NASA SBIR/STTR
Small Business Innovation Research / Small Business Technology Transfer

NASA STTR 2020 Phase I Solicitation

T2.04 Advanced in-space propulsion

Lead Center: MSFC

Participating Center(s): GRC

Technology Area: TA2 In-Space Propulsion Technologies

This subtopic is seeking small business - non-profit research institution partnerships to advance subsystem elements of three important, next generation in-space propulsion technologies: the Electrostatic Solar Sail, Freeform additive fabrication for propulsion elements, and Nuclear Thermal Propulsion low cost fuel testing.

Scope Title

Electrostatic Solar Sail (E-Sail) Advancement

Scope Description

The E-Sail is a propellant-less in-space propulsion system that utilizes electrostatic repulsion of solar wind (off of an electrically biased tether) to generate thrust. Preliminary studies indicate several advantages of this technology, including enabling access to interstellar space with transit times significantly faster than state-of-the-art (SOA) technologies. For this year's E-Sail investments, concepts to advance the Technology Readiness Level (TRL) of the E-sail guidance, navigation, and control system and/or robust models for spacecraft dynamics both during deployment as well as during operation are solicited. Marshall Space Flight Center (MSFC) is currently conceptualizing a 6-12U, ~10km total tether length E-Sail demonstration. Neither a specific architecture nor specific requirements have yet been detailed, however, responders should focus efforts in their proposed work towards this size spacecraft while keeping eventual scaling to as much as a 10x larger spacecraft in mind.

Expected TRL or TRL range at completion of the project: 3 to 6

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Software, and/or Research

Desired Deliverables Description

Phase I proof of concept and/or preliminary guidance, navigation & control (GN&C) designs and/or models that will lead to Phase II medium to high fidelity prototypes ready for system infusion (in case of hardware), system analysis (in case of models), and/or advanced TRL testing (space environments testing) to support a MSFC led technology demonstration mission. Beyond Phase II, infusion into the planned E-Sail Technology Demonstration Missions (TDM) via a Phase III, IIE, directed work, etc. or additional development/test via an Announcement of Collaborative Opportunity (ACO) may be potential opportunities.

State of the Art and Critical Gaps

The E-Sail concept has potential to enable practical access to interstellar space and fast travel beyond our solar system. The E-Sail has several open technology gaps. NASA is systematically reducing known risks of full system implementation prior to a flight demonstration. State of the Art GN&C systems and modeling have limitations due to the complex and changing dynamics of an E-Sail system. A critical gap is robust and high fidelity GN&C modeling and/or concepts for control of the E-Sail vehicle.

Relevance / Science Traceability

An Electrostatic Sail E-Sail is a propellant-less advanced propulsion system that harnesses solar wind by electrostatic repulsion. Note, this contrasts Solar Sails, which utilize optical reflection of solar photons. E-Sail is comprised of thin tethers, which are electrically biased to form large electric fields. These fields create a virtual sail that repels solar ions and generates thrust. A key advantage is this mechanism better maintains thrust as it moves away from the sun – falling off at only 1/distance, substantially better than the solar sail 1/d^2. E-Sail will rapidly improve transit time within and to the edge of the solar system as well as enable out of plan maneuvers not currently possible.

References

https://www.nasa.gov/centers/marshall/news/news/releases/2016/nasa-begins-testing-of-revolutionary-e-sail-technology.html (as of 8/2/2019)

Scope Title

Large Scale Freeform Additive Fabrication using GRCop-42 and Gradient Alloys

Scope Description

NASA is interested in soliciting proposals to develop a process for large scale freeform fabrication using additive manufacturing of GRCop-42 and functional gradient materials. Components such as rocket nozzles and heat exchangers are actively-cooled with internal channel features and require high performance materials in the extreme environment. Typically these components are made from a monolithic alloy, although various alloys and functional gradient materials could increase performance and optimize the overall system. The objective of this solicitation is to complete process development (i.e., directed energy deposition, coldspray, etc.) to fabricate a freeform component that incorporates thin-wall integral channels into a structure. This process should focus on GRCop-42 (Cu-Cr-Nb) and transition to an alternate material using a functional gradient process. The proposer should provide a technique and approach to axially transition from the GRCop-42 to alternate alloy (Superalloy, Stainless, High Entropy Alloys) providing a compatible functional gradient joint to minimize stresses. A thorough development approach would include process development, initial characterization and testing of the GRCop-42 and functional gradient alloys, process demonstration of manufacturing technology demonstrators (MTD), and trade study and/or planning to increase the scale to several feet in diameter.

Expected TRL or TRL range at completion of the project: 3 to 6

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, and/or Research

Desired Deliverables Description

Phase I: Develop a process for fabricating (using directed energy deposition, coldspray, etc.) a freeform structure that incorporates thin-wall integral channels targeting a heat exchanger, combustion chamber, rocket nozzle, channel-cooled structure and provide a trade on combination of compatible materials, with NASA inputs.

Leading to Phase II: Complete fabrication of process development samples using GRCop-42 and functional gradient alloys (Superalloy, High Entropy Alloys) to change the material axially along the component; and complete process characterization, mechanical testing, materials evaluation to provide first order design data. Fabricate manufacturing demonstrator components with integral channels with materials selected. Provide components that NASA could perform benchtop, flow, and/or hot-fire testing. Demonstrate a manufacturing technology component with integral channels and that is larger than 16” diameter with the GRCop-42 and functionally gradient alloys. Provide scale-up to >40” diameter.

State of the Art and Critical Gaps

NASA has been developing various additive manufacturing technologies in GRCop-42 using laser powder bed fusion (L-PBF) and currently working to mature large-scale (>3 ft dia) blown powder directed energy deposition (DED) process using NASA HR-1 and JBK-75. These technologies have been limited to monolithic materials though. Additional development has included bimetallic cladding (radial deposition) to provide superalloy jackets on copper-alloy combustion chambers under the Low Cost Upper Stage Propulsion (LCUSP) project, however this technology is not easily accessible at service companies. While the technology exist to fabricate components at sizes <16” diameter using laser powder bed fusion (L-PBF) using GRCop-42, this is limited to a monolithic material in the axial direction. There are also no current additive techniques to rapidly fabricate GRCop-42 structures larger than this scale.

There are also additional challenges in this approach with a binary transition from one alloy to another. Optimized structures for heat exchanges and combustion devices would include the ability to fabricate large structures with complex internal features and vary/transition alloys along the axial length of a component (not just radial). This would allow for a more compliant bond between a copper-alloy and alternate material instead of a drastic change in alloys. This would reduce risk of joints. A further gap is the ability to produce copper-alloys, such as GRCop-42, in scales larger than 16” diameter. This provides new solutions for designers of large engines and structures providing higher thermal margins on the walls with the use of copper. The copper technology using additive manufacturing does not exist using directed energy deposition (DED) or other technologies at this scale.

Relevance / Science Traceability

Applications to: Propulsion and energy, Liquid rocket engines, Small thrusters, Additive Manufacturing, and Advanced Manufacturing.

References

Gradl, P., Greene, S., Wammen, T. “Bimetallic Channel Wall Nozzle Development and Hot-fire Testing using Additively Manufactured Laser Wire Direct Closeout Technology”. 55th AIAA/SAE/ASEE Joint Propulsion Conference, AIAA Propulsion and Energy Forum. August 19-21, Indianapolis, IN. AIAA-2019.

Gradl, P., Protz, C., Wammen, T. “Additive Manufacturing Development and Hot-fire Testing of Liquid Rocket Channel Wall Nozzles using Blown Powder Directed Energy Deposition Inconel 625 and JBK-75 Alloys”. 55th AIAA/SAE/ASEE Joint Propulsion Conference, AIAA Propulsion and Energy Forum. August 19-21, Indianapolis, IN. AIAA-2019

https://gameon.nasa.gov/projects/rapid-analysis-and-manufacturing-propulsion-technology-rampt/

Gradl, P. “Rapid Fabrication Techniques for Liquid Rocket Channel Wall Nozzles.” AIAA-2016-4771, Paper presented at 52nd AIAA/SAE/ASEE Joint Propulsion Conference, July 27, 2016. Salt Lake City, UT.

Scope Title

Nuclear Thermal Propulsion (NTP) Advancement fuel testing

Scope Description

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 and exposes the engine components and surrounding structures to a radiation environment. NTP thrust is ~25,000 lbf with ~29 lbs/sec flow of hydrogen through the fuel elements. Current fuel element designs are based on cermet (ceramic metal) or carbon with low enriched uranium.

The scope is open to university/Small Business Concern (SBC) partners to propose key innovation on how to best test NTP fuel pieces in the university nuclear reactors that come close to meeting the following test goals:

- Neutron/gamma radiation fluence approximating NTP operation.
- Heat NTP fuel test piece up to 2700K.
- Power density of 5 MW/L.
- Test piece exposed to hydrogen (if possible).
- Maintain steady state up to 15 minutes (or fluence equivalent).

Expected TRL or TRL range at completion of the project: 3 to 6

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, and Research

Desired Deliverables Description

The STTR team provides the following for Phase I and II:

- Irradiation capsule design and thermal analysis predictions to handle a variety of fuel test pieces in the university reactor.
- Instrumentation required to determine how best the fuel performed and validate analysis predictions.
- Development plan for Phase II including a description of the reactor test arrangement and fuel pieces to be irradiated. Start-off with irradiating a surrogate test piece during phase II. Conclude phase II with irradiating a fuel test piece with High Assay Low Enriched Uranium. Include a description of post-test examinations to be performed.

State of the Art and Critical Gaps

Testing various fuel concepts in the same environment as an NTP engine at low cost is not easy. Many current irradiation test facilities can test sample pieces to only a few of the NTP environment conditions.

Relevance / Science Traceability

Research could have a significant positive impact on the design and development of NTP systems. NTP potentially useful for both science and exploration missions.

References

Multiple publicly available references, see for example:

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120003776.pdf (as of 9/30/2019)

https://apps.dtic.mil/dtic/tr/fulltext/u2/a430931.pdf (as of 9/30/2019)