NASA STTR 2020 Phase I Solicitation

T12.05 Deposition and Curing of Thermoset Resin Mixtures for Thermal Protection

Lead Center: JSC

Participating Center(s): ARC, GSFC, LaRC

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

Scope Description

NASA has a need to significantly improve the manufacturing processes of Thermal Protection Systems (TPS) used in human-rated spacecraft with the intention of reducing cost and improving quality and system performance. The fabrication and installation of current TPS are labor intensive, cost prohibitive, and result in many seams between the segments. Future human missions to Mars will require the landing of large-mass payloads on the surface, and these large entry vehicles will require large areas of TPS to protect the structure. A sustained lunar presence will require the development of Lunar-return vehicles which will also need TPS. In order to reduce the cost and complexity of these vehicles, new TPS materials and compatible additive manufacturing techniques are being developed such that thermoset-resin based mixtures can be deposited, bonded and cured on spacecraft structures with automated systems. Typically, these thermoset resin systems are filled with fibers, microballoons, rheology modifiers and other additives. Technologies are sought to mix and feed, and then deposit and cure these highly filled thermoset resin mixtures on the flight structure. Basic requirements and goals for the material system are provided in the references.

This subtopic seeks to develop the materials and subsystems needed to design, fabricate and operate an automated production process for TPS. The technologies needing development include:

1. Compatible thermoset resin mixtures, extruder and tool-path algorithms to produce uniform printed and cured TPS material with voids/flaws less than 1/8”.
2. Printable resins yielding TPS materials with low coefficient of thermal expansion. Approaches could include additives to thermoset resin mixtures or alternate material systems potentially with imbedded and longer fibers.
3. Capability to vary the resin-mixture composition during the layer deposition to produce an insulative layer at the structure and a more robust layer on the outer surface.
4. Scalable material feed systems to transport the material to the extruder head(s). Mixing the raw materials in the feed system is desirable.
5. Cure/set the highly filled thermoset resin mixture on the flight structure without the need for large ovens. Curing can be accomplished by chemical composition and/or external energy sources, such as, but not limited to, radio frequency (RF) generators, ultraviolet (UV) lights, etc.
6. Processes and subsystems to ensure a good bond between the deposited material and high-temperature carbon-fiber composite structures.

During Phase I, the focus should be to develop and demonstrate, on a small scale, a solution to at least one of the technologies described above using a candidate thermoset resin mixture. Concepts for the other technologies should be developed during Phase I and then further developed and demonstrated in Phase II.

References

1. https://techcollaboration.center/wp-content/uploads/Workshops/Past-Years/AM-2017/AM_NASAJSC_StanBouslog.pdf
2. https://techcollaboration.center/wp-content/uploads/Workshops/AMCM/AMCM18_NASAJSC_Hacopian.pdf

Expected TRL or TRL range at completion of the project: 2 to 4

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Research

Desired Deliverables Description

Phase I deliverables should include a small scale demonstration of the resin mixture printing and curing process and also include printed and cured material samples for testing. The goal deliverables for Phase II would include the demonstration of a prototype system with a clear path for scale up to production of a full-size heat shield and the demonstrated capability to print, cure and bond acceptable TPS materials on a small, non-planar composite structure.

State of the Art and Critical Gaps

Current state of the art (SOA) for manufacturing and installing thermal protection on NASA space vehicles is too labor intensive and too costly. Furthermore, the heat shield designs are constrained by manufacturing processes that result in segmented blocks with gap fillers that create flight performance issues. To develop an automated additive manufacturing process for spacecraft heat shields that are monolithic, the development of the materials and technologies to deposit and cure the materials on the flight structures are needed.

Relevance / Science Traceability

Both Human Exploration and Operations Mission Directorate (HEOMD) and Science Mission Directorate (SMD) would benefit from this technology. All missions that include a spacecraft that enters a planetary atmosphere require TPS to protect the structure from the high-heating associated with hypersonic flight. Improved performance and lower cost heat shields benefit the development and operation of these spacecraft. Human missions to the moon and Mars would benefit from this technology. Commercial Space programs would also benefit from TPS materials and manufacturing processes developed by NASA.