NASA SBIR 2014 Phase I Solicitation

H2 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. 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.

Subtopics

H2.01 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 (>50 kW to MW-class) electric propulsion systems. High-power (high-thrust) electric propulsion (>50kW per thruster) may enable dramatic mass and cost savings for lunar and Mars cargo missions, including Earth escape and near-Earth space maneuvers. At very high power levels, electric propulsion may 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. Technologies are sought that increase system efficiency; increase system and/or component life or durability; reduce system and/or component mass, complexity, or development issues; or provide other definable benefits. In general, thruster system efficiencies exceeding 60% and providing total impulse values greater than 10^7. Desired specific impulses range from a value of 2000 s for Earth-orbit transfers to over 6000 s for planetary missions.

Specific technologies of interest in addressing these challenges include:

- Electric propulsion systems and components for alternate fuels such as the use of in-situ resources, condensable or metal propellants, and alternatives to Xenon.

- Novel methods for fabricating large refractory metal parts with complex shapes, with integrated heat pipes. Particular figures of merit include low cost, rapid turnaround, and ability to incorporate internal flow passages.
- Long life cathodes for high power electrostatic or electromagnetic thrusters capable of extended operation at required temperature and current levels for appropriate mission durations.
- Innovative plasma neutralization concepts.
- Highly accurate flow controllers and fast acting valves for pulsed thruster systems High current (MA), high repetition rate (up to 1-kHz), long life (greater than 10^9 pulses) solid state switches for high power inductive pulsed plasma thrusters.
- High-temperature permanent magnets and/or electromagnets; low-voltage, high-temperature wire for electromagnets; superconducting magnets.

Note to Proposer: Subtopic S3.02 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.02.

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

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 range of 3-4.

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 range of 4-5.

H2.02 In-Space Chemical Propulsion

Lead Center: GRC

Participating Center(s): JSC, MSFC

This solicitation intends to examine a range of key technology options associated with non-toxic storable liquid propulsion systems for use in future exploration missions. Efficient propulsive performance and long duration storage attributes have made the use of hydrazine widespread across the aerospace community. However, hydrazine is highly corrosive and toxic, creating a need for non-toxic, high performance propellants for NASA, other government agencies, academia, and the commercial space industry.

Non-toxic engine liquid mono- and bi-propellants technologies are desired for use in lieu of the currently operational hydrazine based engine technologies. Handling and safety concerns with the current toxic chemical propellants can lead to more costly propulsion systems. The use of new non-toxic propellants has the potential to reduce the cost of access to space by lowering overall life cycle costs.

Demonstrations of a hydrazine alternative in a storable liquid mono- or bi-propellant chemical propulsion system implementation relevant to at least one of the following applications are desired: in-space reaction control propulsion, in-space primary propulsion, and launch vehicle reaction control propulsion. Non-toxic technologies could range from pump fed or pressure fed thruster systems from 1 to 1000 lbf.

Specific technologies of interest to meet proposed engine requirements include:

- Non-toxic mono- and bi-propellants that meet performance targets (as indicated by high specific impulse and high specific impulse density) while improving safety and reducing handling operations as compared to current state-of-the-art storable propellants.
- Alternate catalysts, ignition technologies to ignite advanced monopropellants.

- Advanced materials capable of withstanding hot and corrosive combustion environment of advanced mono- and bi-propellants.
- Techniques that lower the cost of manufacturing complex components such as injectors, catalysts, and combustion chambers. Examples include, but are not limited to, development and demonstration of rapid prototype techniques for metallic parts, powder metallurgy techniques, and application of nano-technology for near net shape manufacturing.

Note to Proposer: Subtopic S3.02 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.02.

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

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 range of 3-4.

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 range of 4-6.

H2.03 Nuclear Thermal Propulsion (NTP)

Lead Center: MSFC

Participating Center(s): GRC, JSC

This subtopic seeks to develop innovative NTP technologies supporting the needs of future space exploration.

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 (heat exchanger) 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. 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.

Specific technologies of interest to meet the proposed requirements include:

- 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 hydrogen 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 2X) and higher (6X-10X) order cavitation dynamics.
- Highly-reliable, long-life, fast-acting propellant valves with ultra-low hydrogen leakage that tolerate long duration space mission environments with reduced volume, mass, and power requirements are also desirable. Large propellant tank bottom valves can be expected to leak in the order of 1cc per minute of hydrogen measured at standard temperature and pressure (STP). For deep space missions valve leakage will need to be <.01 cc per minute at STP. Demonstrate a large tank bottom valve that can maintain a .01 cc per minute at STP. The valve should be able to cycle 10 times and maintain that leak rate. Valve cycle time can be on the order of one minute or more.
- 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 cool down 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.
- Technology needed to store the NTP propellant for multiple years in-space as liquid hydrogen with almost zero boil-off for 900 days (includes time from first launch to final trans earth injection burn). Innovations are needed in thermal control materials and design, mechanical refrigeration systems, and vehicle design.

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.

H2.04 Nuclear Thermal Propulsion (NTP) Ground Test Technologies

Lead Center: SSC

Participating Center(s): MSFC

A nuclear rocket engine uses a nuclear reactor to heat hydrogen to very high temperatures, which expands through a nozzle to generate thrust. This topic area seeks to develop advanced technology components and system level ground test systems that support Nuclear Thermal Propulsion (NTP) technology development and certification.

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. 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 (heat exchanger) in the thrust chamber. In addition, the engine components and surrounding structures are exposed to a radiation environment formed by the reactor during operation. The NTP had ground testing done between 1955-1973 as part of the Rover and Nuclear Engine for Rocket Vehicle Application (NERVA) programs. The Rover/NERVA ground tested a variety of engine sizes, for a variety of burn durations and start-ups. These ground tests were mostly exhausted in the open air. Information on the NERVA program can be found at (http://history.nasa.gov/SP-4533/Plum%20Brook%20Complete.pdf).

Current regulations require exhaust filtering of any radioactive noble gases and particulates released to stay within the current environmental regulations. The NTP ground testing requires the development of robust materials, advanced instruments and monitoring systems capable of operating in extreme temperature, pressure and radiation environments. This topic area will investigate large scale engine exhaust scrubber technologies and options for integrating it to the NTP engine for ground tests. The NTP engines are pump fed ~15,000-35,000 lbf with a specific impulse goal of 900 seconds (using hydrogen). The NTP primary test requirements can have multiple start-ups (>8) with the longest single burn time ~50 minutes.

This subtopic seeks innovative technologies in the following areas to facilitate NTP ground testing:

- Advanced high-temperature and hydrogen embrittlement resistant materials for use in a hot hydrogen environment (<4400 °F).
- Efficient non-nuclear generation of high temperature, high flowrate hydrogen (<60 lb/sec).
- Devices for measurement of radiation, pressure, temperature and strain in a high temperature and radiation environment.
- Effluent scrubber technologies for efficient filtering and management of high temperature, high flow hydrogen exhausts.
- Innovative refractory materials which use nano-particle additives and/or unconventional non-cement based refractories that can withstand the extreme plume heating environments experienced during rocket propulsion testing.

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%.
- Applicable Integrated System Health Monitoring and autonomous test operations control systems.
- Modern robotics which can be used to inspect the ground test system exposed to a radiation environment.

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.