Achieving space flight remains a challenging enterprise. It is an undertaking of great complexity, requiring numerous technological and engineering disciplines and a high level of organizational skill. Overcoming Earth's gravity to achieve orbit demands collections of quality data to maintain the security required of the range. The harsh environment of space puts tight constraints on the equipment needed to perform the necessary functions. Not only is there a concern for safety but the 2004 Space Transportation Policy directive states that the U.S. should maintain robust transportation capabilities to assure access to space. This crosscutting SBIR Topic seeks to enable commercial solutions for U.S. space transportation systems providing significant reductions in cost, and increases in reliability, flight-rate, and frequency of access to space. The goal is a breakthrough in cost and reliability for a wide range of payload sizes and types (including passenger transportation) supporting future orbital flight that can be demonstrated on interim suborbital vehicles. The vision is a competitive marketplace with multiple commercial providers of highly reusable space transportation systems and services with aircraft-like operations, high-flight rates, and short turnaround times (days-to-hours, rather than months). Lower cost and reliable space access will provide significant benefits to civil space (human and robotic exploration beyond Earth as well as Earth science), to commercial industry, to educational institutions, for support to the International Space Station National Laboratory, and to national security. While other strategies can support frequent, low-cost and reliable space access, this topic focuses on the technologies that dramatically alter reusability, reliability and operability of next generation space access systems.

Subtopics

O2.01 Secondary/Auxiliary Payload-to-Launch Vehicle Interface Technologies

Lead Center: KSC
Participating Center(s): AFRC

This subtopic includes two major technology areas:

(1) Small payload standard interface technologies (SPSIT)

(2) Entry and ascent experimental platform technologies (EAEPT)
Proposals will be accepted for either area.

Many expendable launch vehicle (ELV) launches do so with excess capacity. The utilization of specific excess volumes within a launch system must be accomplished at a low cost with minimal to no additional risk to the primary payload or launch vehicle. This subtopic seeks to develop commercial solutions that will allow and encourage new enabling launch capabilities and standardization of key payload-to-launch vehicle processes and interface standards with the goal of producing a low cost, low risk platform or process for integrating secondary or auxiliary payloads on existing NASA ELV launches.

The goal is to develop new launch vehicle capabilities such as adapters/platforms, processes, and/or avionics interface standards that can be collectively used to:

- Minimize integration tasks and/or duration of integration efforts to install secondary/auxiliary payloads onto NASA ELV launches
- Facilitate secondary/auxiliary spacecraft and subsystem design while reducing testing duration and complexity
- Impose no additional risk to the primary mission
- Enable novel mission concepts for secondary/auxiliary payloads

**Small Payload Standard Interface Technologies**

Currently, the Poly-Picosatellite Orbital Deployer (PPOD) provides a cost-efficient standard interface and deployment system for CubeSats in the 1 to 3 kg mass range. In addition, the Evolved ELV (EELV) Secondary Payload Adapter (ESPA) provides a standard structural interface for secondary payloads up to 180 kg and is designed for interface into Atlas V and Delta IV launch vehicles. A smaller version of the ESPA ring has been conceptualized for smaller launch vehicles. Both the ESPA and the small ESPA are most cost effective when they accommodate 6 payloads. In addition, for the most part, the avionics and electrical power interfaces are unique to each launch vehicle fleet. This subtopic seeks to develop commercial solutions that could allow the cost effective launch of one or more secondary/auxiliary payloads via an interface (structural, avionics and electrical) that is standard or expandable/upgradable to be compatible with the maximum number of domestic launch vehicles. NASA currently has Pegasus XL, Taurus XL, Falcon 1, Falcon 9, Atlas V and Delta IV on contract.

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.

This subtopic will focus on new interfaces for payloads in the mass range of 3 to 180 kg, which can be grouped as needed for any modularization concepts. A range of 11 to 100 kg has been specifically identified as a region where critical technology demonstrations and new space technologies could use affordable orbital launch opportunities to increase their TRL, potentially reducing their overall cost and risk to development. Enabling affordable launch
capabilities in these ranges could also allow scientific and educational spacecraft (s/c) developers the ability to design to a specific mass range that will result in on-orbit research.

The technologies in this subtopic are highly desirable because although adapters that could support most missions exist, having multiple systems across multiple launch vehicles fleets will contribute to higher integration costs. Standards amongst the s/c and adapter community will reduce integration cost and therefore the per-kilogram cost-to-orbit.

Areas of interest (SPSIT):

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

The critical requirement for all areas of interest identified above is that the design, integration or implementation shall not increase base line risk to the primary spacecraft or the launch vehicle mission success. Implementation of the above enables support for any upcoming missions needing the capability to demonstrate new technology on-orbit by using a standard interface or process.

Phase I Deliverables (SPSIT):

- Assessments of current and future spacecraft/mission/space technologies in the mass ranges will identify current adapter systems, processes and determine the TRL for each system within 3 year timeframe from award date
- Develop draft standards for both spacecraft, adapter, integration process and avionics interfaces

At the completion of phase I, the goal is to have achieved a TRL 3 or better for the adapter systems and processes

Phase II Deliverables (SPSIT):

- Finalize standards within the mass range
- Complete adapter hardware designs
• "Plug-n-play" avionics standards hardware/software
• Conduct PDR and CDR of new technologies
• Finalize standards for the integration process

Higher TRL levels at the completion of Phase II will increase the likelihood of a path for infusion into NASA missions.

Entry and Ascent Experimental Platform Technologies

Current launch capabilities for aerodynamic and hypersonic research are limited to either high cost launches as a primary payload on a launch vehicle, or small packages (typical sounding rocket payload volume and mass ~ 10 ft³, 300 lbm). Sounding rockets that provide the technology testing capabilities are also limited in the altitude and the speeds they can achieve. Therefore, the conceptual design for a new platform is being sought to fill the technology-testing gap. For example, if the vehicle configuration had spare solid rocket motor capacity, this experimental platform could launch as a secondary payload, by occupying the location of a solid rocket motor on a launch vehicle such as the Atlas V or Delta IV.

The new experimental platform would provide expanded testing capabilities to accommodate payloads with larger (2-10 times) size and weight, obtaining greater altitudes and speeds than currently provided using sounding rockets. The platform would provide an affordable way to demonstrate and test new technologies through hypersonic, intra-atmospheric, and reentry phases. The launch vehicle can be any vehicle used by NASA (currently, Pegasus XL, Taurus XL, Falcon 1, Falcon 9, Atlas V and Delta IV are on contract) and must be integrated onto the first stage of a vehicle per the areas of interest listed in Areas of interest section below.

Usage of this experimental platform could support development of a number of advanced technologies through flight-testing in representative environments, where their TRL could be validated and advanced. Such technologies could then be considered viable options for atmospheric entry and ascent technologies for governmental and commercial applications.

Technologies that could be tested in this experimental platform include but are not limited to:

• Thermal protection materials,
• Guidance, navigation and control,
• Vehicle configuration concepts for investigation of both ascent and entry designs for earth, lunar, and Mars space vehicles under supersonic and hypersonic conditions

Objective (EAEPT): Design a cost effective experimental platform with associated payload interface that minimizes the impact to the primary payload and launch vehicle's processing and certification for flight.
Areas of interest (EAEPT): NASA seeks platform designs incorporating the following characteristics:

- Ability to integrate with the launch vehicle late in the mission integration phase,
- Ability to fly a dummy payload(s) (in case the secondary payload does not meet the launch readiness date),
- Mo required mission unique interfaces with the launch vehicle (electrical, environmental control, etc.)
- Does not impose additional risk on the success of the primary mission
- Enables maximum use of the existing design and hardware (i.e., attach structures, case design) of the launch vehicle to minimize risk
- Has minimal impact to the vehicle external mold line and mass requirements, such that the aerodynamic flight environments, dynamic load environments, and thermal environments imposed are of similar or equivalent levels as compared to the vehicles as currently flown
- Is compatible with existing launch vehicle hardware
- Is compatible with current vehicle qualification environments
- Is compatible with vehicle mass requirements
- Facilitates manufacturing and production (support multiple and repeatable flights)
- Accommodates flight specific payload modifications.

Much of this information can be found on line on the Launch Provider's public websites:


Once awarded, NASA (LSP) will facilitate the development of a Non-Disclosure Agreement (NDA) between the small business and launch provider.
Phase I Deliverables (EAEPT):

A final report containing technology design concept(s) demonstrating technical feasibility including:

- Feasibility of concept
- A draft Systems Requirements Document (SRD)
- A detailed path towards Phase II level design maturity
- Detailed report presenting the results of Phase I analysis, modeling, etc.
- Expected TRL at end of Phase I is 3

Phase II Deliverables (EAEPT):

- Preliminary Design Review (PDR) and Critical Design Review (CDR) of the aforementioned platform for use on one of the existing ELVs within NASA's fleet
- Expected TRL at end of Phase II is 5

O2.02 Propulsion Technologies

Lead Center: GRC
Participating Center(s): AFRC, MSFC

O2.03 Spaceport Enhancement & Improvements

Lead Center: GSFC
Participating Center(s): AFRC, GRC, KSC

The key operating characteristics for a Spaceport focus are interoperability, ease of use, flexibility, safety/environmental protection, and multiple concurrent operations. The long-term vision is to have "airport-like" spaceport operations. Therefore, the development of effective spaceport technologies is of primary importance to
NASA. These technologies will need to support both the existing and future vehicles and programs.

**Space-Based Telemetry**

NASA is seeking to reduce or eliminate the need for redundant range assets and deployed down-range assets that are currently used to provide for Line-of-Sight (LOS) Tracking Telemetry and Control (TT&C) with sub-orbital platforms and orbit-insertion launch vehicles.

There are varying applications for space-based transceivers, each necessitating a different set of requirements. The desired focus is very low size, weight, and power (SWaP), tactical grade, highly reliable, and easily reconfigurable transceivers capable of establishing and maintaining unbroken satellite communication links for telemetry and/or control. This technology will serve applications, which include low-cost sub-orbital missions, secondary communications systems for orbit insertion vehicles, low cost and size orbital payloads (typically LEO), and flight test articles. Durations will range from minutes to several weeks and the ability to operate on highly dynamic platforms is critical. High data rate links are highly desired, thus the use of NASA’s TDRSS is emphasized, although other commercial satellite systems, which can provide nearly global and high data rate links can also be explored. Factors to address include:

- Advancements in software based radios and encoding techniques,
- Use of the latest semiconductor technologies (GaN or other),
- Advanced heat dissipation techniques,
- Immunity to corona breakdown,
- Ease of data interfacing.

RF power output requirements range from a few watts to as high as 100 W. Special consideration should be given to transceiver capability vs. packaging that would allow for customizable configurations depending on the target application.

**Range Weather**

NASA seeks innovative technologies to remotely measure electric fields aloft to reduce the threat of destruction of a launch vehicle by rocket triggered lightning. Potential candidate technologies include new algorithms to take advantage of existing dual-polarized Doppler five-cm weather radar capability, or entirely new technologies for the remote sensing of electric fields. The ability to economically measure the incremental ballistic wind velocities along the predicted trajectory of launch vehicles at remote and evolving launch ranges at altitude up to 100 kft via fixed and mobile LIDAR approaches is also highly desirable.

The above technologies are considered to be highly desirable for NASA’s objectives and critical for the realization of true Spaceports.

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: A final report containing optimal design for the technology concept including feasibility of concept, detailed path towards Phase II hardware and software demonstration, and detailed results of Phase I analysis, modeling, prototyping, and testing.

Phase II Deliverables: A working proof-of-concept demonstrated and delivered to NASA for testing and verification with a TRL of 4 to 6.

O2.04 Advanced Composite Tank and Materials Technologies

Lead Center: MSFC
Participating Center(s): GRC, LaRC

This subtopic includes two major technology areas:

(1) Reusable, Reliable and Low Cost Composite Tanks
(2) Advanced Material Integration Technology Development

Proposals will be accepted for either area.

Reusable, Reliable and Low Cost Composite Propellant Tanks (RRLCCPT)

The objective of this subtopic is to help dramatically reduce the cost to low Earth orbit by advancing the technology involved in composite propellant tanks and advanced composite material development. The ability for launch vehicles to combine the significant weight savings of composite tanks with airline like operations could be possible if these tanks are also reusable, reliable, and need little to no maintenance between flights.

Purpose and Current State-of-the-Art: Composite tanks offer significant weight savings, but there are significant shortfalls in terms of reusability, especially when using cryogenic fluids. This lack of reusability severely hampers adoption of this enabling technology in future reusable vehicle. This subtopic will also address emerging composite tank technologies, specifically in the areas of testing and verification pertaining to damage tolerance, safe-life and checkout.

General Operational Needs and Requirements/ Performance Metrics:
Airline-like Operations

Government and commercial reusable launch vehicles are only economically viable if they can achieve high flight rates of dozens of flights per year or more per vehicle. These flight rates themselves are only possible if something akin to airline like operations becomes possible for spaceflight.

Reusability and Reliability

Reusable, reliable, and low cost composite tanks that need little to no maintenance between flights and minimal check-out are required for economic and operational sustainability. These developments can:

- Ease operability of the tank diagnostics
- Enable tank prognostics
- Enable tanks to handle high pressure cycles and loads without leaking or developing structural failure
- Promote ease of manufacture, and by more than one American company
- Promote ease of repair without returning tanks to the manufacturer’s facility
- Promote rapid certification/recertification techniques to meet expected FAA commercial RLV requirements

Data and Technology Development

Of specific concern and interest are safe-life and damage tolerance testing. There is much scrutiny regarding the manner and degree of testing in these areas, specifically after some number of pressure cycles. Also of concern is the effect of temperature on and during cycling and material compatibility. Due to the limited amount of flight and long term performance data there is little to base future design on when the desire is heritage similarity. Thus, development in regards to these specific metrics (safe-life and damage tolerance testing) would be most beneficial to both short and long term missions.

The outcome of this portion of the SBIR is expected to be technologies and data that make possible composite propellant tanks that have improved reliability and performance that will enable a high degree of reusability. Data should show that proper material, manufacturing processes and design are used to produce a vessel that per-formed well under long-term use in a cryogenic condition. The vessel would minimize microcracking, should be damage tolerant and repairable, and have mounting capabilities.

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 (RRLCCPT): Final report containing:
• Optimal design and feasibility of concept,
• Detailed path towards Phase II demonstration,
• Detailed results of Phase I analysis, modeling, prototyping and development testing
• Material coupon data and a prototype sub-scale tank

Desired deliverables at the end of Phase I should be at TRL 3-4

Phase II Deliverables (RRLCCPT): By the end of Phase II, working proof-of-concept technologies, including features and demonstration of long term, high cycle performance at cryogenic temperatures, demonstrated and delivered to NASA for testing and verification.

Deliverables expected at the end of Phase II should be at TRL 5-6.

Advanced Material Integration Technology Development (AMITD)

Advanced materials including ceramic composites and metallic materials, will require technologies that will allow joining of these materials, specifically the development of advanced joining and integration technologies with enhanced temperature and performance capability. Typical materials are carbon and silicon carbide based composites and super alloys. The quality of joined sub-elements should also be evaluated nondestructively to assess the integrity and quality of the joints. Material systems may be similar or dissimilar in nature (composite to metals or composite to composites).

Purpose and Current State-of-the-Art: Currently the most commonly used fabrication approaches (CMC, CVI and PIP) have severe limitations in terms of size and shape of CMC components that can be manufactured with appropriate property attributes and a reasonable cost. Therefore, current design considerations for the manufacturing of large CMC components and structures will be utilizing technologies for joining/attaching smaller-sized components with simpler geometries and dissimilar material systems.

General Operational Needs and Requirements: Ceramic joining and integration is an enabling technology for the successful implementation of CMC’s in a wide variety of high temperature applications. Among the various alternatives available to overcome the limitations of the many fabrication technologies for the manufacture of large CMC components and structures of complex shape, the joining of smaller components with simple geometry appears to be the most promising and practical. Application of simple equipments for curing and during the high temperature joining process is critical. Requirements include, but are not limited to:

• Materials to be joined are silicon carbide or carbon-based matrix fiber reinforced composites to a similar CMC or high temperature metallic alloy
Proposed joining approach should be robust and able to produce joints with tailorable microstructures.

Thermo-mechanical properties of the joint interlayer should be tailorable and close to those of the base materials.

Proposed technologies are expected to be easy to apply in a manufacturing environment at high technology readiness levels.

For CMC-CMC joining, the joint interlayer material should be able to yield ceramic interlayers with temperature capability similar or better than the substrate materials with low porosity.

Performance Metrics: The temperature capability of the ceramic joints in joined CMC should be similar to that of the CMC substrate materials. The chemical composition of the joints should not alter the stress rupture, creep, high temperature mechanical strength, and stiffness of the overall system in any significant manner. The environmental stability, time dependent mechanical properties, and performance of the joints should not be significantly different than the substrate materials.

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

Phase I Deliverables (AMITD): Develop and demonstrate a robust joining concept, understand common test methods for joint testing, and assess the interfacial microstructure and mechanical properties of joints. Assess high temperature durability of joints and effect of joint design on thermo mechanical performance.

Desired deliverables at the end of Phase I should be at TRL 3-4.

Phase II Deliverables (AMITD): Produce and test additional joint prototypes (sub-elements and subcomponents) under representative flight conditions to include anticipated temperatures, heat fluxes, thermal gradients, and environmental effects. Full macro-structural and micro-structural material characterization of joints before and after testing will be required to assess life-limiting failure mechanisms and joint reliability. Provide joined CMC subcomponents or segmented structures with a method to non-destructively evaluate the joint quality.

Deliverables expected at the end of Phase II should be at TRL 5.
As NASA enables commercial space access, there is a critical need for reusable, reliable, low-cost thermal protection systems (TPS). New material and computational technologies offer the potential of more durable and operable TPS for space transportation vehicles that can tolerate high temperatures while improving operability and reducing maintenance time and costs.

This subtopic requests innovative proposals in the following areas:

- **Technologies and systems offering a factor of two or greater reduction in maintenance time and costs**
  - Reusable space transportation vehicles being developed for Earth to orbit access and return,
  - In-space transportation systems using aero-braking and aero-capture, and
  - On-demand payload and crew return systems

- **Multi-use and reusable TPS concepts applicable for insulated composite and metallic vehicle structures**
  - With improved robustness
  - Reduced and/or automated inspection, repair and recertification,
  - While remaining weight competitive to current flight proven TPS

- **TPS non-destructive evaluation techniques and new health management approaches and strategies**
- **Rapid TPS inspection, repair, and flight certifications techniques**
- **Designs and concepts for new TPS attachment methods,**
- **Designs for gaps and joints**
- **TPS designs for control surfaces and interfaces**

**Phase I Deliverables:** Phase I deliverables include a final report detailing optimal design for the technology concept, including a feasibility assessment and summary of analysis, modeling and any prototype development and testing. For concepts that show good feasibility, the final report should also contain a plan for Phase II development and demonstration.

Desired deliverables at the end of Phase I should be at TRL 2-3.

**Phase II Deliverables:** Phase II deliverables include a working proof-of-concept available for NASA inspection and testing if applicable. Opportunities and plans should be identified and summarized for potential commercialization.
Deliverables expected at the end of Phase II should be at TRL 4-5 (minimum).