GCD TechPort Data Sheets
Thermal Protection System Materials (TPSM) Project

3D MAT

ABSTRACT:

The 3-Dimensional Multifunctional Ablative Thermal Protection System (3D MAT) project seeks to design, develop and deliver a game changing material solution based on 3-dimensional weaving and resin infusion approach for manufacturing a material that can function as a robust structure as well as a thermal protection system. The material will be tailored to the needs of the Orion Multi-Purpose Crew Vehicle (MPCV) compression pad for the lunar return mission, EM-1, and beyond. The material will be developed and delivered in a timely manner for MPCV to use it in the upcoming Lunar Return Flight Test (EM-1) and also on the follow on Crewed Flight Test (EM-2).

ANTICIPATED BENEFITS:

3D MAT provides an innovative, robust material solution that will have the combined structural strength and thermal insulation properties for Orion compression pad design needed for MPCV missions. These missions are more demanding than the Low Earth Orbit (LEO) missions, where the use of 2-dimensional laminate materials along with a metal insert are deemed adequate but cannot be extended for Lunar return missions.

US STATES at WORK:

Pennsylvania, California and Alabama. Our Weaver is in Pennsylvania, the RTM Vendor is in California and material characterization is done by SoRI in Alabama.

DETAILED DESCRIPTION:

The 3D MAT Project seeks to design and develop a game changing Woven Thermal Protection System (TPS) technology tailored to meet the needs of the Orion Multi-Purpose Crew Vehicle (MPCV) compression pad design for lunar return EM-1 mission and beyond. The technology being developed is a multifunctional ablative thermal protection system material that is capable of meeting the structural and thermal requirements for the MPCV Orion EM-1 mission and beyond. The Orion compression pads serve as the interface between the Crew Module and Service Module. The Orion compression pads must carry the structural loads generated during launch, space operations and pyroshock separation of the two modules, and then must serve as an ablative TPS withstanding the high heating of Earth re-entry. Current materials do not meet all of the requirements due to either insufficient mechanical strength or limited ability to manufacture to the required dimensions. The goal of 3D MAT is to deliver a prototype compression pad material at Technology Readiness Level (TRL) of 4 in 2014 to enable Orion's further development and use of the material on the MPCV flight in 2017.

TECHNOLOGY DESCRIPTION:

The goal of 3D MAT is to develop a viable 3D woven material for the MPCV EM-1 mission, demonstrate their manufacturability, scale up of one option to the required Orion compression pad size, and advance the TRL for this application via material property, arc jet (aerothermal), creep and pyroshock testing. 3D MAT is leveraging the efforts of NASA's Space Technology Mission Directorate's investment in Woven TPS to design, manufacture, test, and develop a prototype material for Orion compression pads. The technology combines the 3D weaving of quartz yarn (preforms) with a resin transfer molding process to develop a robust, multi-functional material architecture capable of meeting both structural and thermal performance needs for lunar return missions and beyond. Driving requirements for the Orion compression pad include: ability to carry compression moment and shear loads, maintain positive margin against a 500 °F bondline temperature (maximum), be manufacturable to approximately 2.75” thickness by 8.75” diameter, function thermally after exposure to the separation bolt pyroshock event, and shall work with the separation push-off springs.

Technology Area:

TA 09 - Entry, Descent and Landing Systems

Capabilities Provided:

Capabilities: A multifunctional ablative thermal protection system material that is capable of meeting the structural and thermal requirements for the MPCV Orion EM-1 mission and beyond.

Potential Applications: Compression Pad material for MPCV Orion EM-1 mission.

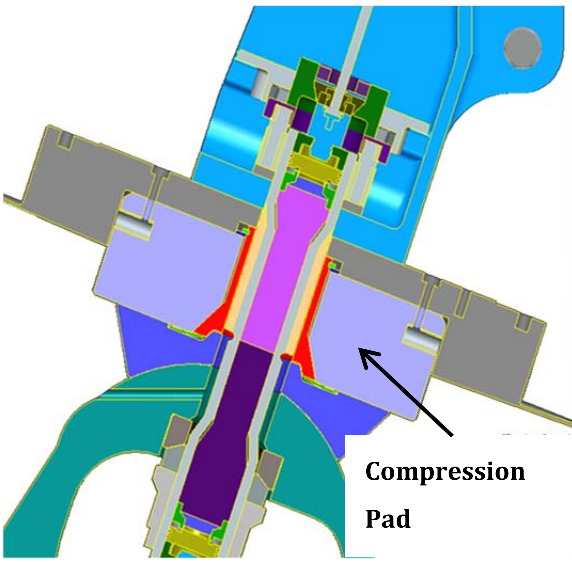


Figure 1: Orion compression pad material requires an upgrade for EM-1 lunar mission

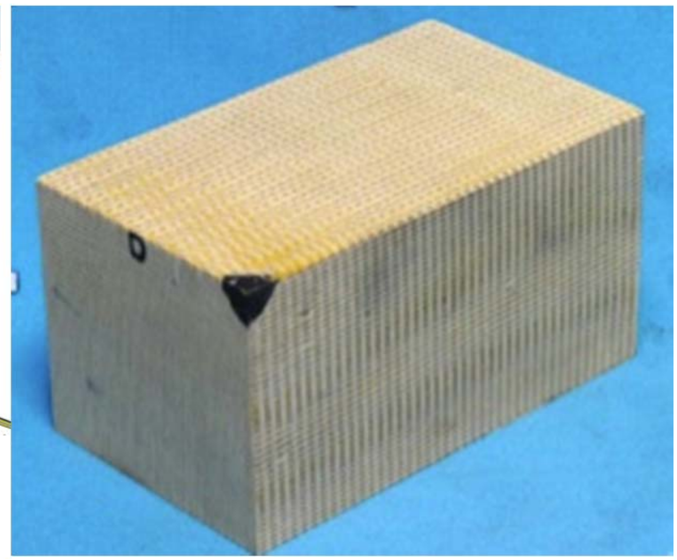


Figure 2: Woven TPS offers a viable solution to meet the structural and thermal load requirements

CA-TPS

ABSTRACT:

The Conformal Ablative Thermal Protection System (CA-TPS) Project seeks to develop and deliver a game changing material solution for future Mars missions and for missions that require ablative TPS in complex regions where integration and cost would pose major challenges. The conformal ablative material is designed to be efficient and capable of withstanding peak heat flux up to ~ 500 W/cm^2, peak pressure up to 0.4 atm, and shear up to 500 Pa. The material is conformal to the geometric details, has superior compliance for integration with structure, excellent thermal properties for reduced mass and utilizes cost effective, off-the-shelf felt materials as the foundation.

ANTICIPATED BENEFITS:

CA-TPS provides a lower cost, mass efficient solution that is easier to integrate due to the compliant and conformal nature of the material. CA-TPS can be used as a heat shield TPS for missions that will encounter peak heat flux ~500 W/cm^2, peak pressures around 0.4 atm, and shear up to 500 Pa. Conformal ablator makes integration much easier for the back shell where geometric complexities such as penetrations and protrusions often requires expensive integration procedures.

US STATES at WORK:

Ohio, New York, Maine and Colorado. Our Felt manufacturers are in Ohio and New York, carbonizing of custom Rayon felt happens in Maine and our scale up vendor is in Colorado.

DETAILED DESCRIPTION:

CA-TPS is leveraging earlier investments made by ARMD’s Hypersonic and HEOMD’s ETDD program that matured the concept from TRL 1 to 2. CA-TPS starts with thick, carbonized rayon felt and the flexible felt is converted to ablative TPS via low density phenolic resin infusion similar to the PICA process. The resulting conformal TPS molded to the required shape prior to resin infusion can then be machined and bonded to the carrier structure. The ease of machining holes to accommodate protrusion on the heat shield or back shell is an attractive feature. The material can be machined with exceptional tolerance and compliance which allows TPS integration with extremely simple seams to form a robust system. The design should result in much larger molded TPS panels that can be directly bonded to most carrier structures and allow for a simplified design of seams between gore panels. This will eliminate the need for gap filler design and strain isolation pads, and should accommodate a wider range of allowable carrier structure imperfections when compared to a rigid material such as PICA.

TECHNOLOGY DESCRIPTION:

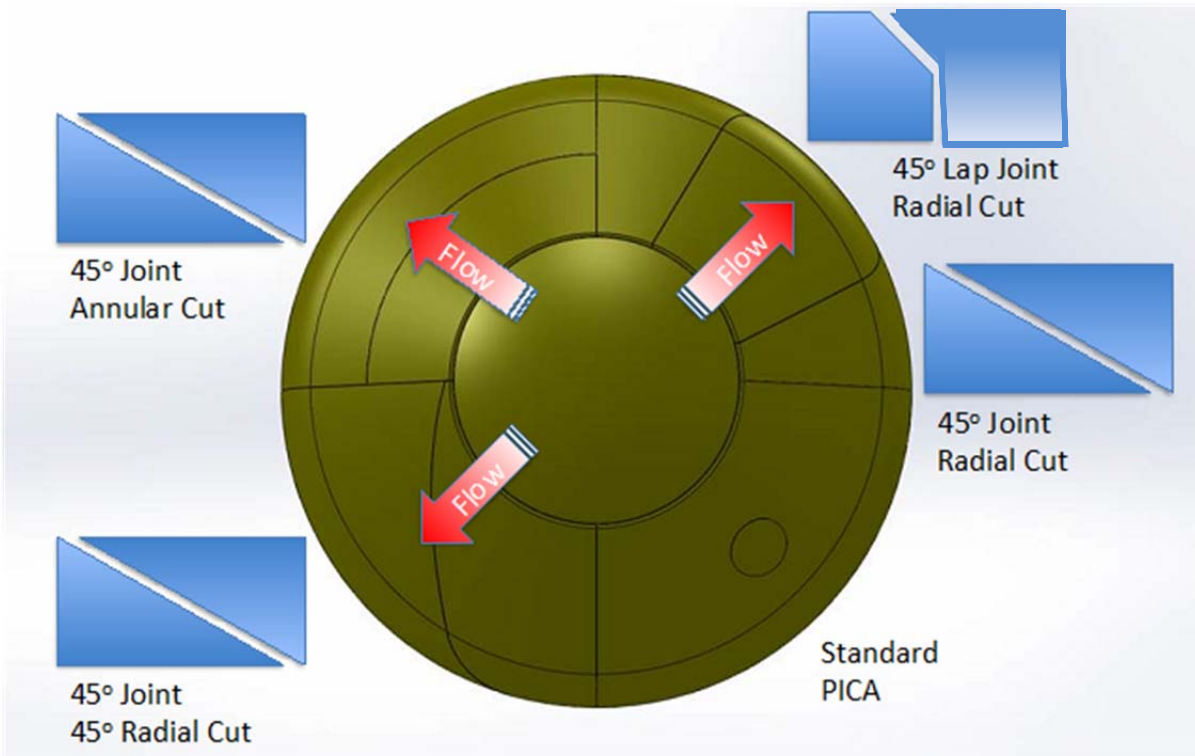
The goal of the CA-TPS Project is to develop and deliver a TRL 5-6 conformal TPS capable of at least 250 W/cm^2 for missions such as MSL, Commercial Off-the-Shelf (COTS) missions, or for the back shell on high energy planetary entry systems. The project has successfully tested materials in aerothermal environments above 500 W/cm^2. CA-TPS is a felt based technology, using commercially available, off the shelf products and currently established industrial manufacturing processes including aerospace grade rayon based felt and phenolic infusion. A conformal TPS over a rigid aeroshell has the potential to solve a number of challenges faced by traditional rigid TPS materials such as tiled Phenolic Impregnated Carbon Ablator (PICA) system on Mars Science Laboratory (MSL) and honeycomb based Avcoat on the Orion Multi-Purpose Crew Vehicle (MPCV). The compliant (high strain-to- failure) nature of the conformal ablative materials allows a much easier integration of the TPS to the underlying aeroshell structure and enable a monolithic-like configuration with larger segments (or parts) to be used. By reducing the overall part count, the cost of installation (based on cost comparisons between blanket and tile materials on shuttle) should be significantly reduced.

Technology Area:

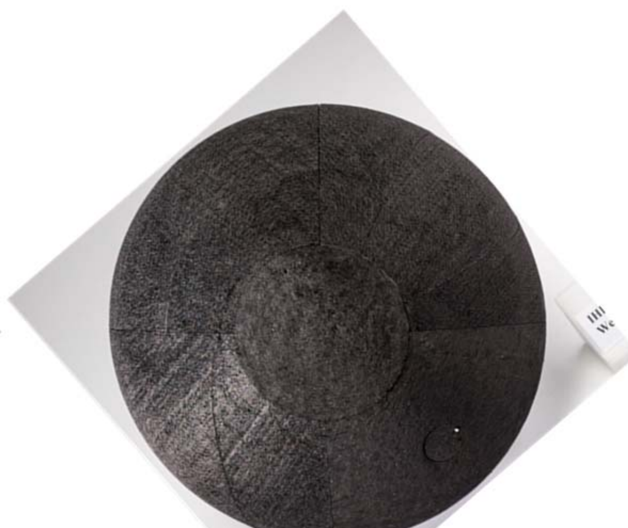
TA 09 - Entry, Descent and Landing Systems

Capabilities Provided:

Capabilities: High strain-to-failure, 500 W/cm2, 0.4 atm, 500 Pa.
Potential Applications: Heatshield and backshell TPS.



Arcjet test sample
Pre-test



Flank heating ~400 W/cm², 30 s
Flank shear ~200 Pa
Shoulder shear ~500 Pa

HEEET

ABSTRACT

The Heatshield for Extreme Entry Environment Technology (HEEET) Project is developing a new ablative Thermal Protection System (TPS) that takes advantage of state-of-the-art 3D weaving technologies to place various carbon and blended fibers in an optimized 3D woven design configuration. Traditional manufacturing processes would then be used to infuse woven preforms with a resin, machine them to shape, and assemble them as a tiled solution on the entry vehicle substructure or heatshield. The woven TPS tiles would then be joined together with an adhesive or other joining approach to make a monolithic heatshield surface.

ANTICIPATED BENEFITS:

- HEEET has the potential to result in 30-40% heatshield mass reduction, compared to traditional Carbon Phenolic (CP) for extreme entry environment missions
- HEEET can enable entry trajectories that are currently not practical with a CP heat shield
- HEEET is being developed with long term sustainability in mind, trying to avoid current challenges with CP

US STATES at WORK:

Pennsylvania, Maine, Tennessee, Ohio and Alabama. Our Weaver is in Pennsylvania, the infusion vendor is in Maine, arc jet and LHMEL facilities in TN and OH, and material characterization is done by SoRI in Alabama.

DETAILED DESCRIPTION:

The Heatshield for Extreme Entry Environment Technology (HEEET) Project seeks to mature a game changing Woven Thermal Protection System (TPS) technology to enable in situ robotic science missions recommended by the NASA Research Council Planetary Science Decadal Survey Committee. Recommended science missions include Venus probes and landers; Saturn and Uranus probes; and high speed sample return missions. Currently, these missions are limited to the use of heritage materials such as Carbon Phenolic (CP) as their only TPS solution. Due to its inherent properties, heritage CP constrains the mission application, and in the long term, poses significant sustainability challenges. The goal of HEEET is to develop a woven TPS technology to Technology Readiness Level (TRL) 5/6 that will provide an alternate TPS solution for these missions. The tailorable woven TPS will reduce entry loads and significantly reduce heatshield mass by 30-40% for extreme entry environment missions. Woven TPS is a science enabler that will allow for a high return on investment made by both NASA's Space Technology Mission Directorate and Science Mission Directorate.

TECHNOLOGY DESCRIPTION:

The goal of the project is to mature woven TPS heatshield architectures to TRL 5/6 by 2017. The HEEET Woven TPS architecture consists of a high density all carbon surface layer (designed to manage recession) below which is a lower density layer composed of a blended CP yarn (insulating layer to manage heat load). This woven architecture is then infused with a mid-density level of phenolic resin. A layer-to-layer weave is typically utilized in HEEET, which mechanically interlocks the different layers together.
This dual-layer approach allows greater mass efficiency by limiting the thickness of the high-density outer layer. By varying the thicknesses of the different layers the mass can be optimized for a given mission. To date, the HEEET materials have been tested to conditions of ~5000 W/cm2 heat flux and five atmospheres of pressure and have shown excellent performance.

Technology Area:

TA 09 - Entry, Descent and Landing Systems

Capabilities Provided:

Capabilities: A sustainable and tailorable heatshield TPS solution to enable extreme entry environment missions.
Potential Applications: Discovery and New Frontiers science missions (Venus probes and landers; Saturn and Uranus probes; and high speed sample return missions.

Exploded view of heatshield showing nose, gore section and rest of conical frustum. The texture and dual layer of HEEET woven material can be seen.