NASA SBIR 2020 Phase I Solicitation

Z8.09 Small Launcher Lunar Transfer Stage Development

Lead Center: MSFC

Participating Center(s): AFRC, GRC

Technology Area: TA2 In-Space Propulsion Technologies

Scope Description

NASA desires to explore the lunar environment using small spacecraft. The lunar environment in this case includes: the lunar surface with specific interest in the south pole, low lunar and frozen lunar orbits, as well as cis-lunar space including Earth-moon LaGrange points and the lunar Near Rectilinear Halo Orbit (NRHOs) intended for Gateway. To allow CubeSats and small spacecraft, defined as total mass less than 180 kg fueled, to exploit these locations, NASA is interested in the development of a low cost cis-lunar transfer stage to guide and propel small spacecraft on Trans Lunar Injection (TLI) trajectories that will enable the spacecraft to enter the above referenced lunar locations or orbits, either with on board propulsion capability or via the transfer stage itself.

Transfer stage architectures and designs shall be compatible with U.S. small launch vehicles that are currently flying or will be launching in the next year. Proposals should identify one or more relevant small launch vehicles and shall describe how their designs fit within the constraints of those vehicles. Transfer stage designs shall contain all requisite systems for navigation, propulsion, and communication in order to complete the lunar mission. Any and all propulsion chemistries and methods may be considered, including electric propulsion, as long as the design closes within the reference mission constraints. Transfer stages shall also include method(s) to deploy smallsat payloads once on a TLI trajectory or upon arrival in lunar orbit.

This subtopic is targeting transfer stages for launch vehicles that have a capability range similar to that sought by the NASA Venture Class Launch Services. Rideshare applications that involve medium or heavy lift launch vehicles (e.g. Falcon 9, Atlas V) or deployment via the International Space Station (ISS) airlock are not part of this topic.

Design reference mission:

- Launch on a small launch vehicle (ground or air launch)
- Payload (deployable spacecraft) mass: at least 25 kg
- Provide sufficient delta V and guidance to enter into TLI after separation from small launch vehicle. An example mission is the CAPSTONE / NRHO Pathfinder 12U (25 kg) CubeSat that requires a Trans Lunar Injection orbit with a C3 of -0.6 km²/s².
- (Optional) provide sufficient delta V and guidance to place a 25 to 50 kg spacecraft directly into lunar NHRO orbit
- Deploy spacecraft from transfer stage
- Safe and dispose of transfer stage
References

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170012214.pdf
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160010585.pdf
https://www.rocketlabusa.com/photons/
https://www.rocket.com/space/space-power-propulsion/bipropellant-space-propulsion

Expected TRL or TRL range at completion of the project

Proposed technologies should mature to TRL 4 to 6 by the end of Phase II effort.

Desired Deliverables of Phase II

Prototype Hardware and Software
Experimental data
Mission design and analysis data

Desired Deliverables Description

A Phase I effort should include a Preliminary Design Review (PDR) level design for a flight-like system and a near-Completion Design Review (CDR) level design for the prototype system. The feasibility of key elements in the system design should be evident through fabrication or testing demonstrations. The phase 1 report should include a mapping of key performance parameters (mass, power, cost, etc.) from the prototype to the flight design, along with potential opportunities for technology demonstration and commercialization. It is highly desired that the Phase II deliverable include demonstration test data for the prototype system along with detailed metrics (mass, power, cost, etc.) which are traceable to a flight design for the reference mission. Efforts leading to Phase II delivery of integrated prototype systems that could either be ground tested or flight-testing as part of a post-Phase II effort are of particular interest.

State of the Art and Critical Gaps

Many cubesat/small sat propulsion units are designed for low delta-V maneuvers such as orbit maintenance, station keeping, or reaction control. Larger delta-V systems are employed for larger satellites and science/exploration missions, but are often costly and integrated as part of the satellite design. Systems typically range from cold-gas to bi-propellant storables with electric systems also viable for very small systems. Aerojet Rocketdyne and Moog are prominent suppliers of SOA thrusters including commonly used variants of the R-4D engine. Rocket Labs has recently introduced an upgraded version of their kick-stage using a monopropellant system to support LEO operations for small sat payloads. While many of the right component technologies are reasonably mature, no integrated system capability has been developed and implemented specifically as a low cost solution for trans-lunar or cis-lunar mission designs.

Relevance / Science Traceability

This subtopic extends the capabilities of the Flight Opportunities Program and Launch Services Program by seeding potential providers to establish lunar/cis-lunar transfer capabilities.

Many technologies appropriate for this topic area are also relevant to NASA's lunar exploration goals. Small stages developed in this topic area would also be potential flight test beds for cryogenic management systems, wireless avionics, or advance guidance systems and sensors.