The Space Operations Mission Directorate (SOMD) is responsible for providing 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. Each of the activities includes both ground-based and in-flight processing and operations tasks. Support that ensures these tasks are accomplished efficiently and accurately enables successful missions and healthy crews.

This topic area, while focused on operational space flight activities, is broad in scope. NASA is seeking technologies that range from addressing how better to improve and lower costs related to ground and flight assets to how best maximize and extend the life of the International Space Station. A typical 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.

The contract should 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 Mission Operations**
Lead Center: ARC  
Participating Center(s): JPL

The objective is to develop advanced capability software systems for mission operations in support of NASA's Space Communications Infrastructure. The current infrastructure for NASA Space Communications provides services for near-Earth spacecraft and deep space planetary missions. The infrastructure assets include the Deep Space Network (DSN), the Ground Network (GN), and the Space Network (SN).

NASA seeks automation technologies that will facilitate scheduling of oversubscribed communications resources. These capabilities should focus on the development of user interfaces and algorithms for the integration of diagnostic and situational awareness tools; and planning, scheduling, and resource optimization tools supporting:

- Increased numbers of missions and customers
- Increased number and complexity of constraints
- Decreased operations budgets
- Scheduling algorithms should be fault-tolerant

Current State-of-the-Art: Diagnosis software tools and resource optimization tools are mature independent software technologies, however the integration of the two is less mature. The challenge is to develop integrated software tools that can leverage the strengths of each class of tool. Diagnosis tools must inform the resource optimization algorithms of the active portions of the system, while the resource optimization tools must inform the diagnosis tools of the current plan in order to facilitate tracking of system state.

User Interfaces: Diagnosis software user interfaces rely on displaying diagnostic information either in fault tree form or spatially highlighting portions of schematics, which are suspect. On the other hand, planning/scheduling/resource optimization tools rely on the display of temporal information in Gantt charts, and other timeline-based methods. An integrated user interface would require the integration of the spatial and temporal information into a single display to facilitate the ease of use and understanding of the integrated tools.

Diagnosis and Situational Awareness: Space Communication Networks are complex systems made up of both physical and wireless connections. When faults occur in the network, isolating the faults in real-time is critical in order to maintain network capability. Model-based diagnostic systems are capable of modeling the connectivity of the system as well as propagating both nominal and off-nominal flow of information in the network. These systems can accurately characterize the state of the system in order to provide situational awareness for both humans as well as intelligent assistant and resource optimization tools. The utilization of the current state of the network is critical to reschedule resources that have failed or degraded.

Planning and Scheduling Tools for Resource Optimization: The goal of schedule optimization is to produce allocations that yield the best objectives. These may include maximizing DSN utilization, minimizing loss of desired tracking time, and optimizing project satisfaction. Each project may have their own definition of satisfaction such as maximal science data returned, maximal tracking time, best allocation of the day/week, etc. The difficulty is that we may not satisfy all of these objectives during the optimization process. Obviously, optimal solution for one objective may produce worse results for the other objectives. One possible solution is to map all of these objectives to an overall system goal. This mapping is normally non-linear. Technology needs to be developed for this non-linear mapping for scoring in addition to regular optimization approaches.
**Areas of Interest:** Integrated diagnosis and resource optimization tools are useful in different phases in the design and development of space communication networks. In early pre-planning phases of mission operations such tools are useful for: procedure development, contingency development, and other preparatory tasks. During the operations phase, such tools are useful for telemetry analysis; fault diagnosis, state determination and situational assessment; plan, procedure, and rules revisions and execution; decision-making; commanding; fault responses; and data management among others.

NASA seeks proposals to develop the following capabilities in support of human situational awareness:

- Methods for acquiring, evaluating, and displaying telemetric information, so as to provide users with flexibility and easy access to desired information in desired format.
- Methods to determine situational information from multiple data sources, possibly noisy and incomplete, and present those to the user;
- Methods to track actions of other users or systems, including automated systems, and keep user aware of the situation.
- Methods to track user intent and provide the appropriate situational information;
- Methods for controlling the degree of automated/manual control, and tools for transitioning control between user and automation with minimal loss of context and situational awareness.
- Methods for creating, validating, evaluating, and revising model-based diagnostics models, taking into account collaborative aspects and reference materials required to build models (architecture diagrams/schematics, sensor definitions, fault modes, configurations and other reference materials).
- Techniques for checking or simulating model-based diagnostic models, in order to acquire a level of trust or assurance that the model is correct with respect to the configuration of the network.
- Methods for creating, validating, evaluating, and revising operations plans, taking into account collaborative aspects, complex flight rules, resource limitations and need for one-time constraints and exceptions.
- Techniques for checking or simulating plans, procedures, sequences and other combinations of commands and actions, in order to acquire a level of trust or assurance that the combination is correct and will satisfy desired safety and operations properties in actual execution.
- Methods to change the planning/scheduling optimization functions to incorporate high priority requests.

**Performance metrics:** Measures of performance will compare human generated results vs. human/computer results for nominal and off-nominal network conditions. Experiments should be run on simulated communications test-bed(s), which can seed failures of different classes at different points in time.

Schedule quality will be determined by a number of factors including: (1) level of up time on the network, (2) degree of priority allocation (higher priority items scheduled first), (3) degree of contiguity allocation (items are scheduled as a group) and (4) other factors.

For the proposed technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware demonstration and testing. Delivery of a demonstration unit for NASA testing at the completion of the Phase II contract is also required.

Phase I Deliverables: Propose demonstration of integrated fault diagnosis/resource optimization tool on a number of communication asset allocation problem sets (involving dozens of missions, communications assets, and operational constraints). End Phase deliverable (TRL 4-5) would include a detailed rationale for technology return-on-investment (ROI) based on knowledge of current and future operations flows.
Phase II Deliverables: A demonstration of the integrated fault diagnosis/resource optimization tool with fault
diagnosis/situational awareness system on actual or surrogate communication asset scheduling datasets.
Deliverables (TRL 6) would include software system, use cases and evidence of utility of deployment of developed
technology.

O3.02 ISS Utilization

Lead Center: JSC
Participating Center(s): ARC, GRC, KSC, MSFC

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 would make it possible to measure the diffusion coefficient of experimental systems using the Light
  Microscopy Module (LMM). This peer-reviewed science was considered a decade ago but not developed
  due to technology limitations. It should now be possible to measure diffusion coefficients from which the
  molecular temperature of the location being viewed could be deduced for known particles and solvents
  using the Stokes-Einstein equation. Innovative additions of a local oscillator used in conjunction with analog
  detectors could mitigate errors introduced by stray light.
- Providing compact laser tweezers and supporting software. Development of a compact robust Holographic
  Laser Tweezers (LT) instrument based on the recent developments of holographic techniques could
  expand the types of experiments conducted on orbit. 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 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. Novel self-calibration methods could be added to commercially available designs to further enhance the instrument and its capabilities. 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 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; 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/science/experiments/Discipline.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 Life Extension and Operational Enhancements

Lead Center: JSC

Participating Center(s): ARC, GSFC

NASA is exploring a wide range of both critical and highly desirable technologies that would, in the mid-term, aid in ISS life extension or provide operational enhancements.

Potential areas of investigation include the following:
• Providing detection technologies for leakage from modules and fluid systems.
• Enhanced on-orbit maintenance capabilities such as corrosion detection and re-mediation.
• MMOD detection, MMOD damage detection, evaluation and recovery.
• Methods for re-lubrication of rotating parts.
• Technologies that can isolate and resolve issues without crew interaction or that can perform nominal crew housekeeping activities such as self-cleaning air inlet filters and surfaces are highly desirable and could improve efficiency enough to allow more crew time for operation of scientific payloads.

Technologies to aid in life extension or operational enhancements of the ISS are not limited to the above examples and other areas will be considered for award.

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 technology feasibility in the laboratory (TRL 2-4) 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, preferably on orbit (TRL 4-6).

O3.04 Vehicle Integration and Ground Processing
Lead Center: KSC
Participating Center(s): MSFC, SSC
This subtopic seeks to create new and innovative technology solutions, which 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.

Current State of the Art: The propulsion testing and launch vehicle processing activities at NASA account for a large portion of the life cycle costs of today’s space programs. The technologies in use today at these facilities date back to the beginnings of manned space flight. A majority of the test infrastructure at Stennis Space Center and launch processing facilities at Kennedy Space Center indeed go back to the Apollo era and early shuttle design days of the 1960’s and early 70’s. Technology solutions typically take 3-6 years from inception in the SBIR Phase I program to having a direct impact on the processing activity. NASA needs to invest in these vehicle integration and ground-processing technology needs now to be in place for the NASA heavy launch vehicle concepts of the future.
Propellant servicing operation for both propulsion testing and launch operations are in need of technology advancement to make these operations safer and more cost efficient. The hardware and practices in use today do indeed date back to 1960’s investments. Technology solutions are needed to increase visibility into processes real-time (smart instrumentation), more efficient cryogenic propellant storage solutions, a new generation of cryogenic couplings to allow cold mate and de-mate operations without ice or frost buildup, and to reduce our usage of massive amounts of gaseous helium (a scarce, non-renewable global resource).

Changes in environmental regulations have had a tremendous negative impact on the coatings used to protect our NASA test and launch infrastructure. Many of the coatings used in the last 10 years are no longer available due to changes in the environmental law banning the use of certain chemicals. KSC and SSC are located in some of the worst corrosion environments in the country. At KSC, the addition of the acidic exhaust plumes from solid rocket motors, make these conditions even worse. New advancements in coatings and materials are needed to reduce the infrastructure maintenance costs of these facilities.

Due to the lightweight, high strength properties, composite materials are being sought more often to solve weight reduction efforts on future launch vehicles. New materials mean new problems for the ground operations team charged with insuring these vehicles are safe to fly. New inspection tools are needed to confirm structural integrity during the processing flow after field repairs or accidental contact.

The following areas are of particular interest:

**Propellant Servicing Technologies**

Technologies for advanced, energy efficient cryogenic fluid storage, transfer and propellant servicing of launch vehicles and propulsion test facilities. These efforts include:

- Cost effective technology solutions to support helium facility supply infrastructure and helium conservation initiatives to reduce/eliminate helium usage during LH2 and LO2 system operations and recover /re-purify helium from large volume waste streams;
- Techniques and technologies to reduce parasitic heat loads in large cryogenic storage tank structural design to enable more economical zero boil-off storage concepts;
- Advances in smart instrumentation for in-situ fluid flow analysis and process control, surviving and operating under cryogenic and launch conditions to enable real-time monitoring of propellant servicing processes and high efficiency purging operations of cryogenic systems; and
- Non-frosting/icing quick-disconnect development to support cryogenic propellant servicing operations.

**Control of Material Degradation**

Technologies are needed for the prediction, prevention, detection and mitigation of corrosion/erosion in spaceport and propulsion test facility infrastructure and ground support equipment including steel refractory concrete. Material solutions must meet current and emerging environmental restrictions and endure today’s corrosive and highly acidic launch environments. These needs include:
- Methodology to predict long-term corrosion protection performance of coatings for steel operating in a marine environment;
- Damage responsive coatings with corrosion inhibitors;
- Replacement options for poor-performing refractory concrete exhibiting low temperature cure characteristics or means of providing large area coverage with modular units that can be cured off site;
- Protective coatings for non-painted surfaces;
- Innovations in thermal spray metallic coatings equipment and alloys;
- Non-chrome protective coatings/sealants for aluminum alloys; and
- New environmentally friendly protective coating options to replace products lost due to EPA regulation changes.

**Spaceport Processing Evaluation/Inspection Tools**

Technologies in support of defect detection in composite materials; methods for determining structural integrity of composite materials and bonded assemblies; and non-intrusive inspection of Composite Overwrapped Pressure Vessels (COPV), Orion heat shield and other composite systems. Technologies must support identifying composite material defects, evaluating material integrity, damage inspection and/or acceptance testing of composite systems. Technology solutions are also desired for in-situ evaluation of refractory concrete as installed in the flame trenches associated with propulsion test and launch pad infrastructure. Provide solutions that reduce inspection times, provide higher confidence in system reliability, increase safety and lower life cycle costs.

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:** Demonstration of technical feasibility (TRL 2-4).

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

The technology in this subtopic may also be applicable to Topic O2, Space Transportation.

**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, including radiation damage to sensor systems and components. Cameras and sensors 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
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. Areas of interest in the near term are for space environment, radiation tolerant, HDTV and digital cinema cameras and sensors. Mid and Long term goals include radiation tolerant reprogrammable encoders and improved distribution systems for video data signals. These systems are highly desired by the human spaceflight programs.

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 detailed designs and development plans with plausible data and rationale that demonstrates why the designs and plans should mitigate radiation effects on the sensors.

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 define expected lifespan of the sensors.
This subtopic addresses acoustic monitoring technologies for current International Space Station (ISS) and future long duration spaceflight missions.

Specifically, this subtopic calls for proposals to develop and demonstrate acoustic sensor technology enabling real-time, remotely performed measuring and monitoring of sound pressure levels and noise exposure levels in long-duration space vehicles. These technologies are the building blocks towards a network of continuously monitored, real-time acoustic sensors providing sound pressure level information as a function of frequency and/or time at multiple locations. Additionally, these technologies shall provide:

- Typical sound level meter,
- Typical acoustic dosimeter processing and analysis functionality,
- Capability for hazard level alerting.

Current State of the Art: Acoustic monitoring is currently being performed on the ISS using a hand-held sound level meter (SLM) that is moved to 60 different locations where a 15 second measurement is performed. Each SLM survey session takes 2 hours of crew time, and the survey is performed once every 2 months, thus reduced crew time needed will be an important benefit.

Because of the length of the survey, only a portion of the ISS can be measured during a single session. Similarly, acoustic dosimetry at fixed locations is performed once every 2 months, but only at three locations for each session because of crew-time and hardware limitations. Advanced acoustic monitoring technology will provide the capability to allow for more frequent and directed acoustic measurements and will allow nighttime measurements. These benefits will permit more precise trending, environmental monitoring and will provide a better validation of acoustic models, i.e., we will be able to isolate the impacts of various operations or pieces of hardware.

Areas of interest: Current automated acoustic monitoring methods used in ground-based systems perform measurements in isolated areas, e.g., around airports. However, the technology employed is large and heavy, using conventional data acquisition boards, transducers, and transmitters.

NASA seeks proposals for acoustic monitors for spaceflight vehicle applications that:

- Are miniaturized,
- Are lightweight,
- Integrate data acquisition, sampling, and processing into the sensor
- Transmit the processed data wirelessly,
- Low-power consumption
- Can be a part of a multi-sensor system

The functional SLM goal is to provide average sound pressure level measurements over a short time duration (e.g. 20 seconds) as a function of frequency. The functionality required includes:
• Type II measurement accuracy over the octave band frequency range from 63 Hz to 20 kHz,
• Dynamic range of 90 dB or better,
• 1/3 octave band frequency representation,
• Narrow band frequency representation with selectable frequency resolution.

The following SLM functionality is desired:

• Type I measurement accuracy over the octave band frequency range from 63 Hz to 20 kHz,
• Octave band noise floor of 10 dB re 20 micropascals
• Fractional octave (1/1, 1/3, 1/12) band frequency representation.

The functional Acoustic Dosimeter goal is to provide noise exposure levels and data logging, i.e., log of sound levels as a function of time. The functionality required includes:

• Type III accuracy over the audible frequency range,
• Logging of A-weighted Overall Sound Pressure Levels every 30 seconds for a period of 24-hours,
• Dynamic range of 90 dB or better.

The following Acoustic Dosimeter functionality is desired:

• Noise floor of 30 dB re 20 micropascals.

The goal for the hazard level alert functionality is to provide continuous acoustic monitoring with logic that sends a signal (to trigger a non-auditory alert) if hazardous noise levels of 85 dBA and above are detected. This is a new crew-health related function that will reduce the crew’s risk for exposure to high noise levels, and will protect the crew in the case of an off-nominal noise event. The functionality desired includes:

• Perform continuous acoustic data sampling
• Send an electronic signal if noise levels are 85 dBA or above

The following hazard level alert functionality is desired:

• Pre-trigger capability so onset of hazardous noise is measured.
The technology from this SBIR subtopic is highly desired for use on ISS and for future long duration space missions for the long-term.

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. For Phase II, a demonstration in the JSC Acoustics and Noise Control Lab (ANCL) is being requested so that testing can be performed in the ISS Acoustic Mockup. As a result, an SBIR testing facility waiver will be needed.

Potential Phase III activities are envisioned to be a demonstration of the sensor’s capability on board ISS as a Station Detailed Test Objective (SDTO)

Phase I Deliverables:

- Sensor preliminary design
- Breadboard microphone transducer (proof of concept)
- Test data showing acoustic performance of breadboard sensor
- Forward plan for sensor development, including plans for in-situ calibration
- The expected TRL at the end of Phase I is 3-5

Phase II Deliverables:

- Sensor design in flight-like package
- Test data showing acoustic performance of flight-like sensor
- Demonstration of multiple sensors in ground facility (NASA JSC ANCL)
- The expected TRL at the end of Phase II should be 6.

O3.07 Cryogenic Fluid Management Technologies

Lead Center: KSC

The ultimate objective of this Cryogenic Fluid Management (CFM) Technologies solicitation is to demonstrate a variety of critical CFM technologies in a micro-gravity space environment via a deployable or non-deployable test bed.

The initial phase (Phase I) will identify and develop prototype experiments that could be integrated into a universal
platform for demonstration of these experiments in their relevant micro-gravity environment.

The second phase (Phase II) of this solicitation would develop a universal and innovative test bed platform that could be launched as a secondary payload on an expendable launch vehicle.

State of the art: CFM technologies are, for the most part, limited to ground tests that do not provide a complete and accurate demonstration of the technologies in their true operational environment. This increases risk in the development of emerging technologies for future applications in the areas of space based propellant depots, low gravity descent and ascent operations, and future space or planetary based architectures.

Areas of interest:

The purpose of these experiments would be to allow testing of:

- Designs for fluid and propellant transfer plumbing
- Multi-layer insulation (MLI) designs
- Various mass gauging designs
- Thermal control and boil-off control designs in a true micro-gravity space environment

Sample technologies in current queue at NASA centers that require testing in such type of platform include:

- Vapor Cooling
- Orientation
- Para-ortho H₂ conversion
- Fluid Transfer Coupling
- Thermodynamic Vent System
- Automated Rendezvous and Docking
- Thick MLI blanket
- Broad area cooling (vapor cooled, active cooled)
- Sun Shield
- Mass gauge
  - Radio Frequency (RF)
  - Pressure Volume Temperature (PVT)
  - Level Sensor (Cryo-Tracker)

- Instrumentation
  - Cryo tracker
  - Mass flow rate (fill, vent)
  - Tank pressure
  - Temperature (liquid, vent, tank wall, transfer lines, structure)
  - System acceleration
• Liquid Acquisition Device (LAD)
• Settling
• Propulsion (H₂/O₂ thruster, solar thermal)
  ◦ H₂/O₂ thruster
  ◦ Solar thermal

• Propellant Positional Device (PPD) (magnetic, screen)
• Cryo-Cooler
• Mixing (Vehicle maneuvers (roll), pumps)
• Structural interface (conic, struts)

The identification and design of critical CFM components that could be utilized in future exploration architectures in the space environment are being solicited for this platform. The technologies and future development of the platform supporting them would allow demonstration and proof of concepts for the designs and hardware necessary for mechanisms such as fluid transfers in propellant depots and in planetary spacecraft prior to the actual full development, design, fabrication, and launch of hardware. These CFM technologies and platform would provide a simple, low cost and innovative method to prove technologies and could avoid large and costly design modifications or possible multiple launch requirements for future space based architectures.

A viable option for the low cost approach involves launching as a secondary payload on launch vehicles currently in use such as an Atlas V or Delta IV. Such launch vehicles hold a high level of design maturity, contributing to a huge savings in development costs. In addition, through riding as a secondary payload, a majority of the launch costs could be absorbed by the primary mission. In a typical launch vehicle configuration, the secondary payload is attached to a launch vehicle’s second stage propellant tank beneath the primary payload. After separation of the primary payload, the platform would either deploy and operate as a free flying spacecraft and perform the various CFM demonstrations, or could remain attached to the propellant tank to prove fluid transfer capabilities, along with additional experiments. A third option is to utilize the residual propellants from the launch vehicle to fill a “receiver” tank on the platform, which would subsequently deploy to perform various additional demonstrations.

The platform would be processed and integrated in the typical fashion of spacecrafts launched today. A platform that remains completely passive (non-operational and containing no commodities) until separation of the primary payload greatly reduces ground-processing requirements. Individual experiments could also be integrated with the platform prior to integration to the launch vehicle to further reduce operational complexities.

The second phase of the project would design a platform so as to encompass additional requirements such as:

• The capability to support and integrate multiple CFM technology experiments per mission
• Demonstrating innovative, fluid transfer designs
• MLI designs
• Various mass gauging designs
• Thermal control and boil-off control designs
• Validation of CFD propellant models
• Testing of propellant management devices
• Mixing pumps
• Thermodynamic vapor cooling systems
• Environmental thermal shielding designs

Design of the platform would need to ensure that it does not impose additional risk to the mission success of the primary payload and is capable of remaining completely passive and inert until the primary payload is successfully deployed. This includes launching with empty tank(s), lines, etc., and maintaining the ability for residual cryogenic propellants to be transferred from the launch vehicle upper stage to the proposed secondary payload upon completion of the primary mission.

Optional configurations could include multiple tanks with self-contained fluids, however the use of residuals, with innovative propellant transfer lines, from an upper stage promotes cost savings in both the propellant commodities, pressurization systems required for pre-launch processing, limit hazard and safety concerns for the primary mission, and the passive nature reduces the complexities added in the analyses and operations required for integration with the launch vehicle and primary mission.

The platform, itself, would contain tank to tank fluid transfer capabilities, avionics, thermal control systems, telemetry capabilities and, if deployable, an attitude control system. The platform design would be capable of interfacing with the launch vehicle separation system and avionics. Additional potential experiments and uses include validation of CFD propellant models, testing of propellant management devices, mixing pumps, thermodynamic vapor cooling systems, and environmental thermal shielding designs.

Performance metrics: A platform that is capable of remaining passive and inert through completion of the primary mission on an EELV. The platform shall be capable of supporting at a minimum of four CFM demonstrations per mission. The designs for the experiments are to be such that they are capable of demonstrating CFM technologies supporting the operational requirements of future space based architectures in cryogenic temperature ranges.

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

Phase I Deliverables: Demonstration of technical feasibility (TRL 3-4).

Phase II Deliverables: Prototype design and demonstration of innovative technology testing platform, capable of integrating multiple CFM experiments (TRL 4-6). A ready to launch version of this as an EELV secondary payload performing demonstrations of CFM technologies is highly desired.