Conformal Ablative Thermal Protection System for Planetary and Human Exploration Missions

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CONTEXT & OBJECTIVE

NASA OCT Game Changing Development Program
What is our Mission?

To focus on transformative space technologies that will lead to advances in space and terrestrial capabilities, serve as a stimulus to the US economy while providing inspiration and opportunity to our nation's youth

Goals

- Develop Game Changing technologies that produce dramatic impacts for NASA's Space Exploration and Science Missions
- Capitalize on opportunities to leverage funding and cost-share from external organizations in technology areas mutually benefiting NASA and the other organizations
- Formulate and implement technology projects that deliver the required performance to stakeholders on schedule and within cost
- Deliver technology knowledge that is used internally for NASA missions as well as externally throughout the aerospace community

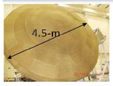
Vision

- Recent focus of the TPS community has been on ablatives
- Lessons learned:
  - Only 2 rigid TPS alternatives (PICA and AVCOAT) have been maturing each having significant integration issues
    - Low strain-to-failure makes direct bonding problematic
  - Existing systems are expensive and time consuming to install
  - Work was initiated under ETDD and ARMD to develop improved TPS

The Vision is to develop and deliver a high strain-to-failure conformal TPS to TRL 5 capable of reducing the cost and complexity of protecting an flight aeroshell

Why Conformal?

SOA
- Limited number of certified TPS
- PICA tile on a rigid heatshields is limited by small size billet manufacturing and low strain-to-failure resulting in high tile count and gaps with filler design
- Honeycombed concepts (AVCOAT) require extensive touch-labor, large curing ovens, and complicated NDE



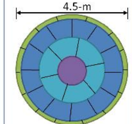
MSL: 113 PICA Tiles

Conformal Solutions

Carbon felt w/ phenolic matrix (C-PICA) | Carbon felt w/ silicone matrix (C-SICA)

Dragon

Goal



MSL: <35 Conformal tiles (notional for ~1m² part)

Benefits
- Larger TPS part size reduces overall part count and would reduce assembly and integration costs
- High strain to failure TPS allows broader structural design options for rigid aeroshell structure

Systems Engineering Approach to Material Development

Mission Application Assessment

- MSL-like entry
  - 4.5 m diameter, composite heatshield structure
  - Peak heat rate=226 W/cm², peak shear=490 Pa, peak pressure=0.33 atm (+3-sigma design values)
- COTS LEO entry
  - Generic Environments include 25% margin
  - Highest heat load for a capsule shallow trajectory (28,400 J/cm²)
  - Heat rates for capsule and lifting ~150 W/cm², Max shear ~325 Pa (lifting), Max pressure ~0.25 atm (lifting)

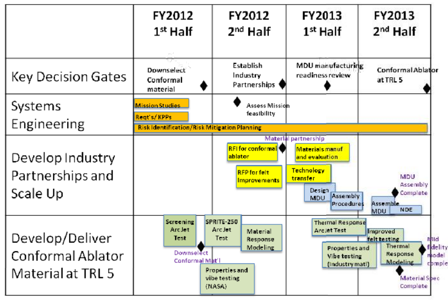
Material Performance Goals

- Demonstrate performance capability of conformal ablator under relevant aerothermal heating conditions
  - Goal to survive MSL-like heating, pressure, and shear environments
  - Goal to survive COTS-like heating loads

Key Performance Parameters

Conformal Ablators Key Performance Parameters	Category *Definition*	State-of-the-Art Value	Justification
KPP-C1	**Survivable for MSL-like and COTS aerothermal environments** *Capability required for future Mars and COTS missions*	PICA: >250 W/cm², 0.33 atm, 490 Pa shear	Current goal for Conformal Ablator is to meet MSL-like conditions while satisfying COTS heat shield conditions
KPP-C2	**Strain to Failure > 2%** *Material property that provides an indication of compliance when bonded to an underlying structure*	PICA (<1%) Avcoat (~1%)	High strain to failure and use of felts for substrates enables factor of >10 reduction in heat shield parts count
KPP-C3	**Manufacturing Scalability** *Assesses the likelihood that the technology concept will successfully scale to the large sizes required by mission architectures*	20" x 40" PICA max tile size (1m cast monolithic)	Eventual application will require large panels, seams, and close-outs. Heat loads define ablator thickness. The MDU, arcjet testing, and analysis will prove scalability of the ablator to full scale.
KPP-C4	**Response Model Fidelity** *Ability to reliably and repeatably predict the thermal response of the material to the applied environments*	Mean: bias error 30%, Time to peak error 30% Recession 150%	Working from low to mid to high fidelity models - need the ability to estimate thicknesses for target mission design

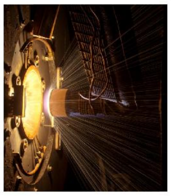
CA250 Project Schedule



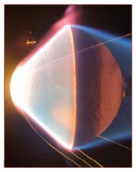
Perform Arc Jet Testing and Materials Properties Testing to Downselect Best Material

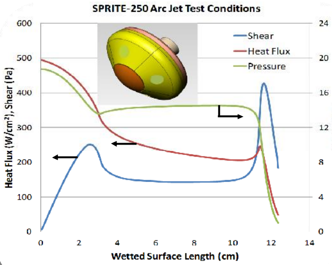
Arc Jet Testing Approach

- Test n material variations in stagnation conditions to determine best 2 materials



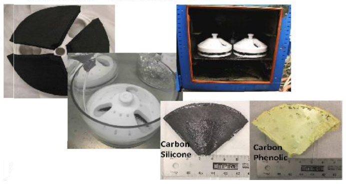
- Test 2 best materials in r_b= 20cm, 55° sphere-cone configuration to achieve p, τ, and q conditions similar to MSL





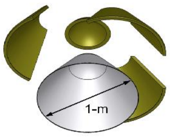
Conformal Materials Manufacturing Approach

- Place in Mold – Infuse & Cure – Dry



Establish Industry Partnerships for Scale-Up

- Industry Request For Information – Conformal TPS Manufacturing Scale-Up
  - Objective
    - Manufacturing Plan for felt-based conformal ablator materials of at least 1-m diameter: which includes the necessary processes, procedures, equipment, and any services required
    - Non-destructive methodologies necessary to examine variations in the felt structure and the resulting conformal ablator and for bond verification
    - Proposed specifications for certified TPS processing and NDE evaluation of the ablative materials
    - Design support and manufacture of a 1-meter class manufacturing demonstration unit (MDU)
  - Vendor will be required to supply small-scale samples for testing followed by large-scale materials for application to the 1-m diameter MDU



- Current maximum available thicknesses of carbon felt is ~2-cm, the Project is working to develop thicker felt (6-7 cm) with industry partners
- Work-to-go planned to reach TRL5 in 2 years
  - Technology transfer for scale up, and evaluation of industry materials
  - Development of attachment and seam techniques
  - Perform further arc jet tests and thermal properties tests to provide data for development of a mid-fidelity material response model
  - Develop mid-fidelity material response model
  - Manufacture MDU
  - Develop NDE techniques to evaluate material and bond conformance
  - Develop material specifications
  - Begin technology push to new missions

CONCLUSION & OUTLOOK

***Game Changing*: we are looking to create a high strain-to-failure TPS with dramatic reduction in cost and complexity**

Work-to-date shows promise that we can achieve our TRL 5 goal for conformal ablator with industry partnerships and focused testing