



An Update to a Conformal Ablative Thermal Protection System for Planetary and Human Exploration Missions

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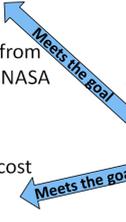
Context and Objective

NASA STMD Game Changing Development Program What is our Mission?

To focus on transformative space technologies that will lead to advances in space and terrestrial capabilities

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

- Focus of the spacecraft design community has been on "heritage" ablative materials for TPS
- Lessons learned during recent builds:
 - Rigid lightweight TPS heritage alternatives (PICA and AVCOAT) have been having significant integration issues
 - Low strain-to-failure of PICA makes direct bonding problematic and requires small tile sizes and gap fillers for large heatshields
 - High touch labor requirements for AVCOAT results in large costs and long schedules, high CTE limits choice of structure materials
- Work was initiated under ETDD and ARMD and continued under STMD/GCDP to develop improved TPS to solve these issues

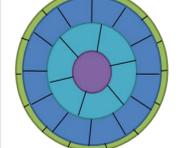
The Vision is to develop and deliver a high strain-to-failure conformal TPS to TRL 5-6 capable of reducing the cost and complexity of protecting an flight aeroshell

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

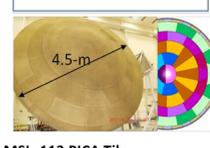


- Goal**
- Deliver TRL5/6 Conformal Ablator



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



Continued Systems Engineering Approach to Material Development

Technical Requirements Definition

- Stakeholder expectations assessed to understand the technical problem and establish the design boundary
- Define anticipated ConOps
- Define mission objectives
- Define performance metrics
- Define functional requirements
- Define system boundaries

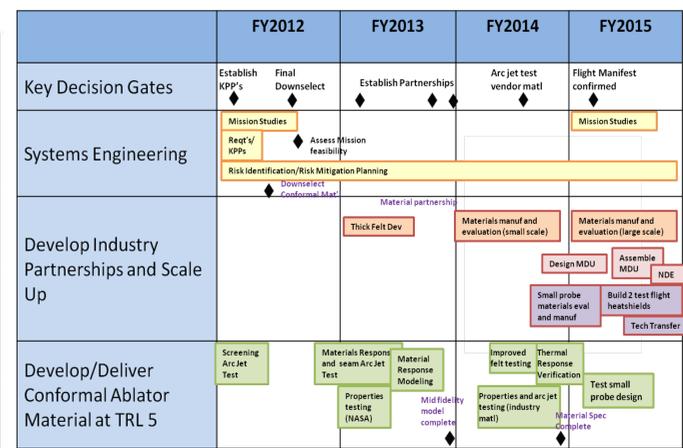
Continuous Risk Management (CRM)

- CRM utilized to provide systematic method for identifying, analyzing, tracking, and communicating risks on a continuous basis
- Embed risk management into normal day-to-day activities to identify and manage risks
- Delegate risk management responsibility to lowest possible organization to mitigate or accept risk
- Dedicate Risk Management Officer to lead risk management

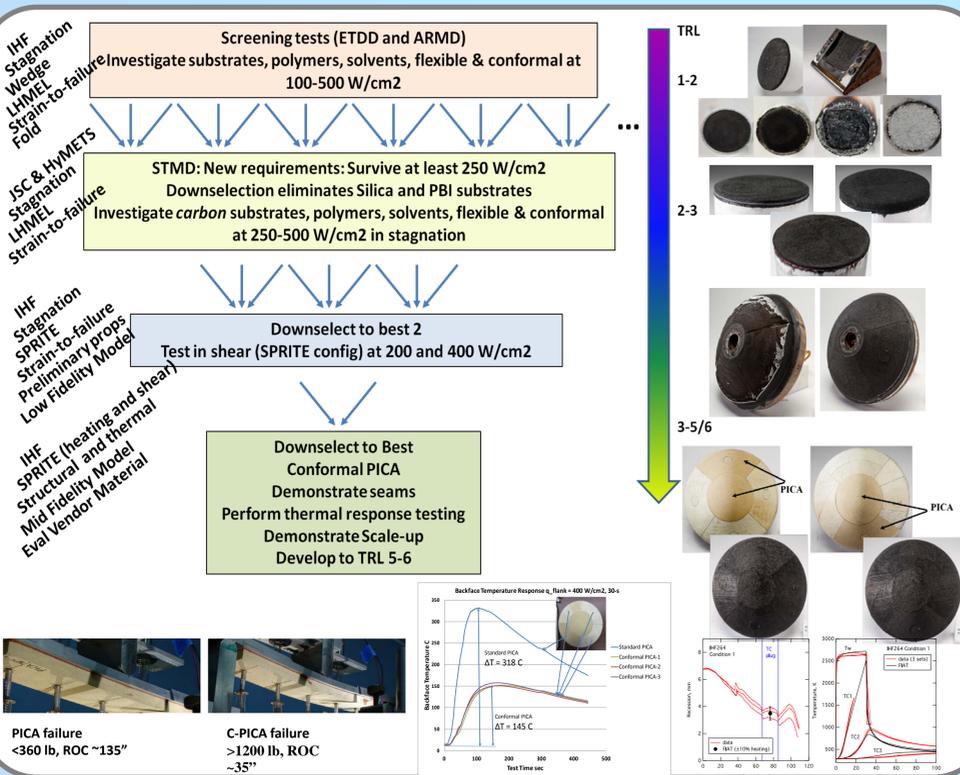
CA-TPS Key Performance Parameters

Conformal Ablators Key Performance Parameters	Category Definition	State-of-the-Art Value	TRL 5 Threshold/Goal	Justification
KPP-C1	Survivable for MSL-like and COTS aerothermal environments <i>Capability required for future Mars and COTS missions</i>	PICA: >250 W/cm ² , 0.33 atm, 490 Pa shear	250 W/cm ² / >500 W/cm ²	Current goal for Conformal Ablator is to meet MSL-like conditions while satisfying COTS heat shield conditions
KPP-C2	Strain to Failure <i>Material property that provides an indication of compliance when bonded to an underlying structure</i>	PICA (<1%) Avcoat (~1%)	>1% / >2%	High strain to failure and use of felts for substrates enables factor of >10 reduction in heat shield parts count
KPP-C3	Manufacturing Scalability <i>Assesses the likelihood that the technology concept will successfully scale to the large sizes required by mission architectures</i>	20" x 40" PICA max tile size (1m cast monolithic)	1m x 1m / 2m x 2m	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 <i>Ability to reliably and repeatably predict the thermal response of the material to the applied environments</i>	Mean: bias error 30% Time to peak error: 30% Recession: 150%	Mean bias error < 40% / 10% Time-to-peak error < 40% / 10% Recession error < 50% / 25%	Working from low to mid to high fidelity models - need the ability to estimate thicknesses for target mission design

CA-TPS Schedule



Testing, Results and Modeling



Establish Industry Partnerships

Conformal TPS Manufacturing Scale-Up

- Vendor is required to supply for 1-m or larger MDU:
 - Small-scale samples for matl props and SPRITE followed by large-scale materials for application to the MDU
 - Manufacturing Plan for C-PICA at least 1x1-m scale
 - Non-destructive methodologies necessary to examine variations in the felt structure and the resulting conformal ablator and for bond verification
 - Design support and manufacture of a large manufacturing demonstration unit (MDU)

Felt Thickness Scale Up

- State of the art for carbon felt ~1.0-in thick, density 0.8-1.0 g/cm³
- Vendor completed processing of 10-cm thick rayon felt (white goods) at ~525 ounces per square yard (OPSY) - density ~0.23 g/cm³ - material manufactured was 2-m wide by 18-m long
- Material carbonized
- Final thicknesses ~7.5-cm, density ~.127g/cm³

Small Probe Vendor

- Technology transfer TPS manufacturing to Small Probe Provider Terminal Velocity Aerospace (TVA) and provide flight test article
 - Perform all work required for Conformal PICA and Conformal Silica-Silicone technology transfer to TVA for small entry probes in FY'15 along with two aeroshell with instrumented TPS
 - Vendor to obtain and deliver flight test data in FY16+ - ReBR/RED flight tests
 - Includes:
 - Plan, build test articles, and perform arc jet testing
 - Vibro/acoustic testing
 - RF transparency testing
 - Manufacture and install TPS and instrumentation for 2 test flight vehicles
 - Technology transfer -- process documentation, training, testing



Game Changing Results

We have created a high strain-to-failure TPS with a dramatic reduction in complexity that should result in lower life cycle cost for heatshield design, manufacturing and integration.