SYSTEM LEVEL AEROTHERMAL TESTING FOR THE
ADAPTIVE DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT).

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Adaptive Deployable Entry and Placement Technology

Key ADEPT Components

- Rigid Nose
- Robust Fabric Joints
- Ribs
- Struts
- Main Body
- 3d Woven TPS

Front Surface - Plain Weave
Aft Surface - Ortho Weave

Deployment Prototype Time Lapse Video

1 m Class Technical Maturation

- Develop and integrate technologies for a mechanically deployable decelerator for missions to Venus, Mars, and other destinations.
Primary Objective:
Demonstrate *simplified* ADEPT SPRITE-C configuration maintains integrity during test.

Secondary Objectives:
1. Monitor temperatures of key design features.
2. Evaluate fabric joint designs.
3. Measure recession.
5. Determine if rigid nose ablation products effect downstream design features.
Key TPS Design Features

**FLOW FEATURES**
- Bow Shock
- Separation
- Reattachment
- Streamlines & Heating Contours

**JOINT ANATOMY**
- 2-ply of 2-layer PW
- 6-layer (4PW/2OW)
- Frayed edges
- 14 layers
- 1.5" x 2.0"
- High density structural stitching

**3D WOVEN FABRIC**
- Nose/Gore Acreage Interface
- Nose
- Gore Close-Out

**TOP VIEW ACREAGE**

**BOTTOM VIEW ACREAGE**

**CROSS SECTIONAL VIEW**
- Joint/Stitching & Insulating Layers
- Shielding Layer Infusion

**TRAILING EDGE TENSION CORD POCKET**
- Joint/Stitching & Insulating Layers

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5
Test Environment Predictions

**Condition 1**

IHF 21.5-in nozzle, 10" from nozzle exit plane

- $I_{arc} = 2000$ A
- $m_{air} = 200$ g/s, $m_{air+} = 55$ g/s, $m_{Ar} = 26$ g/s
- $P_{arc} = 240$ kPa

**Condition 2**

IHF 21.5-in nozzle, 10" from nozzle exit plane

- $I_{arc} = 2200$ A
- $m_{air} = 110$ g/s, $m_{air+} = 160$ g/s, $m_{Ar} = 30$ g/s
- $P_{arc} = 193$ kPa

Shear Stress & Pressure Plots for Acreage Material

Test Conditions Match Mars DRM Predictions
Test Article Description

Pre-Test

**Test Article 1**
Condition 1 for 60 sec
- Graphite Nose
- Six Layer C-Fabric
- Phenolic Infused Joints

**Test Article 2**
Condition 1 for 40 sec
Condition 2 for 40 sec
- Conformal PICA Nose
- Six Layer C-Fabric
- Phenolic Infused Joints

Post-Test

**Test Article 3**
Condition 2 for 60 sec
- Graphite Nose
- Six Layer C-Fabric
- Phenolic Infused Joints
- Various Resin Infused Joints

**Test Article 4**
Condition 2 for 60 sec
- Graphite Nose
- Four Layer C-Fabric
- Various Resin Infused Joints
- Insulating Fabric at Rib Interface

Stag pt heat load

~7.2 kJ/cm²

~7.2 kJ/cm²

~3.6 kJ/cm²

~3.6 kJ/cm²
Instrumentation & Imagery

**Thermocouple Locations & Pyrometer Pointing**

**HD Video, Infrared Thermography & Pyrometry**

- West View Ports
- HD Video
- IR Video
- Optical Pyrometers
- Still Camera
- GoPro Cameras

**Test Article C2 @ 40 sec**

- Thin Film TCs to monitor rib temperature

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Results: Fabric Performance

Acreage Fabric Observations

Pre-Test
Post-Test
Mechanically Shed Fibers

Acreage Fabric Temperature Response

Time (sec)
Temperature (°C)

570 °C ΔT
410 °C ΔT

Recession Measurements Along Gore Centerline

Gore Thickness (mm)
Radial Coordinate (mm)

50
100
150
175

2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

6-layers
5-layers
4-layers
3-layers
2-layers

Engineering Fidelity Response Model

Fabric Recession (mm)
Time (sec)

Engineering Response Model Predicts Recession (+/- 15%)

Significant delta T between forward and aft surface of fabric. Thermal analysis model correlates well with measurements.
Results: Fabric Joint Performance

Infrared Imagery

Rib Interface Temperatures for Various Joint Configurations

Resin-Infused Shielding Layers Are Robust Under These Environments

*Infused & Insulated Joint Showed Best Overall Performance.

Non-Infused Shielding Layers Shed After Burning Through Top Plies

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Results: Upstream Ablator & Dual Heat Pulse

**Graphite versus Conformal PICA Nose @ Condition 1**
- Thermally massive graphite nose piece took time to reach thermal equilibrium, likely causing downstream temperature increases observed.

**TEST ARTICLE C1 @ 40 SEC**

**TEST ARTICLE C2 @ 40 SEC**

**SURFACE TEMPERATURE COMPARISON**

- Ablator upstream of fabric does not have much effect on performance of fabric.

**Dual Heat Pulse Capability Demonstrated** - SPRITE-C with C-PICA nose TPS
- 1st pulse - Heat Rate 120 W/cm² (stag point), duration 40 sec (test article left overnight in test chamber)
- 2nd pulse - Heat Rate 60 W/cm² (stag point), duration 40 sec
Lessons Learned & Future Work

**Lessons Learned**

1. **More Instrumentation**
   - Facility is generally limited to 12-channels per test article
   - Modify design to incorporate custom miniaturized data acquisition systems

2. **Develop more robust TC mounting technique.**
   - 5 out of 32 of the foil TCs did not survive assembly

3. **Develop better handling procedures.**
   - Fabric skirt was prone to shifting/geometry changes during preparation and handling, need more consistent geometry, especially at the free trailing edge.

4. **Develop insulating joint concept**, especially for less severe entry environments (i.e.-Mars).
   - Quartz fabric at joint/rib interface shows promise for limiting conduction into structure

5. **Understand ‘payload’ environment better**, including heat transfer, contamination (outgassing and decomposition of the fabric skirt) and fabric permeability.

**Future Work**

1. **Design Flight-Like Arc-Jet Test Article**
   - Incorporate Flight-Like Structural Features, Payload Simulator & Seals.

2. **Load Test Post-Heated Joints to Failure.**
   - Evaluate various designs for ultimate load strength.

3. **Utilize Computed Tomography Imaging to Aid in Material Properties Characterization.**
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