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

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Outline

ADEPT Overview
Test Objectives
Test Design
Results
Lessons Learned & Future Work
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.

Chamber Set-Up

Test Article Alignment
Key TPS Design Features

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

JOINT ANATOMY
- 1/16”
- 9/16”
- 1/8”
- Frayed edges
- High density structural stitching

FLOW FEATURES
- 3D WOVEN FABRIC
- 14 layers
- INSIDE
- OUTSIDE

JOINT STITCHING & INSULATING LAYERS
- Nose/Gore Joint Interface
- Gore Acreage
- Joint/Rib/Gore Interface
- Gore Close-Out
- Rib Tip Close-out
- Warp Fibers
- Weft Fibers

CROSS SECTİONAL VIEW
- 2-ply of 2-layer PW
- 6-layer (4PW/2OW)
- 4-layer PW

3D WOVEN FABRIC
- Joint Stitching & Insulating Layers
- Shielding Layer Infusion

TOP VIEW ACREAGE
- 3D Woven Fabric
- Nose/Gore Acreage Interface

BOTTOM VIEW ACREAGE
- Joint Shielding Layers
- Shielding Layer Infusion
Test Article Description-Assembly

EXPLODED VIEW

- Rib Sub-Assembly (SS303, qty 8)
- Jackscrew to lengthen ribs
- Sting Adapter
- Base Assembly SS303
- Carbon Fabric Skirt
- Rigid Nose (no adhesives)
- Bushing SS303
- TC Signal Routing Channels

AFT SIDE

FORWARD SIDE

6/15/2016
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**

- SPRITE-C Shear Stress & Pressure (Gore Centerline)
- Shear Stress (Pa)
- Pressure (Pa)

- Radial Coordinate (m)
### Test Article Description

<table>
<thead>
<tr>
<th>Test Article 1</th>
<th>Test Article 2</th>
<th>Test Article 3</th>
<th>Test Article 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1 for 60 sec</td>
<td>Condition 1 for 40 sec</td>
<td>Condition 2 for 60 sec</td>
<td>Condition 2 for 60 sec</td>
</tr>
<tr>
<td>• Graphite Nose</td>
<td>• Conformal PICA Nose</td>
<td>• Graphite Nose</td>
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</tr>
<tr>
<td>• Six Layer C-Fabric</td>
<td>• Six Layer C-Fabric</td>
<td>• Six Layer C-Fabric</td>
<td>• Four Layer C-Fabric</td>
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<tr>
<td>• Phenolic Infused Joints</td>
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<td>• Various Resin Infused Joints</td>
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<td>• Insulating Fabric at Rib Interface</td>
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- **Pre-Test**

- **Post-Test**

- ~7.2 kJ/cm² Stag pt heat load
- ~3.6 kJ/cm² Stag pt heat load
Instrumentation & Imagery

Thermocouple Locations & Pyrometer Pointing

- SPRITE-C1
- SPRITE-C3
- SPRITE-C2
- SPRITE-C4

Thin Film TCs to monitor rib temperature

HD Video, Infrared Thermography & Pyrometry

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

Top View Port
- HD Video

East View Port
- HD Video
- Fiber Optic Pyrometer Electronics

Test Article C2 @ 40 sec

C1 & C2 Surface Temperatures

6/15/2016
Results: Test Video- C2, Condition 1

West Sting: SPRITE-C #2  12:48:59:24 $
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)

Engineering Fidelity Response Model

Time (sec)

Fabric Recession (mm)

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

Non-Infused Shielding Layers Shed After Burning Through Top Plies

*Infused & Insulated Joint Showed Best Overall Performance.
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

Pre-Test

ARC JET TEST (2 EXPOSURES)

Post-Test
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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