# NASA SBIR 2016 Phase I Solicitation

## H5.04 In-Space Structural Assembly

**Lead Center: LaRC**

**Participating Center(s): ARC, JSC, KSC, MSFC**

In-space assembly (ISA) of spacecraft systems has been proposed and demonstrated several times as way of assembling systems too large to fit into a single launch vehicle and enabling installation of orbital replacement units. The International Space Station and the repair missions of the Hubble Space Telescope are two good examples.

Efficient structural assembly in space, namely structures with low-mass and high-stiffness and strength, can be achieved by system level design that takes advantage of robotic assembly. For deep-space exploration, the key technology gaps for a robust ISA capability are the joining and unjoining technology (mechanical and electrical), design modularity, and the reuse of components. These technologies will enable a capability that makes future long duration vehicle systems more affordable than the current single-launch, single-use approach to space vehicle design.

The need for on-orbit repair/assembly/servicing are well documented Ref. 1-3. This subtopic seeks in-space assembly and structures manufacturing innovations in two areas of special interest for proposed deep-space space exploration missions:

- Reversible joining technology for structural components and modules.Â Â
- In-space and surface systems that recycle spent metallic and composite components to produce additive manufacturing feedstock. Design solutions must minimize mass, power, and complexity while meeting all other mission requirements including contamination control, load bearing strength and stiffness of the assemblage.

**Capability #1: Reversible Joining Technology**

The ability to join structural and spacecraft components in-space allows for the assembly of vehicles (perhaps aggregated from multiple launches) and for re-use of vehicle subsystems. The joining technology should be reversible for maximum flexibility and utilize simple approaches (electro-mechanical or other) amenable to robotic assembly and disassembly. In addition, the joining technology must provide for mechanical, electrical and optionally thermal load transfer. Â

This subtopic capability seeks innovative joining technologies and capabilities for in-space assembly, disassembly, and re-use of deep-space exploration vehicle subsystems such as cargo tugs that use solar electric power for propulsion. Joining in-space of structural trusses that support multiple solar arrays for solar electric propulsion is one class of needed joining technology. The assembled truss must provide power connections either integral to the structural joint or as a non-mechanical load bearing harness with connectors. The second class of in-space joining is for modular subsystems nominally three-dimensional shapes (square or rectangular) with power, data, and mechanical load carrying connections. While these modules could represent orbital replacement units (ORUs), the modules could serve to construct an entire space vehicle.

In particular, novel reversible joining systems for robotic operations are needed that minimize mass, energy and complexity while maximizing assembled stiffness, strength and stability.

Nominal joining applications are:

- Class 1: Structural Truss Joints.
  - Strength: > 0.4 g (Mars Extensible) in all degrees of freedom assuming a fixed joint with 1 meter rigid offset of a 100Kg point mass.
  - Power Transmission: > 5 kW.
  - Operating Temperature: -100Â° C to +100Â° C.
  - Assembly/Disassembly: Â > 20 times.
- Class 2: Module Joints.
  - Strength: > 0.4 g (Mars Extensible) with 0.25 meter cubic module connected on one face with uniform density of 640 Kg/m$^3$.
  - Power Transmission: > 5 kW.
  - Data Transmission: 25 low voltage lines.
  - Temperature: -100Â° C to +100Â° C.
  - Assembly/Disassembly: Â > 20 times.

In Phase I, contractors should prove the feasibility of proposed innovations using suitable analyses and prototype tests.Â In Phase II, operational joining hardware for assembly and disassembly. Technology Readiness Level (TRL) at the end of Phase II is expected to be 3-4 or higher.

**Capability #2: In-situ Surface ManufacturingÂ**

Sustainable extraterrestrial presence will require innovative approaches to lightweighting launch masses. The ability to manufacture structures onsite affords an alternative to carrying components of surface systems as part of the launch mass and volume. Additive manufacturing (AM) offers the flexibility to achieve this objective since it enables the conversion of various feedstocks into functional components, especially. Maximum benefits can be realized if the AM method can take advantage of resources available onsite, including both ISRU extracted planetary metals and discarded materials.

State of the art AM techniques can process material classes ranging from metals to plastics and ceramics. Typically, AM equipment use pristine forms of these material feedstocks.Â This manufacturing capability will permit the construction of various surface systems using feedstock carried as part of the launch and taking advantage of AM in this manner can contribute to the reduction of volume required to carry partly or fully assembled surface systems during launch. However, the impact of AM can be maximized if it is also able to utilize a broader suite of materials, especially those generated from repurposing objects/components required only for launch and transport to the exploration destination, in-space and surface presence. For example, metallic or composite parts from vehicles needed only for transit to the planetary surface, can be recycled to construct pressure vessels for life support and propulsion. The ability to repurpose what would otherwise be discarded materials and/or fabricate with processed extracted planetary materials (such as iron, aluminum, and silicon) takes full advantage of limited resources available to make sustained presence affordable. Further, automated AM offers a means to construct surface systems ahead of the arrival of humans.

Proposals are sought for additive manufacturing concepts that can enable manufacturing from extracted planetary materials and/or the recycling/repurposing of structural components from space vehicles to produce pressure vessels. This does not include the process of ISRU to extract the materials, just the use of the extracted materials in AM. (See H1.01 In-Situ Resource Utilization for processes to extract materials.) Â Of interest are the following: Â

Design concepts for AM approaches to accommodate feedstocks that are composites of various material types including but not limited to:Â

- Processing techniques to recycle and repurpose structural composites having thermoset matrices and carbon fiber reinforcement to yield AM feedstocks.
- Processing techniques to recycle and repurpose structural metallic vehicle components to yield AM feedstocks.
- Approaches to join additively manufactured components from disparate materials.
- Approaches to use minimal power in the manufacture of components.
- Mobile AM methods that operate on power generated from planetary surface resources.

Nominal manufacturing applications are:

- Class 1: Pressure vessels.
    - Size: Â > 0.25 $m^3$.
    - Strength: > 14.7 psi.
    - Operating Temperature: -100Â° C to +100Â° C.
- Class 2: Two-Dimensional Platform for Mobile Carrier.
    - Size: Â > 3 meter X 2 meter with thickness based on strength.
    - Strength: > 0.4 g (Mars) with 300 Kg mass uniformly distributed.
    - Operating Temperature: -100Â° C to +100Â° C.

In Phase I, contractors should prove the feasibility of proposed innovations using suitable analyses and prototype tests. In Phase II, prototype manufacturing systems capable of processing multiple material classes. Technology Readiness Level (TRL) at the end of Phase II is expected to be 3-4 or higher.

References:


- Barnhart, David; Will, Peter; Sullivan, Brook; Hunter, Roger; and Hill, Lisa: â€œCreating a Sustainable Assembly Architecture for Next-Gen Space: The Phoenix Effect,â€ 30th Space Symposium, May 2014, Colorado Springs CO.
- Erkorkmaz, Catherine; Nimelman, Menachem; and Ogilvie, Andrew: â€œSpacecraft Payload Modularization for Operationally Responsive Space,â€ 6th Responsive Space Conference, April 28-May 1, 2008, Los Angeles, CA.

- Troutman, Patrick A.; Krizan, Shawn A; Mazanek, Daniel D.; Stillwagen, Frederic H.; Antol, Jeffrey; Sarver-Verhey Timothy R.; Chato, David J.; Saucillo, Rudolf J.; Blue, Douglas R.; and Carey, David: â€œOrbital Aggregation and Space Infrastructure Systems (OASIS)â€, IAC-02-IAA.13.2.06, 53rd International Astronautical Congress, 10-19 Oct. 2002, Houston Texas.