

## Conformal Ablative Thermal Protection System for Planetary and Human Exploration Missions: Overview of the Technology Maturation Efforts funded by NASA's Game Changing Development Program.

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The Office of Chief Technologist (OCT), NASA has identified the need for research and technology development in part from NASA's Strategic Goal 3.3 of the NASA Strategic Plan to develop and demonstrate the critical technologies that will make NASA's exploration, science, and discovery missions more affordable and more capable. Furthermore, the Game Changing Development Program (GCDP) is a primary avenue to achieve the Agency's 2011 strategic goal to "Create the innovative new space technologies for our exploration, science, and economic future." In addition, recently released "NASA Space Technology Roadmaps and Priorities," by the National Research Council (NRC) of the National Academy of Sciences stresses the need for NASA to invest in the very near term in specific EDL technologies. The report points out the following challenges (Page 2-38 of the pre-publication copy released on February 1, 2012):

***Mass to Surface:** Develop the ability to deliver more payload to the destination. NASA's future missions will require ever-greater mass delivery capability in order to place scientifically significant instrument packages on distant bodies of interest, to facilitate sample returns from bodies of interest, and to enable human exploration of planets such as Mars. As the maximum mass that can be delivered to an entry interface is fixed for a given launch system and trajectory design, the mass delivered to the surface will require reductions in spacecraft structural mass; more efficient, lighter thermal protection systems; more efficient lighter propulsion systems; and lighter, more efficient deceleration systems.*

***Surface Access:** Increase the ability to land at a variety of planetary locales and at a variety of times. Access to specific sites can be achieved via landing at a specific location(s) or transit from a single designated landing location, but it is currently infeasible to transit long distances and through extremely rugged terrain, requiring landing close to the site of interest. The entry environment is not always guaranteed with a direct entry, and improving the entry system's robustness to a variety of environmental conditions could aid in reaching more varied landing sites."*

The National Research Council (NRC) Space Technology Roadmaps and Priorities report highlights six challenges and they are: 1) Mass to Surface, 2) Surface Access, 3) Precision Landing, 4) Surface Hazard Detection and Avoidance, 5) Safety and Mission Assurance, and 6) Affordability. In order for NASA to meet these challenges, the report recommends immediate focus on Rigid and Flexible Thermal Protection Systems.

Rigid TPS systems such as Avcoat or SLA are honeycomb based and PICA is in the form of tiles. The honeycomb systems is manufactured using techniques that require filling of each (3/8" cell) by hand and within a limited amount of time once the ablative compound is mixed, all of the cells have to be filled and the entire heat-shield has to be cured. The tile systems such as PICA pose a different challenge as the mechanical strength characteristic and the manufacturing limitations require large number of small tiles with gap-fillers between the tiles. Recent investments in flexible ablative systems have given rise to the potential for conformal ablative TPS>

A conformal TPS over a rigid aeroshell has the potential to solve a number of challenges faced by traditional rigid TPS materials. The compliant (high strain to failure) nature of the conformal ablative materials will allow integration of the Thermal Protection System (TPS) with the underlying aeroshell structure much easier and enable monolithic-like configuration and 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. The conformal ablator design will include a simplified design of seams between gore panels, which should eliminate the need for gap filler design, and should accommodate a wider range of allowable carrier structure imperfections when compared to a rigid material such as PICA.

The Conformal TPS element of the project leverages the past investments made by ARMD and ETDD projects and the goal is to develop and deliver a TRL 5 conformal TPS capable of  $\sim 250$  W/cm<sup>2</sup> for missions such as MSL or Commercial of the shelf (COTS) missions. The capabilities goal for the conformal TPS is similar to an MSL design reference mission ( $\sim 250$  W/cm<sup>2</sup>) with matching pressures and shear environments. Both conformal and flexible carbon-felt based materials have been successfully tested in aerothermal environments above 500 W/cm<sup>2</sup> under the Aeronautics Research Mission Directorate (ARMD) Fundamental Aeronautics Program (FAP) Hypersonics Project and ESMD Entry Descent Landing (EDL) Technology Development Program (TDP), respectively. Results on a myriad of materials developed during FY11 will be used to determine which materials to start with in FY12. It is planned that, early in the project execution, a decision on the leading two candidate materials will be performed based primarily on early screening tests conducted in Feb. 2012 and the FY11 testing and evaluation performed under ARMD FAP Hypersonics Project and ESMD EDL TDP.

In FY12, the conformal TPS element will focus on establishing materials requirements based on MSL-type and COTS Low Earth orbit (LEO) conditions ( $q \sim 250$  W/cm<sup>2</sup>) and develop and deliver Conformal Ablative TPS. This will involve down selecting, manufacturing and testing two of the best candidate materials from the ARMD and EDLTDP efforts, demonstrating uniform infiltration of resins into baseline  $\sim 1$ " thick carbon felt, selecting primary Conformal material formulation based on arc jet and material property testing, developing and demonstrating advanced instrumentation for felt-based materials and based on the material property and arc jet data, developing low fidelity material response model so that the conformal TPS thickness for missions can be established. In addition, in FY12, the project intends to develop Industry Partnerships.

In FY13, based on the previous year's effort, development and refining metrics for mission utilization of conformal ablator technology along with assessment for potential mission stakeholders will be carried out. In the second year, the project will develop and deliver CA250 to TRL 5 by continue material characterization testing that includes thermal, arc jet and structural properties and a mid-fidelity thermal response model. In addition, developing and demonstrating joining technique/seams in aerothermal environment will lead to system level technology maturation and demonstration. One of the end deliverables in year 2, will be a 1m class manufacturing demonstration unit (MDU) that will be designed in close collaboration with one or more mission stakeholders identified in FY12. Successful engagement with Industry and technology transfer in FY13 is a key goal for this project element.