



NASA SBIR 2019 Phase I Solicitation

Z3.01 Advanced Metallic Materials and Processes Innovation

Lead Center: MSFC

Participating Center(s): JPL, LaRC

Technology Area: TA15 Aeronautics

Solid State Joining

This subtopic addresses specific NASA needs in the broad area of metals and metals processes with the focus for this solicitation on solid state welding and processing of specialty material: bulk metallic glasses.

Topic areas for solid state welding revolve around joining metallic materials preferably using solid state welding processes such as friction stir, thermal stir, and ultrasonic stir welding. Higher melting point materials of interest include the nickel based super-alloys such as Inconel 718, Inconel 625, titanium alloys such as Ti-6Al-4V, GRCoP, and Mondaloy. Lower melting point materials of interest include Aluminum alloys such as 2195 and 2219. The technology needs for solid state welding should be focused on process improvement, structural efficiency, quality, and reliability for propulsion and propulsion-related components and hardware. This year, NASA is also looking for a mobile friction stir prototype unit for in-space applications

Note: For 2019 solicitation, additive manufacturing has been deleted, unless it specifically addresses needs in specialty metals.

For the 2019 solicitation, the solid state joining focus is:

- Development of diagnostics to accurately measure temperature and forces during welding with the goal of temperature feedback control and accurate force measurement during self-reacting friction-stir welding (FSW) for improved force control.
- Development of new technologies to overcome tool wear issues for friction-stir welding, specifically to have enhanced life with a single pass weld of 1200 inches of 0.625 inches thick Aluminum 2000 series.
- Friction-stir processing of high melting point materials such as Ni-base alloys, titanium alloys, and ferrous alloys.
- Development of a mobile friction-stir welding prototype technologies for in-space manufacturing that addresses:
 - Welding machine operation (tolerances, forge forces, travel speed, spindle speed) in microgravity.
 - Thermal changes in microgravity where convective heat transport no longer occurs.

Potential benefits include Earth-based Flight Software (FSW), such as Space Launch System, Orion, and Commercial Crew Program. Increasing the quality, shortening the development time for FSW processing parameters, and increasing the life of the FSW tool will decrease costs and shorten schedule time for developing and manufacturing of any large scale Aerospace hardware like fuel and oxidizer tanks and crew modules. In

addition, increasing the use of lightweight aluminum tanks on other space missions could also aid in decreasing costs, decreasing schedule and increasing innovation.

Desired deliverables include:

- For Earth-based FSW: analysis supported by FSW samples.
- For in-space FSW: analysis, concept to minimize FSW setup in an in-space application.

The expected TRL for this project is 3 to 5.

Specialty Metals - Bulk Metallic Glass (BMG)

In the specialty materials processing area, the focus for this solicitation is on bulk metallic glass (BMG) alloys. Specific areas of interest relate to optimized processing to fabricate these materials while retaining their unique structures and properties.

Of specific interest for BMGs are innovative processing methods for rapid prototyping of net shape bulk metallic glass components. Product forms of interest are uniformly thin walled structures, structures of high dimensional accuracy and precision (from nm to cm scales), and structures with features larger than the critical casting thickness of the BMG alloy but still amorphous. Consideration must be given to the availability of BMG feedstocks or accommodating the raw materials for in-situ alloy fabrication. Any approach must demonstrate control of contaminant elements (e.g. oxygen and carbon) or show an immunity to their presence.

For the 2019 solicitation of specific interest for bulk metallic glasses are innovative processing methods that:

- Rapid prototyping, while maintaining high dimensional accuracy.
- Uniform thin walled structures that again, retain high dimensional accuracy.
- BMG structures with features that are larger than the critical thickness, but still amorphous.

This scope is relevant to the Space Technology Mission Directorate's Game Changing Development (GCD) effort for BMG mechanisms that are being designed for Lunar and Icy World missions. The technology provides alternative manufacturing pathways to reduce fabrication risk for bulk metallic glass gears and similar high precision mechanical components.

Desired deliverables include a test article demonstrating the proposed manufacturing process for a BMG component sized greater than the critical casting thickness and a report discussing the process' suitability for dimensional control including repeatability and reproducibility, processed material properties, and finished product material impurity (oxygen and carbon) levels.

The expected TRL for this project is 3 to 5.

References:

Solid State Joining

- <https://blogs.nasa.gov/Rocketology/tag/friction-stir-welding/>
- <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150009520.pdf>
- <https://www.nasaspaceflight.com/2017/05/sls-core-stage-recovering-weld-pin-change/>

Specialty Metals - Bulk Metallic Glass (BMG)

- Hofmann, DC et.al, "Optimizing Bulk Metallic Glasses for Robust, Highly Wear-Resistant Gears," Advanced Engineering Materials, 2016 DOI: 10.1002/adem.201600541

Hofmann, DC et.al, "Castable Bulk Metallic Glass Strain Wave Gears: Towards Decreasing the Cost of High-

