiple layers of fabrics with a hard upper torso and metal bearings. These fabric layers provide physical and mechanical protection for the astronaut, as well as thermal isolation and pressurization for EVA in vacuum. There are several materials development advances that could significantly revolutionize space suit design. These advances consist of combining some of the functions provided by the current suit layers into fewer layers or using new materials to improve suit sizing methods. There is a need not only to improve existing properties of the space suit such as flame retardancy or decreased mass but also add new properties such as microbial growth resistance, selective permeability, static build-up resistance, improved MMOD protection, and radiation shielding. These improvements would increase mission safety and the useful life of the space suit. Increased radiation protection could increase the number of hours crew members spend performing EVAs over their career. Materials that reduce charge build up or decrease shock hazards would alleviate risks associated with interfacing different vehicles or performing EVAs in a plasma environment. Materials that are self healing could improve astronaut protection by detecting punctures and small cuts and even repairing suit damage. In addition, there is a need for micrometeorite shielding technology of the crew during EVAs.

Vacuum Regenerable Trace Contamination Control for spacesuits is also sought. A spacesuit is a small, closed environment in which the atmosphere is continually recycled. Therefore, a means of removing air borne trace contaminants is needed to protect the health of the crew member during an Extravehicular Activity (EVA). The primary contaminants in question for space suit applications are thought to be ammonia and formaldehyde, and the Spacecraft Maximum Allowable Concentrations (SMAC) for these contaminants are 7 mg/m³ and 0.3 mg/m³, respectively. Expected generation rates for these two contaminants are approximated at ~80 mg of ammonia and ~0.3 mg of formaldehyde during an 8 hour EVA. The current Portable Life Support System (PLSS) concept uses a
CO₂ and humidity control technology that regenerates with a 3 to 10 minute vacuum cycle. A trace contamination control technology that could regenerate with this same vacuum cycle, that minimizes mass, power, and system pressure drop is desired.

Sub Topics:
Active Debris Removal Technologies Topic T6.02

After more than 50 years of human space activities, orbital debris has become a problem in the near-Earth environment. The total mass of debris in orbit is close to 6000 tons at present. The U.S. Space Surveillance Network is currently tracking more than 22,000 objects larger than about 10 cm. Additional optical and radar data indicate that there are approximately 500,000 debris larger than 1 cm, and more than 100 million debris larger than 1 mm in the environment. Because of the high impact speed between orbiting objects in space, debris as small as 0.2 mm poses realistic threat to Human Space Flight (EVA suit penetration, Shuttle window replacement, etc.) and other critical national space assets.

Recent modeling studies indicate that debris mitigation measures commonly-adopted by the international community will be insufficient to stop the debris population growth in low Earth orbit (LEO, the region below 2000 km altitude). To better preserve the space environment for future generations, active debris removal (ADR) of large and massive upper stages and spacecraft must be considered. The need for ADR is also highlighted in the National Space Policy of the United States of America, released by the White House in June 2010. The Policy explicitly directs NASA and the Department of Defense to “pursue research and development of technology and techniques to mitigate and remove on-orbit debris.” Orbital debris is also one of the NASA Grand Challenges outlined by the Office of the Chief Technologist.

An end-to-end ADR operation includes, in general terms, launches; propulsion; guidance, navigation & control; proximity operations; precision tracking; rendezvous; stabilization (of the spinning/tumbling targets); capture/attachment; and deorbit/graveyard maneuvers. Some of the technologies involved in the ADR process do exist, but the difficulty is to make them more cost effective. Other technologies, such as ways to stabilize a large and massive spinning/tumbling upper stage and the capture mechanisms, are new and will require major innovative research and development efforts. In addition, many of the potential ADR targets are upper stages with leftover propellants stored in pressurized containers. Any capture mechanisms of those upper stages will have to be carefully designed to reduce the possibility of explosion.

The focus of this subtopic is to support the development and advancement of cost-effective technologies and techniques to address any of the sub-components described above for active debris removal in LEO. The ultimate goal is to develop the full capability of an end-to-end ADR demonstration in LEO in 5 to 10 years.
The exhaust plume from a launch vehicle rocket engine generates severe acoustic waves, which cause acoustic loading on the ground structures and vehicle payload. Prediction and reduction of the acoustic levels in the near field of launch vehicle lift-off is an important factor that should be taken into consideration early in the design process of the space launch complex.

The Kennedy Space Center is dedicated for ground systems operation. It is crucial that ground support equipments (GSE) and launch pad structures are designed to withstand the launch-induced environments produced by the first-stage rocket exhaust plume.

High-fidelity prediction technique such as computational aeroacoustics (CAA) can be used to resolve the acoustic flow field in an accurate fashion. It is understood that CAA prediction can be computationally intensive and often prohibitive for a large domain as in the launch environment. However, recent advances in computational resources and methodology have allowed CAA to overcome these difficulties. In the past few years, researchers have employed CAA in the launch environment\cite{1,2,3}. These results are promising, but they need to be validated against actual data. The economical way of getting acoustic data is from static firing in a subscale or full scale environment. The problem with static firing test is that they do not reveal the dynamic environment. Flight data from actual launch would yield much better data, but such data are limited and costly. The best alternative would be to collect data from a demonstration launch vehicle.

It is proposed that a capability be developed to perform launch acoustics research by launching a demonstration reusable vehicle from one of the launch pads at KSC or Cape Canaveral Air Force Station (CCAFS), with acoustic sensors installed on the vehicle and in the vicinity of the launch complex. The capability will allow raw data to be processed into one-third octave band sound pressure level and used for benchmarking results obtained from CAA analysis.

References:

This STTR topic seeks commercial solutions that will allow and encourage standardization of key payload to launch vehicle, and subsystem interface standards to reduce the cost associated with analysis, integration, and preparation required to design and then configure space systems for launch. The goal is a set of launch vehicle adapters, processes, and avionics interface standards that can be collectively used to facilitate spacecraft and subsystem design while reducing testing duration and complexity, overall reducing mission risk and while enabling novel mission concepts.

These sets of systems will focus on new standards for payload in the following mass ranges:

- 1 to 10kg.
- 11 to 50kg.
- 51 to 100kg.
- 101 to 180kg.

These ranges have been identified as the regions where critical technologies demonstrations and new space technologies could be used to increase TRL level at a lower cost with reduced risk. Enabling these capabilities will allow spacecraft developers the ability to design to a specific mass range that will result in on orbit research.

This STTR will be used to evaluate each of the current and future launch vehicles in determining where cross cutting standards can be applied to the entire NASA launch vehicle fleet.

The STTR has been classified as highly desirable. This rating was determined because there are adapters in place that could support the missions. However, to have multiple systems across multiple launch vehicles will contribute to higher cost for integration of that mission. By having standards amongst the space craft and adapter community will reduce the per kilogram cost to orbit.

A significant fraction of mission costs are typically unique designs and approaches to perform relatively routine functions such as launch accommodations and subsystem-to-subsystem interface and communications. By standardizing many of these approaches, spacecraft and payload developers can design their systems with an expectation of a predictable, low-cost integration flow. Launch service providers can mitigate mission risk through the use of predictable and proven interfaces standardized to streamline analytical/physical integration processes and test flows.

Specific areas of interest:
Launch adapters and systems and associated spacecraft standards.

Standardized spacecraft and/or payload integration test flows, processes and qualification techniques.

Standardized electrical interface standards, sometimes known as plug and play electrical power and data bus standards for streamlined subsystem integration.

Priority should be given to practical solutions that:

- Enable low-cost and reliable reusable standards and adapter systems.
- Demonstrate a higher likelihood of being incorporated into a wide number of commercial or government space access system, or systems.
- Can achieve flight or high-fidelity ground-based demonstrations within the next three years; longer-term development proposals will be accepted, but will be considered at a lower priority for funding.

Sub Topics:
Flexible Polymer Foams Systems for Fireproofing and Energy Absorption Topic T7.03

NASA has a growing need for flexible polymer foams for cryogenic insulation, fireproofing, energy absorption and other aerospace applications. NASA Chemists and Engineers at Langley Research Center and Kennedy Space Center have been developing high performance polyimide foams for the last 15 years or more for such applications with great success in varying densities, addressing cell content and effects on performance properties, and additionally producing composites of such foams with enhanced thermal conductivity. In addressing applications for these high performance foams, it has also been identified that increased flexibility with structural integrity foams are also needed in polyurethane foam systems. Advances in novel approaches to polyurethane foam systems are desired to address increased flexibility, good flame retardancy and acoustic attenuation properties for future vehicle and ground systems. The goal is explore new flexible foam systems that control cell content and offer “breathable” characteristics allowing for foam use in potential ice mitigation in such applications as umbilical systems. Delayed time to ignition, decreased peak heat release rates and smoke generation in non-halogen flame retardancy are also advantageous for response to this solicitation.

Sub Topics:
Autonomous Multi-Robotic Systems Topic T8.01
Current NASA research/development and mission capabilities are primarily focused on single, automated robotic systems. For example, exploration of remote planetary surfaces has used single automated Telerobotic vehicles, dependent on human control, which limits the area covered, scope of mission and risk of a single point mission failure.

The goal of this topic area is to develop technologies and capabilities that will lead to fully autonomous systems that are able to learn and adapt to changes in their environment that were not predicted to accomplish the mission goals with minimal or no human involvement required. Of specific interest in this topic area is techniques for cooperation among multiple robotic vehicles to achieve complete mission objectives autonomously that cannot be accomplished by current robotic architectures. This would permit the exploration of larger spatial areas/volumes, increase system redundancy and enable distributed capability deployment, where vehicles can have varying sensor/manipulator capabilities to better achieve a broad range of objectives. The system would autonomously distribute required tasks amongst themselves based upon each vehicle's capabilities/equipment package and adapt to changes in the environment, learned knowledge and failures on individual vehicles.

Three possible examples of multiple cooperating vehicles systems are described below, but other concepts will be considered:

- A “Parent” vehicle would provide transportation, control and logistical support for multiple “Child” vehicles, extending data gathering and mapping operations. For example, a Walker/Gecko could provide access to subterranean areas, the Walker navigating large rock fields, while the Gecko would be employed for exploring lava tubes and caves. The system requirements include: docking, deployment, recovery, and storage of the Child vehicles; re-fueling the Child vehicles; local navigation and communication, and adapting to potential failures, including the loss of communication.

- A flying swarm of a large number of smaller vehicles, operating autonomously yet cooperatively, could extend the exploration range while maintaining direct surface contact as the swarm "hops" from point to point. Such a design has the added benefit that individual failure would not condemn the mission to fail (e.g., 80% of individuals could fail with 100% mission success). A swarm design presents new problems such as how the swarm will effectively fly in formation and how the swarm will determine course of action. Because much of the environment is unknown, the swarm must adapt to unforeseen situations. Centralized control and predetermined script execution is likely not practical. Without directions from a central controller, individual members of the swarm are limited to local observations and communication with neighboring members. From these observations, individuals must make autonomous decisions and take individual action. From these actions, a behavior emerges. Thus, the challenge is to design the swarm for desired emergent behavior beyond just formation flying, the swarm must demonstrate decisions on actions to complete an exploratory mission without a central controller, but rather the combined action of autonomous individuals.

- A sensor network, a distribution of a large number of connected, capable devices distributed over a region, could extend the range of exploration without the requirement for mobility. Conventional sensor network design is limited to a sense and send scenario where individual devices periodically sense the environment and send information through a multi-hop network of others to the central controller. However, a much more complex mission could be accomplished by a "virtual swarm" over the distribution. While the individual devices remain fixed after initial deployment, the application could move around the network as required to complete the mission. To take full advantage of the architecture and achieve maximum success, the application must adapt to unforeseen circumstances presented by the environment. A successful demonstration will exhibit communication among a fixed set of devices that directs where and when observations are taken and what actions will be taken to complete a mission (i.e., virtual mobility). Devices must not be directed by a central controller or a predetermined script but must exhibit adaptive behavior to
Phase I activities should include an assessment of current technology capabilities relative to future requirements, identify technology gaps and lay out a technology development roadmap for an integrated system. An integrated software simulation of the proposed concepts is desirable. Potential subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of an integrated prototype system of multiple cooperating autonomous vehicles.

Sub Topics:
Autonomous Systems for Atmospheric Flight and Remote Sensing Topic T8.02

Increasing levels of automation capabilities in the aviation arena, provides unique opportunities and challenges for civil aviation, and the aerial transport communities. Flight will be transformed as these capabilities mature and evolve into integrated systems. In particular, autonomous and robotic, manned and unmanned civil aircraft systems will lead to a plethora of new markets, vehicle, and missions. These new systems with broad range of capabilities, and a huge diversity of shapes and sizes, must safely utilize the future National Airspace System. Both operational and machine autonomy will require tremendous breakthroughs through the new technology frontiers in machine intelligence, autonomy, robotics, and inter-connections of these technologies. Breakthroughs in these areas could lead to such societal capabilities as autonomous cargo carrying, surveillance, air taxis, small unmanned civil aircraft, Zip aircraft, on-demand VTOL aviation, airborne wind energy platforms and a host of other emerging distributed aviation systems. For purposes of this solicitation, autonomous vehicles have varying levels of autonomy that range from automated capability to fully autonomous flight where the system has the ability to learn, reason, and adapt. Military applications have demonstrated the ability to do automated flight but their use in civil aviation requires additional research and development. The primary interest of this sub-topic is to advance the technologies for robotic and autonomous vehicle perception, cognition, as well as system integration. Proposals should be written around one of the following themes described below:

- Autonomous and robotic air-vehicles can enable new markets reduce operational cost, and improve safety. Autonomous systems can be applied far beyond remotely piloted aircraft. Maximum machine effectiveness can only be realized through vehicle autonomous systems ability to learn, reason and adapt. Current practice is to have a reliance on stored information, which is complemented by GPS position information. If there is an on-board, real-time means to sense and react to the local environment (including air and ground features and traffic), then autonomous and robotic air-vehicle can be fully utilized. But addressing how adaptive systems can still be 'trusted' in critical flight environments and achieve FAA certification is a technical issue that must be resolved. Proposals are sought to develop innovative approaches and enabling technologies for autonomous, robotic, and embodied intelligent air-vehicles. Example scenarios could include but are not limited to carrying passengers and cargo through the NAS, search, rescue, and surveillance operations, and sentries to patrol coastal waters, and land borders. Proposal should consider perception, cognition, as well as GPS enabled, GPS-denied, and cooperating and non-cooperating traffic environments.

- There are a broad range of technical subjects relevant to these new aviation markets and highly diverse aircraft operations include Machine and Operational Autonomy, Off-Nominal Autonomy, Future Consensus and Statistically Based Regulatory Processes, Safety Assurance, Software Certification, Electric and Redundant Propulsion Systems, Airspace Separation Assurance and Detection, Peer-to-Peer Deconfliction, Wireless Sensor Networks for Smart Aircraft Sub-Systems, Fault Tolerant Systems, and Multi-Spectral Sensing and Data Fusion. Proposals are also sought in the integration of these technologies in combination to achieve new societal capabilities across specific aircraft configurations. Therefore, emergent vehicle
autonomy platforms that can showcase capabilities that were previously unable to be performed (without autonomy). One example would be the ability to follow complex flight paths such as dynamic soaring, where autonomy enables an entirely new ability through both predictive and optimal trajectory planning and execution. Likewise extreme Short and Vertical Takeoff and Landing aircraft have key gust response sensitivities that could be greatly enhanced through degrees of autonomy within the control loop to achieve much faster response, and therefore new flight capabilities. Of particular interest is the ability to showcase how spiral development and rapid experimentation in aerial robotics can provide early lessons learned and guidance for future larger-scale technology investment. Such efforts could leverage the ability of dynamically-scaled sub-scaled vehicle testing to push very low high risk technology readiness levels to higher levels that more easily justify research investment.

- Autonomous Remote Sensing Measurement Technologies required to support Advanced Flight Testing, Earth Science, and Intelligence, Surveillance and Reconnaissance (ISR) Applications. NASA's HYTHIRM project (AIAA-2010-241) has demonstrated an emerging capability to obtain quantitative global thermal surface temperatures associated with a hypersonic vehicle in flight. The available technology adequately measured the acreage surface temperature of the Shuttle lower surface during reentry. Future hypersonic cruise vehicles or advanced launcher configurations will challenge affordable human-in-the-loop remote imaging capability in terms of high speed tracking, spatial/spectral resolution and temperature sensitivity. A next generation system would entail a “smart payload” with a UAS optimally designed around it. The payload would ultimately permit autonomous long range target acquisition, tracking, image stabilization and enhancement, real-time sensor re-configuration and aircraft attitude/orientation to optimize the data collection thus significantly increasing mission flexibility while reducing operational costs. Phase I proposal should include an assessment of current imaging technology capabilities for spatially resolved thermal imagery along with requirements for a next generation autonomously controlled sensor/platform system. Proposals should consider Identification of technology gaps and lay out of a technology development roadmap. Software and hardware demonstrations are encouraged. Integration and autonomous control of the following technologies include: system simulation software; advanced high resolution focal plane array development including multi-color focal plane arrays; large apertures; miniaturization of high frame rate multi-waveband (i.e., visible, NIR, SWIR, MWIR, LWIR) including spectral/hyperspectral sensors; advanced radiometric simulation software; real time imaging processing and post processing deconvolution algorithms; adaptive optics; target recognition and low latency tracking algorithms; active feedback for platform command and control functions and local navigation and communication. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable of integrating with a UAS.

Sub Topics:
Autonomous Navigation in GNSS-Denied Environments Topic T8.03

Current NASA research/development and mission capabilities for exploration of remote planetary surfaces are primarily focused on automated telerobotic systems dependent on human control. More fully autonomous systems will be required for future missions, particularly where communications with Earth may be limited, unavailable for extended periods of time and have significant delays.

This subtopic is to investigate the autonomous navigation capabilities required for land and possibly aerial vehicle operation in areas lacking GNSS and/or magnetic compass to expanded exploration roles within planetary environments. A specific area of interest is to investigate biologically inspired algorithms and capabilities, such as techniques us by insects, such as Honey Bees, to accomplish this goal. Optical flow, image motion across the field of vision, offers unique capabilities for hazard detection and avoidance, landmark navigation, distance judgment, cave navigation, speed regulation, and visual odometry. Current technology is very computationally intensive. It is desired that with hardware support, high speed optic flow measurements can be obtained to speed up and simplify the extraction of motion information from the visual scene, which would both enhance obstacle and hazard detection and avoidance, as well as speed up the navigation process. This will be very critical if VTOL flight can be
achieved, as a fuel-limited, in-motion VTOL vehicle is ill positioned to wait for a complicated and time consuming image analysis to be accomplished. Additionally, current laser scanner/imaging technology used for generating terrestrial 3D maps have mass and power requirements that are excessive for smaller planetary robotic exploration systems. Low mass, low power 3D mapping systems accommodated on planetary missions could be employed to support autonomous vehicle navigation and maneuvering operations. One example would be a parent vehicle that could launch multiple smaller vehicles that would autonomously explore larger regions and then navigate back to the parent vehicle to transmit data and refuel. In addition to navigation, these vehicles could gather detailed, photorealistic 3D maps that can be fused with associated science data and used by scientists, students, and the general public for “participatory exploration” activities.

Initial activities would include an assessment of current technology capabilities that could be compared to requirements to identify technology gaps, lay out a technology development roadmap, and develop a software simulation of proposed system and operation. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable autonomous navigation in environments that do not allow GNSS or magnetic compass navigation and have limited or no communication between vehicles.

Sub Topics:
Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing Topic T9.01

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

- Polymer Matrix Composites (PMCs) Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant, repairable, and self-healing technologies; advanced materials and manufacturing processes for both cryogenic and high-temperature applications.

- Ceramic Matrix Composite (CMCs) and Ablatives CMC materials and processes are projected to significantly increase safety and reduce costs simultaneously while decreasing system weight for space transportation propulsion.

- Solid-state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites, and high strength and high temperature or functionally graded materials.

- New advanced super alloys that resist hydrogen embrittlement and are compatible with high-pressure
oxygen; innovative thermal-spray or cold-spray coating processes that substantially improve material properties, combine dissimilar materials, application of dense deposits of refractory metals and metal carbides, and coating on nonmetallic composite materials.

- Advanced NDE Methods Portable and lightweight NDE tools provide characterization of polymer, ceramic and metal-matrix composites, areas include, but are not limited to, microwaves, millimeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.

- Improvement in techniques for predicting the self-generated dynamics of space propulsion system when operated at off-design conditions.

- Improvement in techniques for predicting the acoustic field produced by the operation of a space propulsion system in near ground operation.

- Predictive capability of the performance and internal environment for systems, solid or liquid propellants, undergoing multi-phase combustion. Of special interest are systems utilizing nano-energetics solid fuels.

- Predictive capability improvements for the coupled fluid-structural problem with focus on accurate prediction of heat-transfer that occurs in the chamber of a nuclear thermal rocket.

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

- Development of databases and instrumentation advances required for validation of previously mentioned predictive capabilities.

Sub Topics:

Test Area Technologies Topic T10.01

Innovative Component Technologies

The focus of this topic is the development of innovative rocket test facility components (e.g., valves, flowmeters, actuators, tanks, etc.) for ultra high pressure (>8000 psi), high flow rate (>100 lbm/sec), and cryogenic environments. Robust and reliable component designs which are oxygen compatible and can operate efficiently in high vibro-acoustic, transient environments are being sought. Components which can also provide coupled high-speed (kHz-MHz) measurement and control of rocket propellant feed systems with minimum induced system losses are desirable. Proposals of innovative valve design concepts which will provide true linear performance for installed configurations and/or provide dynamically adjustable valve trimming are encouraged. Expected TRL at end of Phase I is 2, and at the end of Phase II is 4.

Advanced Rocket Facility Environment and Health Monitoring

Development of practical, industrial-grade, advanced flow/thermal diagnostics and smart sensors to monitor the near field environment (thermal, acoustic, emission) that a rocket test facility is exposed to during an engine/stage testing is requested. Examples of advanced rocket test environment diagnostics would include high-speed robust scanning or visualization of rocket exhaust plumes for simultaneous heat flux, species/temperature and/or near-field acoustics. In addition to the rocket test induced environments, infrastructure health monitoring and management for test facilities and for widely distributed support systems (WDSS) such as gas distribution and cooling water is needed. Capabilities being sought for WDSS include remote monitoring of vacuum lines, gas leaks, and fire, where the use of wireless technologies in order to eliminate running miles of power and data wires would be beneficial in this application. The proposed innovative systems must lead to improved safety and reduced test
costs by allowing real-time analysis of data, information, and knowledge through efficient interfaces to enable integrated awareness of the system condition by users. Need for improved technologies are mid-term, and highly desirable. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

**Development of New Materials for Rocket Plume Deflection**

Refractory materials are commonly used to provide thermal protection of rocket plume deflectors on test facilities and launch pads. Advancement of refractory materials or development of new materials for the requirement of minimizing erosion (1500 BTU/ft²/sec) and shear/normal loads caused by the direct impingement of rocket exhausts is desired. Unlike launch facilities, test facilities are exposed to the plume environments for long durations (on the order of minutes) making the material requirements for minimum erosion even more stringent. The newly proposed material would need to be competitive to the material, installation and repair costs of current commercial grade high-temperature refractory materials. Also, the material development proposal should demonstrate the performance of the material in dynamically similar environments as would be present on the rocket test stand. Expected TRL at end of Phase I is 2, and at the end of Phase II is 4.

**Technologies for Propellant Conservation**

The objective is to minimize usage of costly gases (helium and hydrogen) through devices that can recover/recycle efflux from cryogenic test facilities (currently no recovery is done). This could include technologies such as real time gas sampling/contamination monitoring system for propellant and purge systems that could also help minimize use of non renewable resources such as Helium, or Helium reclamation carts for recapture of inert/purges. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

**Sub Topics:**

Energy Conservation and Sustainability Topic T10.02

John C Stennis Space Center (SSC) is a large rocket propulsion test facility located in southern Mississippi close to the Louisiana state line. Energy consumption is very large to sustain the static engine testing and supporting facilities. In an effort to conserve on energy and enhance the sustainability of these and other SSC facilities, interest exists in pursing innovative approaches to energy savings, water efficiency, CO₂ emission reductions, improved environmental quality. This includes the use of green technologies that support LEED certification. Technologies which have potential to support multiple centers or programs are highly desirable. The following listing includes some specific areas of interests for supporting SSC's energy conservation goals:

**Innovative Energy Conservation Technologies**

SSC is interested in innovative technologies for reducing energy consumption and improving building sustainability through the use of alternative energy sources including of geothermal, natural gas and solar. Those using renewable sources of energy are highly desired. The goal is to reduce overall energy consumption and the Center's carbon footprint. Energy conservation technologies must also be cost effective to implement and maintain. Concepts will be evaluated based on their potential efficiency, ease of implementation and maintenance, and flexibility of applications (including, but not limited to, HVAC, preheating hot water heaters, and other means of extracting energy), as well as, applicability to the Center's mission. Proposals will also be evaluated based on the maturity level to which the technology will be developed and innovative techniques. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.
Innovative Facility Sustainability Technologies

SSC is interested in innovative technologies for enhancing building and facility sustainability. The goal is to reduce the life-cycle costs for sustainability facilities and testing through the use of green or renewable products. Specific areas of interest include technologies which help sustain a healthy workplace including mold spore filtration, self-decontamination and air purification. Concepts will be evaluated on the innovativeness, maturity level of the technology and long-term viability of the concept. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Lighting Technology

Stennis Space Center is interested in developing innovative technologies, systems, or methodologies that will reduce the energy consumption and heat generation from facility lighting while maintaining the desired level of illumination for safety and effective work environments. SSC is interested in innovative lighting technologies for the test areas, office areas and parking lots. Innovative approaches for bringing natural lighting through skylights or other receptors are also of interest. These lighting technologies will need to reduce energy consumption while maintaining a comfortable and safe working environment. Technologies can be for replacement a technology or optimization of current facility lighting system. SSC is particularly interested in replacing costly lighting in the test area (test stands, hydrogen/oxygen environments, hazardous and potentially corrosive environments). The lighting should be in compliance with IESNA RP 7-01, Practice for Industrial Lighting. Proposals will be evaluated based on the maturity level to which the technology will be developed and innovative techniques that will provide a reasonable life expectancy. Proposals will also be evaluated on implementation strategy and ease of maintenance. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Solar Technology

Reduction in energy consumption and subsequent energy cost is a high priority at SSC. SSC is interested in developing new technologies for the efficient and effective use of photovoltaic/solar cell to reduce energy costs. Major issues in the development and use of solar panel include efficient system design and installation as well as effective maintenance. Innovative approaches and tools to facilitate the design of efficient solar cell systems, effective application of solar cells systems for building rooftops or a separate field area of solar cells are desired as well as innovative approaches to the monitor the health of the system and maintenance methods to insure the most effective and efficient operations of the system in an environment with high humidity, extensive rain showers, high pollen counts, rapid mold and fungal growth, etc. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Sub Topics: