



NASA SBIR 2011 Phase I Solicitation

O2 Space Transportation

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 Nano/Small Sat Launch Vehicle Technology

Lead Center: KSC

Participating Center(s): ARC

The space transportation industry is in need of low-cost, reliable, on-demand, routine space access. Both government and private entities are pursuing various small launch systems and architectures aimed at addressing this market need. Significant technical risk and cost exists in new system development and operations - reducing incentive for private capital investment in this still-nascent industry. Public and private sector goals are aligned in reducing these risks and enabling the development of small launch systems capable of reliably delivering payloads to low Earth orbit. The Nano/Micro Launch Vehicle (NMLV) will provide the nation with a new, small payload access to space capability. The primary objective is to develop a capability to place nano and micro satellites weighing up to approximately 20 kilograms into a reference orbit defined as circular, 450 kilometer altitude, from various inclinations ranging from 0 to 98 degrees.

This SBIR subtopic seeks commercial solution in the areas of nano and micro spacecraft launch vehicle technologies.

This subtopic will particularly focus on higher risk entrepreneurial projects for dedicated nano and micro spacecraft launch vehicles. This subtopic seeks proposals including, but not limited to, the following areas:

- Sub-orbital booster conceptual designs of system/architectures capable of reducing the mission costs associated with the launching of small payloads to LEO.
- Sub-orbital booster technologies traceable to an orbital capable Nano/Micro Launch Vehicle (NMLV)*, whereby specific technologies are identified for Phase II development and test.

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

Phase I Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product.

Also required are for all technologies are performance predictions, cost objectives, and development and demonstration plans for the Nano/Micro Launch Vehicle (NMLV). Formulate and deliver a verification matrix of measurements to be performed in Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

The report shall also provide options for commercialization opportunities after Phase II.

Phase II Deliverables: Working engineering model of proposed Phase I components or technologies, along with full report on development and measurements, including populated verification matrix from Phase I. The prototype hardware shall emphasize launch cost reduction technologies, and possess sufficient design information to fabricate, integrate, and operate the selected high-risk component(s) for demonstration. Refinement of the sub-orbital booster design is required as knowledge is gained through the critical component development process. Exit TRL 5-6 is expected at the end of Phase II

*The NMLV would be a smaller vehicle than the Pegasus launch vehicle which is considered a Small Launch Vehicle (SLV).

O2.02 Propulsion Technologies

Lead Center: GRC

Participating Center(s): AFRC, ARC, MSFC

Current launch to orbit vehicles, both expendable and reusable, require months of preparation for flight. Although there are available (in-production) practical propulsion options for such a vehicle, the costs for outfitting the booster stage are in the hundreds of millions of dollars. If reusable, additional months are required to verify all components and systems before re-flight. These costs severely limit what missions NASA can perform. The propulsion systems are a major focus during this time, yet aircraft engines are checked and certified for re-flight in less than an hour. While rocket engines actually have many similarities to aircraft engines, there are several factors that drive the complexity and therefore the cost of rocket engines. These include toxic propellants that require special protections for personnel and the environment, cryogenic propellants that require complex tank fill operations and costly specialized ground support equipment, high combustion chamber temperatures for increased performance and thrust, and high combustion chamber pressures for increased performance and reduced engine size and weight.

To move more toward low cost access to space, the above barriers to low-cost propulsion systems must be addressed and overcome. Of primary focus are non-toxic propellant combinations that provide adequate performance without requiring excessive specialized handling equipment and procedures, and engines that provide reliable and adequate performance without needing to push the far limits of temperature and pressure environments. Component technologies that move toward these top-level goals that are of interest include:

- Ablative materials and manufacturing techniques that increase capability while reducing production time and cost.
- Innovative chamber cooling concepts that reduce manufacturing complexity, reduce pressure drop, and minimize performance losses caused by cooling.
- Development of non-toxic propellants and technologies that enable their use such as catalysts, compatible materials, feed/storage systems, etc.
- Low-cost nozzle materials, manufacturing techniques, and coatings to reduce the amount of active cooling required.
- Ignition concepts that require low part count and/or low energy to be used as either primary or redundant ignition sources.
- Manufacturing techniques that lower the cost of manufacturing complex components such as injectors and coolant channels. Examples include, but are not limited to, development and demonstration of rapid prototype techniques for metallic parts, power metallurgy techniques for the manufacture of geometrically complex parts, and application of nanotechnology for near net shape manufacturing.
- Sensors, instruments, and algorithms to diagnose the health of the engine valves, injector, igniter, chamber, coolant channels, etc. without requiring hours of manual inspections.

Specified target metrics include:

- A cost target of
- Reduced ground support equipment.

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- Increased performance margin (e.g., operating temperature % of material limit, operating stress % of component limit, etc.).

These are critical technology improvements that are required in the next 3 - 8 years. Projects are required to demonstrate the component or technology to a TRL level of 5 - 6 in order to allow for infusion into low-cost earth-to-orbit propulsion systems. The NASA Office of Chief Technologist has developed Technology Roadmaps that identify technology gaps and needs to enable certain future missions. This subtopic calls for technologies that are discussed in more detail in the Technology Area 1 (Launch Propulsion Systems) and Technology Area 13 (Ground & Launch Systems Processing) roadmaps. These are available for viewing at (<http://www.nasa.gov/offices/oct/home/roadmaps/index.html>). Proposals should reference specific elements from these and other relevant roadmaps and explain how the proposed technology will address identified technology gaps and needs.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase II 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: Lab-scale component or technology demonstrations and reports of target metric performance.

Phase II Deliverables: Subscale component or technology demonstrations and reports of target metric performance. Opportunities and plans should also be identified and summarized for potential commercialization.

02.03 21st Century Spaceport Ground Systems Technologies

Lead Center: KSC

Participating Center(s): AFRC, ARC, GRC, GSFC

This subtopic seeks innovative solutions that will allow spaceport launch service providers to operate in an efficient, low cost manner and increases capabilities associated with integration, checkout, and preparations required to configure and ready space systems for launch. The goal is a set of technologies, processes, and strategic concepts that can be collectively used to facilitate launch vehicle processing by reducing complexity, turn-around times, and mission risk while implementing novel concepts for the processing of launch vehicles.

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. Additional key operating characteristics for a spaceport focus are interoperability, ease of use, flexibility, safety/environmental protection, support multiple concurrent operations, and the de-coupling of pre-launch processing from other users on the range.

Specific areas of interest:

- End-to-End Command and Control Services.
- Technologies and Capabilities that enable flexible and adaptable control by integrating enterprise capabilities with remote and distributed control functions while simultaneously maintaining security and safety for critical operation.
- Communications Services and RF/Optical Services to enable virtual distributed teams for control, engineering, safety analysis and support.
- Technologies and Capabilities that enable multi-government teams to operate existing or new assets in the most cost efficient manner. In addition, technologies or capabilities that would move existing government provided capabilities and provide a path to commercialization in the future.
- Preventative and condition based maintenance along with self-healing capabilities for ground systems.
- Technologies and Capabilities that reduce required work content, through an automated understanding of when and if maintenance work needed to be performed, in addition, capabilities that reduce cost or provide additional mission assurance capabilities at comparable or reduced cost.
- De-coupled pre-launch processing where the strategy for de-coupling involves the spaceport's capacity, configurability and Space-Based capabilities.
- Technologies and Capabilities that reduce the amount of ground operations that must be coordinated with other Range users, which would enable every user on the Range to believe they are the only user of the range throughout the ground flow.
- Spaceport and Range technologies and capabilities that increase launch attempts per day and/or consecutive days across the entire Florida Launch and Range Complex.
- Technologies and Capabilities that provide, localized, accurate forecasting of weather in support of Ground Operations.
- Improve security and control of range hazard areas.
- Technologies and Capabilities that improve the security of the range while reducing the cost to perform and monitor the Range volume.
- Innovative systems for payload recovery techniques with advancements in the areas of Mid-Air Retrieval (MAR) systems and guided payload recovery systems (such as a guided parafoil system).
- Technologies and Capabilities that allow in-flight recovery of small vehicles and payloads. In addition, Technologies and Capabilities that significantly reduce the cost of recovery operations.

Priority will be given to innovative solutions that:

- Enable low-cost concepts that reduce operations and life cycle costs.
- Demonstrate a transition path into spaceport operations.

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- Can achieve high-fidelity ground-based demonstrations within the next 4 years; longer-term development proposals will be accepted, but will be considered at a lower priority for funding.

Research should be conducted to convincingly prove technical feasibility during Phase I, with clear pathways to demonstrating and delivering functional prototypes, meeting all objectives, in Phase II.

Phase I Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4). Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables: Working model of proposed product, along with full report of development and measurements, shall emphasize cost reduction and efficiency technologies, and include a populated verification matrix from Phase II (TRL 5). Opportunities and plans should also be identified and summarized for potential commercialization.

02.04 Advanced Tank Technology Development

Lead Center: MSFC

Participating Center(s): JSC

The objective of this subtopic is to dramatically reduce the cost of achieving low Earth orbit by advancing the technology required for spaceflight propellant tank development. The ability for launch vehicles to combine the significant weight savings of composite tanks and composite overwrap pressure vessels (COPVs) with airline like operations could be possible if these tanks are reusable, reliable, and need little to no maintenance between flights.

Composite and composite overwrap tanks offer significant weight savings, however, 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 designs. This subtopic seeks to mature such emerging technologies pertaining to high performance, light-weight tanks and pressure vessels suitable for cryogenic and non-cryogenic temperatures at high pressures; seeks to develop technologies that extend life and/or decrease cost while being mindful of permeability, damage tolerance, safe-life and checkout issues; and seek out seal and joint development, increasing tank robustness and life while not increasing weight or cost; all against the current state-of-the-art capabilities and technologies.

Areas of interest to develop and/or demonstrate are as follows:

- **Material Development:** New composite material development specifically for cryogenic use demonstrating cycling, reparability, and knowledge of permeability and damage tolerance. Data should clearly show

materials and processes used in producing a vessel that performs well under long-term use in a cryogenic condition. Vessel performance and cycling should be analyzed at and during operational conditions (i.e., cryogenic conditions) to verify material integrity. The vessel would minimize micro cracking, should be damage tolerant and repairable, and have mounting capabilities. Permeability of the material should be addressed and evaluated against current material usage and limitations.

- Reusability and Reliability: Reusable, reliable, and low cost tanks that need little to no maintenance between flights and minimal check-out are required for economic and operational sustainability. These innovative propellant tank (either cryogenic or non-cryogenic) 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 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 during cycling and on material integrity. 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.

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

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

O2.05 Advanced Propulsion Testing Technologies

Lead Center: SSC

The aim of this subtopic is to develop new technologies to reduce cost and schedule, improve reliability and quality, and increase safety of Rocket Propulsion Testing. To this end, proposals for technology development will be accepted for any of the following four subject areas:

- Critical Vacuum Sensing.
- Helium Recovery.
- Robust Components.
- Advanced Propulsion Test Data Management.

Critical Vacuum Sensing Technology

Develop new innovative methods for remotely and automatically locating and quantifying vacuum leaks in large vacuum chambers subject to harsh environmental conditions. A new test stand, A3, is being built at SSC to test rocket engines at altitude conditions. Information on A3 Test Stand can be found at the following URLs:

- <http://sscfreedom.ssc.nasa.gov/etd/ETDTestFacilitiesA3.asp>.
- http://www.tulane.edu/~sse/FORUM_2010/pdfs/e1.pdf.
- http://www.nasa.gov/centers/stennis/pdf/436170main_A-3%20Test%20Stand%20FS-2010-03-00093.pdf.

To simulate altitude during rocket engine testing, A3 test stand produces a vacuum of 0.15psia inside a large, 40 ft diameter, rocket engine test chamber using 27 chemical steam generators and a 2-stage diffuser/ejector system. If vacuum leaks occur, the desired simulated altitude may not be achievable thus any leaks must be located and repaired. However, personnel access to the vacuum test chamber during operation is restricted due to the hazardous nature of its operation. This makes locating vacuum leaks difficult, if not impossible. Therefore, automated remote detection and location of areas of air in-leakage is required. Due to the unique nature of this test facility, innovation in these technologies is necessary. Performance metrics include accuracy and sensitivity in detecting leaks in the harsh operational environment with high levels of noise and vibration while not producing false leak indications, as well as robust design for the harsh environment.

Helium Recovery Technology

Helium is a rare and nonrenewable resource with many properties critical to the commercial, military, and fundamental scientific research sectors. NASA consumes approximately 1 million pounds of helium each year, primarily for purging of cryogenic propellant systems in which the helium is discharged to atmosphere and lost. The goal of this subtopic thrust area is to develop innovative helium recovery technologies that economically dissociate helium from large volumes of mixtures of helium, air, and hydrogen purge discharge, and pressurize the reclaimed helium for storage and reuse. The total cost of recovering and reusing helium, from both capital and energy expenditure, should be less than procuring the same amount of helium from traditional sources. Also, particular emphasis is placed on portability (i.e., not a fixed installation) and speed of separation (near-real-time) that accommodates a single system servicing numerous distinct sources of helium, air, and hydrogen mixtures developed over the range of rocket propulsion testing and ground and flight operations and the temporal transient nature of production of these mixtures.

Robust Component Technologies

Rocket propulsion test hardware as well as ground and flight launch operations hardware regularly experience large and rapid changes in pressures, temperatures, vibration, and fluid flow rates while demanding high precision control and reliability. Typical ranges in these parameters are pressures from vacuum all the way up to 10,000 psi, working fluids at ambient temperature all the way down to -420F, vibration environments in the 100's of G RMS acceleration. These parameters can span their entire range in milliseconds. State of the art propulsion system testing hardware has evolved over time as better materials and experience in hardware interactions with these environments have progressed. Innovation in component performance diagnostics technology is required to continue the current progression in hardware operational reliability, cost, and weight optimization. Accordingly, the goal of this subtopic thrust area is to develop innovative in situ hardware performance measurement and diagnostics technology along with the accompanying data acquisition and management systems required for utilization the new technologies.

Advanced Propulsion Test Data Management Capability

Substantial advances in data capture and storage technologies have exponentially increased real and near-real time data availability in rocket propulsion testing. Effective utilization of this increase in data availability requires evolution of data management technologies, methods, and concepts that will enable greater and more effective real-time access, manipulation, and application in the control and quality of propulsion systems testing. Recent initiatives in development of hardware-in-the-loop technologies, merging measured and simulation data in real time feedback with propulsion test hardware have demonstrated the feasibility and utility of this technology. The goal of this subtopic thrust area is to develop innovative ways to take advantage of increased propulsion test data availability utilizing high performance hardware such as GPU based computer systems along with innovation in algorithms and software to implement new data management technologies, methods, and concepts.

In these subject areas, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward hardware and/or software development as appropriate, which occurs during Phase II and culminates in a proof-of-concept system.

Phase I Deliverables: A final report describing optimal design for the technology concept including feasibility, trade studies, detailed results of Phase I analysis, modeling, prototyping, and testing as applicable. The report should also contain a detailed path towards Phase II hardware and/or software proof-of-concept system. The technology concept at the end of Phase I should be at a TRL of 3-4.

Phase II Deliverables: A working proof-of-concept system successfully demonstrated in a relevant environment and delivered to NASA for testing and verification. The technology at the end of Phase II should be at a TRL of 6-7.