NASA SBIR 2011 Phase I Solicitation

O3 Processing and Operations

The Space Operations Mission Directorate (SOMD) provides mission critical space exploration services to both NASA customers and to other partners within the U.S. and throughout the world: from flying out the Space Shuttle, to assembling and operating the International Space Station; ensuring safe and reliable access to space; maintaining secure and dependable communications between platforms across the solar system; and ensuring the health and safety of our Nation's astronauts. Activities include ground-based and in-flight processing and operations tasks, along with support that ensures these tasks are accomplished efficiently and accurately enables successful missions and healthy crews. This topic area, while largely focused on operational space flight activities, is broad in scope. NASA is seeking technologies that address how to improve and lower costs related to ground and flight assets, and maximize and extend the life of the International Space Station. A typical flight focused approach would include:

- Phase I: Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.
- Phase II: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions.

The proposal shall outline a path showing how the technology could be developed into space-worthy systems. For ground processing and operations tasks, the proposal shall outline a path showing how the technology could be developed into ground or flight systems. The contract shall deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract and, if possible, demonstrate earth based uses or benefits.

Subtopics

O3.01 Remotely Operated Mobile Sensing Technologies for inside ISS

Lead Center: ARC

Participating Center(s): JPL

This subtopic seeks proposals to develop technologies that advance capabilities for space telepresence and mission operations situation awareness, fault diagnosis, isolation, and recovery onboard the ISS using an onboard free-flyer as a mobile sensor platform. In order to increase productivity and reduce risks on long-missions on spacecraft, such as the ISS, leading toward human exploration, commercialization, and colonization of space, ground personnel have a need to remotely command a wide-variety of sensors on mobile platforms to collect data from a variety of positions within spacecraft. The sensors include, but are not limited to, those capable of performing imaging, identifying inventory, and measuring electromagnetic radiation, temperature, acoustics, atmospheric properties, and chemical concentrations. To increase crew productivity, it is highly desirable that the mobile platform be capable of being deployed by ground command, move to the commanded location, collect data, and then return to its storage dock where it is recharged all without requiring crew assistance.

This subtopic solicitation calls for developing a variety of software and hardware technologies that would enable a free-flyer to operate in multiple modules inside ISS including but not limited to:

- Free-flyer localization capability without engineering environment.
- Collision avoidance capability.
- Adjustable autonomous control software that supports safe operation with low-bandwidth, intermittent command communication loop with varying latencies > 10 sec.
- EXPRESS rack-based auto-docking, recharging, refueling, deployment mechanism with matching free-flyer mechanism.
- Quiet propulsion capability meeting ISS noise limit requirements (
- Vision-based object identification capability.
- RFID-based inventory identification capability.

Proposals may address any one or a combination of the above or related subjects.

Three SPHERES satellites have operated inside ISS since 2006. In addition to performing dozens of experiments, these satellites demonstrate that mobile platforms in the form of free-flyers can be operated on ISS. However, these satellites have not been operated by ground personnel and their current design is inadequate to meet the needs described above for several reasons, e.g., the satellites require crew assistance to operate, require that batteries and CO_2 cartridges (propellant) be replaced by crew between test sessions, and are confined to a work area bounded by external beacons used by the satellites to localize themselves within their workspace, approximately 2x2x2 meters. However, the SPHERES satellites may be useful in demonstrating technologies called for by this subtopic. Proposals are encouraged that leverage the SPHERES satellites operating onboard ISS and SPHERES engineering units at the NASA Ames Research Center. More information on SPHERES is at:

- http://www.nasa.gov/mission_pages/station/research/experiments/SPHERES.html.
- http://ssl.mit.edu/spheres.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Report with a feasibility study including: simulations and measurements demonstrating the approach used to develop and test the prototype, constraints on other systems, concept of operations, verification matrix of measurements with pass/fail ranges for each quantity to be verified at the end of Phase II, and the Phase II integration path.
- Proof-of-concept simulation and/or bench top demonstration (TRL 3-4).

Phase II Deliverables:

- Midterm Technical Report.
- Final Phase II Technical Report with specifications including: design, development approach, tests to verify the prototype, verification matrix of measurements with pass/fail ranges for each quantity verified, constraints on other systems, and operations guide. Opportunities and plans for potential commercialization should also be included.
- Fully-functional engineering prototype of proposed product (TRL 5-6).

O3.02 ISS Utilization

Lead Center: JSC

Participating Center(s): ARC, GRC, KSC

NASA is investigating the near- and mid-term development of highly-desirable systems and technologies that provide innovative ways either to leverage existing ISS facilities for new scientific payloads or, to provide on orbit analysis to enhance capabilities and reduce sample return requirements.

Current utilization of the ISS is limited by available upmass, downmass, and crew time as well as by the capabilities of the interfaces and hardware already developed. Innovative interfaces between existing hardware and systems, which are common to ground research, could facilitate both increased, and faster, payload development.

Desired capabilities include, but are not limited to, the below examples:

- Enabling additional cell and molecular biology culture techniques. Providing innovative hardware to allow for safe, contained transfer of cells from container to container within the Microgravity Sciences Glove Box (MSG) would permit new types of studies on ISS. On orbit analysis techniques that would reduce or remove the need for downmass - such as a system for gene array tests, or kits for DNA extractions for long term storage - are also examples of hardware possibilities that would extend and enable additional research.

- Providing compact Dynamic Light Scattering (DLS) hardware. Development of a compact robust DLS instrument based on diode lasers and photo detectors capable of providing significant power and weight savings now make it possible to measure the diffusion coefficient of experimental systems using the Light Microscopy Module (LMM) on the International Space Station (ISS). The light scattering instrument (laser, detector, optics) to be mounted on a Leica DM/RXA microscope camera port should be about the size of a 40mm diameter tube around 60mm long) with associated support electronics (including the correlator) being able to fit into a volume of about 30mm x 100mm x 100mm, or less. The intensity dynamic range should be able to cover between 10^-10 to 10^-7 Watts. The relaxation time range should be capable to spanning 200nsec to 50sec. This peer-reviewed science was considered a decade ago but not developed due to technology limitations. It is now possible to meet the required performance criteria (with the above size and power requirements) to measure diffusion coefficients. From the measured diffusion coefficient, particle size can be extracted, or the temperature determined for the location being viewed (e.g., in a capillary cell with a temperature gradient along it) can be deduced (for known particles and solvents) using the Stokes-Einstein equation.

- Providing compact laser tweezers and supporting software. Development of a compact robust Holographic Laser Tweezers (LT) instrument and associated control scripts for use with a microscope on the International Space Station (ISS) based on the recent developments of holographic techniques. This could expand the types of experiments conducted on orbit. The laser tweezers that would mount on a Leica DM/RXA microscope should be less than ~100mm on a side and the associated control electronics should be less than ~150mm on a side. This technology should now be robust side it is solid-state and no longer requires gimbaled mirrors. This peer-reviewed science was previously considered but not developed because of the size and technology limitations of a decade ago. LT holds open the possibility of performing scientific experiments that manipulate groups of particles that evolve uniquely in space when gravitational sedimentation and jamming no longer exist. Any new LT and its corresponding control software should allow for tracking of particle positions to better than one micron in 3D (before the concentration becomes too high) and impart rotational forces. Being able to accurately track the position of particles while measuring the forces on them is important for laying the foundations of colloidal engineering. Because of its use on space station, the instrument should be self-calibrating. The instrument would need to meet the size and volume limitations of the Light Microscopy Module (LMM).

- Providing additional on-orbit analytical tools. Providing flight qualified hardware that is similar to commonly used tools in biological and material science laboratories could allow for an increased capacity of on-orbit analysis thereby reducing the number of samples, which must be returned to Earth. Examples of tools that will reduce downmass or expand on-orbit analysis include: sample handling tools; mass measurement devices; a (micro) plate reader; a mass spectrometer; an atomic force microscope (for biological and material science samples), non-cryogenic sample preservation systems; autonomous in-situ bioanalytical technologies; centrifuges for analysis and for providing fractional-g environments; microbial and cell detection and identification systems; and fluidics and microfluidics systems to allow autonomous on-orbit experimentation and high throughput screening.

- Providing Nanorack compatible inserts to enable additional life science payloads. Development of 1, 2 and/or 4 cube design biological payload hardware for use with the ISS Nanorack platform would decrease the need for development of multiple control racks and reduce development time of future payload experiments.

- Enabling additional payloads. Innovative methods for further subdividing payloads lockers would allow for numerous pico-payloads. Developing multi-generational or multi-use habitats would reduce the upmass and downmass required to conduct biological experiments on ISS.

The existing hardware suite and interfaces available on ISS may be found at: http://www.nasa.gov/mission_pages/station/research/experiments_category.html.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Written report detailing evidence of demonstrated technology (TRL 5 or 6) in the laboratory or in a relevant environment and stating the future path toward hardware and software demonstration on orbit.

Phase II Deliverables: Hardware and/or software prototype that can be demonstrated on orbit (TRL 7).

O3.03 ISS Demonstration & Development of Improved Exploration Technologies

Lead Center: JSC

Participating Center(s): ARC

The focus of this subtopic is on technologies and techniques that may advance the state of the art of spacecraft systems by utilizing the International Space Station as a technology test bed.

Successful proposals will address using the long duration, microgravity and extreme vacuum environment available on the ISS to demonstrate component or system characteristics that extend beyond the current state of the art by:

- Increasing capability/operating time including overall operational availability.
- Reducing logistics and maintenance efforts.
- Reducing operational efforts, minimizing crew interaction with both systems and the ground.
- Reducing known spacecraft/spaceflight technical risks and needs.
- Providing information on the long-term space environment needed in the development of future spacecraft technologies through model development, simulations or ground testing verified by on orbit operational data.

While selection for award does not guarantee flight opportunities, the proposed demonstrations should focus on increasing the TRL in the following technology areas of interest:

- Propulsion (in-space and novel, electromagnetic and/or very high specific impulse systems).
- Power and energy storage.
- Robotics tele-robotics and autonomous (RTA) Systems.
- Human health, life support and habitation systems.
- Science instruments, observatories and sensor systems.
- Nanotechnology.
- Materials, structures, mechanical systems and manufacturing.
- Thermal management systems including novel heat radiation techniques.
- Spacecraft (including ISS) plasma and contamination in-situ diagnostics.
- Environmental control systems, including improved carbon dioxide removal.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.

Phase II Deliverables: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

O3.04 Vehicle Integration and Ground Processing

Lead Center: KSC

Participating Center(s): SSC

This subtopic seeks to create new and innovative technology solutions to improve safety and lower the life cycle costs of assembly, test, integration and processing of the ground and flight assets at our nation's spaceports and propulsion test facilities. The following areas are of particular interest:

Control of Material Degradation

Technologies are needed to reduce costs due to material degradation of materials in spaceport and propulsion test facility infrastructure and ground support equipment, Material solutions must meet current and emerging environmental restrictions and endure today's corrosive and highly acidic launch environments. These needs include:

- New environmentally friendly technologies for paint removal and surface preparation that can be applied to large structures. New technologies must achieve better performance than conventional abrasive blasting techniques by reducing the cost of collecting and/or processing waste while keeping blasting rates the same or better than conventional technologies. These technologies must work for inorganic zinc coating.
- New environmentally friendly technologies for prevention/reduction of microbial corrosion in steel piping systems utilizing brackish or untreated water.
- Sub-scale or laboratory tests that can be used to evaluate the suitability of refractory concrete for use in launch pad and rocket test facilities flame deflectors. Proposed tests must show that they are relevant to full scale blast effects.
- Innovative refractory material application methods to ensure field applications have the same properties (strength, density, performance, etc...) as small scale test coupons.

Spaceport Processing Evaluation/Inspection Tools

Innovative solutions are desired that reduce inspection times, provide higher confidence in system reliability, increase safety and lower life cycle costs. Technologies must support identifying composite material defects, evaluating material integrity, damage inspection and/or acceptance testing of composite systems. These include:

- Technologies in support of defect detection in composite materials.
- Methods for determining structural integrity of composite materials and bonded assemblies.
- Non-intrusive inspection of Composite Overwrapped Pressure Vessels (COPV), Orion heat shield and other composite systems.
- In-situ evaluation of refractory concrete as installed in the flame trenches associated with propulsion test and launch pad infrastructure.

Hypergolic Propellant Sensing Technologies

Technologies for leak detection and leak visualization for hypergolic propellants, such as:

- Novel, cost effective technology solutions to provide leak detection of hypergolic propellants at concentrations of 10ppb with minimal environmental sensitivity (i.e., humidity). Sensors and leak detection systems should provide quantitative data with minimum interferences, drift, and exposure and recovery time.

- Novel, cost effective technology solutions to provide leak detection of hypergolic propellants at concentrations of 1ppm with minimal environmental sensitivity (i.e., humidity). Sensors and leak detection systems should provide quantitative data with minimum interferences, drift, and exposure and recovery time.

- Technology to provide leak visualization of hypergolic propellants to support operations (propellant loading, pressurization, leak check).

Cold Gas Storage and Servicing of Launch Vehicle Systems

Storing high-pressure pneumatic gases in a chilled state increases the on board density of gasses used for pressurization during flight. Traditional solutions embed these 3000 - 6000 psig metallic tanks into the flight vehicles' main cryogenic propellant tanks. To achieve the lightest weight tanks, final pressurization takes place after the tanks are immersed to maximize strength gained by the lower temperatures. Under these conditions, it takes several hours to achieve thermal equilibrium with the host tank and maximize mass density of the compressed gas. Solutions are sought to reduce this time to less than 60 minutes to achieve thermal equilibrium of the compressed gas with the host liquid cryogen tank and maximize pneumatic gas mass on board the flight vehicle.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware or software demonstration and delivering a demonstration unit or package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Demonstration of technical feasibility (TRL 2-4).

Phase II Deliverables: Demonstration of technology (TRL 4-6)

O3.05 Advanced Motion Imaging

Lead Center: MSFC

Participating Center(s): JSC

Digital motion imaging technologies provide great improvements over analog systems, but also present significant challenges. Digital High Definition Television (HDTV) cameras flown on the Shuttle and International Space Station have shown higher susceptibility to ionizing radiation damage, manifested by visible "dead" pixels in the image. In order to practically deploy HDTV cameras, sensors and processors need to survive operations on orbit for years without debilitating radiation damage that degrades image quality and performance.

The focus of this subtopic is the development of components, systems, and core technologies that advance the capabilities to capture, process and distribute high-resolution digital motion imagery without performance degradation from ionizing radiation that would require frequent upmass to orbit to replace components or systems.

Current State of the Art

HDTV cameras flown on the Space Shuttle and the International Space Station have proven to be highly susceptible to damage from ionizing radiation. This damage is manifested by bad pixels that eventually render the camera useless after short periods of on-orbit use, usually less than one year. In addition, upmass and downmass constraints make the use of large format motion picture film cameras impractical, so a digital equivalent is needed for large venue documentary film productions, such as IMAX films.

Domains of Interest

Domains of interest in the near term address needs for space environment, radiation tolerant, HDTV and digital cinema cameras and down-stream video processors. Mid and Long term goals include radiation tolerant, reprogrammable, highly bandwidth efficient encoders and improved distribution systems for video data signals. Current HDTV transmissions from the ISS require approximately 25 Mbps. Bitrates with equal or better video quality are desired at half that bit rate. These systems are highly desired by the human spaceflight programs.

Technologies of Interest

Technologies are sought that provide high resolution, progressively scanned motion imagery with limited or mitigated radiation damage to sensors, are viable for astronaut hand-held applications or external spacecraft use, and that provide imagery that meets standards commonly used by digital television or digital cinema production facilities. Commercial HDTV cameras used for internal hand-held use have generally been small and light (5" x 6" x 11", between 2 and 3 pounds), run off rechargeable batteries, and utilize standard lens mounts. Future cameras for exterior applications ideally would be smaller and more modular in design (no larger than 4" x 5" x 7" and 2.5 pounds). The critical technology need is the radiation tolerance of the sensor, not the size, weight and mass of the camera that results from such a sensor.

While commercial HDTV and Digital Cinema cameras for use on Earth are mature technologies, there are no flight-proven radiation tolerant HDTV and Digital Cinema cameras and sensors currently available. Commercial cameras flown on the Shuttle and ISS thus far do function, but degrade within a year on orbit. While hard to classify, the current TRL for these cameras within the context of spaceflight operations could be considered to be a 5 or 6. The ultimate goal is to develop radiation-hardened camera sensors capable of surviving three or more years in space.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration, and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Deliverables for Phase I will include designs and development plans with plausible data and rationale that demonstrates why the designs and plans should mitigate radiation effects on the sensors, and a detailed path towards Phase II hardware demonstration. The report shall also provide options for commercialization opportunities after Phase II.

Phase II Deliverables: Deliverables for Phase II will include developmental hardware suitable for testing in a lab or space flight environment (TRL 6) as well as a test plan, relevant data, and defined expected lifespan of the sensors.

O3.06 Environmental Control Systems & Technologies for NR & Cubesats

Lead Center: ARC

A significant challenge faced by free-flying spacecraft and shared by ISS-bound experiment packages is the requirement for a controlled (or at least known) environment while the payload is awaiting launch on the launch vehicle or is in transit to the ISS. Due to the retirement of the Space Shuttle, NASA has a need for flight qualified, environmentally conditioned transportation systems compatible with new space launch systems capable of sustaining and extending the life of perishable materials and specimens until experiment packages can be installed and properly interfaced on-board ISS. This solicitation seeks to develop innovative environmental control technologies for the ground and space transportation of nanorack cubes and cubesats.

Cubesat integration timelines frequently call for passively mating to the launch vehicle or deployer system many weeks in advance of launch. The environment that the payload experiences plays a major role on the shelf life of certain materials and specimens within the spacecraft. Technologies capable of monitoring and extending the shelf life of perishable payloads are of interest to NASA as the environment in and around the launch vehicle is not always controlled in a manner favorable to a payload. Technologies can be either integrated directly into the Cubesat or external to the Cubesat.

Two applications for these technologies are sought:

- ISS Nanorack Transportation System.
    - This system will have the ability to maintain temperatures within relevant ranges for biological and/or perishable Nanorack payloads from time of experiment preparation at the payload processing facility until installation into the host facility on ISS. This also includes ground transportation phases of the mission.
    - The Transportation System will also provide a time history of relevant parameters ie temperature, relative humidity, vibration, etc, during the transportation periods up to payload installation on ISS.
- Cubesat applications.
    - Cubesat applications involve technologies that may be incorporated into the Cubesat spacecraft itself, or systems that can be used as adjuncts to monitor and control the environment in and around the Cubesat payload/spacecraft. These technologies can be passive and/or active in nature.

- Cubesat applications will also provide a time history of relevant parameters ie temperature, relative humidity, etc during the dwell time on the pad while awaiting launch.

Innovative approaches to this problem will significantly increase the utility of Nanoracks modules and/or Cubesat spacecraft in that this technology will enable an expanded set of experiment types and mission scenarios. Such a capability may also be extended in support of ground control experiments where on-orbit environments must be duplicated in the lab.

Nanorack information can be found here: http://nanoracks.com.

Cubesat information can be found here: http://cubesat.org/.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Report with a feasibility study including: simulations and measurements demonstrating the approach used to develop and test the prototype, constraints on other systems, concept of operations, verification matrix of measurements with pass/fail ranges for each quantity to be verified at the end of Phase II, and the Phase II integration path.
- Proof-of-concept simulation and/or bench top demonstration (TRL 3-4).

Phase II Deliverables:

- Midterm Technical Report.
- Final Phase II Technical Report with specifications including: design, development approach, tests to verify the prototype, verification matrix of measurements with pass/fail ranges for each quantity verified, constraints on other systems, and operations guide. Opportunities and plans for potential commercialization should also be included.
- Fully-functional engineering prototype of proposed product (TRL 5-6).