



## NASA SBIR 2014 Phase I Solicitation

### 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 (SNTTP) 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

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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.