NASA SBIR 2019 Phase I Solicitation

H5.02 Hot Structure Technology for Aerospace Vehicles

Lead Center: LaRC

Participating Center(s): AFRC, JSC, MSFC

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

This subtopic encompasses the development of reusable, hot structure technology for structural components exposed to extreme aerodynamic heating environments on aerospace vehicles. A hot structure system is a multifunctional structure that can reduce or eliminate the need for a separate thermal protection system (TPS). The potential advantages of using a hot structure system in place of a TPS with underlying cool structure are: reduced mass, increased mission capability such as reusability, improved aerodynamics, improved structural efficiency, and increased ability to inspect the structure. Hot structure is an enabling technology for reusability between missions or mission phases, such as aerocapture followed by entry, and has been used in prior NASA programs (HyperX and X-37) on control surfaces and leading edges, as well as Department of Defense programs.

This subtopic seeks to develop innovative low-cost, damage tolerant, reusable and lightweight hot structure technology applicable to aerospace vehicles exposed to extreme temperatures between 1000° C to 2200° C. The aerospace vehicle applications are unique in requiring the hot structure to carry primary structural vehicle loads and to be reusable after exposure to extreme temperatures during atmospheric entry. The material systems of interest for use in developing the hot structure technology include: advanced carbon-carbons (C-C), ceramic matrix composites (CMC), or advanced high temperature metals. Potential applications of the hot structure technology include: primary load-carrying aeroshell structure, control surfaces, and propulsion system components (such as hot gas valves and passively-cooled nozzle extensions).

Proposals should introduce novel approaches to address the current need for improvements in operating temperature capability, toughness/durability, and material system strength properties. Focus areas should address one or more of the following:

Improvements in manufacturing process and/or material design to achieve repeatable and uniform material properties, that should be scalable to actual vehicle components - specifically, property data obtained from flat-panel test coupons should represent the properties of flight articles.

- Material/structural architectures and multifunctional systems providing significant improvements of interlaminar mechanical properties while maintaining in-plane and thermal properties compared to state-of-the-art C-C or CMC. Examples include: incorporating through the thickness stitching or 3D woven preforms.
- Functionally graded manufacturing approaches to optimize oxidation protection, damage tolerance, and structural efficiency, in an integrated hot structure concept, to extend performance for multiple cycles up to 2200° C.

For this subtopic, research, testing, and analysis should be conducted to demonstrate technical feasibility during

Phase I and show a path towards Phase II hardware demonstration. Phase I feasibility studies should also address cost and risk associated with the hot structures technology. At completion of Phase I, project deliverables should include: coupon specimens of components adequate for thermal/mechanical and/or arc-jet testing and a final report that is acceptable for publication as a NASA Technical Memorandum. Emphasis should be on the delivery of a manufacturing demonstration unit for NASA testing at the completion of the Phase II contract. In addition, Phase II studies should address vehicle integration. Opportunities and plans should also be identified and summarized for potential commercialization.

Hot structures technology is relevant to Human Exploration & Operations Mission Directorate (HEOMD) where the technology can be infused in spacecraft and launch vehicles to provide either improved performance or to enable advanced missions with reusability, increased damage tolerance and durability to withstand long-term space exploration, and to allow for delivery of larger payloads to space destinations. The Advanced Exploration Systems program would be ideal for further funding a prototype hot structure system and technology demonstration. The Commercial Space Transportation program also has interest in this technology for their flight vehicles.

Additionally, Exploration Systems Development programs that could use this technology include the Space Launch System (SLS) for propulsion applications. Potential NASA users of this technology exist for a variety of propulsion systems, including the following:

Upper stage engine systems, such as those for the Space Launch System.

- In-space propulsion systems.
- Lunar/Mars lander descent/ascent propulsion systems.
- Nuclear thermal rocket propulsion systems.
- Solid motor systems, including those for primary propulsion, hot gas valve applications, and small separation/attitude-control systems.
- Propulsion systems for the Commercial Space industry which is supporting NASA efforts.

Also, the Air Force is interested in such technology for its Evolved Expendable Launch Vehicle (EELV), ballistic missile, and hypersonic vehicle programs. Other non-NASA users include Navy, Army, the Missile Defense Agency (MDA), and the Defense Advanced Research Projects Agency (DARPA). The subject technology can be both enhancing to systems already in use or under development, as well as enabling for applications that may not be feasible without further advancements in high temperature composite technology.

The expected Technology Readiness Level (TRL) range at completion of this project is 1 to 4.

References:

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- Glass, D. "Ceramic matrix composite (CMC) thermal protection systems (TPS) and hot structures for hypersonic vehicles." 15th AIAA International Space Planes and Hypersonic Systems and Technologies Conference. 2008.
- Walker, S., et al. "A Multifunctional Hot Structure Heat Shield Concept for Planetary Entry." 20th AIAA International Space Planes and Hypersonic Systems and Technologies Conference. 2015.

Liquid Rocket Propulsion System Nozzle Extensions

- “Carbon-Carbon Nozzle Extension Development in Support of In-Space and Upper-Stage Liquid Rocket Engines” paper; Paul R. Gradl and Peter G. Valentine; 53rd AIAA/SAE/ASEE Joint Propulsion Conference, Atlanta, GA; AIAA-2017-5064; July 2017; https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008949.pdf
- “Carbon-Carbon Nozzle Extension Development in Support of In-Space and Upper Stage Liquid Rocket Engines” presentation charts; Paul R. Gradl and Peter G. Valentine; 53rd AIAA/SAE/ASEE Joint Propulsion Conference, Atlanta, GA; AIAA-2017-5064; July 2017; https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008945.pdf

Note: The above references are open literature references. Other references exist regarding this technology, but they are all International Traffic in Arms Regulations (ITAR) restricted. Numerous online references exist for the subject technology and projects/applications noted, both foreign and domestic.