Aerothermal Ground Testing of Flexible Thermal Protection Systems for Hypersonic Inflatable Aerodynamic Decelerators

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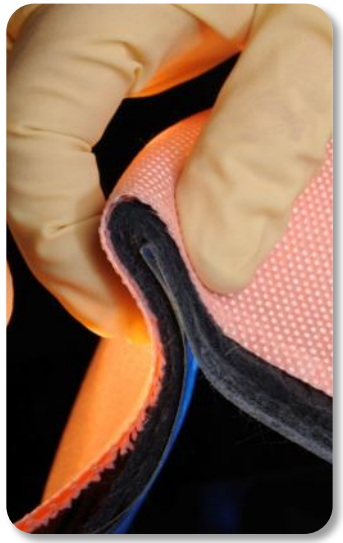
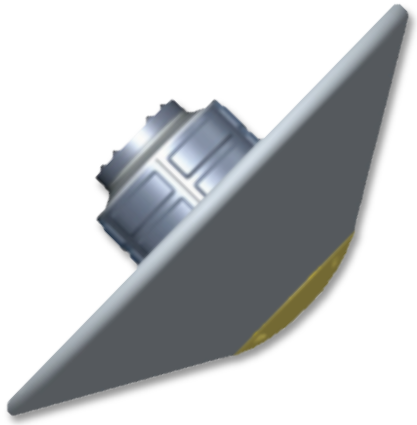
Outline

- Flexible Thermal Protection System (FTPS) Overview
- Previous Work
- Test Conditions
- Testing Methodology
- Boeing LCAT Facility
- CFD Analysis
- Hardware Design
- Conclusions
- Future Plans

Flexible Thermal Protection System Overview

- Flexible TPS (FTPS) Benefits
  - Larger Heatshield
  - Reduced Ballistic Coefficient
  - Greater Payload Mass Delivered
  - Higher Landing Altitude
- FTPS Requirements
  - Flexible (Foldable)
  - Handle Rigors of Packing and Stowage
  - Handle Aerothermal Loads
  - Light Weight
  - Compact to Small Volume

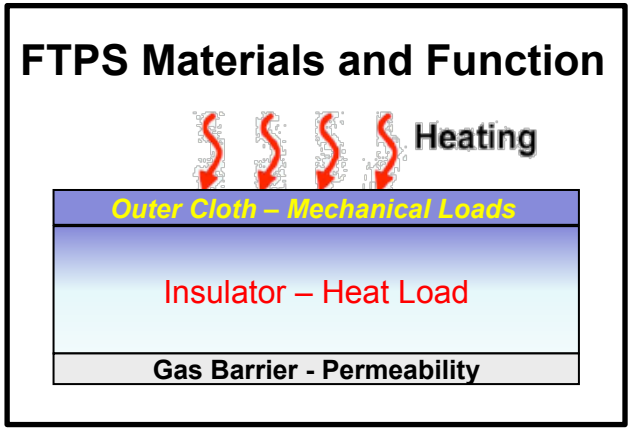




Flexible Thermal Protection Systems Components

A FTPS is Constructed from Three Basic Components

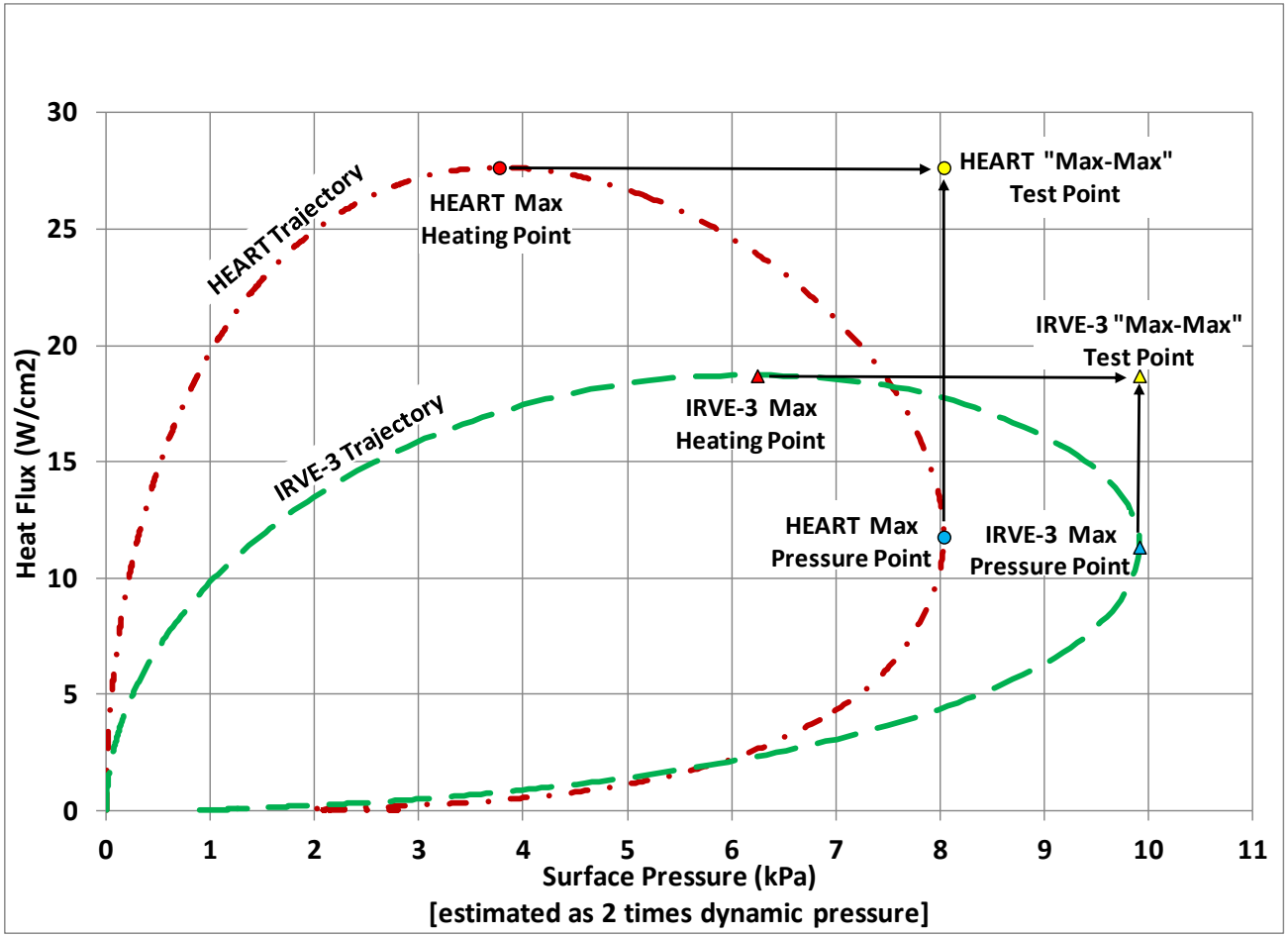
1. Outer Cloth – Handles Mechanical Loads
   - Aerodynamic Shear
   - Protects Insulator from Abrasion and Handling Issues
2. Insulator – Manages Heat Load
   - Insulator Sized to Maintain Supporting Structure at Desired Temperature
3. Gas Barrier – Prevents Hot Gas Penetration to Support Structure



Previous Aerothermal Testing

- Tested in Three Different Facilities
  - 8-Foot High Temperature Tunnel
    - High Shear Force
    - Limited Heat Flux
  - Laser Hardened Materials Evaluation Laboratory
    - No Flow
    - Optical Property Uncertainty
  - Panel Test Facility
    - Low Pressure

Test Conditions

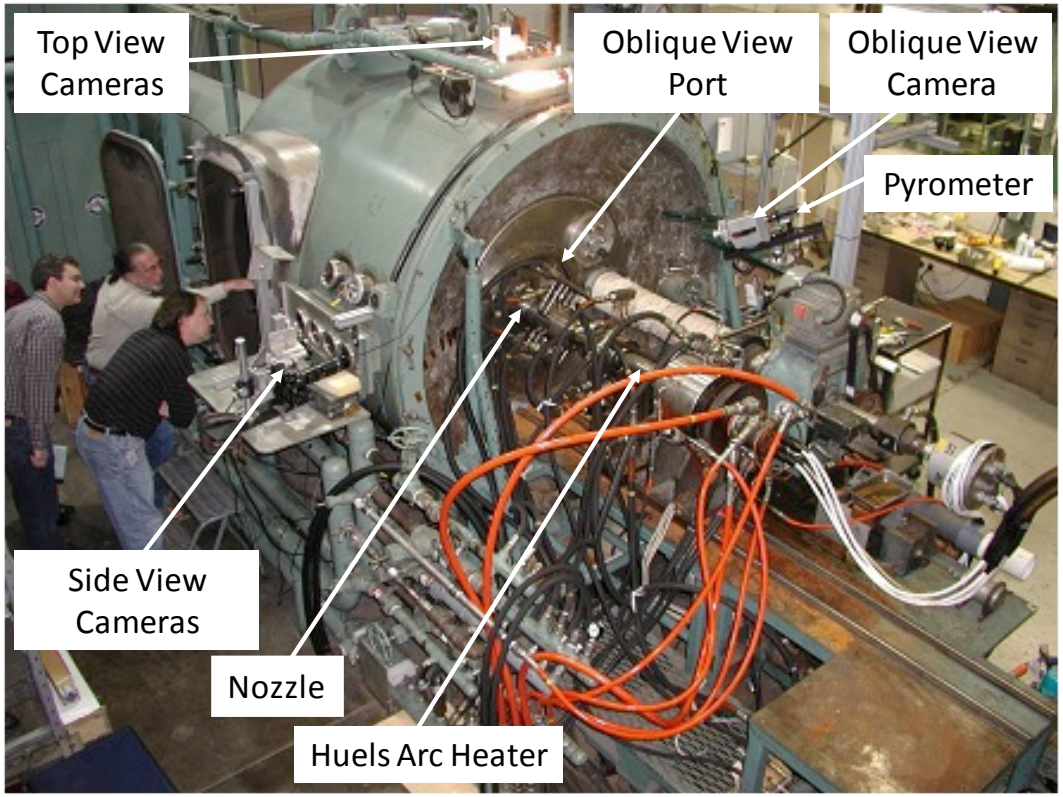


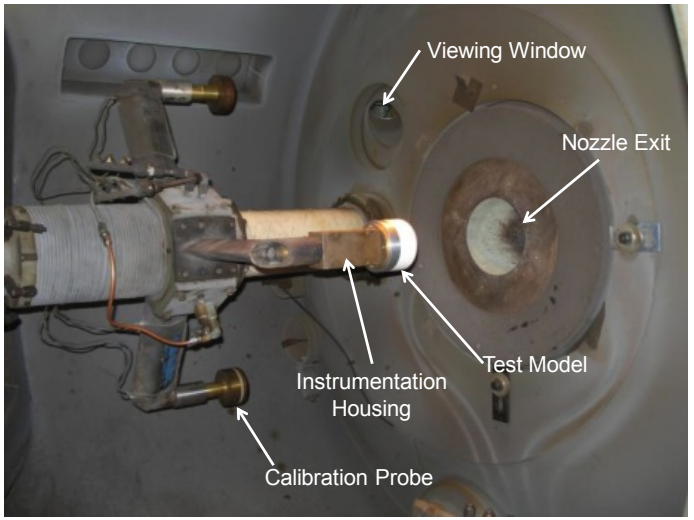
Test Conditions	
Heat Flux (W/cm^2)	Surface Pressure (kPa)
20	3.1
30	4.8
40	6.6
50	4.0

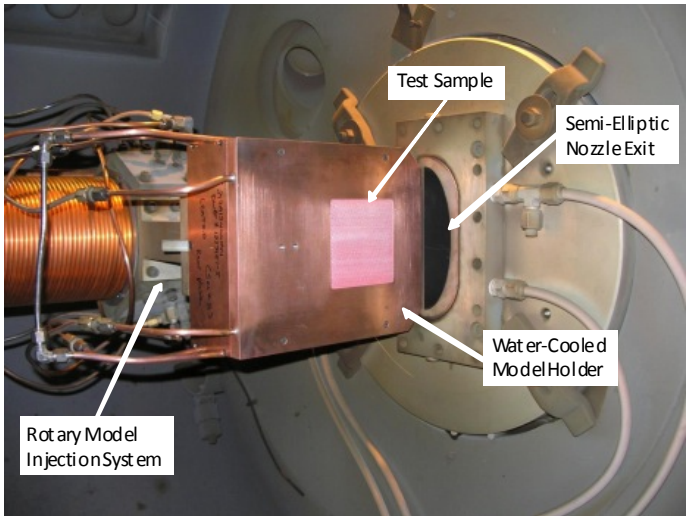
Testing Methodology

- Focusing on IRVE-3 and HEART Trajectories
  - Validation and Verification for model Development
  - FTPS Development for HEART Vehicle
- Max-Max for Quick Screening
  - Over-Test of Combined Heating and Pressure
  - Can Lead to False Negatives
  - Multiple Material Systems
- Stagnation and Shear Testing
  - Matching Heat Flux and Pressure

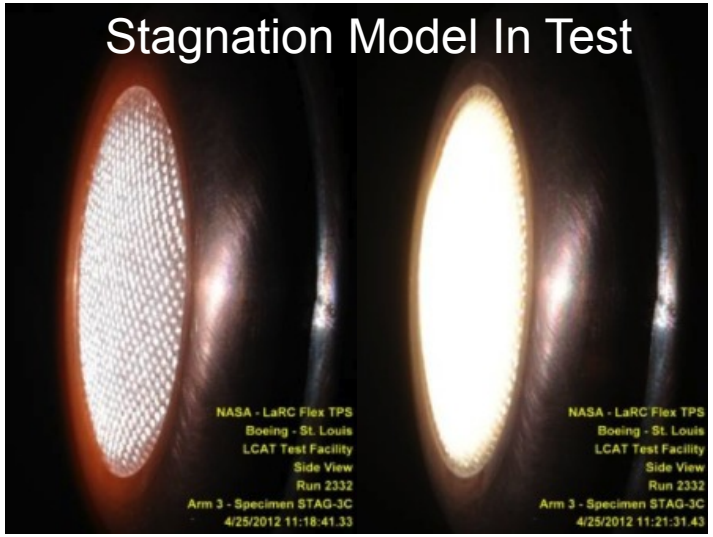
Boeing LCAT Facility

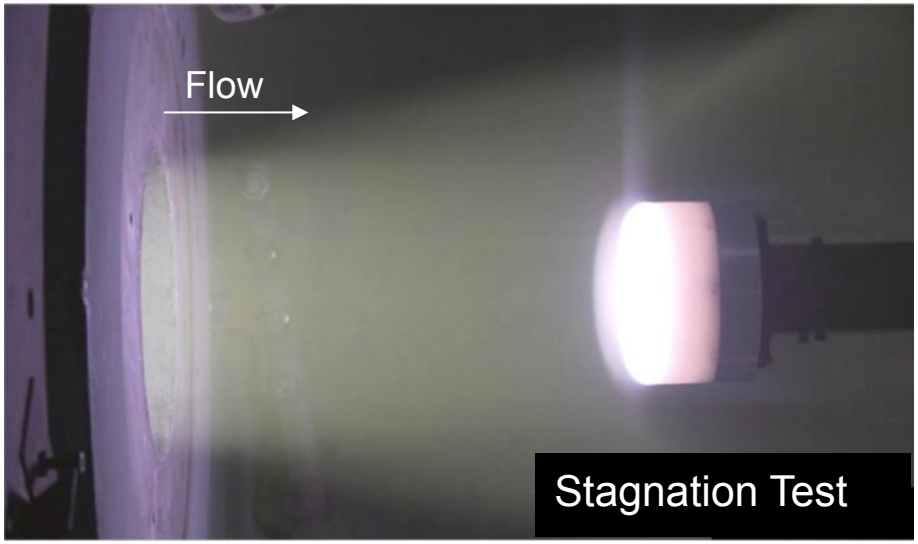


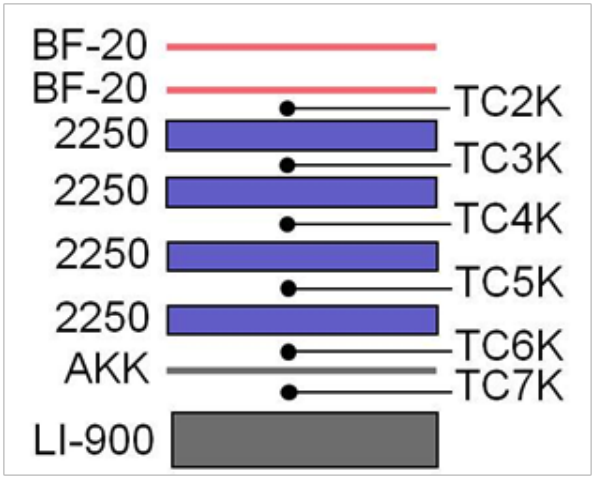




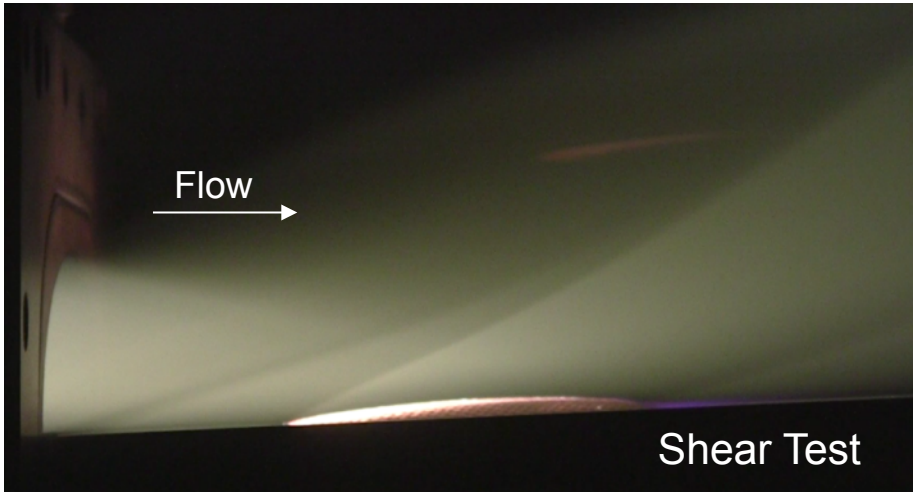
Testing



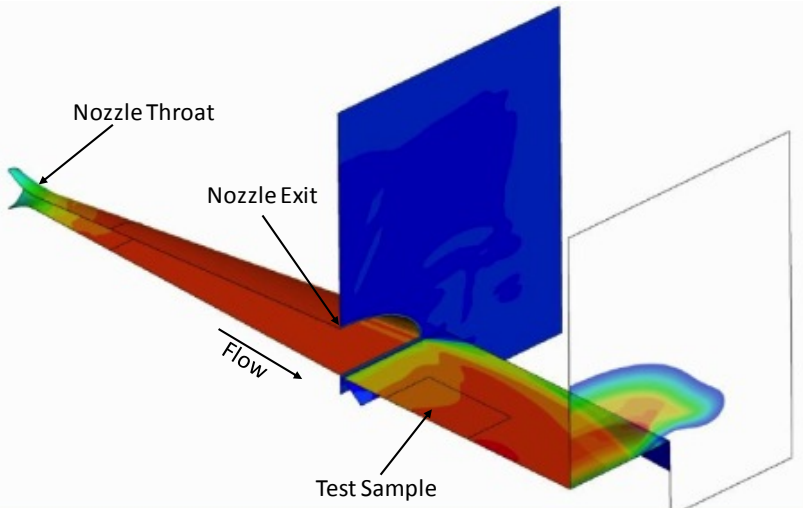


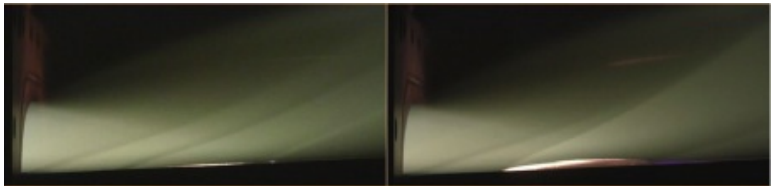


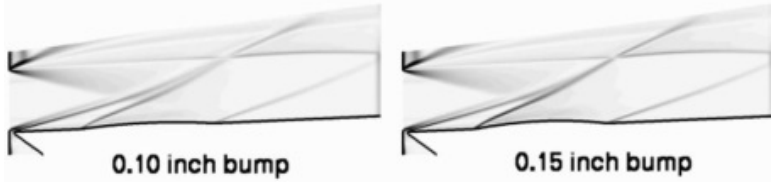
Instrumentation

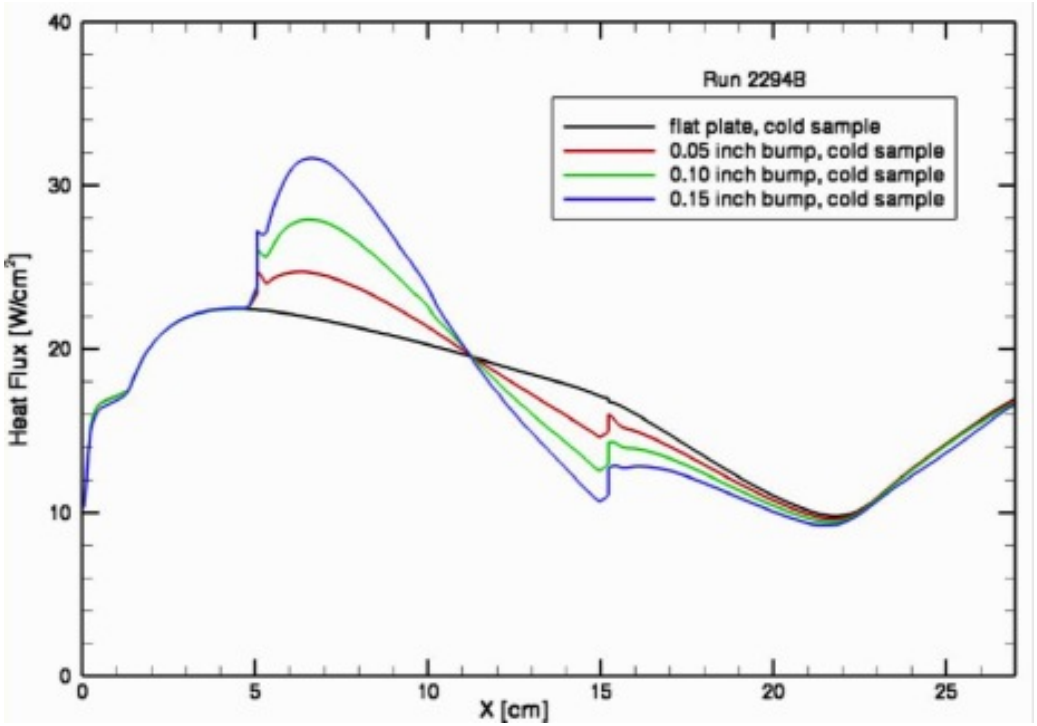


Comparison: Analysis to Shear Testing

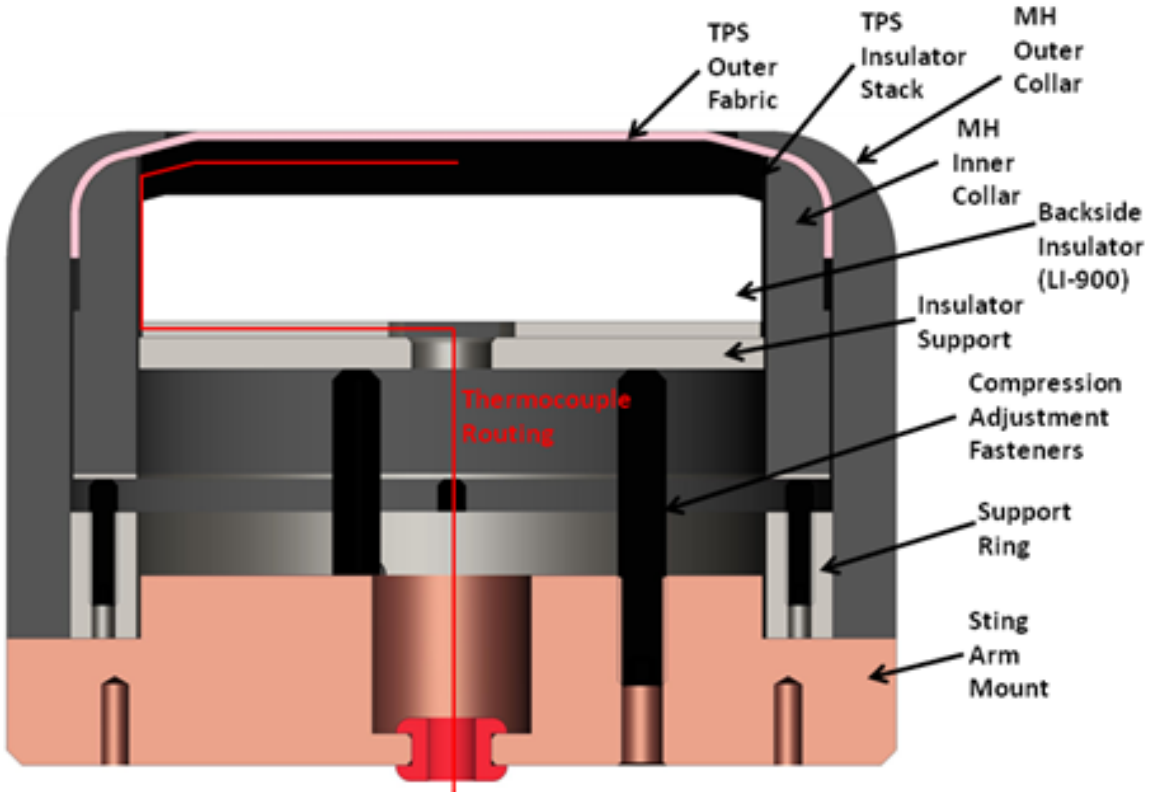


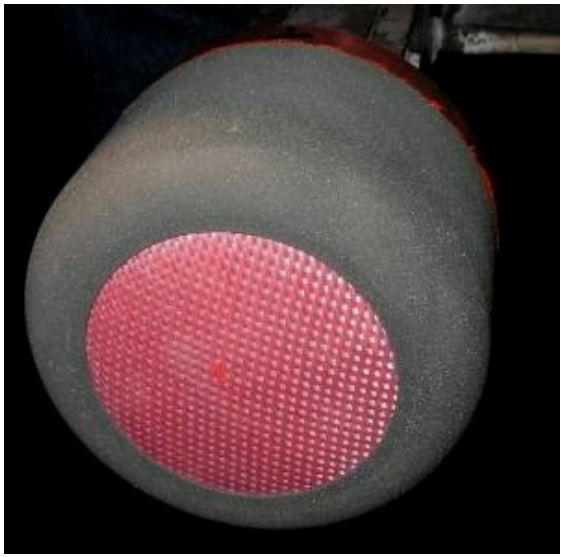




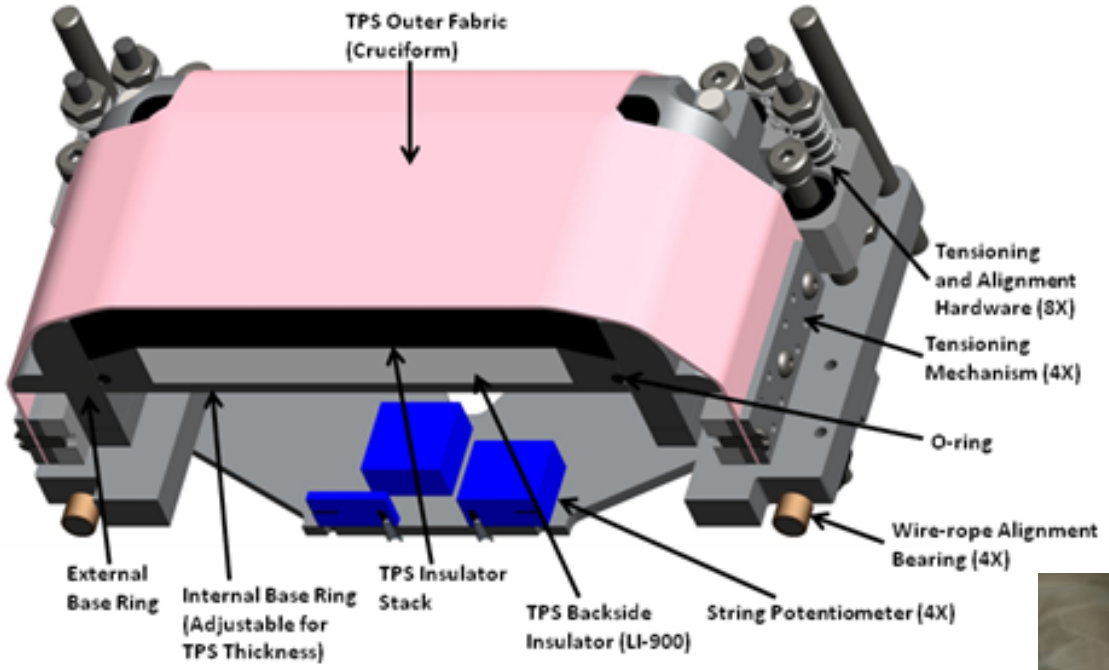


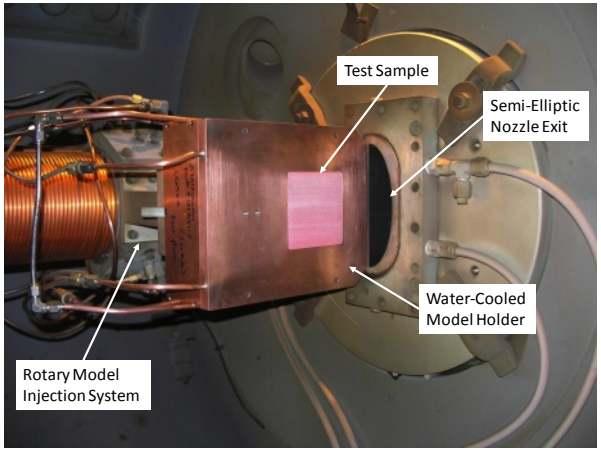
Model Holder Design
Stagnation

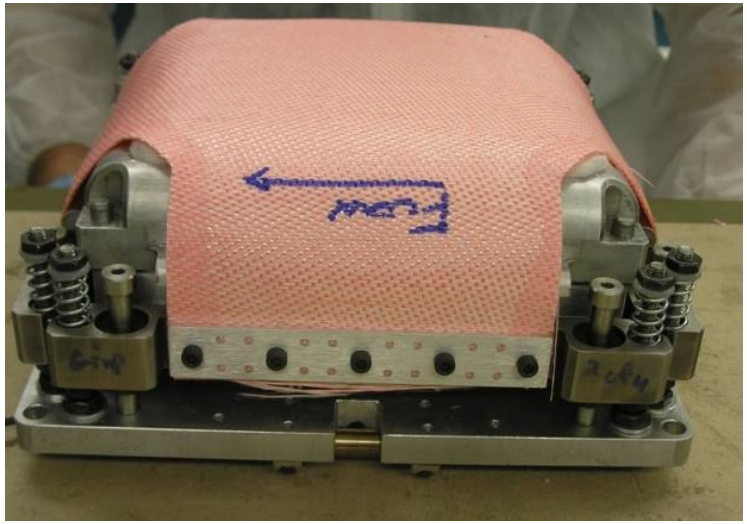




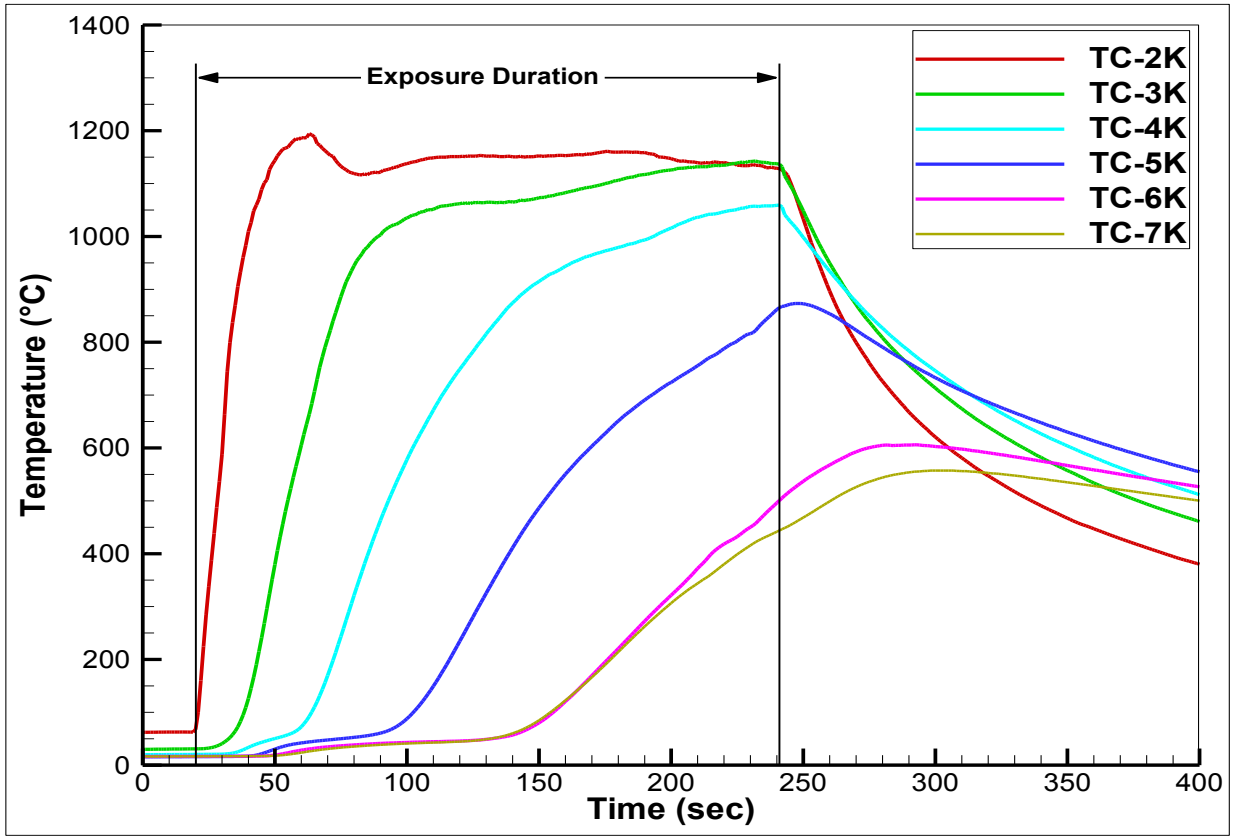
Model Holder Design
Shear

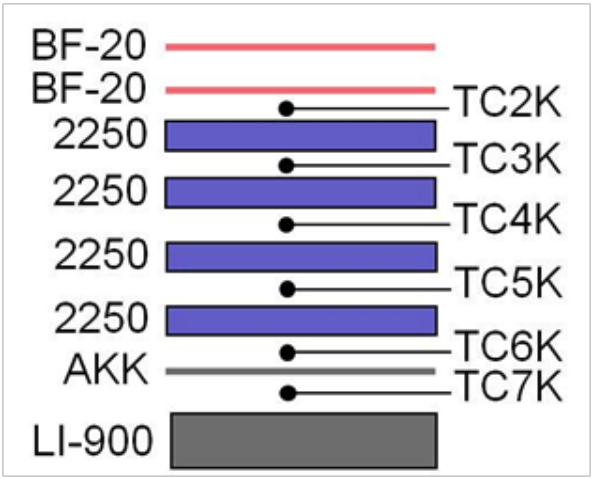






Sample Test Results





Conclusions

- Test Methodology and Associated Hardware Developed
- Successful Testing in Boeing LCAT Facility
- Acquiring Validation/Verification Data for Code Development
- Supporting Development of FTPS Development for HEART Vehicle
- Analysis of Geometry Shape Change in Shear Testing
- Continue Test Technique Development
- Continue Testing In LCAT Facility