X-38 SEAL DEVELOPMENT

Donald M. Curry and Ronald K. Lewis
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

Jeffrey D. Hagen
Lockheed Martin Space Operations
Houston, Texas

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Donald M. Curry
Ronald K. Lewis
NASA Johnson Space Center

Jeffrey D. Hagen
Lockheed Martin Space Operations

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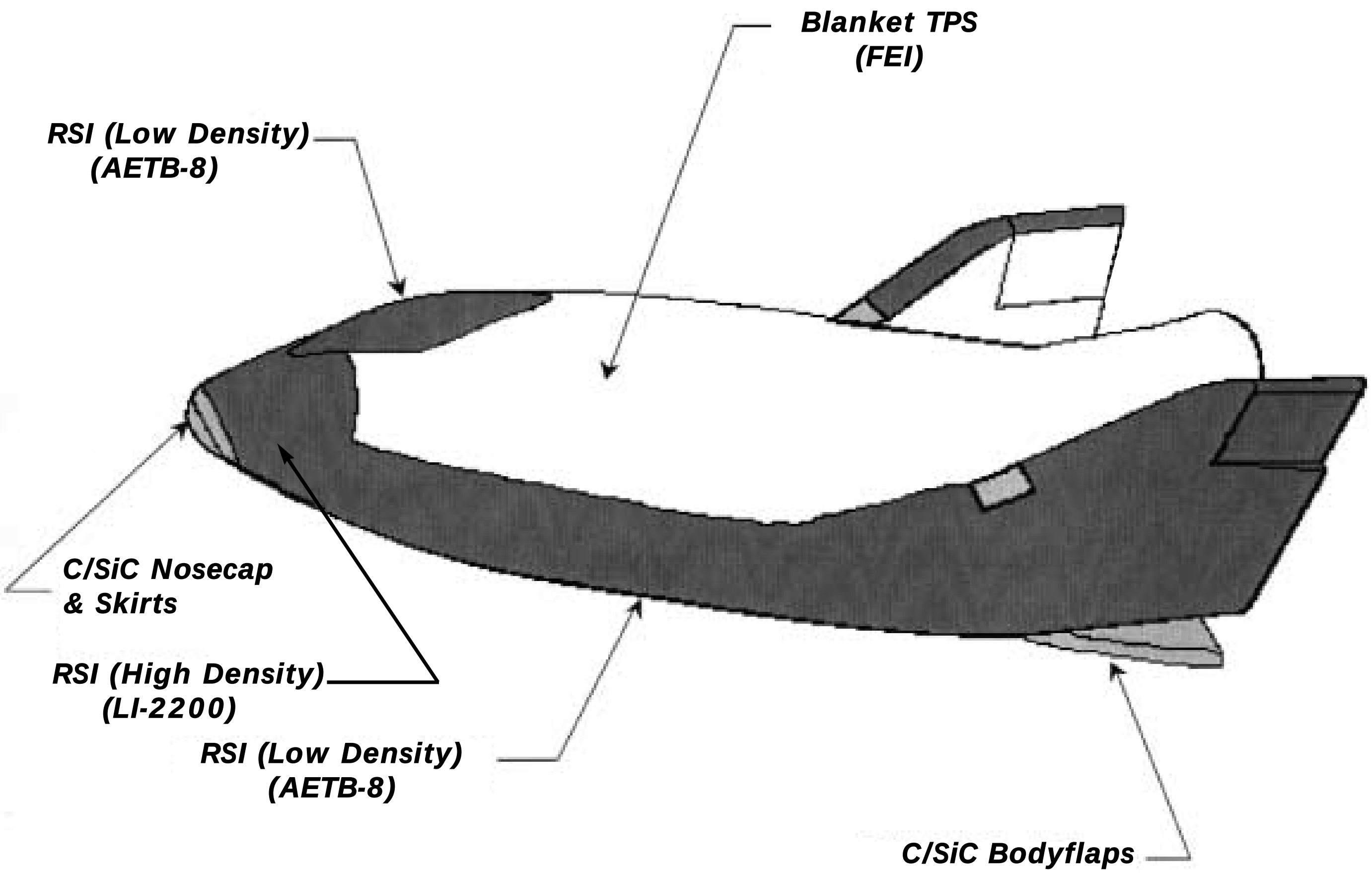
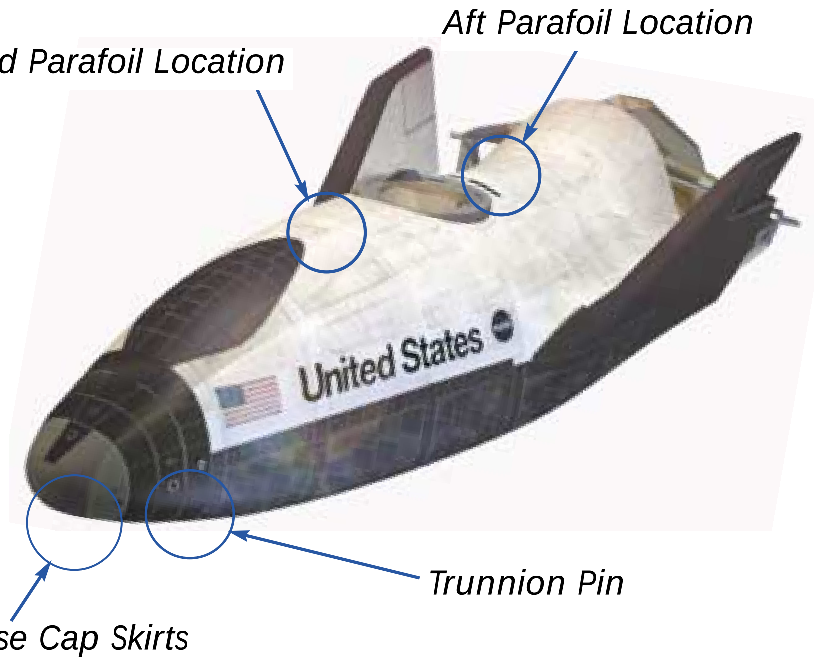
X-38 – Crew Return Vehicle

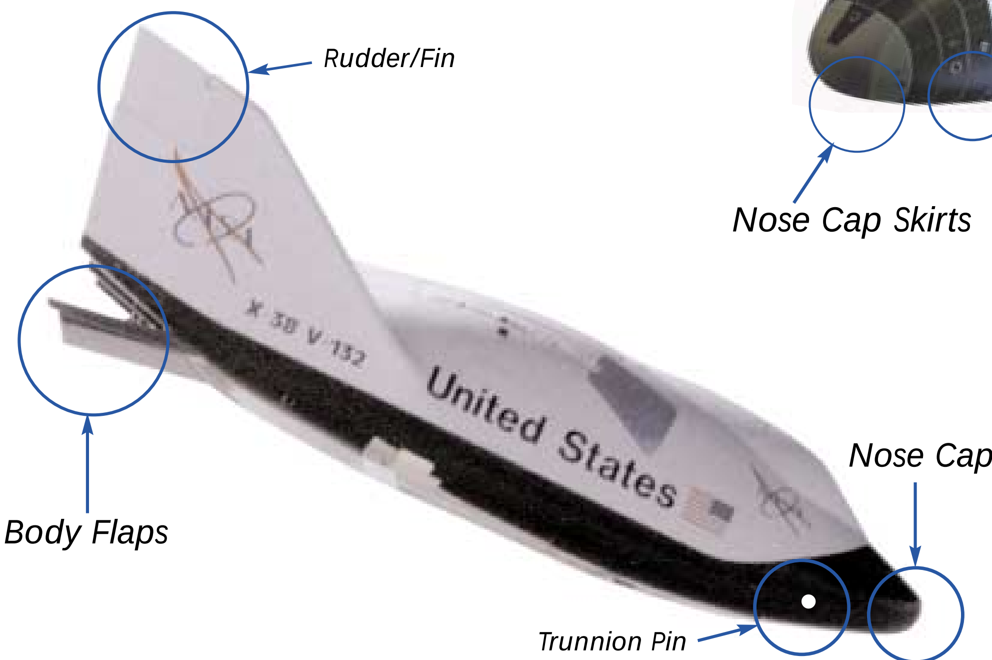
- An element of the International Space Station (ISS)
- Three Scenarios
  - ISS castastrope
  - Emergency medical evacuation
  - Period of Space Shuttle unavailability
- X-38 Program Purpose:
  - To greatly reduce the costs and schedule for the development of crew Return Vehicles (CRVs) and Crew Transfer Vehicles (CTVs) through the use of the rapid development methodology associated with an X-project
    - Ground Testing
    - Atmospheric Testing
    - Space Flight Testing

X-38 TPS Configuration

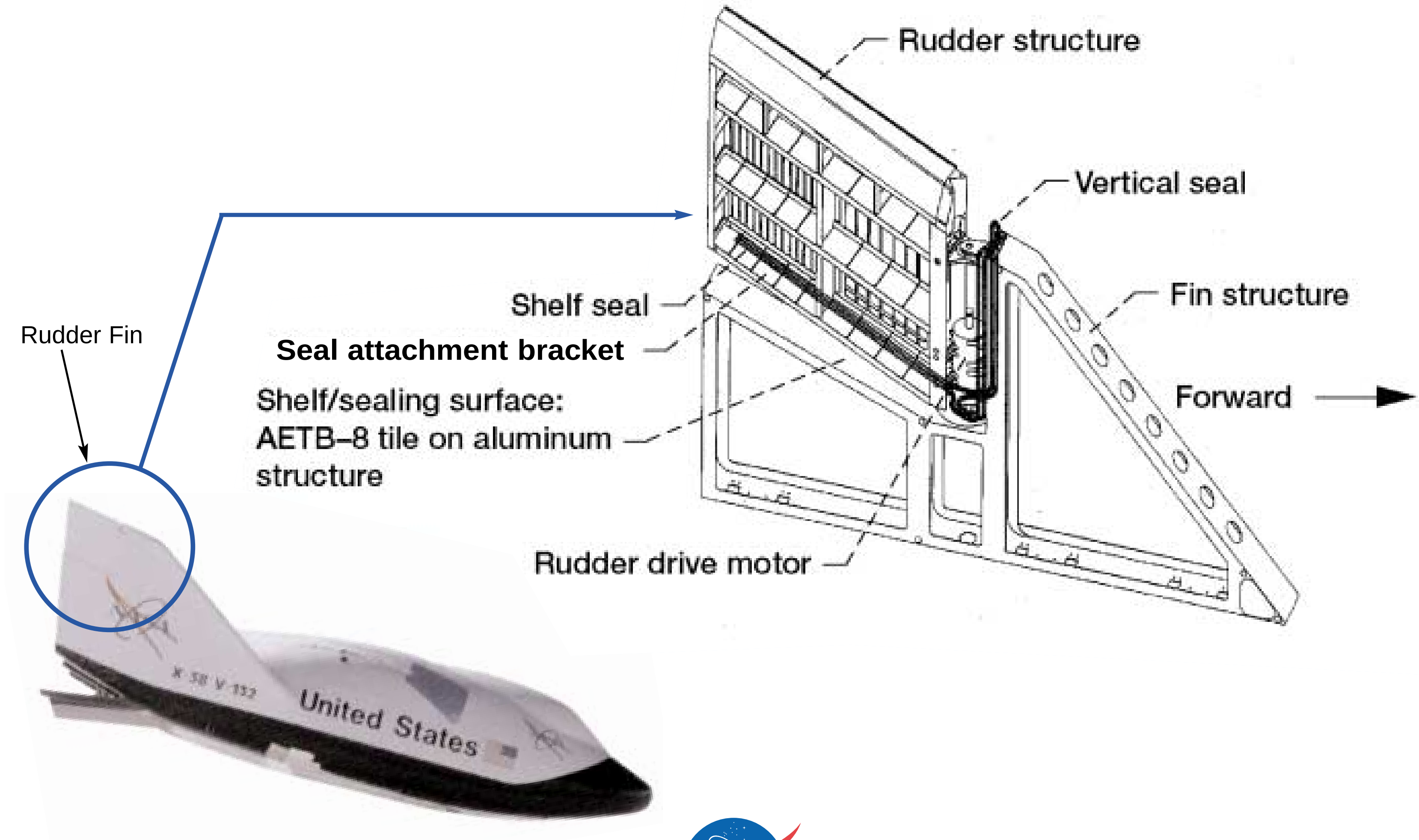


X-38 Seal Locations



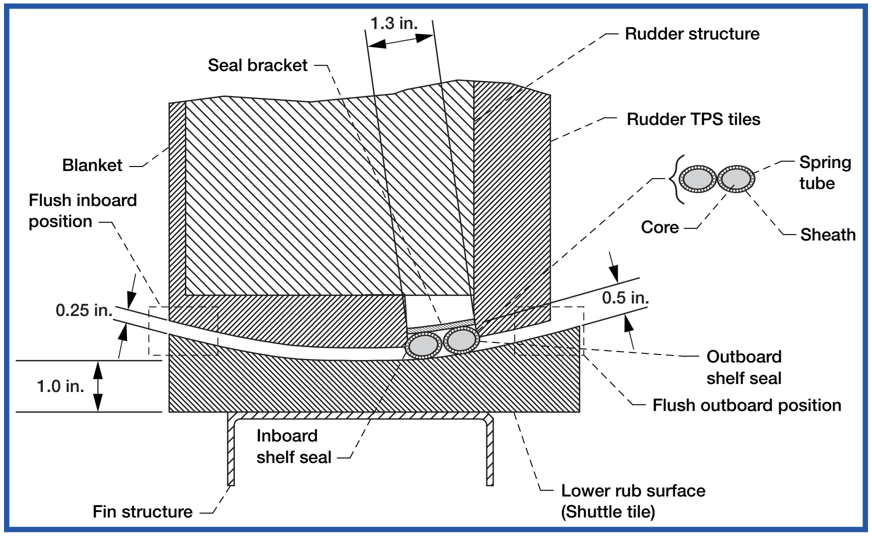


X-38 Rudder/Fin Seal Assembly

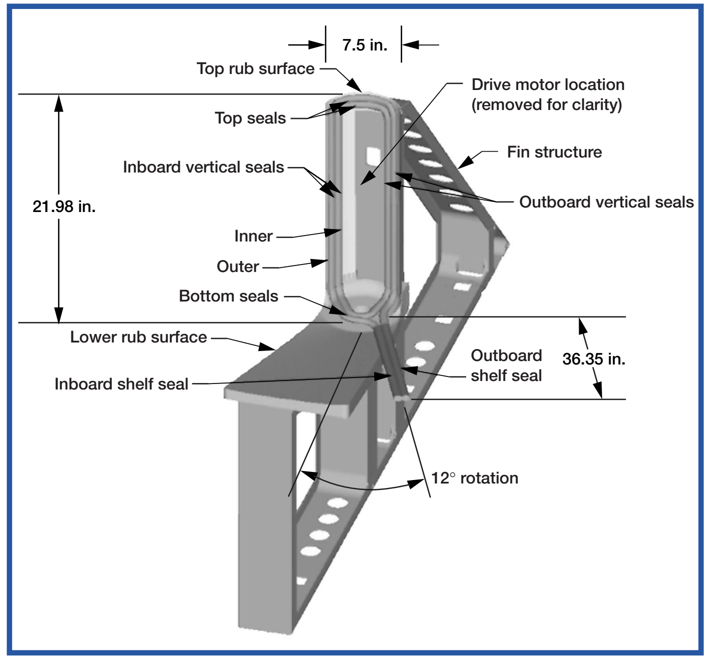


Baseline X-38 Rudder/Fin Seal Design

Cross Section of Rudder/Fin Seal Shelf Location

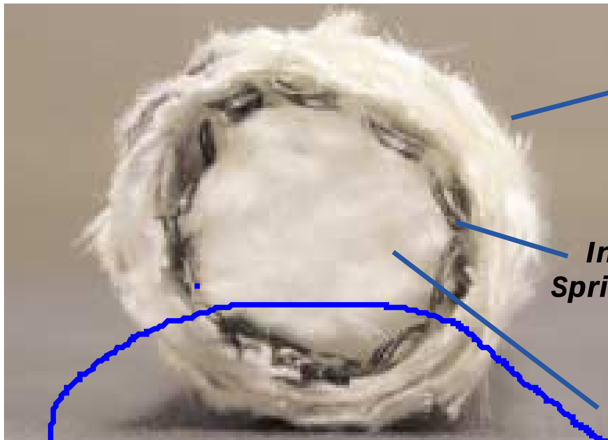


Rudder Shown at Flush Inboard Position

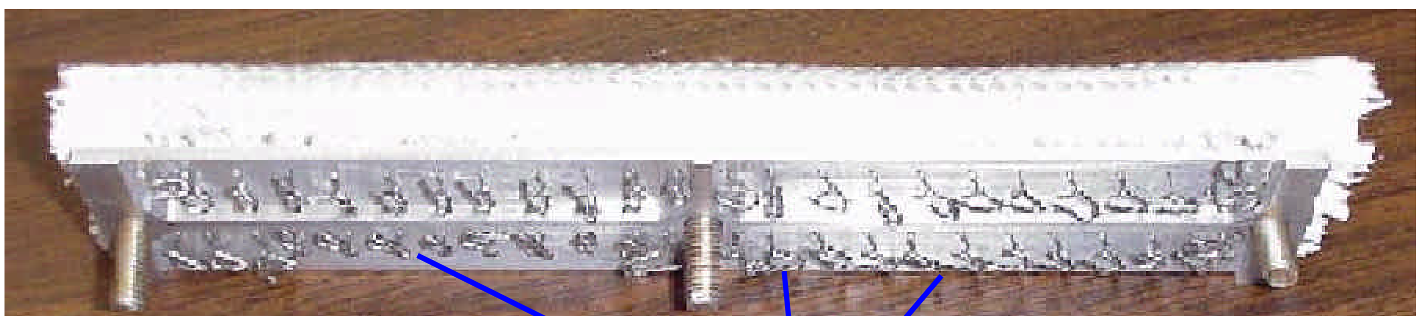


- *Main Seal Components*
  - *Core: 6 pcf Saffil Insulation*
  - *Spring Tube: Inconel X-750*
  - *Sheath: Two Layers of Nextel 312 Fabric*
- *Nominal 20% Compression and 0.25-in. Gap*

Rudder / Fin Seal to Bracket Assembly

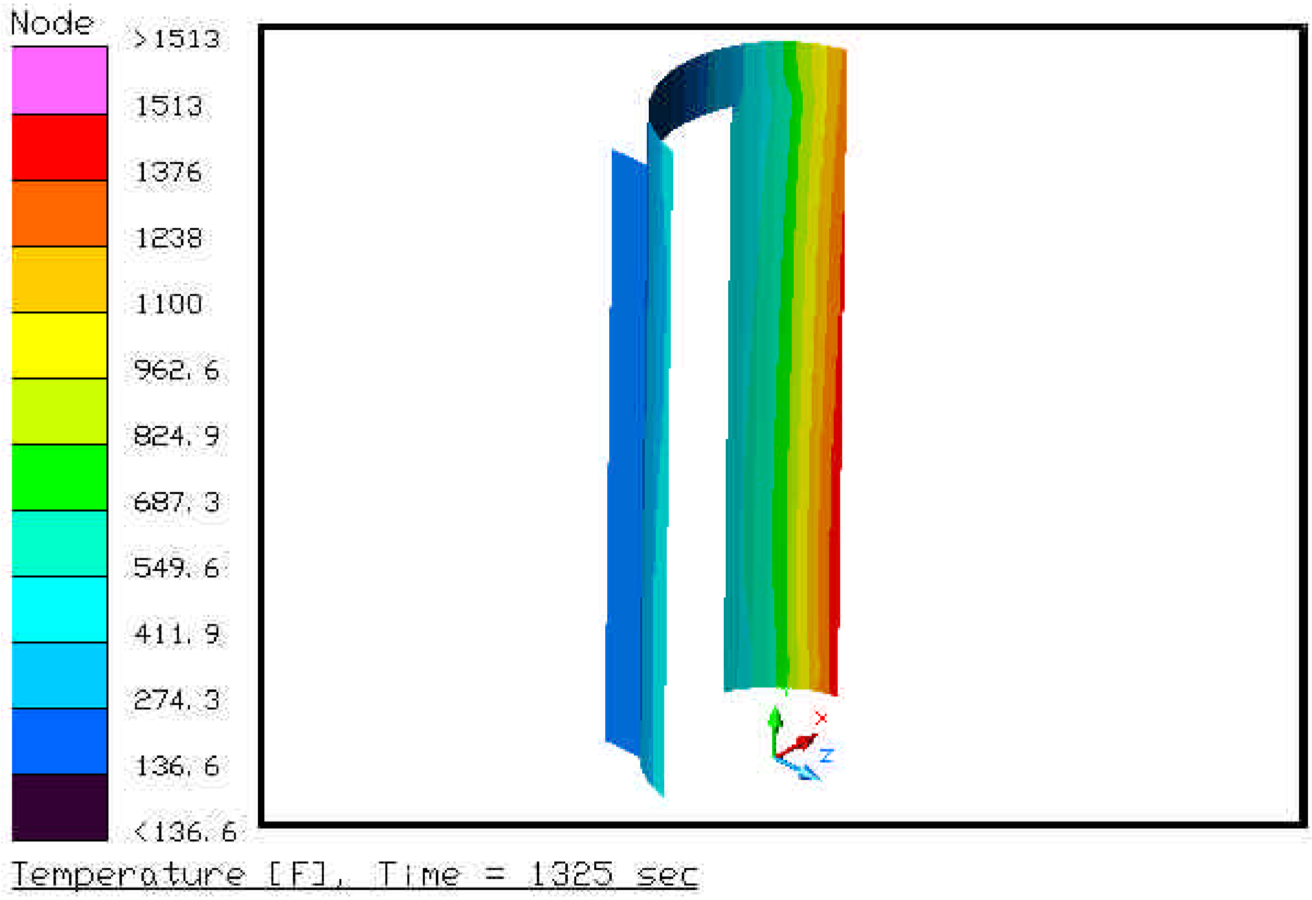


Cross Section of Seal



Mechanical attachment of Seal to Bracket

X-38 Rudder / Fin Vertical Rub Surface Inconel – 0.10 in.



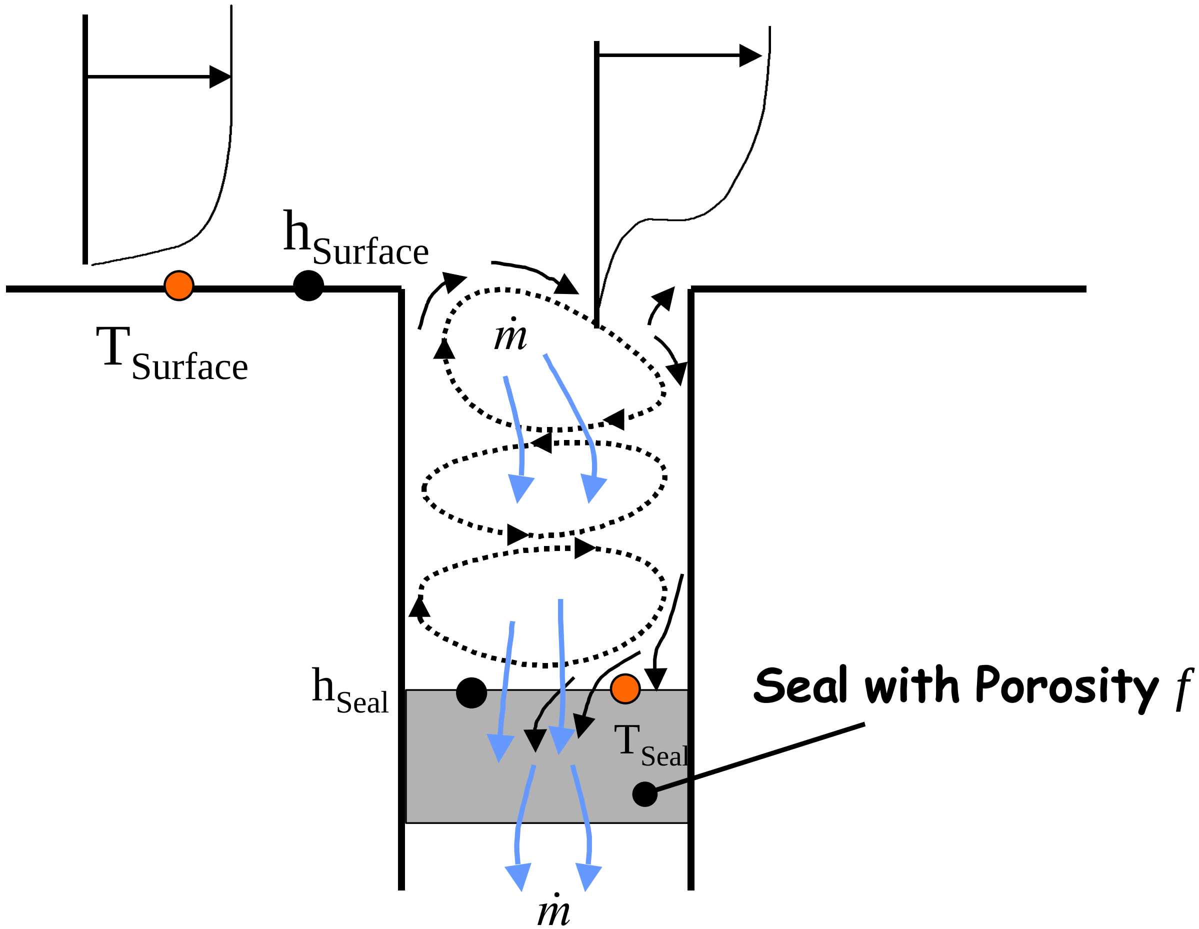
X-38 Rudder / Fin Seal Analysis

- Flow Characteristics
  - 20% Seal Compression
  - Permeability = 1.0 E-09 Ft^2
  - Mass Flux Computed using Darcy Relation:

$$m_{dot} = \frac{r * A * K * DP}{m * L}$$

- Thermal Analysis
  - Thermal Equilibrium Assumed between Seal/Structure and Gas Flow
  - Heat Transfer to Seal Surface Modeled using Nestler Correlation
  - Influx Gas Temperature Assumed to be Equal to External Wall Temperature

Seal Analysis Model



Governing Differential Equations for Equilibrium Thermal Assumption

<u>Composite Fluid – Solid Energy Equation</u>

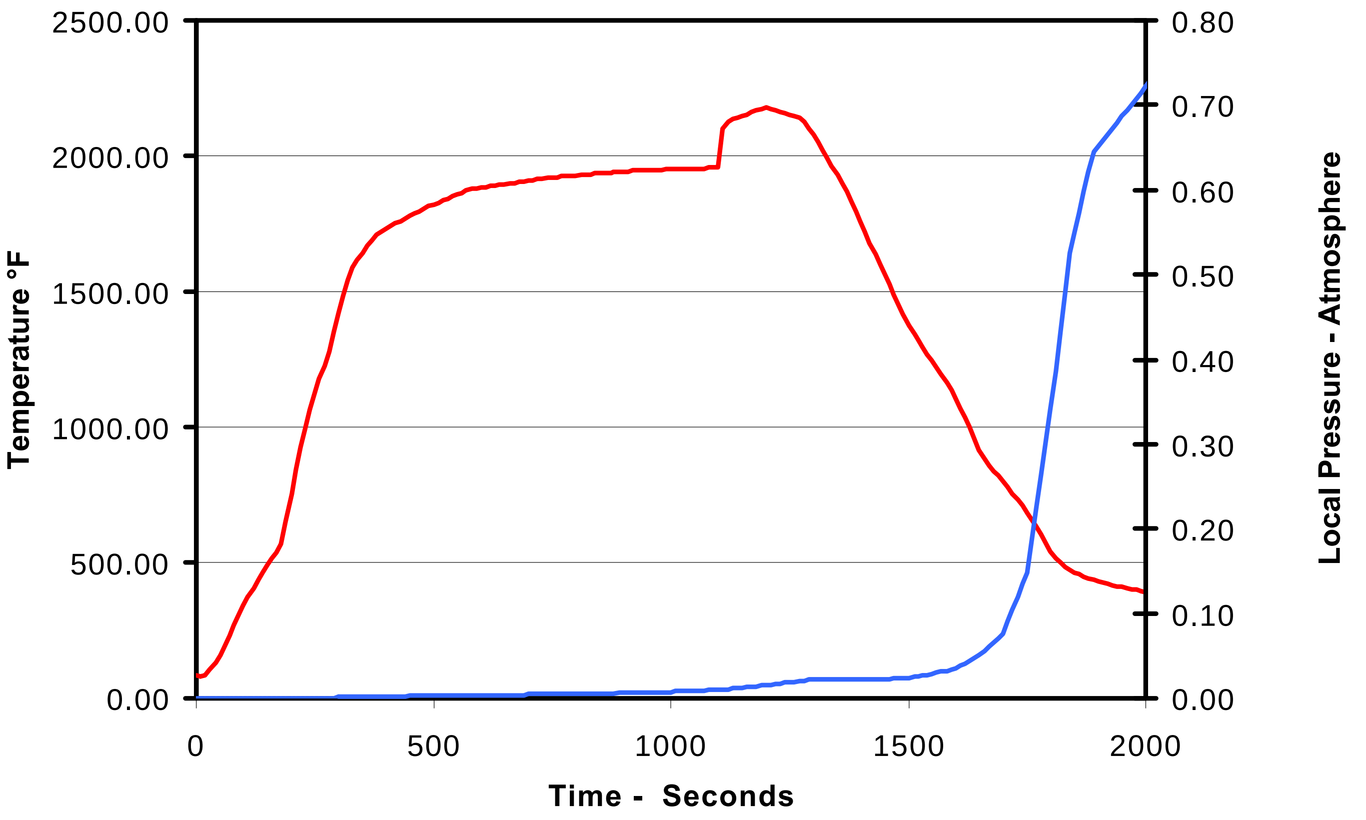
$$r\,C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(K \frac{\partial T}{\partial x}\right) + \dot{m}''\, C_{p_f}\, f\, \frac{\partial T}{\partial x}$$

ρ, C_P & K are Composite Properties
C_{Pf} is a Fluid Property
$T_s = T_f$ ^{o} T (Thermal Equilibrium)

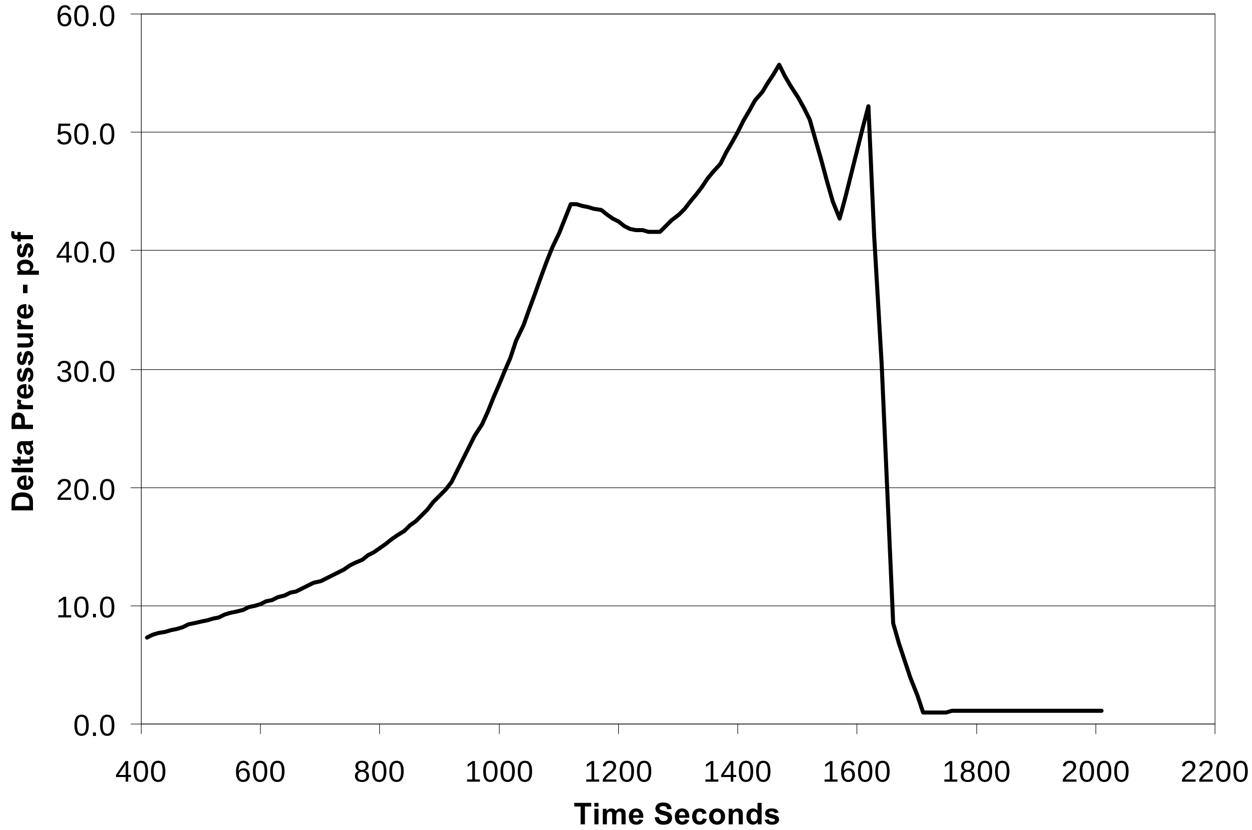
<u>Darcy's Momentum Equation</u>

$$-\frac{dP}{dx} = amn + brn^2$$

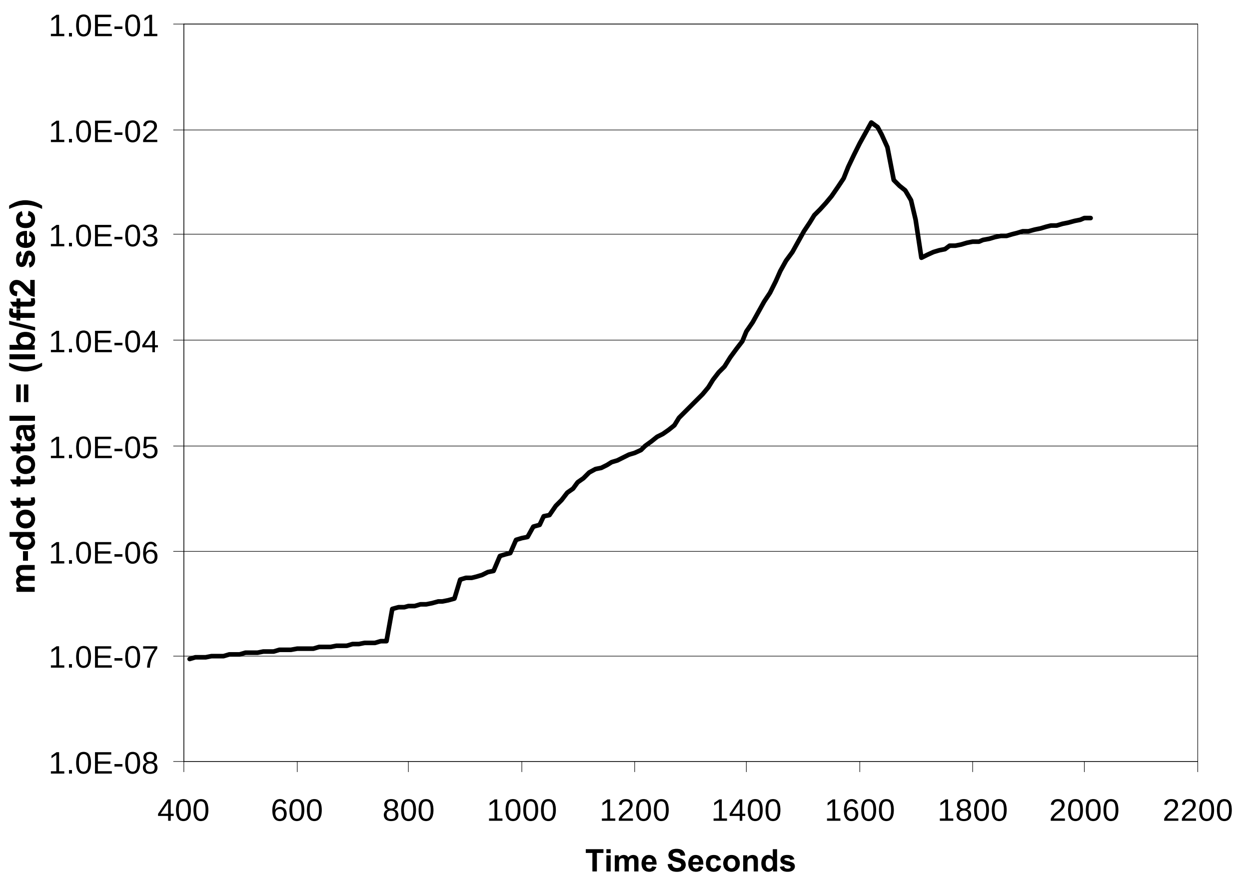
X-38 Rudder / Fin Seal Windward Surface Air Bulk Temperature and Pressure for Cycle 8 Trajectory



X-38 Rudder / Fin Seal Pressure Across the Gap Filler Seal Cycle 8 Trajectory

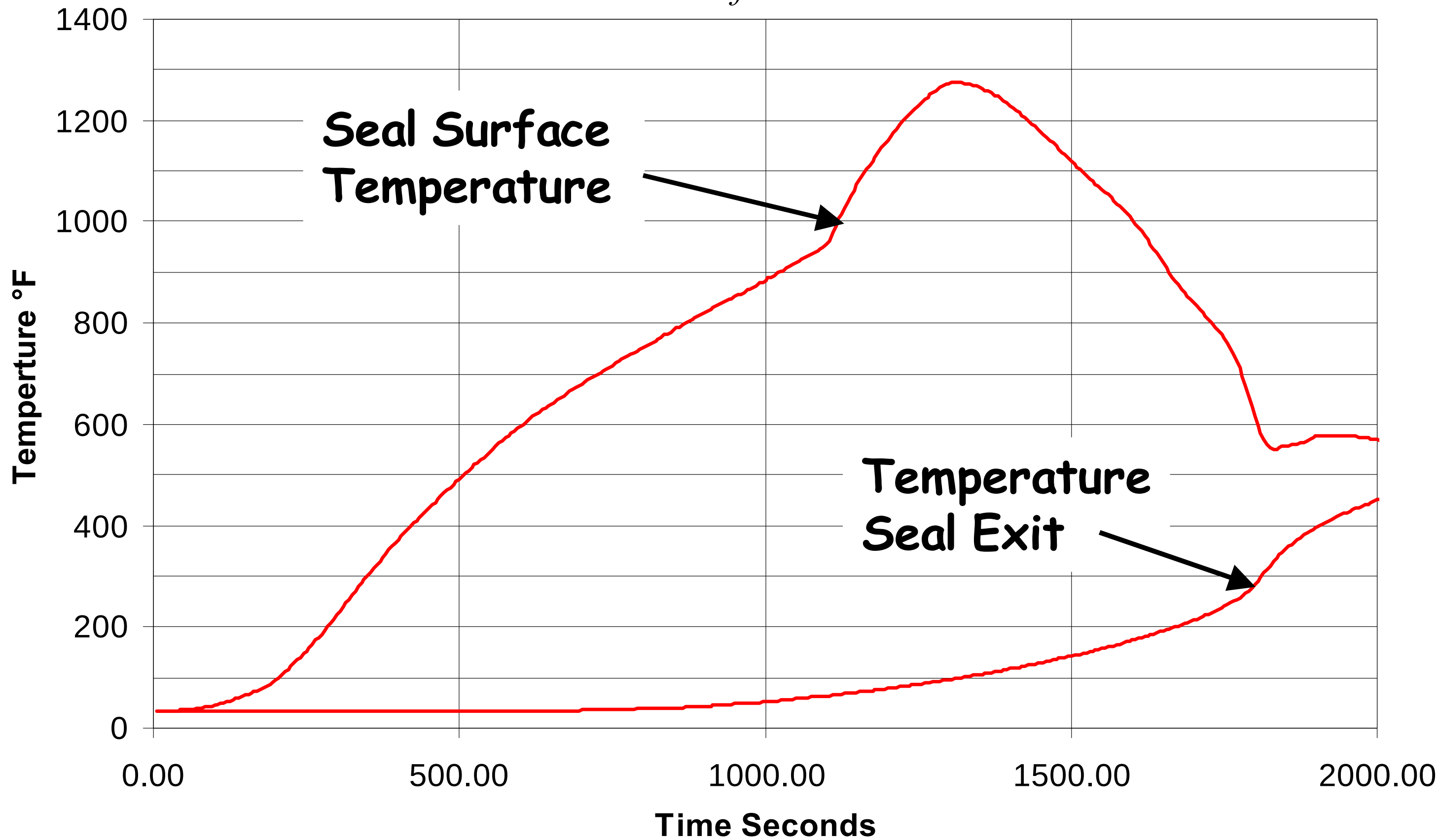


X-38 Rudder / Fin Seal Mass Flow
Cycle 8 Trajectory

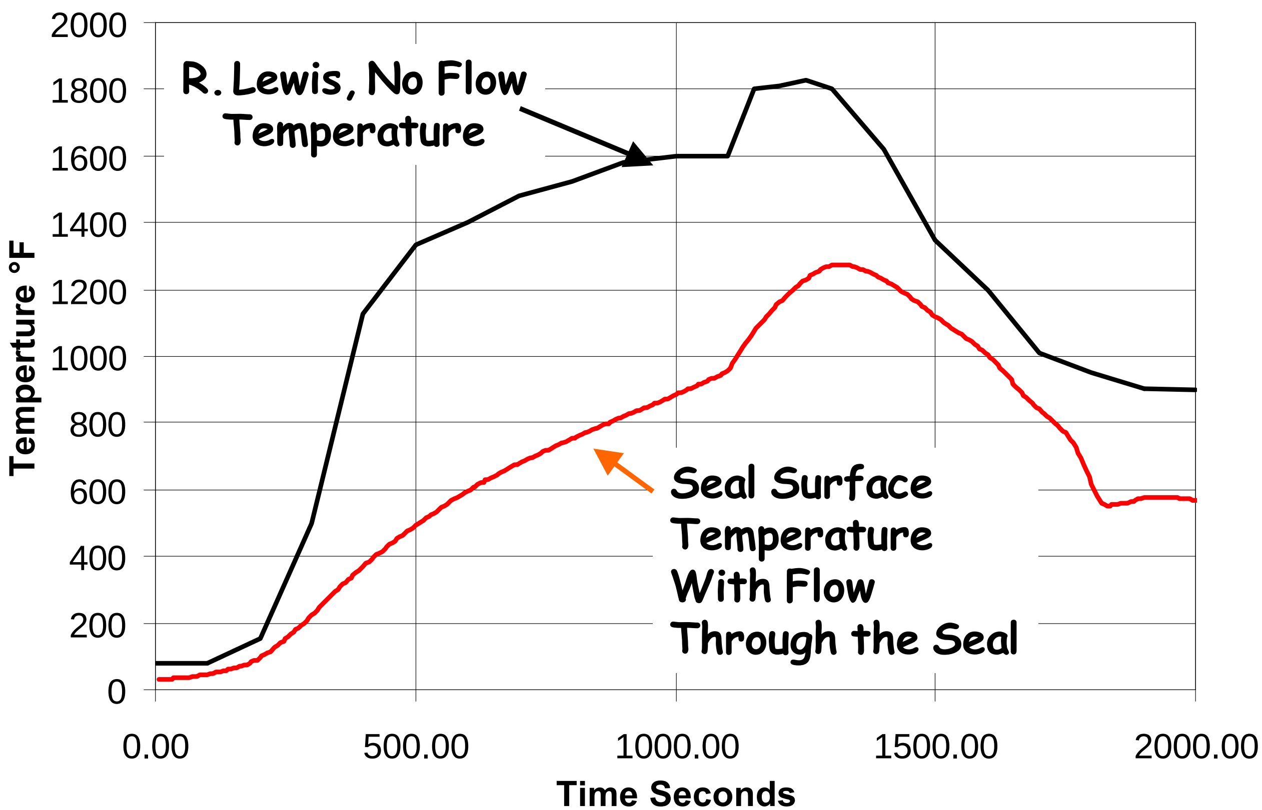


X-38 Rudder / Fin Seal Temperature and Pressure Cycle 8 Trajectory

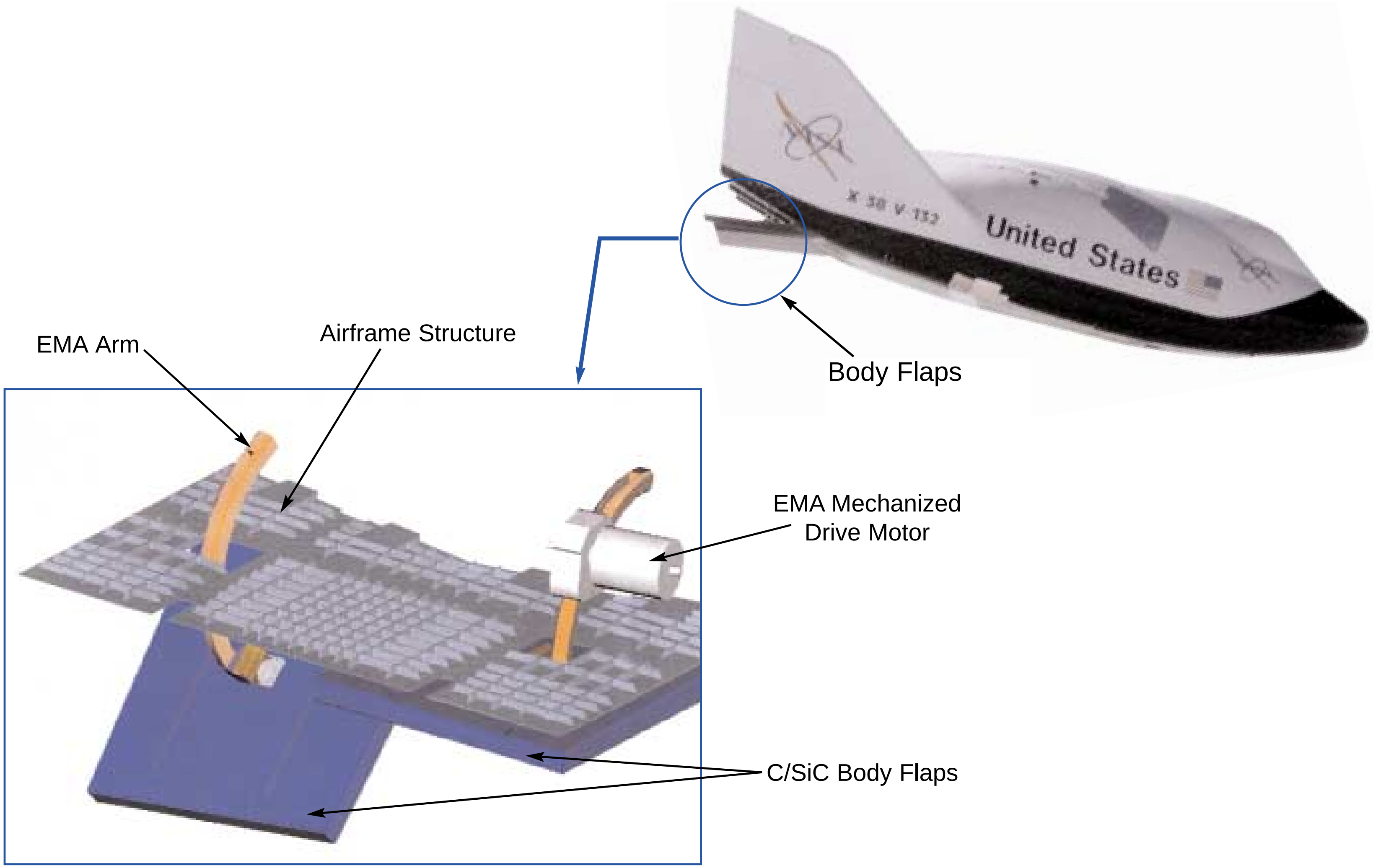
$$\dot{q}_{seal} = \dot{q}_{surface} * 0.04$$



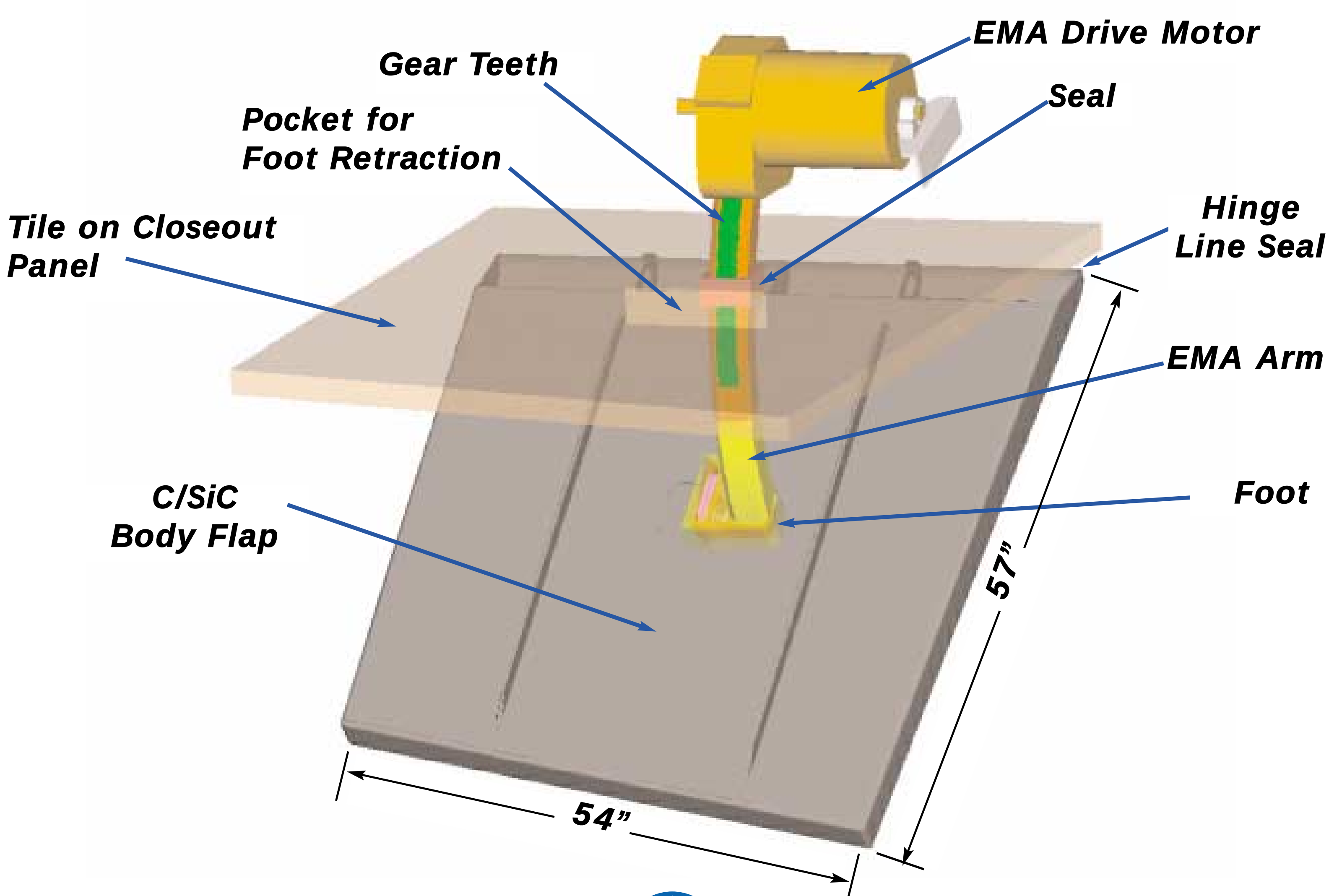
X-38 Rudder / Fin Seal Cycle 8 Seal Surface Temperature Comparison



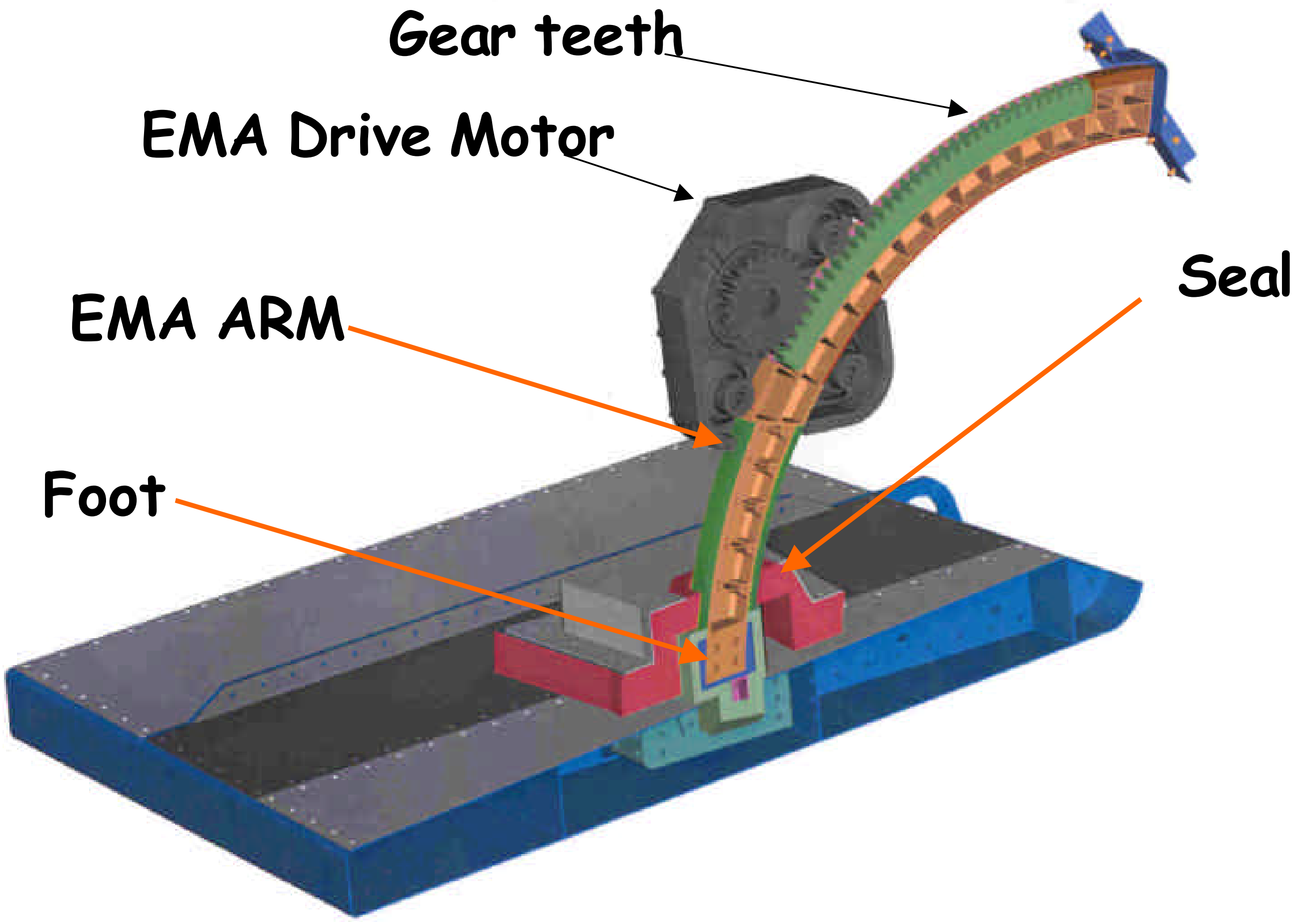
X-38 Body Flap Assembly



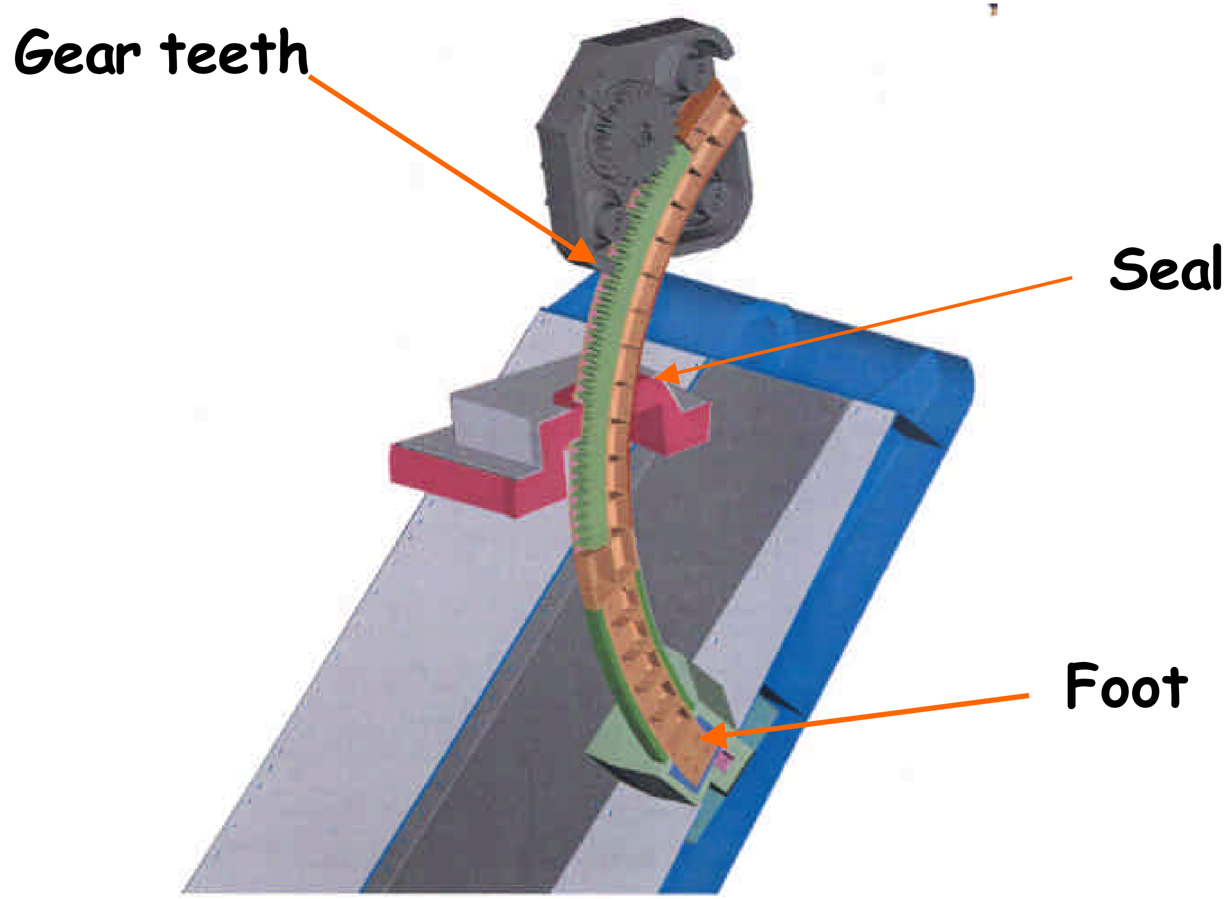
Baseline X-38 Bodyflap Seal Design



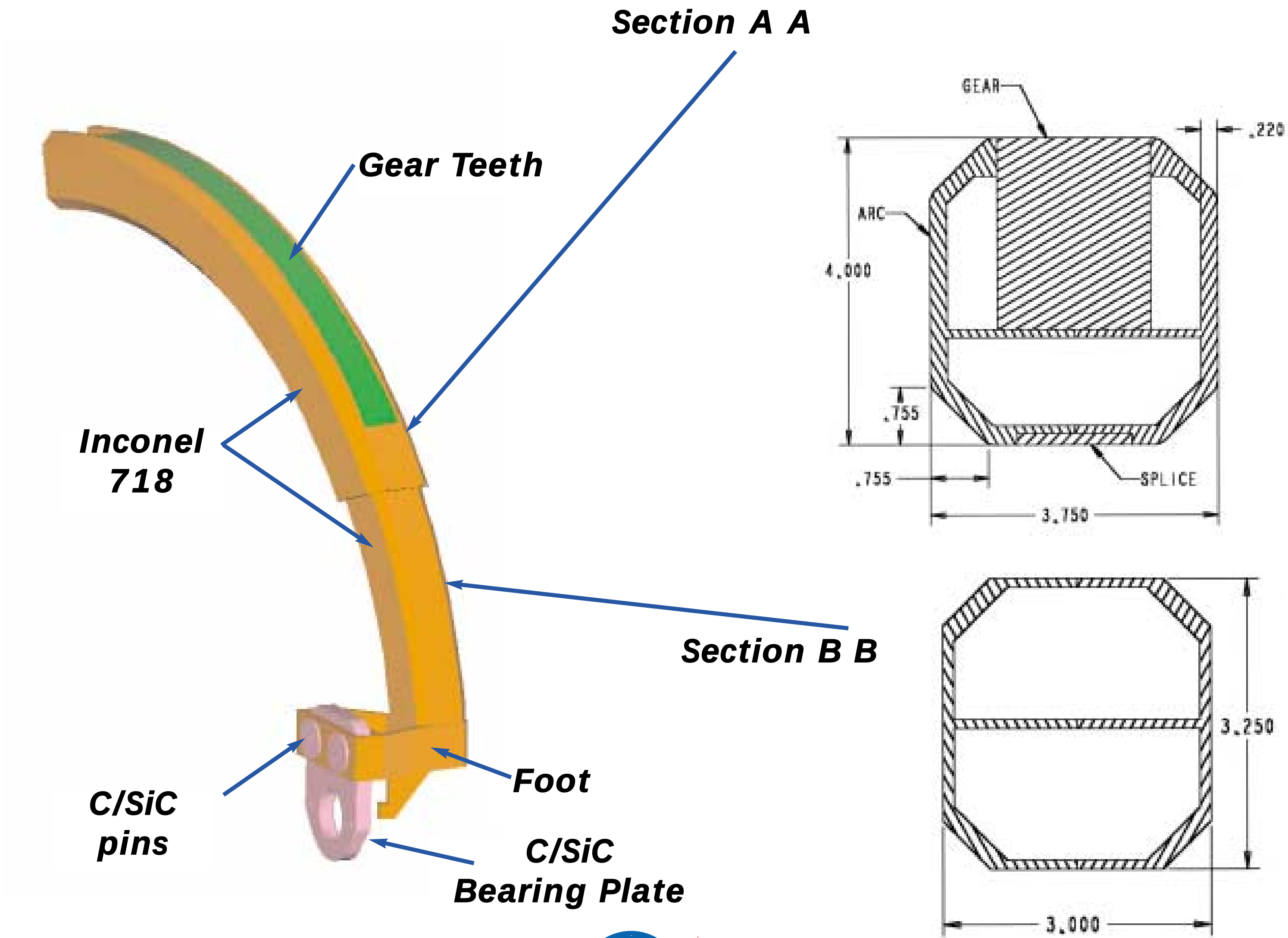
X-38 Bodyflap Seal Design (Undeflected)



X-38 Bodyflap Seal Design (45° Deflection)



EMA Arm Without Thermal Shield



X-38 Body Flap EMA TPS Concept Evaluation

- **Problem:**

  Conventional TPS do not meet the requirements for the X-38 Body Flap Electro Mechanical Actuator (EMA) Arm

- **Requirements:**

  High temperature, low conductivity, durable, and rub resistant TPS

X-38 Body Flap EMA TPS Concept Evaluation

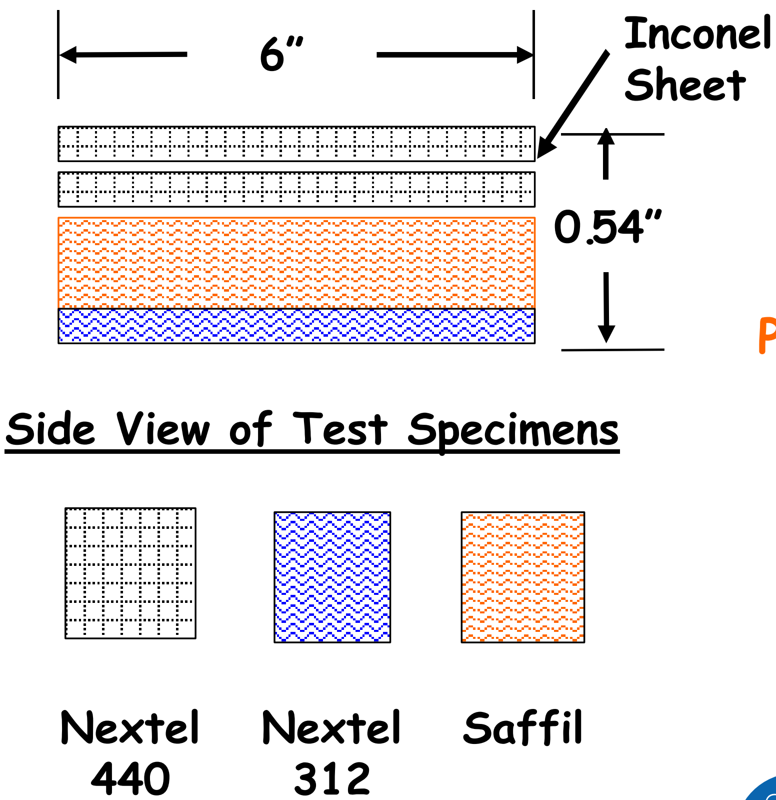
- **New Concept:**

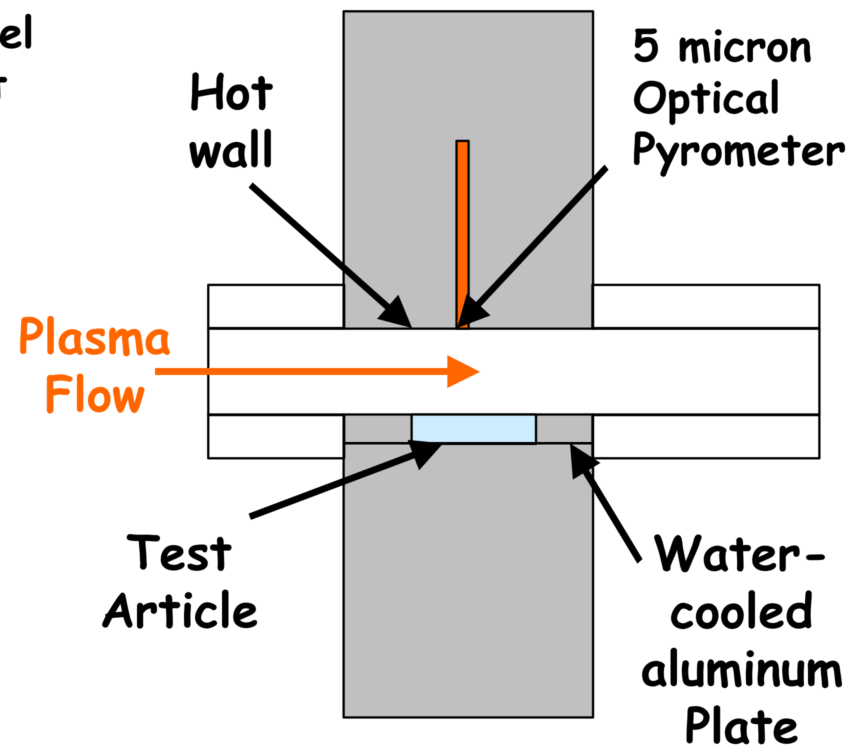
  Two layers of Nextel 440 with a thin sheet of Inconel between them

- **Purpose:**

  Evaluate a new TPS concept for the X-38 Body Flap Electro Mechanical Actuator (EMA) Arm

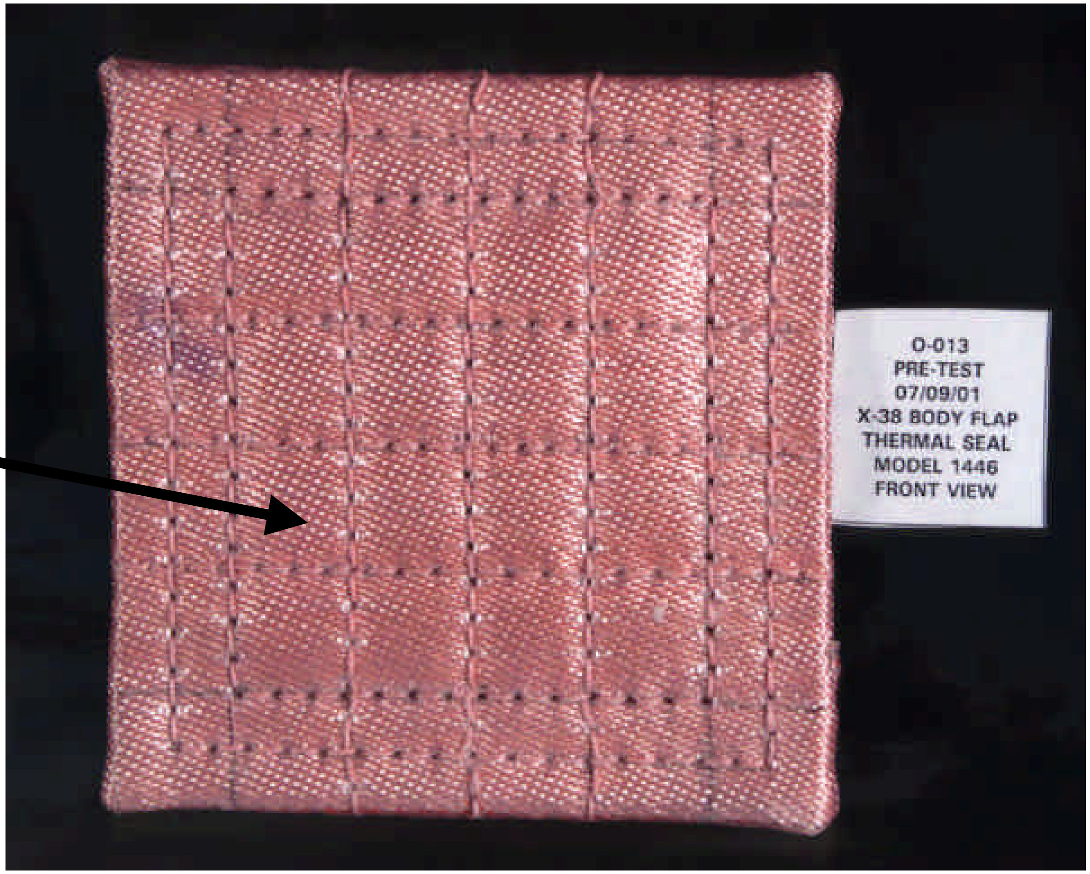
X-38 Body Flap EMA TPS Concept Evaluation Test Setup Top View of Cross Section of Channel Nozzle (Schematic)





X-38 Pre – Test Photograph

Nextel
440



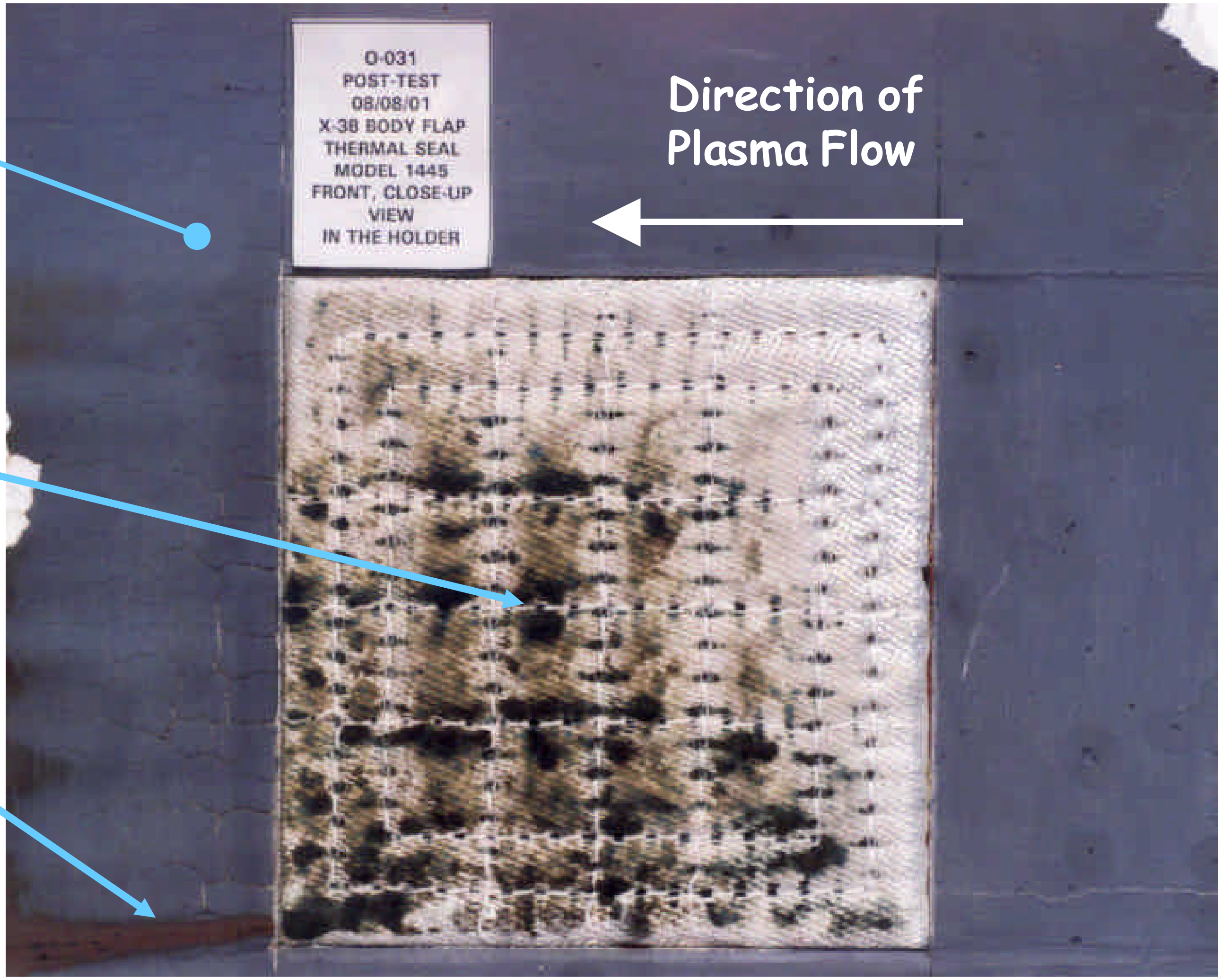
X-38 Body Flap Thermal Shield Concept Evaluation

- **Results:**

  New TPS concept failed due to severe surface degradation and easy fragmentation from the force of a pressure seal

- **Possible Solutions:**
  - **Coated Niobium (C-103) Heat Shield (Baseline)**
  - **Reusable Surface Insulation (RSI) “Donut” Rings**

X-38 Post – Test Photograph 2500°F



Silfrax Closeout Insulation

Some Charring

Molten Inconel Flow

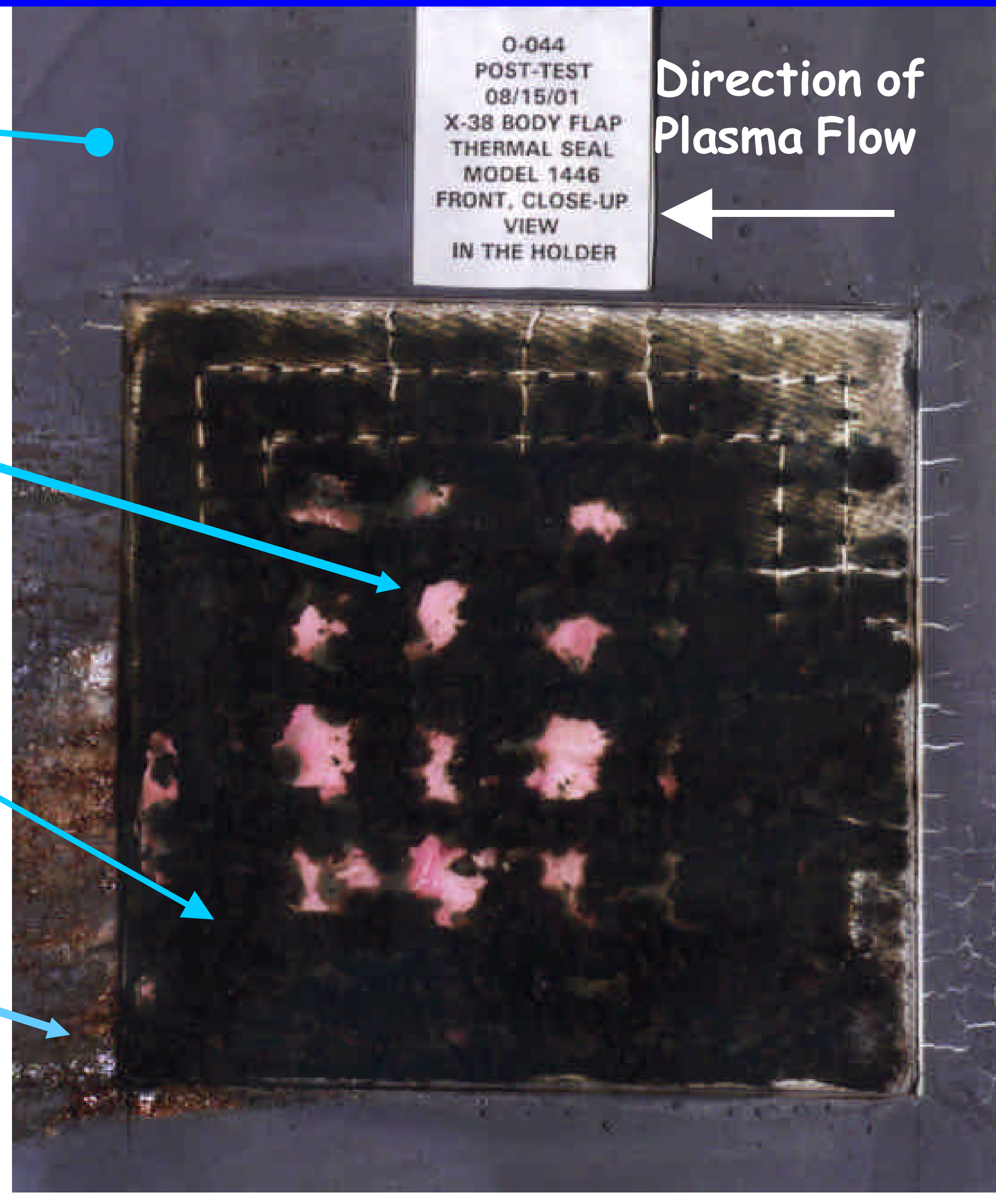
X-38 Post – Test Photograph 2800°F

Silfrax Closeout Insulation

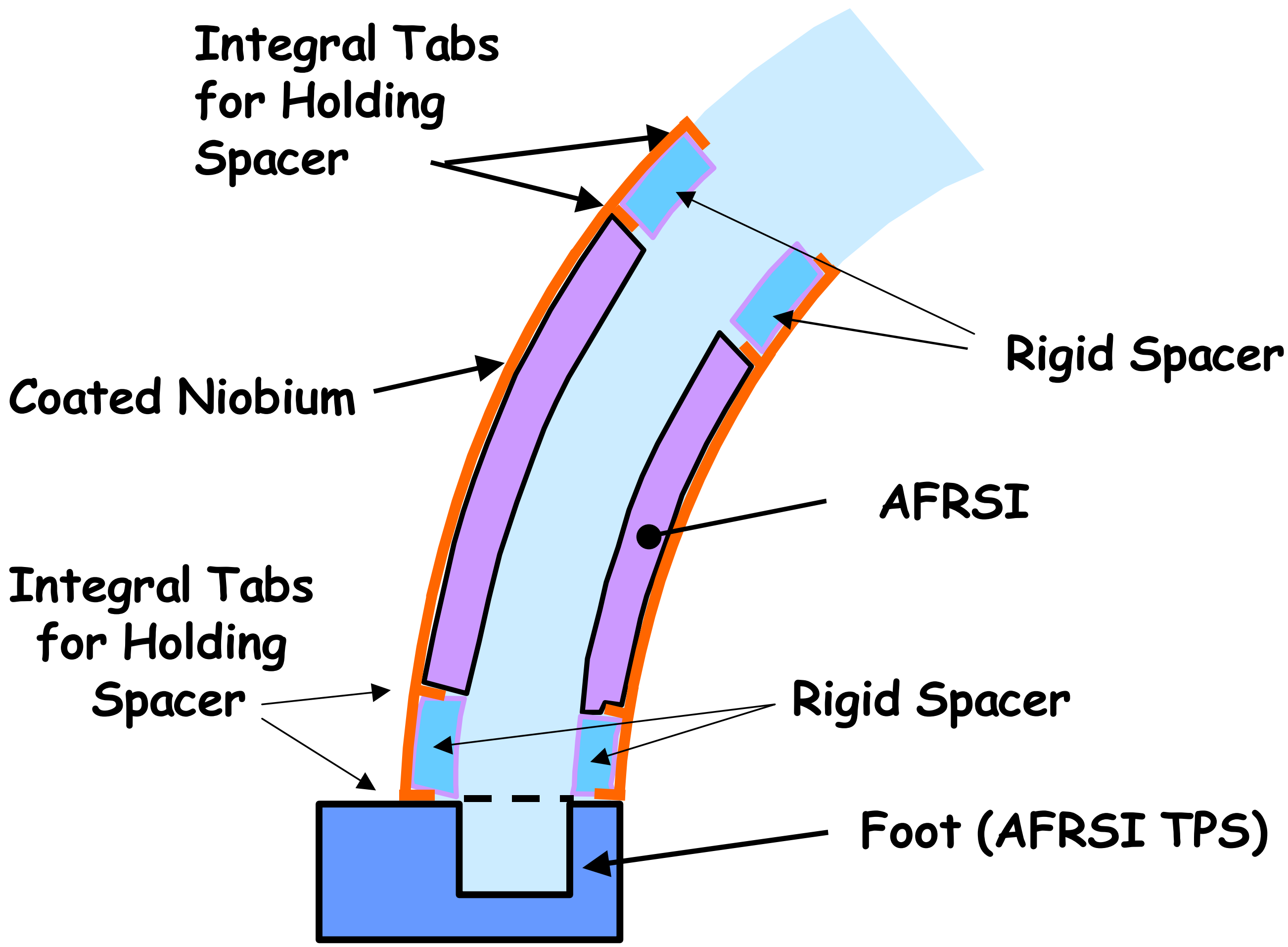
Fused Nextel 440 and Inconel

Severe Charring

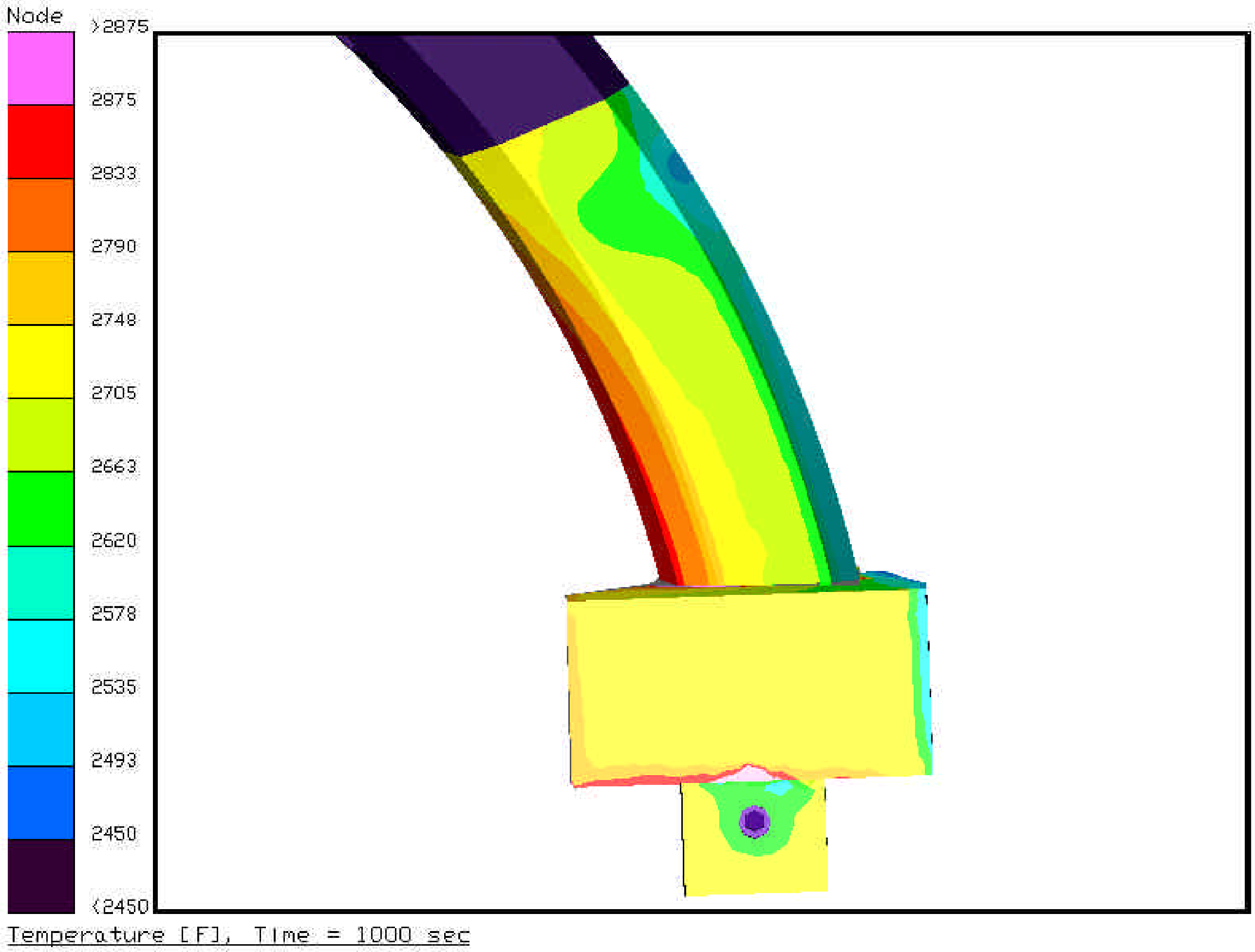
Molten Inconel Flow



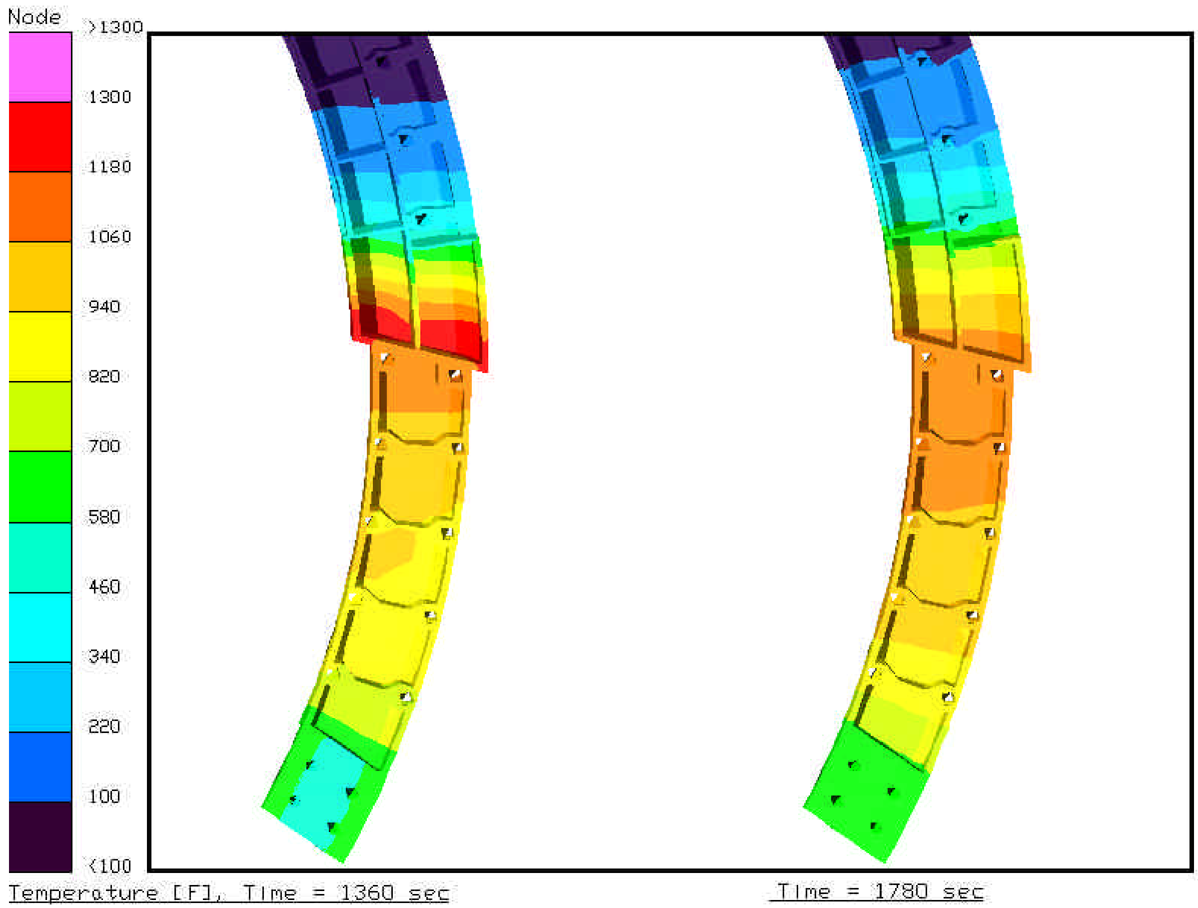
EMA Arc Niobium TPS



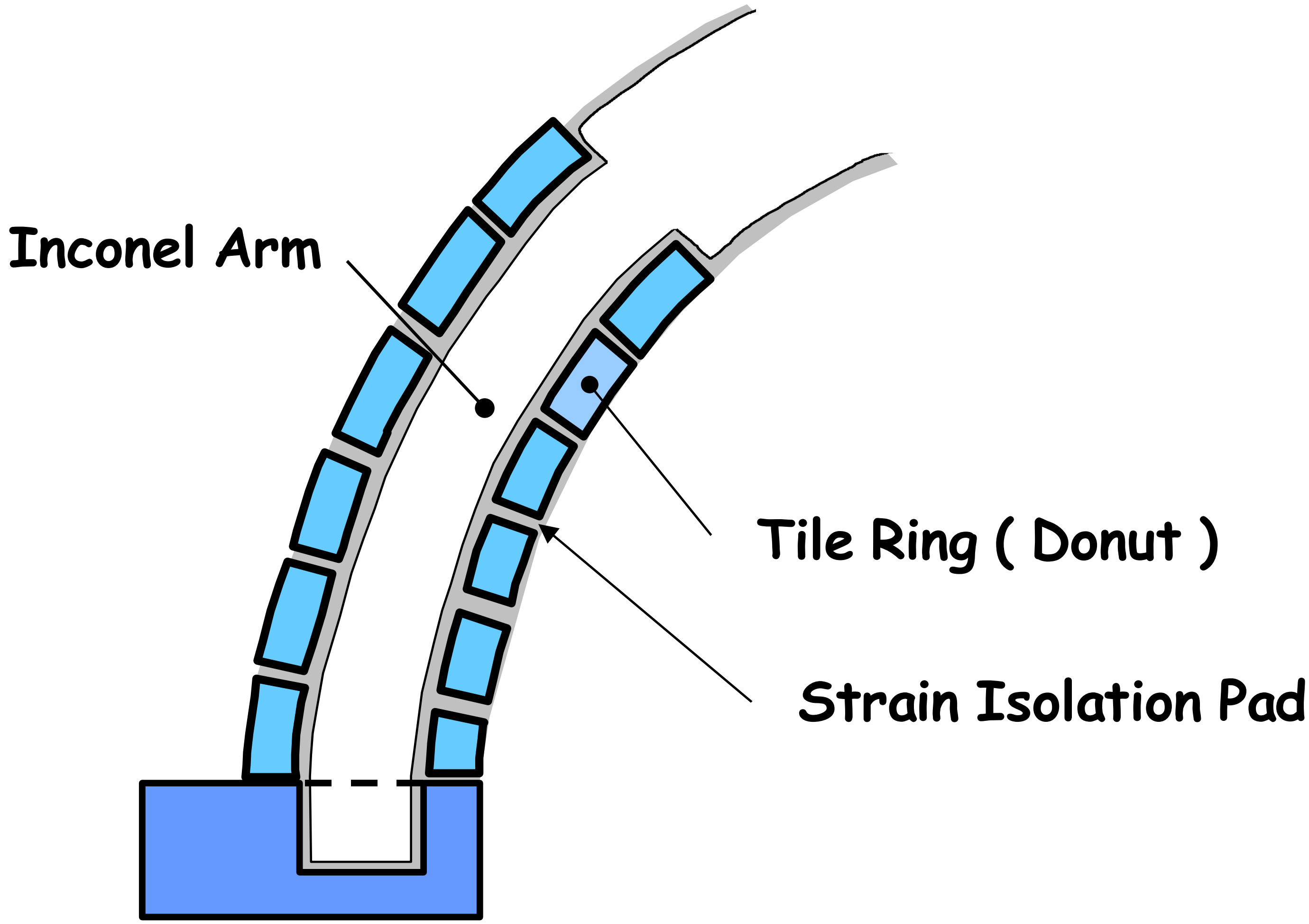
EMA Niobium Surface Temperature



EMA Actuator Arm Temperature



EMA Arc Tile Donut TPS



Current Activities Rudder / Fin Seal

Rudder / Fin Seal

- Thermal / Structural Analysis / Design of Vertical Rub Surface
- Modification of Seal Rub Test Fixture
- Mechanically Attaching Seal to Bracket for Rub Testing
  - Horizontal Tile Surface
  - Vertical Rub Surface
- Horizontal Rub Surface
  - Requires Smooth Tiles

Current Activities (Continued)
Body Flap – EMA Arm Seal

Body Flap – EMA Arm Seal

- Perform Rub Tests
  - EMA Arm TPS w / Inconel Spring Seal
    - Coated Niobium
    - Tile Ring (Donut)
  - EMA Arm Gear Teeth
    - Spring Tube Seal
    - Inconel Spring Seal