NASA SBIR 2020 Phase I Solicitation

Z3.03 Development of material joining technologies and large-scale additive manufacturing processes for on-orbit manufacturing and construction

Lead Center: MSFC

Participating Center(s): GSFC, LaRC

Technology Area: TA12 Materials, Structures, Mechanical Systems and Manufacturing

Scope Title

Development of Material Joining Technologies for On-Orbit Manufacturing and Construction

Scope Description

Technology development efforts are required to enable On-Orbit Servicing, Assembly, and Manufacturing(OSAM) for commercial satellites, robotic science, and human exploration. OSAM is an emerging national initiative to transform the way we design, build, and operate in space. The goal of the initiative is to develop a strategic framework to enable robotic servicing, repair, assembly, manufacturing, and inspection of space assets.

An in-space material joining capability is an important supporting technology for the long duration, long endurance space missions that NASA will undertake beyond the International Space Station (ISS). Historically structures in space have been assembled using mechanical fastening techniques and modular assembly. Structural designs for crewed habitats, space telescopes, antennas, and solar array reflectors are primarily driven by launch considerations such as payload faring dimensions and vibrational loads experienced during ascent. An in-space material joining capability can potentially eliminate constraints on the system imposed by launch, enabling the construction of larger, more complex and more optimized structures. Material joining is an essential complementary capability to large scale additive manufacturing technologies being developed by NASA and commercial partners. Material joining is also a critical capability for repair scenarios (ex. repair of damage to a structure from micrometeorite impacts).

This subtopic seeks innovative engineering solutions to robotically join materials, fully or semi-autonomous, for manufacturing in the external space environment. Current State-Of-the-Art (SOA) terrestrial joining methods such and laser beam, electron beam, brazing, friction/ultrasonic stir and arc welding should be modified with an effort to reduce the footprint, mass and power requirements for on-orbit applications.

Phase I is a feasibility study and laboratory proof of concept of a robotic welding process and system for external in-space manufacturing applications. Targeted applications for this technology include joining and repair of components at the subsystem level, habitat modules, trusses, solar arrays, and/or antenna reflectors. The need to repair a damaged structure may require the need to not only join material but cut and remove material. A single process with the ability to not only join material but also cut/remove material is a priority. The Phase I effort should provide a laboratory demonstration of the joining process and its applicability to aerospace grade metallic materials and/or thermoplastics, focusing on joint configurations which represent the priority in-space joining applications identified above. Work under Phase I will inform preliminary design of a mobile welding unit and a concept of operations for how the system would be deployed and operate in the space environment, with a focus on specific scenarios: for example, repair of a metal panel following micrometeorite damage, longitudinal joining of two metal curved panels, and joining of a truss to an adjacent truss. The Phase I should also provide an assessment of the proposed process operational capabilities (for example: classes of materials which can be welded with the process, joint configurations which can be accommodated, and any expected impacts of the microgravity environment on joint efficiency relative to terrestrial system operation), volume, and power budget. A preliminary design and concept of operations are also deliverables under the phase I. Concepts for ancillary technologies such as post-process inspection, in-situ monitoring, or robotic arms for manipulation of structures to be joined may also be included in the Phase I effort.

Phase I requires a demonstration/proof of concept that: a) the process selected enables high-value applications of in-space welding for repair and assembly and b) system shows potential for being operated remotely with very little intervention/setup. Phase II includes finalization of the design and demonstration of a ground-based prototype system. Phase III would seek to evolve the technology toward a flight demonstration, either via a system mounted externally on ISS, Gateway, Restore-L or as a free-flyer.

References

G. L. Workman and W. F. Kaukler, â€œLaser Welding in Space,â€ 1989.

Tamir, David, et al. "In-Space Welding: Visions and Realities." 1993.

Paton, Boris EvgenÊ¹evich, and V. F. LapchinskiÄ. Welding in space and related technologies. Cambridge International Science Publishing, 1997.

I. D. Boyd, R. S. Buenconsejo, D. Piskorz, B. Lal, K. W. Crane, and E. De La Rosa Blanco"On-Orbit Manufacturing and Assembly of Spacecraft: Opportunities and Challenges", 2017.

S. Carioscia, B. A. Corbin, and B. Lan, "Roundtable Proceedings: Ways Forward for On-Orbit Servicing, Assembly, and Manufacturing (OSAM) of Spacecraft", 2018.

Expected TRL or TRL range at completion of the project: 4 to 5

Desired Deliverables of Phase II

Prototype, Hardware

Desired Deliverables Description

Phase I: laboratory demonstration/proof of concept of joining capability for external in-space manufacturing, initial design of system

Phase II: ground-based prototype system

Phase III: flight demonstration (Gateway, IRMA, Restore-L or free-flyer)

State of the Art and Critical Gaps

External in-space manufacturing has primarily focused on fabrication of structures in the space environment. Material joining is an essential supporting technology to these capabilities. Research on joining tapered off to some extent following the cancellation of the In-Space Welding Experiment (ISWE) for space shuttle. With the emergence of the OSAM initiative, a renewed interest and focus on manufacturing structures in the space environment as an enhancing capability for long duration missions and as a way to remove design constraints imposed by payload fairings and launch loads, additional work on development of an in-space material joining capability should be a priority. In-space joining represents an essential complementary technology to in-space fabrication techniques.

Relevance / Science Traceability

ISS, Gateway, Restore-L, ISAT, IRMA

Scope Title

Development of Large-Scale Additive Manufacturing Processes for On-Orbit Manufacturing and Construction

Scope Description

Technology development efforts are required to enable On-Orbit Servicing, Assembly, and Manufacturing (OSAM) for commercial satellites, robotic science, and human exploration. OSAM is an emerging national initiative to transform the way we design, build, and operate in space. The goal of the initiative is to develop a strategic framework to enable robotic servicing, repair, assembly, manufacturing, and inspection of space assets.

The ability to additively manufacture large scale structures in-space in an enabling capability needed to fully realize the game changing impacts of on-orbit servicing, assembly and manufacturing. Current state of the art on-orbit manufacturing systems are constrained to a build volume similar to terrestrial additive manufacturing processes with a build volume. Structural designs for crewed habitats, space telescopes, antennas, and solar array reflectors are primarily driven by launch considerations such as payload faring dimensions and vibrational loads experienced during ascent. A large-scale, free-form additive manufacturing capabilities can potentially eliminate constraints on the system imposed by launch, enabling the construction of larger, more complex and more optimized structures.

This subtopic seeks innovative engineering solutions to robotically fabricate and/or repair large structures, fully or semi- autonomous, in the external space environment. Current SOA terrestrial large-scale additive manufacturing processes such as wire-fed directed energy deposition and additive friction stir should be modified with an effort to reduce the footprint, mass and power requirements for on-orbit applications.

Phase I is a feasibility study and laboratory proof of concept of a robotic large-scale additive manufacturing process and system for external in-space manufacturing applications. Targeted applications for this technology include fabrication of truss structures, build-up of structural material for retrofitting spent tanks to habitat modules, and/or solar arrays back planes. Additional targeted applications include the repair of structures such as spacecrafts and/or payloads damaged during the ascent stage, habitat modules with micrometeoroid impact, and out-of-service components due to unforeseen circumstances and/or scheduled repairs. The Phase I effort should provide a laboratory demonstration of the manufacturing process and its applicability to aerospace grade metallic materials, focusing on structures which represent the priority in-space manufacturing applications identified above. Work under Phase I will inform preliminary design of a robotic additive manufacturing process and a concept of operations for how the system would be deployed and operate in the space environment. The Phase I should also provide an assessment of the proposed process operational capabilities, volume, and power budget. A preliminary design and concept of operations are also deliverables under the Phase I. Concepts for ancillary technologies such as post-process inspection, in-situ monitoring, or robotic arms for manipulation of structures to be fabricated may also be included in the Phase I effort.

Phase I requires a demonstration/proof of concept that: a) the process selected enables high-value applications of in-space fabrication of large-scale structures and b) system shows potential for being operated remotely with very little intervention/setup. Phase II includes finalization of the design and demonstration of a ground-based prototype system. Phase III would seek to evolve the technology toward a flight demonstration, either via a system mounted externally on ISS, Gateway, Restore-L or as a free-flyer.

References

G. J. Clinton, R, â€œNASAâ€™s In Space Manufacturing Initiatives: Conquering the Challenges of In-Space Manufacturing,â€ 2017. [Online]. Available: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170011108.pdf [Accessed: 10-Oct-2019].

I. D. Boyd, R. S. Buenconsejo, D. Piskorz, B. Lal, K. W. Crane, and E. De La Rosa Blanco"On-Orbit Manufacturing and Assembly of Spacecraft: Opportunities and Challenges", 2017.

S. Carioscia, B. A. Corbin, and B. Lan, "Roundtable Proceedings: Ways Forward for On-Orbit Servicing, Assembly, and Manufacturing (OSAM) of Spacecraft", 2018.

Expected TRL or TRL range at completion of the project: 4 to 5

Desired Deliverables of Phase II

Prototype

Desired Deliverables Description

Phase I: laboratory demonstration/proof of concept of large-scale additive manufacturing system for external in-space manufacturing, initial design of system

Phase II: ground-based prototype system including autonomous capability

Phase III: flight demonstration (Gateway, IRMA, Restore-L or free-flyer)

State of the Art and Critical Gaps

External in-space manufacturing has primarily focused on fabrication of 3D printed truss structures and beams. The In-Space Robotic Manufacturing and Assembly Project funded by the STMD (Space Technology Mission Directorate) Technology Demonstration Mission Program is planning the demonstration of 3D printed truss structures and beams. The technology advancement to multiple degrees of freedom, large-scale fabrication of structures is a priority for on-orbit manufacturing.

Relevance / Science Traceability

ISS, Gateway, Outpost, IRMA, Restore-L