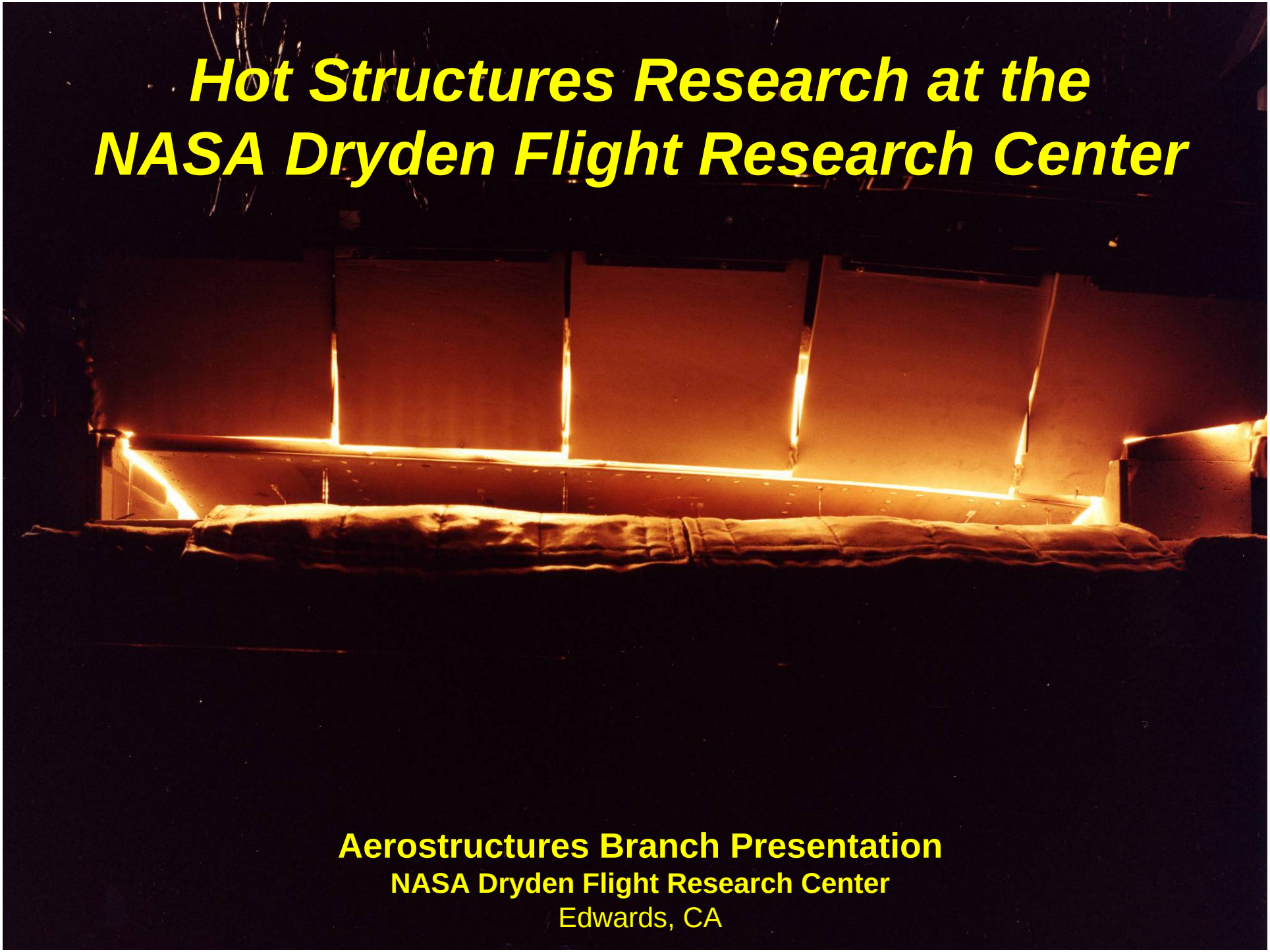
Hot Structures Research at the NASA Dryden Flight Research Center



Aerostructures Branch Presentation

NASA Dryden Flight Research Center

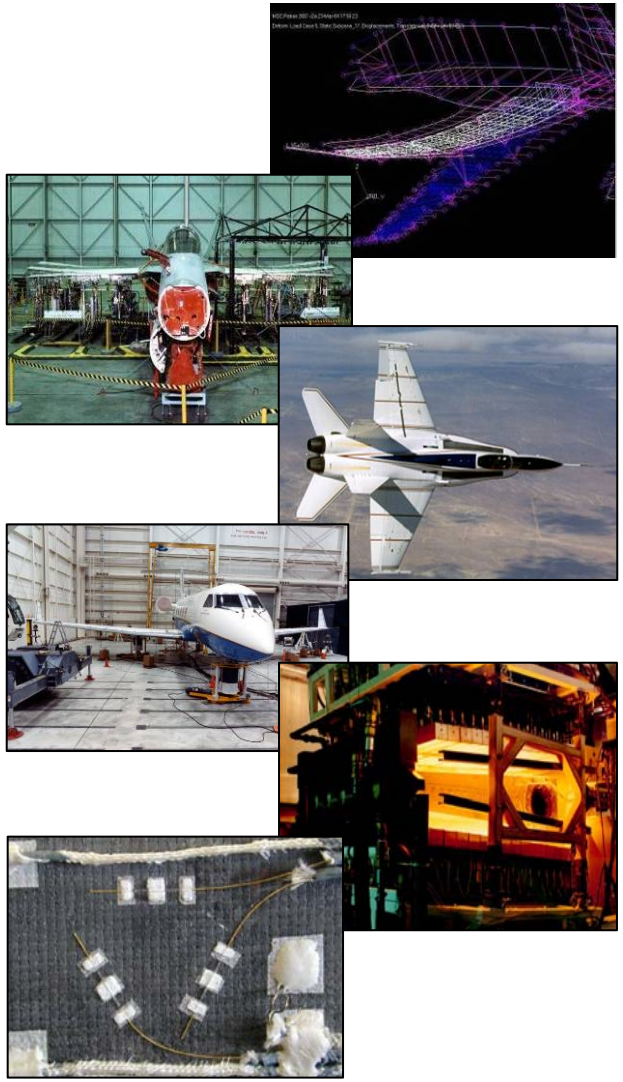
Edwards, CA

Outline

- Aerostructures Branch
- Flight Loads Lab Capabilities
- Hot Structures Research

NASA Dryden's Aerostructures Branch

- **Aerostructures Experience Base**
  - **Structural, thermal, & dynamic analysis**
    - **Finite-element analysis (FEA)**
    - **Aerodynamic loads analysis (CFD)**
    - **Flutter analysis**
    - **Aeroservoelastic analysis (ASE)**
    - **Aeroheating / heat transfer analysis**
  - **Structural, thermal, & dynamic ground-test techniques**
    - **Structural loads calibration and equation derivation**
    - **Proof loads testing**
    - **Ground vibration and structural mode interaction testing**
    - **Thermal / structural testing**
  - **Advanced structural instrumentation**
    - **Strain, temperature, heat flux, deflection, etc.**
    - **Fiber-optic strain and temperature sensors**
  - **Flight test techniques for analysis validation and safety-of-flight support**
    - **Flight test planning**
    - **Structural and thermal flight data analysis**



NASA Dryden's Flight Loads Laboratory

Flight Loads Lab Capabilities

- **General Description**
  - A unique laboratory for structural and thermal testing of aerospace structures
  - Large 164’ x 120’ high-bay test area
- **Structural Loading Capabilities**
  - Structural loading equipment including load frames, load cells, and hydraulic actuators
  - 44 channels of hydraulic load control (expanding to 80)
  - Aircraft ground vibration and structural mode interaction testing
- **Thermal Loading Capabilities**
  - Vacuum furnaces, low and high temperature chambers, liquid and gaseous nitrogen supply systems
  - Quartz lamp and graphite element heating
  - 20 MW of available power to support thermal testing
  - 9000 gal of LN_2 storage for cryogenic testing
- **Non Destructive Evaluation**
  - Infrared Pulsed Thermography
  - Acoustic Emission Sensing
- **Data Acquisition and Control System**
  - Potential of 1280 channels of data acquisition
  - Potential of 512 channels of thermal control

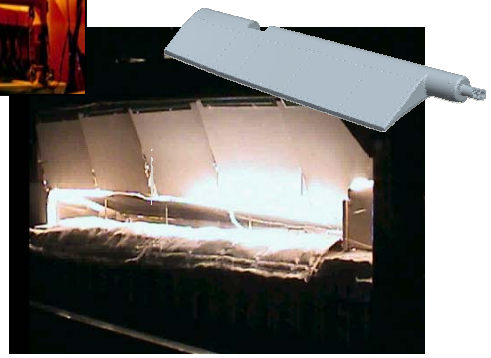
E2C Hawkeye Loads Calibration Test

Carbon-Carbon Elevon Thermal/Structural Test

Flight Loads Lab Capabilities
Combined Thermal / Structural / Cryogenic Loading

Shuttle Elevon Seal Test

- **Flight environment can be simulated through cooling, heating and structural load application**
- **Hydraulic actuators and load cells with capacities up to 300,000 lbf**
- **Temperature Range: -320°F to >3000°F**
  Temperature Rise Rate: ≈150°F/sec max
  Heating Rate: ≈100 Btu/ft^2-sec

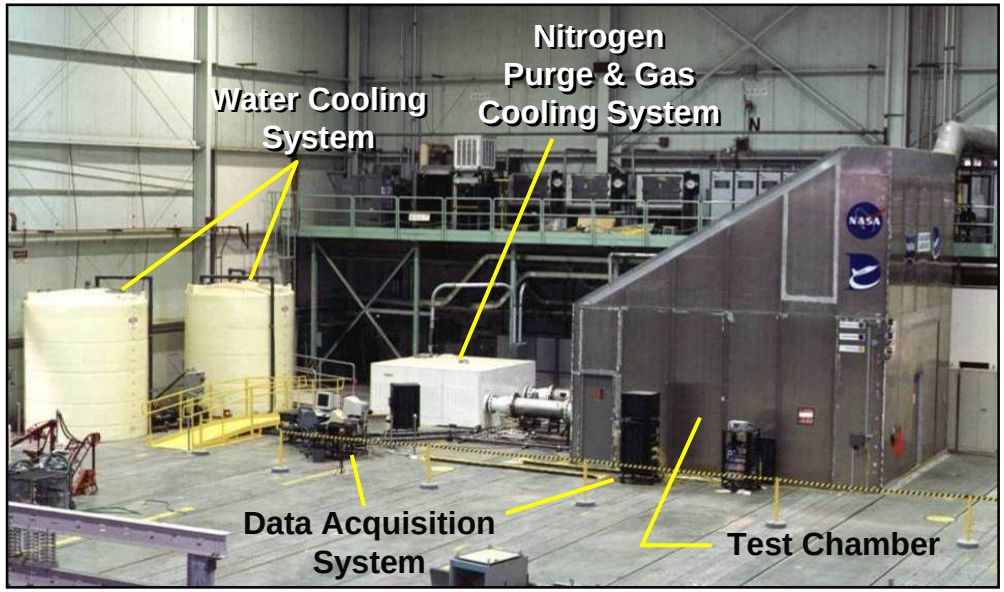


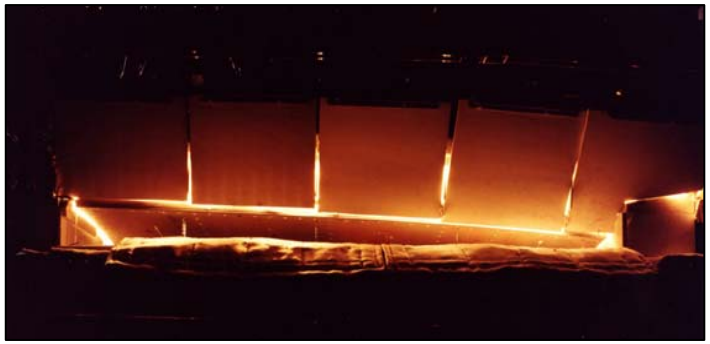
Hot Structures Testing

Thermal / Cryo Testing with Mechanical Loading

Flight Loads Lab Capabilities
Chamber for Large-Scale Hot Structures Testing

- **Nitrogen Atmosphere Test Chamber**
  - Approx. 10’x10’x10’ test area
  - Nitrogen purged
  - Quartz lamp & graphite heating systems
  - Hydraulic systems
  - High-strength strongback
  - Over 300 data channels
  - Water / gas cooling systems
  - Video system

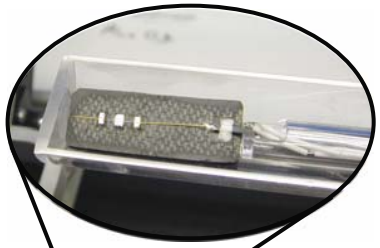
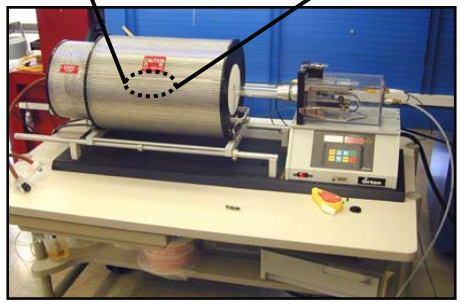
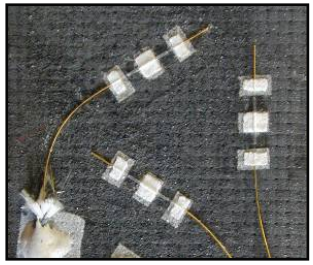
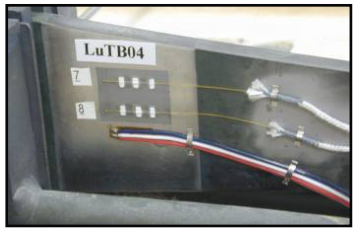


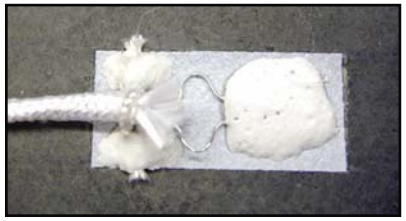
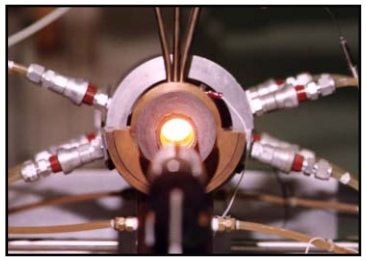
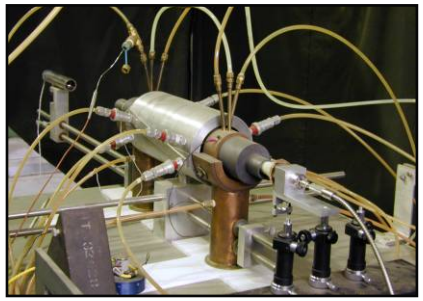


X-37 C/C Flaperon in Chamber

Flight Loads Lab Capabilities
Advanced Structural Instrumentation

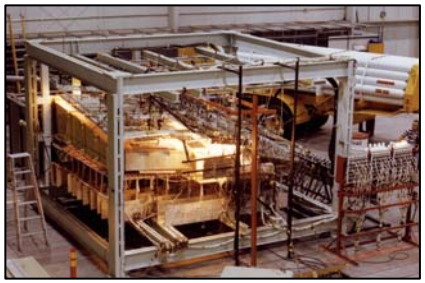
- **Strain, temperature, heat flux measurements on advanced materials including:**
  - **Metallics, metal matrix composites, superalloy honeycomb, C/C and C/SiC**
- **Sensor evaluation and calibration systems**
  - **Strain sensors from -320°F to 3000°F**
  - **Temperature sensors from -320°F to 4000°F**
  - **Heat flux gages to 400 Btu/ft^2-sec**
- **Attachment techniques**
  - **Epoxy based adhesives**
  - **Ceramic & graphite cements**
  - **Plasma and Rokide thermal spraying**
- **Advanced sensor application research**
  - **Fiber-optic strain and temperature**
  - **Ground and flight testing**

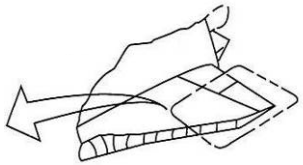





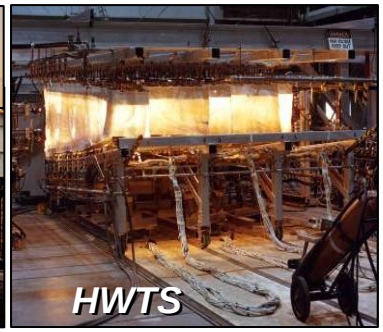
Hot Structures Research at NASA Dryden

- **1960's**
  - **X-15**
    - **Thermal stress testing / flight qualification**
    - **Aeroheating analysis**
- **1970's**
  - **U.S. Space Shuttle**
    - **Elevon seals test**
    - **Thermal / structural analysis**
  - **YF-12 (SR-71 precursor)**
    - **Thermal loads testing**
    - **Cold-wall heat flux flight experiment**
  - **Hypersonic Wing Test Structure (HWTS)**



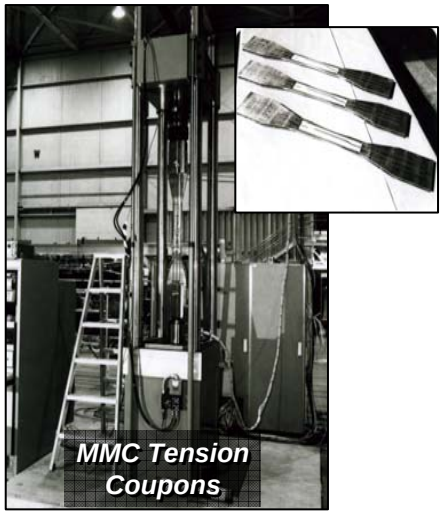


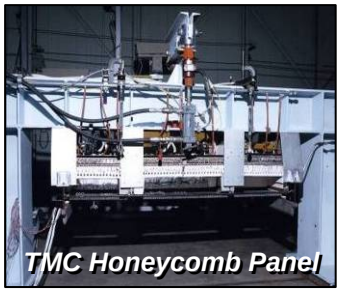
Space Shuttle Elevon Seals Test

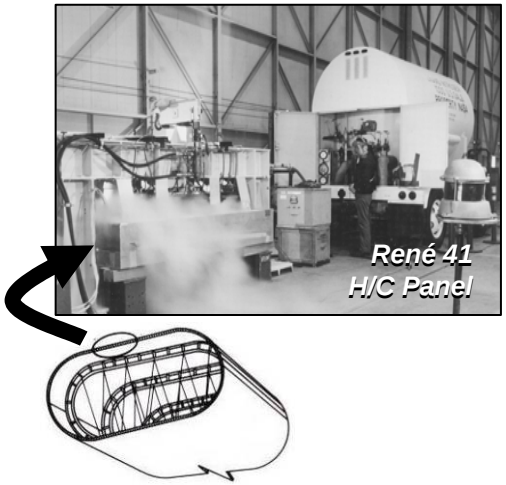


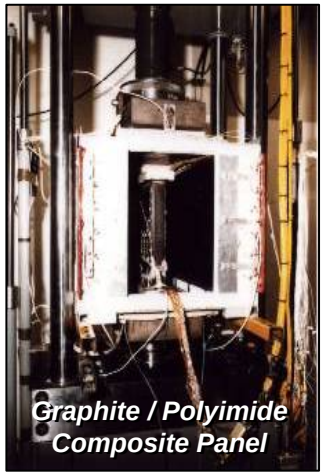
Hot Structures Research at NASA Dryden

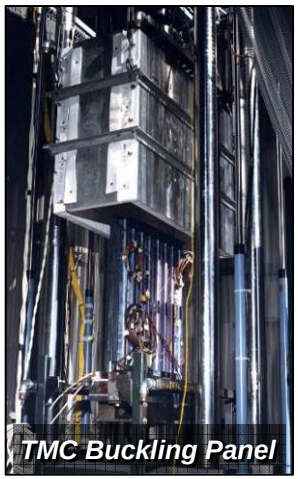
- **1980's**
  - **Thermal / Structural Tests**
    - **MMC tension coupons**
    - **Graphite / polyimide composite panel**
    - **Superalloy honeycomb (H/C) TPS**
    - **René 41 honeycomb panel**
    - **TMC buckling and honeycomb panels**
    - **Ti 6-4 buckling panel**
  - **Test technique and instrumentation development**
  - **Thermal / structural analysis**







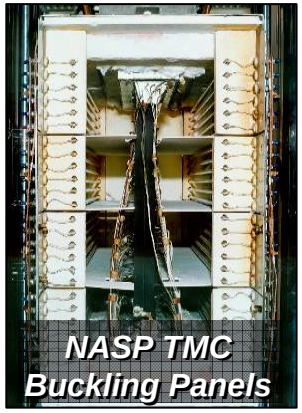




Hot Structures Research at NASA Dryden

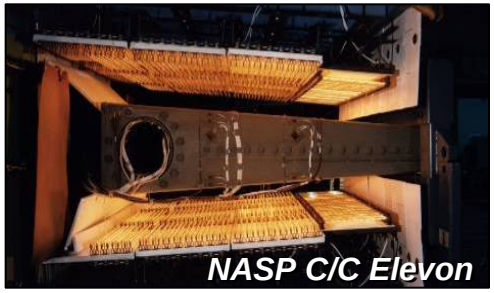
- 1990's
  - X-30 National AeroSpace Plane (NASP)
    - Various honeycomb, hat stiffened, joined, and buckling panel tests
    - Titanium Matrix Composite (TMC) Side-Shear Panel
    - Carbon-Carbon (C/C) Elevon
  - PHYSX Glove Aerodynamic Heating Simulation Test
  - X-33 High-Temperature Strain Gage Instrumentation Development

NASP TMC Side Shear Panel


NASP TMC Buckling Panels

PHYSX Glove Aerodynamic Heating Simulation

X-33 Strain Gage Instrumentation


NASP C/C Elevon

Hot Structures Research at NASA Dryden

- 2000's
  - NASP / Next Generation Launch Technology (NGLT) Carbon-Carbon Elevon
  - X-37
    - C/SiC Bodyflap Subcomponent
    - C/SiC Flaperon Subcomponent
    - C/C Flaperon Subcomponent & Qualification Unit

Hot Structures Research at NASA Dryden

- X-37 C/C Flaperon Qual Unit Test
  - Tested in nitrogen atmosphere
  - Instrumentation
    - 206 thermocouples channels
      - 82 on control surface (18 temp control)
      - 124 on test setup
    - 14 fiber-optic strain sensors
    - 12 deflection measurements
  - Key Test Challenges
    - Developing techniques to bond strain and temperature sensors to C/C substrate for >2500°F
    - Achieving correct thermal boundary conditions to facilitate correlation to analysis

Hot Structures Research at NASA Dryden

Strain Sensing on Hot Structures

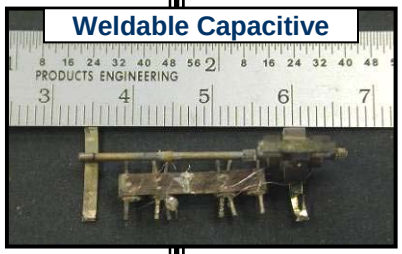
Evolution of Hot-Structures Strain Measurements

1960-1970 | **1980-1990** | **>2000**

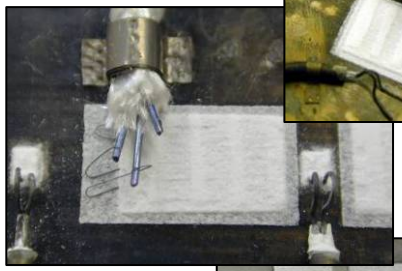
Flame-Sprayed Resistive

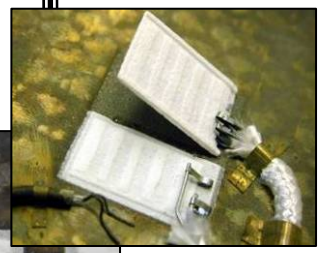
Weldable Resistive

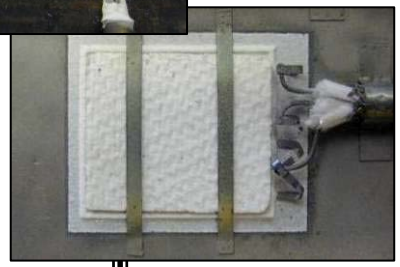
Weldable Capacitive



Large thermal outputs and measurement uncertainties

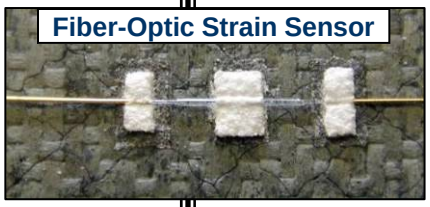


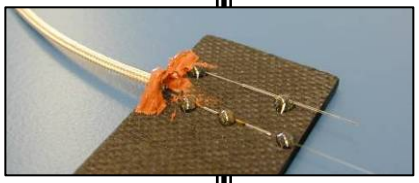




Improved temperature-compensation using flame-sprayed resistive gages

Fiber-Optic Strain Sensor





Improved measurement accuracy applying Silica and Sapphire EFPI Technology

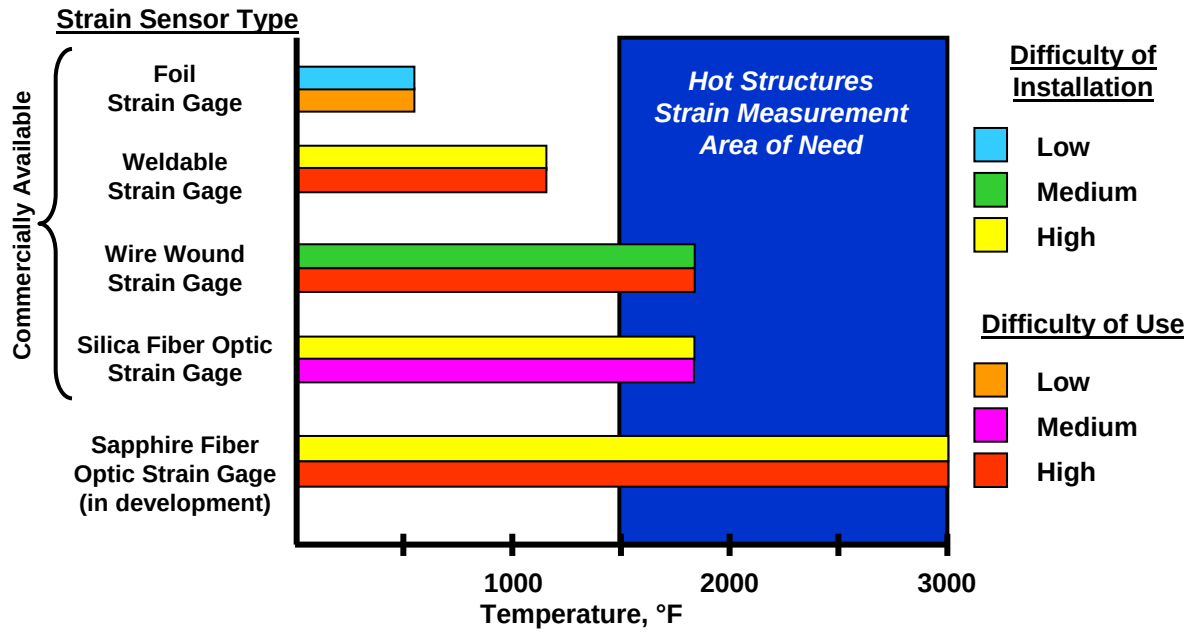
Hot Structures Research at NASA Dryden

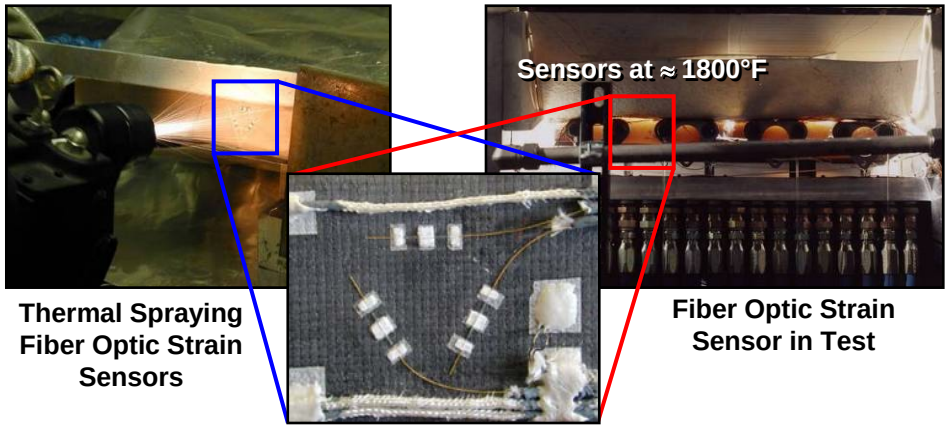
Key Problem

Currently have the ability to test hot structures at temperatures beyond our ability to measure what's happening

Key Challenge

- Advance fiber-optic strain sensing technology beyond 2000°F
- Durable high-temp fiber-optic sensors



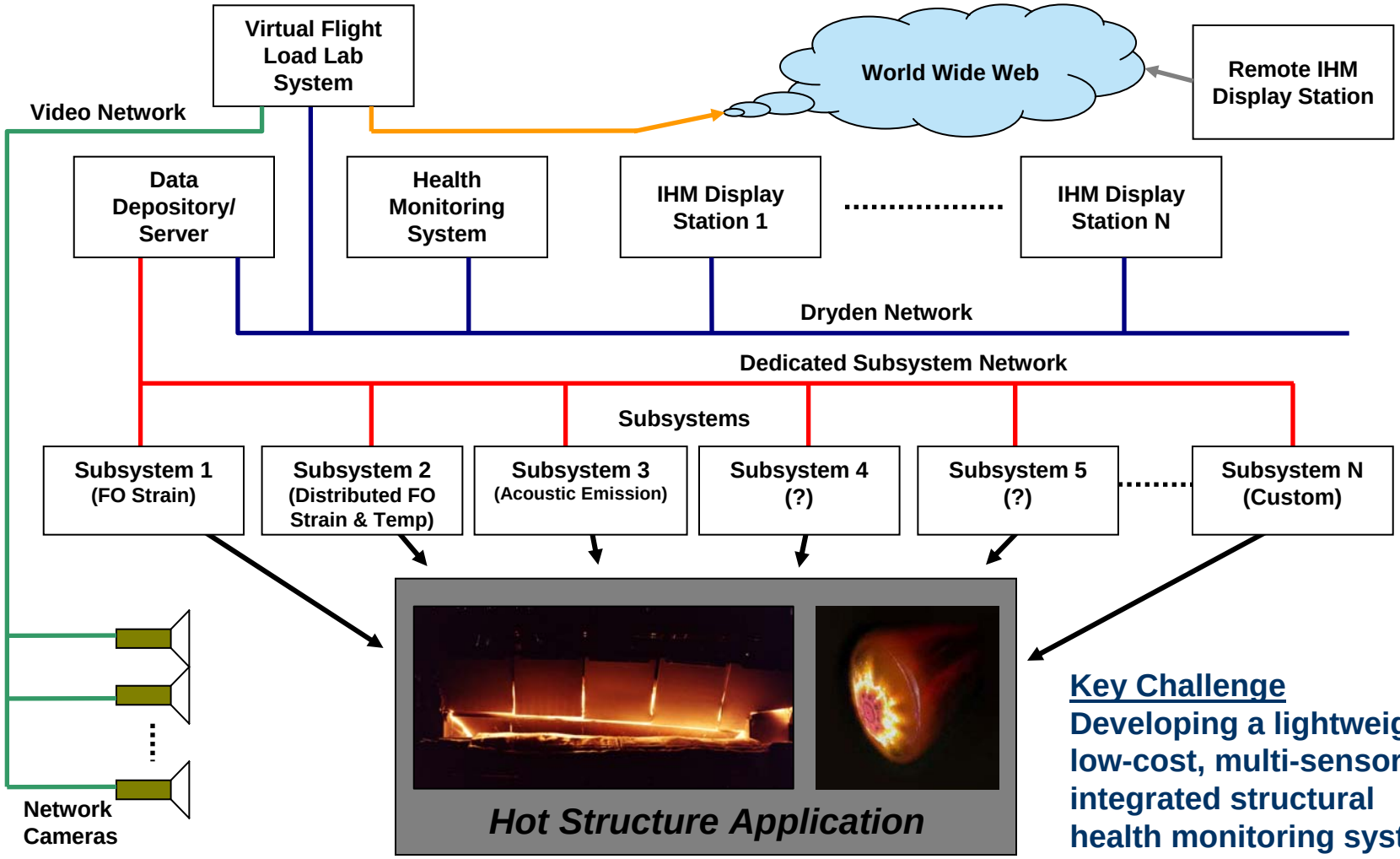


Thermal Spraying Fiber Optic Strain Sensors

Fiber Optic Strain Sensor in Test

Hot Structures Research at NASA Dryden

Integrated Structural Health Monitoring of Hot Structures



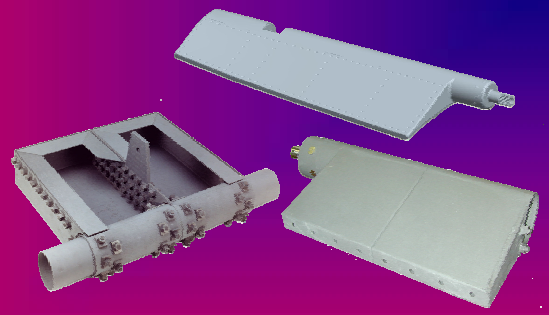
Key Challenge

Developing a lightweight, low-cost, multi-sensor integrated structural health monitoring system

Hot Structures Research at NASA Dryden Focused on Future Aerospace Applications

Unique Ground Test Facilities and Test Capabilities

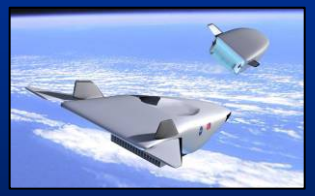
Crew Exploration Vehicles



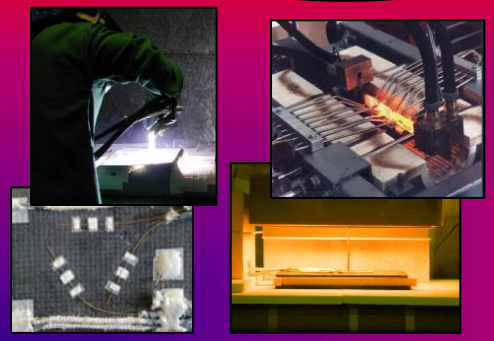
Advanced High-Temperature Composite Materials & Structures

Revolutionary Aerospace Vehicles

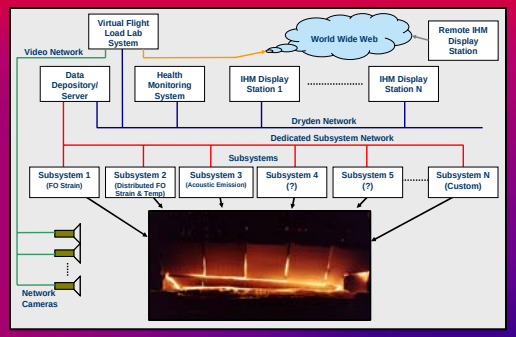
Hypersonic Vehicles



Re-entry Vehicles



Advanced High-Temperature Sensor Development



Systems Integration for Structural Health Monitoring

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