NASA SBIR 2015 Phase I Solicitation

H2 Space Transportation

Lead Center: GRC

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. Human Exploration requires advances in operations, testing, and propulsion for transport to the earth orbit, the moon, Mars, and beyond. NASA is interested in making space transportation systems more capable and less expensive. NASA is interested in technologies for advanced in-space propulsion systems to support exploration, reduce travel time, reduce acquisition costs, and reduce operational costs. 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 vehicles. 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 acquisition, reusability, reliability, and operability of space transportation systems.Â

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Subtopics

H2.01 In-Space Chemical Propulsion

Lead Center: GRC

Participating Center(s): JSC, MSFC

The goal of this subtopic is to examine a range of key technology options associated with space engines that use methane as the propellant. Successful proposals are sought for focused investments on key technologies and design concepts that may transform the path for future exploration of Mars. In-space propulsion is defined as the development and demonstration of technologies for ascent, orbit transfer, pulsing attitude/reaction control, and descent engines. Key operational and performance parameters include:Â

- Reaction control thruster development in the 5 to 100 lbf thrust class with a target vacuum specific impulse of 325-sec. The reaction control engines would operate cryogenic liquid-liquid for applications requiring integration with main engine propellants; or would operate gas-gas or gas-liquid for small total impulse type applications. RCEs operating on liquid cryogenic propellant(s) should be able to tolerate operation for limited duty cycles with gaseous or saturated propellants of varying quality.
- Ascent/descent pressure-fed engines with 1,500 to 25,000 lbf thrust with a target vacuum specific impulse

of 350 to 360-sec. The engine should be capable of throttling to 5:1 (20% power), and the chamber pressure should range from 200 to 650 psig.

- Ascent/descent pump-fed engine development is projected to range from 10,000 to 25,000 lbf thrust with a minimum vacuum specific impulse of 360-sec. The propulsion system should be capable of stable throttling to 10:1 (10% power). The engine shall achieve 90% rated thrust within 0.5 second of the issuance of the â€˜Engine ONâ€™ command.

Specific technologies of interest for operation with liquid and gaseous methane are sought. Relevance of the technology to compatibility and applicability to challenges with methane must be identified. In addition, these engines should be compatible with the future use of in situ produced propellants such as oxygen and methane. For all proposed technologies, the proposer shall show in the proposal how the component would fit in a system cycle based on thermal capabilities and pressure budgets. Propulsion technologies of interest that support the performance parameters defined above include:Â

- New additive manufacturing techniques that can be demonstrated to allow for rapid manufacturing, surface finishes, structural integrity, and significant costs savings for complex combustion devices and turbomachinery components compared to the conventional manufacturing. Manufacturing methods must scale to a final flight component.
- Low-mass propellant injectors that provide stable and uniform combustion over a wide range of propellant inlet conditions.
- Combustion chamber designs using high temperature materials, coatings, and/or ablatives for combustion chambers, nozzles, and nozzle extensions.
- Regenerative cooled combustion chamber technologies which offer improved performance and adequate chamber life.
- Turbopump technologies specific to liquid methane that are lightweight with a long shelf life that can meet deep-throttle requirements, including small durable high speed turbines, high fatigue life impellers, zero net positive suction head (NPSH) inducers, low leakage seals, and long life in situ propellant fed bearings.

Phase I Deliverables - Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a demonstration. Bench or lab-level demonstrations are desirable. The technology concept at the end of Phase I should be at a TRL of 4 to 5

Phase II Deliverables - Emphasis should be placed on developing and demonstrating the technology under simulated mission conditions. The proposal shall outline a path showing how the technology could be developed into mission-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. The technology concept at the end of Phase II should be at a TRL of 5 to 6.Â Â

H2.02 Nuclear Thermal Propulsion (NTP)

Lead Center: MSFC

Participating Center(s): GRC, SSC

Solid core NTP has been identified as an advanced propulsion concept which could provide the fastest trip times with fewer SLS launches than other propulsion concepts for human missions to Mars over a variety of mission years. The current NASA Strategic Space Technology Investment Plan states NTP is a high priority technology needed for future human exploration of Mars. NTP had major technical work done between 1955-1973 as part of the Rover and Nuclear Engine for Rocket Vehicle Application (NERVA) programs. A few other NTP programs followed including the Space Nuclear Thermal Propulsion (SNTP) program in the early 1990's. The NTP concept is similar to a liquid chemical propulsion system, except instead of combustion in the thrust chamber, a monopropellant is heated with a fission reactor in the thrust chamber. In addition, the engine components and surrounding structures are exposed to a radiation environment formed by the reactor during operation.

This solicitation will examine a range of modern technologies associated with NTP using solid core nuclear fission reactors and technologies needed to ground test the engine system and components. The engines are pump fed ~15,000-35,000 lbf with a specific impulse goal of 900 seconds (using hydrogen), and are used individually or in clusters for the spacecraft's primary propulsion system. The NTP can have multiple start-ups (>4) with cumulative run time >100 minutes in a single mission, which can last a few years. The Rover/NERVA program ground tested a variety of engine sizes, for a variety of burn durations and start-ups with the engine exhaust released to the open air. Current regulations require exhaust filtering of any radioactive noble gases and particulates released to stay within the current environmental regulations. The NTP primary test requirements can have multiple start-ups (>8) with the longest single burn time ~50 minutes.

Specific engine technologies of interest to meet the proposed requirements include:Â

- High temperature (> 2600K), low burn-up composite, carbide, and/or ceramic-metallic (cermet) based nuclear fuels with improved coatings and/or claddings to maximize hydrogen propellant heating and to reduce fission product gas release and particulates into the engine's exhaust stream.
- Long life, lightweight, reliable turbopump modeling, designs and technologies including seals, bearing and fluid system components. Throttle ability is also considered. Zero net positive suction head (NPSH) hydrogen inducers have been demonstrated that can ingest 20-30% vapor by volume. The goal would be to develop inducers that can ingest 55% vapor by volume for up to 8 hours with less than 10 percent head fall off at the design point. Develop the capability to model (predict) turbopump cavitation dynamics. This includes first order rotating and alternating cavitation (1.1X â€“2X) and higher (6X-10X) order cavitation dynamics.
- High temperature and cryogenic radiation tolerant instrumentation and avionics for engine health monitoring. Non-invasive designs for measuring neutron flux (outside of reactor), chamber temperature, operating pressure, and liquid hydrogen propellant flow rates over wide range of temperatures are desired. Sensors need to operate for months/years instead of hours. Robonaut type inspections for prototype flight test considered.
- Concepts to cooldown the reactor decay heat after shutdown to minimize the amount of open cycle propellant used in each engine shutdown. Depending on the engine run time for a single burn, cool down time can take many hours.
- Low risk reactor design features which allow more criticality control flexibility during burns beyond the reactor circumferential rotating control drums, and/or provide nuclear safety for ground processing, launch, and possible launch aborts.

Specific ground test technologies of interest to meet the proposed requirements include:Â

- Effluent scrubber technologies for efficient filtering and management of high temperature, high flow hydrogen exhausts. Specific interests include:
  - Filtering of radioactive particles and debris from exhaust stream having an efficiency rating greater than 99.9%.
  - Removal of radioactive halogens, noble gases and vapor phase contaminants from a high flow exhaust stream with an efficiency rating greater than 99.5%.
- Technologies providing a low power nuclear furnace to test a variety of fuel elements at conditions replicating a full scale NTP engine.

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 (TRL 2-3). 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 engineering model of proposed product, along with full report of component and/or breadboard validation measurements, including populated verification matrix from Phase I (TRL 4-5). Opportunities and plans should also be identified and summarized for potential commercialization.Â Â

H2.03 High Power Electric Propulsion

Lead Center: GRC

Participating Center(s): JPL, MSFC

The goal of this subtopic is to develop innovative technologies that can lead to high-power (100-kW to MW-class) electric propulsion systems. High-power solar or nuclear electric propulsion may enable dramatic mass and cost savings for lunar and Mars cargo missions, including Earth escape and near-Earth space maneuvers, and at very high power levels enable piloted exploration missions.

Innovations and advancements leading to improvements in the end to end performance of high power electric propulsion systems are of interest. Methods are sought to increase overall system efficiency; improve system and/or component life or durability; reduce system and/or component mass, complexity, and development issues; or provide other definable benefits. In general, thruster system efficiencies exceeding 60% and providing total impulse values greater than 10^7 N-sec are desired. Specific impulse values of interest range from a minimum of 1500-sec for Earth-orbit transfers to over 6000-sec for planetary missions.

Specific technologies of interest in addressing high power electric propulsion challenges include but are not limited to:Â

- Advanced concepts for high power plasma thruster systems that provide quantifiable benefits over state of the art high power electric propulsion systems. Proposals addressing advanced technology concepts should include a realistic and well-defined roadmap defining critical technology development milestones leading to an eventual flight system.
- Electric propulsion systems and components that enable the use of alternative space storable propellants, such as condensible or metal propellants and potential in-situ resource derived propellants.
- Advanced manufacturing methods for the fabrication of high power thruster components and associated systems; of particular interest is additive manufacturing for complex parts and components. Figures of merit include lower cost, rapid turnaround, and material and structural integrity comparable to or better than components or systems produced using current fabrication methods.
- Components for inductively pulsed plasma thrusters, in particular highly accurate flow controllers and fast acting valves; and solid state switches capable of high current (MA), high repetition rate (up to 1-kHz), long life (equal to or >10^9 pulses) operation.

In addressing technology requirements, proposers should identify candidate thruster systems and potential mission applications that would benefit from the proposed technology.

Phase I Deliverables - Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a demonstration. Bench or lab-level demonstrations are desirable. The technology concept at the end of Phase I should be at a TRL of 4 to 5

Phase II Deliverables - Emphasis should be placed on developing and demonstrating the technology under simulated mission conditions. The proposal shall outline a path showing how the technology could be developed into mission-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. The technology concept at the end of Phase II should be at a TRL of 5 toÂ 6.Â Â

H2.04 Cryogenic Fluid Management for In-Space Transportation

Lead Center: GRC

Participating Center(s): JSC, MSFC

This subtopic solicits technologies related to cryogenic propellant (such as hydrogen, oxygen, and methane) storage, transfer, and instrumentation to support NASA's exploration goals. This includes a wide range of applications, scales, and environments consistent with future NASA missions. Specifically, listed in order of NASAâ€™s current priority:Â

- Simple mass efficient techniques for vapor cooling of structural skirts (aluminum, stainless, or composites) on large upper stages containing liquid hydrogen and liquid methane (can include para-to-ortho hydrogen catalyst for hydrogen applications).

- Lightweight, multifunctional cryogenic insulation systems (including attachment methods) that can survive exposure to the free stream during the launch/ascent environment in addition to high performance (less than 0.5 W/m^2 with a warm boundary of 220 K) on orbit or <5 W/m^2 on Mars surface.Â
- Advanced cryogenic spacecraft components including:
    - Valves (minimum Â½â€ tube size) for low (< 50 psi, Cv > 5, goal of 100+) pressure liquid hydrogen with low internal (~ 1 sccm, goal of < 0.1 sccm) and external (~ 3 sccm, goal of < 0.1 sccm) leakage (> 500 cycles with a goal of 5,000 cycles).
    - Isolation valve/regulation (minimum Â½â€) for high pressure (>4500 psi) gaseous helium systems (< 70 K fluid, Cv > 2.1) with low internal (~ 1 sccm) and external (~ 3 sccm) leakage (> 500 cycles with a goal of 5,000 cycles).
    - Spherical all-composite 1-2 m diameter propellant tank for Mars application using LO_2/LCH_4; Pressure from 350-1000 psig; Temperature range from ambient to 77 K (LN_2); and Ghe permeability less than 1x10-4 sccs/m^2 (at 500 psi, 77 K).
- Micro-gravity cryogenic pressure control components for thermodynamic vent systems including:
    - Improved alternatives to state of the art spray bars for using fluid dynamics to collapse the ullage and thoroughly mix a propellant tank in micro-gravity.
    - Low voltage (28 VDC) two-phase flow tolerant mixing pumps of flow rates between 10 and 40 gpm.
    - Novel methods of packaging and manufacture to minimize feedthroughs to the tank and ease of installation into a tank.
- Innovative concepts for cryogenic fluid instrumentation including:
    - Fiberoptic and wireless concepts to enable accurate measurement (with minimal sensitivity to electromagnetic interference) of propellant pressures and temperatures in low-gravity storage tanks
    - Cryogenic pressure transducers (0 â€“ 50 psia typical range, 1% full scale accuracy, 0.5 Hz response) at 20 K.
    - Low power (< 15 W goal) video camera systems for viewing fluid dynamics within a propellant tank (3 â€“ 5 m diameter).
- Wicking materials or other novel methods/materials of liquid acquisition for use with liquid oxygen, liquid methane, and liquid hydrogen for low temperature heat pipes or tank expulsion.

Phase I proposals should at a minimum deliver proof of the concept including some sort of testing or physical demonstration (not just a paper study). Phase II proposals will be expected to provide component validation in a laboratory environment preferably with a hardware deliverable to NASA.Â