



NASA Hypersonic Ground Test Facilities and Laboratories

STAC Symposium

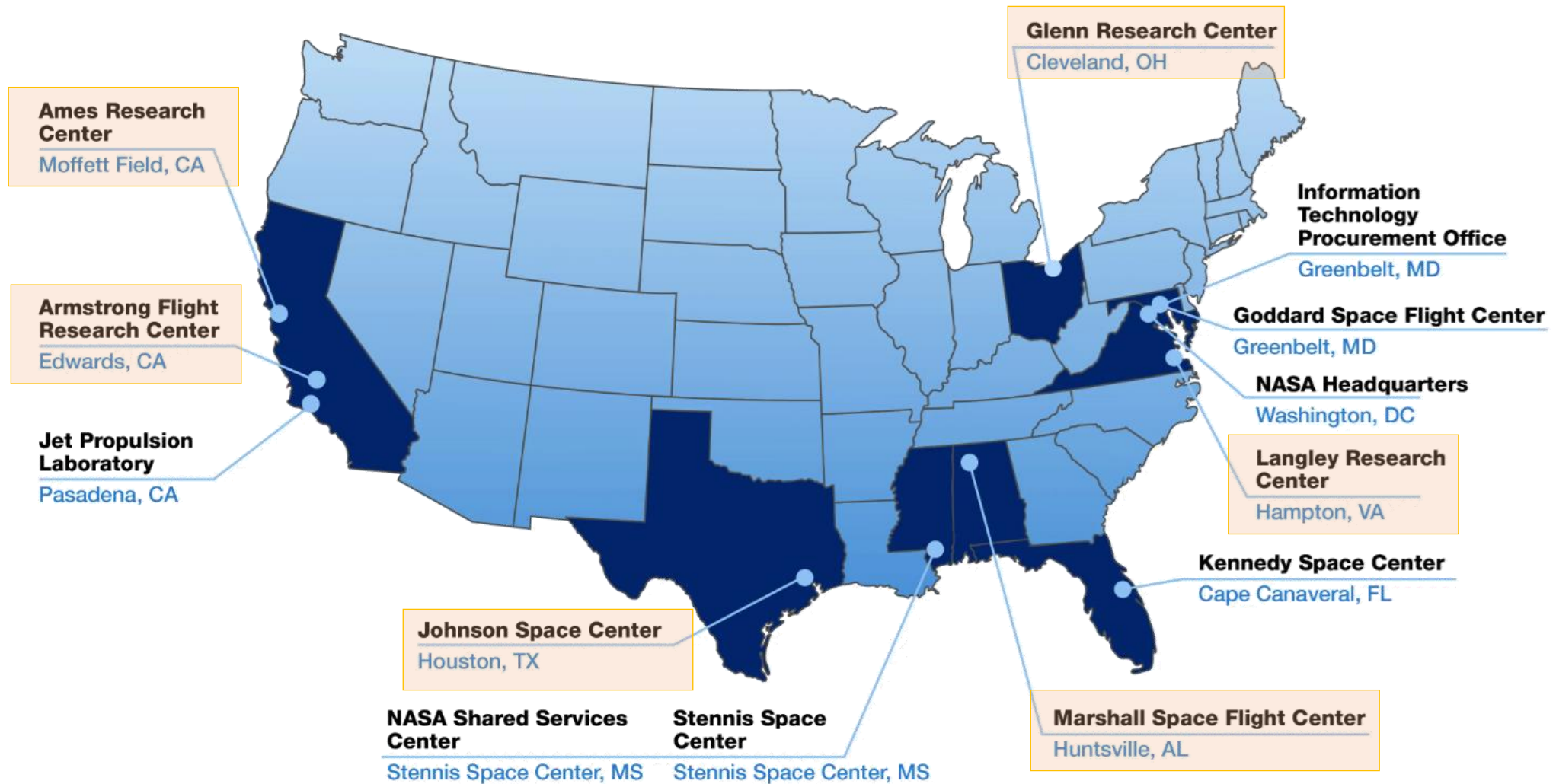
5 Feb 2025



- Propulsion Facilities
 - Aerodynamic Facilities
 - Structural Testing Labs
 - Materials Testing Labs
- Overview of Capabilities
 - Location
 - Technical Point of Contact



Locations of NASA Facilities





Propulsion Facilities



LaRC 8-Ft. High Temperature Tunnel (8-Ft. HTT)

Flight Mach: 3 – 7
Aaron.W.Fuchs@nasa.gov



LaRC Arc-Heated Scramjet Test Facility (AHSTF)

Flight Mach: 4.7 - 8
Hubert.H.Senter@nasa.gov



LaRC Direct-Connect Supersonic Combustion Test Facility (DCSCTF)

Flight Mach: 4.5 – 7
Hubert.H.Senter@nasa.gov



GRC Propulsion Systems Lab (PSL)

Flight Mach: 4.7 - 6
Alicia.Graham@nasa.gov



GRC 10x10

Flight Mach: 2.0 - 3.5
Jonathan.M.Kubiak@nasa.gov



GRC 1 X 1

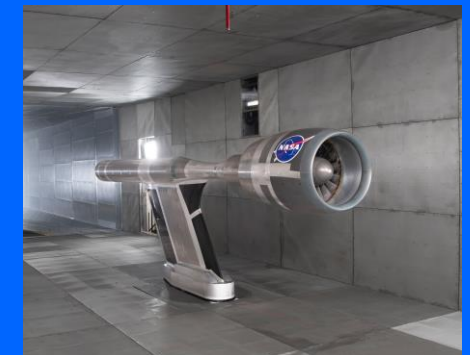
Flight Mach: 1.3 - 6
Gwynn.A.Severt@nasa.gov



GRC 9 X 15

Low-Speed Wind Tunnel Facility

Flight Mach: 1.3 - 6
Michelle.Lasic@nasa.gov





Aerodynamic Facilities



LaRC 14 X 22 Subsonic Wind Tunnel

Speed: 348 ft/s
Lisa.Brown@nasa.gov



ARC 11 Ft Transonic Facility

Flight Mach: 0.2-1.45
Maureen.A.Delgado@nasa.gov



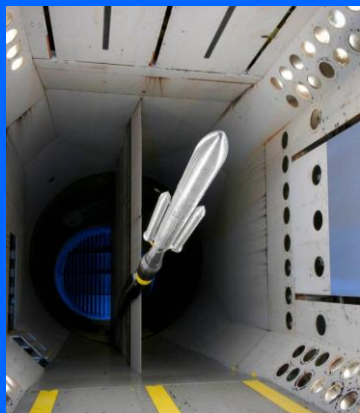
LaRC National Transonic Facility (NTF)

Flight Mach: 1.-1.2
Kevin.R.Harrell@nasa.gov



LaRC Transonic Dynamics Tunnel

Flight Mach: Up to 1.12
Anthony.D.Olszewski@nasa.gov



ARC 9 X 7 Ft Supersonic Wind Tunnel Facility

Flight Mach: 1.55 - 2.55
Maureen.A.Delgado@nasa.gov



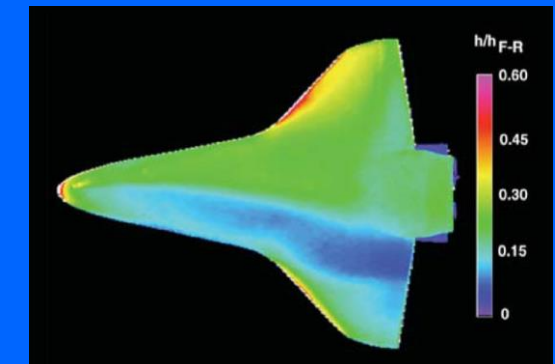
LaRC Unitary Plan Wind Tunnel (UPWT)

Flight Mach 1.5-4.6
Vic.Z.Tumwa@nasa.gov



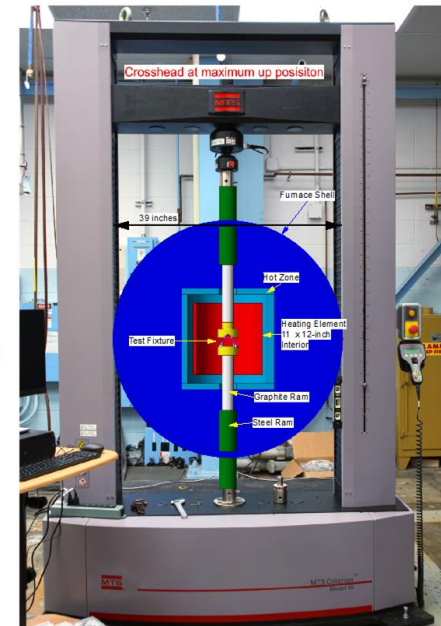
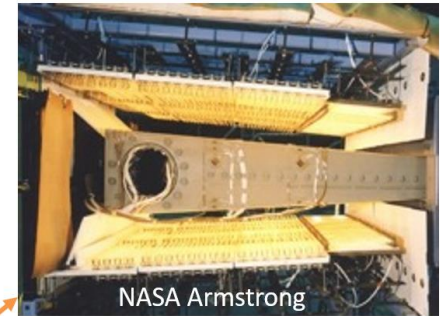
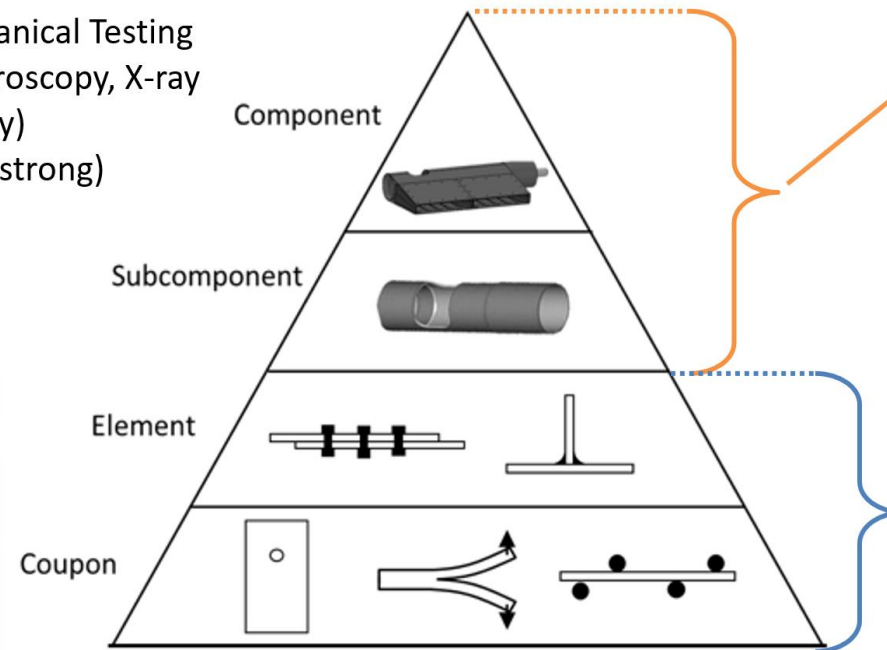
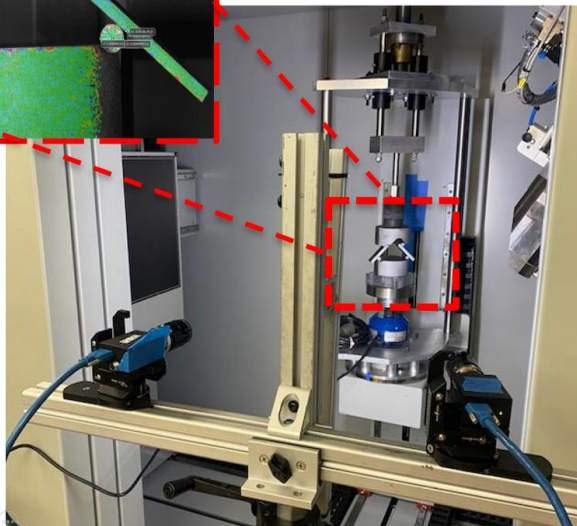
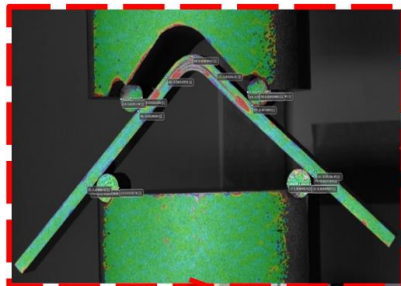
LaRC Aerothermodynamics Lab (LAL)

Flight Mach: 6 and 10
Karen.T.Berger@nasa.gov



All mechanical testing required for a material system to mature up the building block approach (BBA) is found at NASA Langley or contractual partner

- Elevated Temperature Mechanical Property Testing
- Fatigue, fracture, and torsion testing
- *In-situ* micro-X-ray Computed Tomography Mechanical Testing
- Material characterization (Scanning Electron Microscopy, X-ray Diffraction, and Transmission Electron Microscopy)
- Large scale thermal-structural testing (NASA Armstrong)



In-Situ Micro-X-ray CT
Mechanical testing
with Digital Image
Correlation

POC David.E.Glass@nasa.gov

4000°F Inert Mechanical Testing (FY26)

➤ Physical Description

- 164' W x 120' D x 40' H
- 5 ton overhead crane
- Tie-down tracks and trenches
- Flight line access

➤ Workforce

- Skilled engineering and technical workforce
- Structural, thermal and dynamic analysis
- Mechanical, electrical, instrumentation

➤ Structural Loading

- 84 channels of hydraulic load control
- Uniaxial load frames machines
- Hydraulic actuators, load cells
- Ground vibration and structural mode interaction testing

➤ Thermal Loading

- Quartz lamp & graphite element heating
- 264 channels of thermal control
- Low and high temperature chambers
- Large nitrogen chamber (20' W x 24' D x 24' H)
- Liquid and gaseous nitrogen supply systems

➤ Instrumentation

- Conventional and fiber optic sensing
- Low and high-temperature sensing
- Sensor characterization systems

➤ Structural Evaluation

- Digital Image Correlation
- Transient infrared pulsed thermography
- Acoustic emission

➤ Data Acquisition

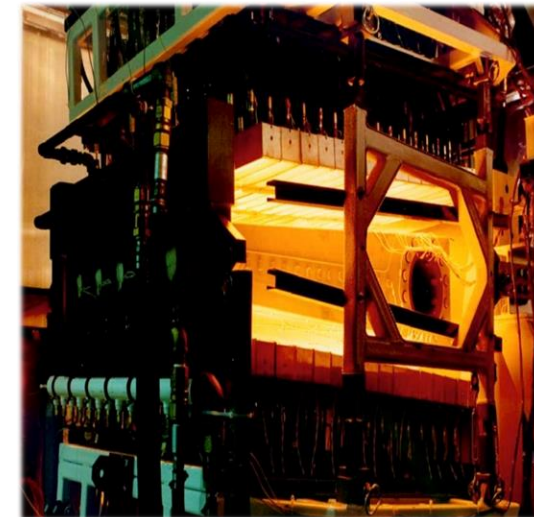
- Over 2000 channels of data acquisition



G-III Loads Calibration



Phantom Eye GVT



Carbon-Carbon Control Surface

POC: Michael.Yandell@nasa.gov



Materials Labs



Ames Arc-jet Test Complex

150MW

Ernest.F.Fretter@nasa.gov



MSFC High Temperature Emissivity Measurement Systems (HiTEMS)

Temp Range 600-2,000 C

Meghan.Carrico@nasa.gov



MSFC Hot Gas Test Facility

Hydrogen/Air - Mach 4

Jacob.A.Parton@nasa.gov



JSC Radiant Heater Test Facility (RHTF)

Temperatures greater than 2900 F

Tien.Q.Nguyen@nasa.gov



GRC Superalloy Additive Manufacturing Labs

Example GRX-810

Christopher.A.Kantz@nasa.gov

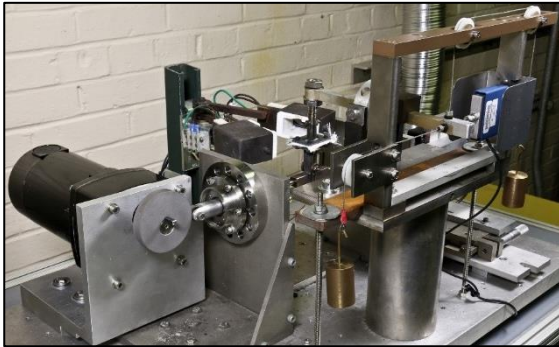
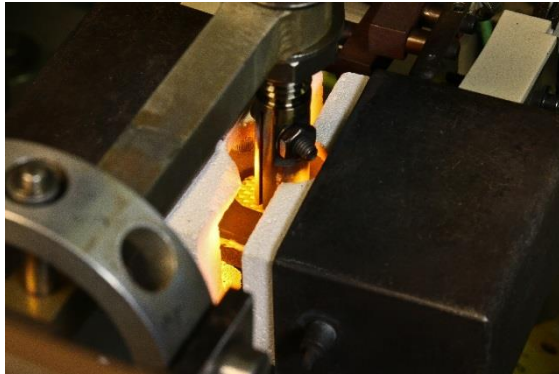


LaRC Hypersonic Material Environmental Test System (HyMETS)

400kW Segmented Arc-Jet

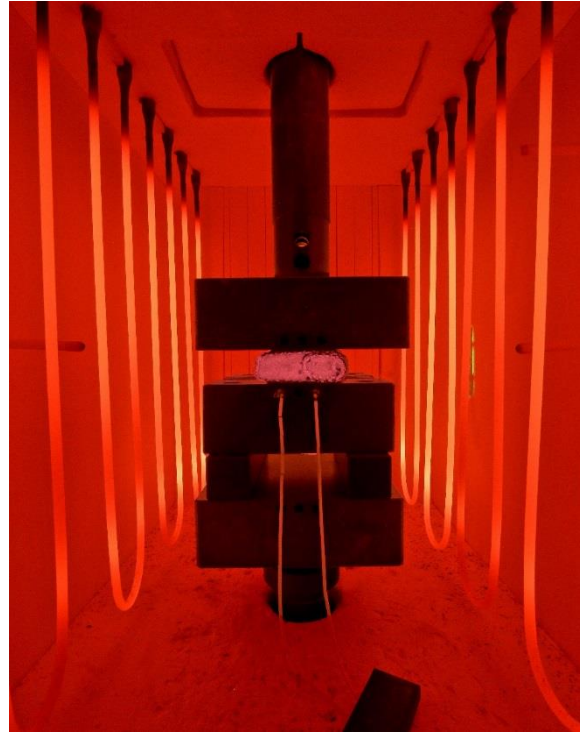
Scott.C.Splinter@nasa.gov





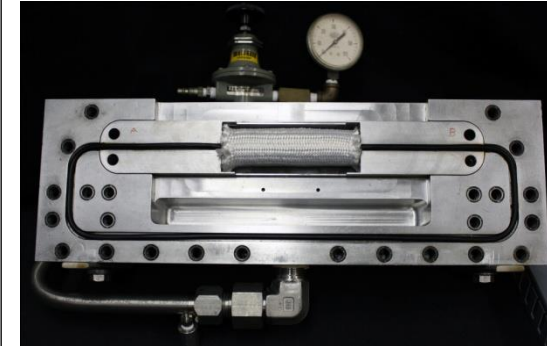
Wear/durability testing of candidate seal materials

- Reciprocating motion with 2 in. stroke
- Measurements of friction and normal loads
- Temperatures: RT to 2200°F



Seal compression and wear/durability testing

- Reciprocating motion with 6 in. stroke and loads up to 3300 lbf
- Measurements of compression and friction loads, resiliency
- Temperatures: RT to 3000°F



Seal leakage testing

- Leakage measurements against various sealing surface materials
- Pressures up to 100 psid
- Temperatures:
 - Shaft seals: RT to 1000°F
 - Thermal barriers: RT



NASA – We are here to help



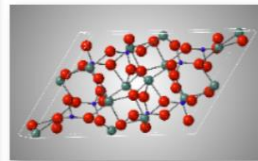
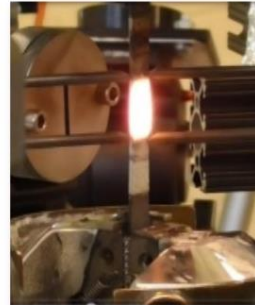
If you missed the POC information for a Lab/Facility, Contact:
Shelly.m.Ferlemann@nasa.gov



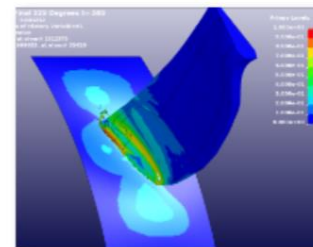
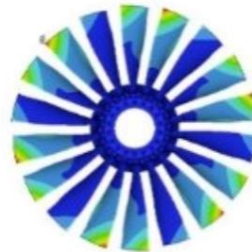
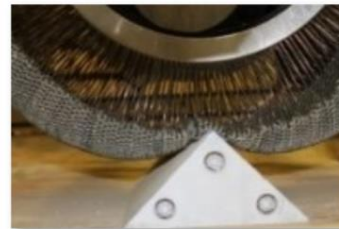
GRC Materials, Structures, and Mechanisms for Extreme Aerospace Environments



Materials research and development for propulsion, power, energy storage, and space and planetary environments



Mechanisms research and development for actuation, mobility, and rotating systems

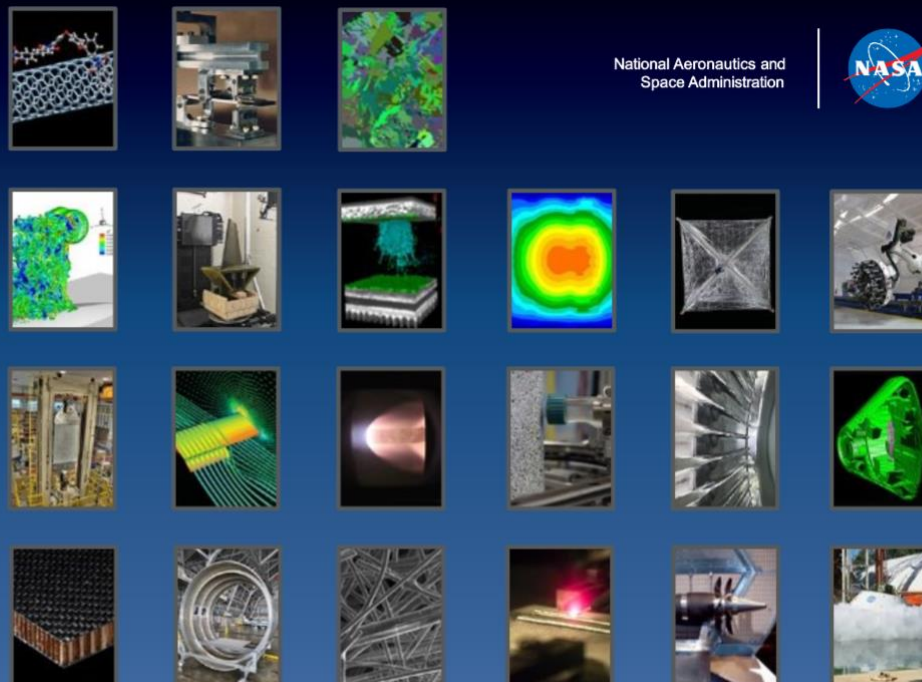


Structures and Mechanisms Engineering for Flight and Test Systems



Our Capabilities

- Advanced Materials & Processing**
 Expanding the range of operational environments through materials synthesis, advanced processing, characterization, and modeling and simulation
- Durability, Damage Tolerance and Reliability**
 Conducting research to quantify durability and damage tolerance and to validate performance of structural materials; developing predictive tools for the space radiation environment, transport, and risk for human missions
- Structural Mechanics and Concepts**
 Conducting research in the areas of structural mechanics, heat transfer, and advanced structural concepts; developing structural and thermal protection systems technologies
- Nondestructive Evaluation Sciences**
 Developing methods for automated and large area inspection, modeling and data analysis, material state awareness, and intelligent measurement and sensor systems
- Structural Dynamics**
 Performing basic and applied research related to the dynamic behavior of aircraft and spacecraft structures, including full-scale impact dynamic testing and analysis of aerospace vehicles
- Materials & Structures Experiments**
 Providing the hands-on technical expertise to perform mechanical and environmental manufacturing and testing



National Aeronautics and
Space Administration



Structures and Materials

Research Directorate
Langley Research Center

Contact Us

<https://researchdirectoratelarc.nasa.gov>

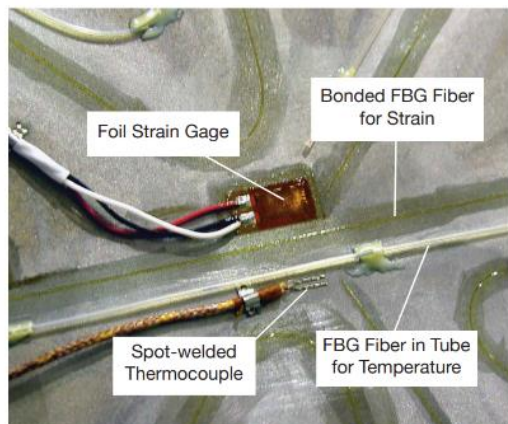
www.nasa.gov
NP-2023-09-092-LaRC



AFRC Fiber Optic Sensing System (FOSS) Technology



Reducing FOSS technology's size, power requirement, weight, and cost to effectively extend opportunities for broader fields of application.



Size comparison between Fiber Bragg Grating (FBG) fiber-based sensors, a foil strain gage and thermocouple



Passive Aeroelastic Tailored Wing heavily instrumented with FOSS technology for shape sensing during load testing.



Application of FOSS for wing loads calibration and shape sensing

FOSS Benefits

- Immune to electromagnetic / radio-frequency interference and radiation
- Lightweight optical fibers
- Multiplex 1000s of sensors on one optical fiber
- Narrowband wavelength tunable laser source to interrogate sensors
- Similar installation as conventional strain gages

FOSS Applications

- Conventional measurement parameters such as: strain, temperature, load, 3D shape, displacement, cryogenic liquid level
- Structural health monitoring
- Key Projects: LOFID Re-Entry Flight Test, Ikhana Flight Test, Global Observer Flight Test / Wing Loads Test / Fuselage Test, Composite Crew Module, Passive Aeroelastic Wing



Global Observer Wing instrumented with FOSS for shape sensing

Wave Division Multiplexing (WDM) FOSS Specifications



Parameters	Units
Fiber channel count	4
Max sensing fiber length	No limit
Fiber type	Single-mode fiber
Max no. of sensors/fiber	32
Max sample rate	400 Hz
Onboard storage	64 GB
Interface	Gigabit ethernet
Power	13 W at 28 VDC
Weight with enclosure	3.72 lbs
Size (application specific)	3.4 in x 6.85 in x 2.78 in

Launch Capable Optical Frequency Domain Reflectometry (OFDR) FOSS Specifications



Parameters	Units
Fiber channel count	4
Max sensing fiber length	40 ft
Fiber type	Single-mode fiber
Max no. of sensors/fiber	2000
Max sample rate	50 Hz
Interface	Gigabit ethernet
Power	70 W at 28 VDC
Weight with enclosure	30 lbs
Size (application specific)	18.5 in x 6.63 in x 6.25 in

Contact Information

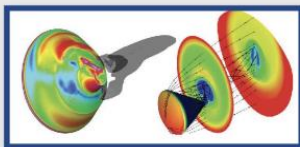
Allen Parker
Research Engineer
Armstrong Flight Research Center
661-276-2407
E-mail: allen.r.parker@nasa.gov

Providing customers with world-class entry system technologies for 5+ decades – ranging from initial concepts through design, analysis, and testing – culminating in successful flight missions

Aerothermal Modeling & Analysis

Navier-Stokes Simulation of Hypersonic Flows

- Develop and employ the DPLR and US3D computational fluid dynamics (CFD) codes for high-fidelity modeling of reacting, non-equilibrium flows
- Predict aerothermal environments to establish TPS material requirements for atmospheric entry vehicles

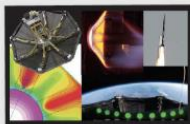


Nonequilibrium Gas Radiation Analysis

- NEQAIR computes radiative emission and absorption along a line-of-sight for a variety of gases/atmospheres
- Enables prediction of radiative heating experienced during high speed (re)-entries for missions including Lunar return, Mars return, and Gas Giant entries

Entry Vehicles & System Engineering

Perform/coordinate systems level integration for entry vehicles, including the direct application of new technologies and capabilities to analyze, design, develop, test, evaluate, manufacture, integrate, certify, and operate entry vehicles and systems.



- Rapid design and analysis for future planetary exploration and entry vehicle concepts
- Entry vehicle systems engineering
- TPS sizing and margins policy
- Entry, Descent, and Landing (EDL) instrumentation
- Post-flight data and hardware evaluation and analysis
- TPS project management, mission infusion, hardware production support, and TPS integration support

Flight TPS Materials

PICA - Phenolic Impregnated Carbon Ablator

Successfully flown on Stardust, Mars Science Lab, OSIRIS-REx, Mars 2020, and SpaceX's Dragon

SIRCA - Silicone Impregnated Reusable Ceramic Ablator

Transverse Impulse Rocket System (TIRS) cover TPS on Mars Pathfinder and Mars Exploration Rovers



Orion's 3D-MAT Compression Pad and Bolt Installation

3D-MAT

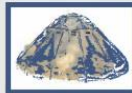
Extremely strong 3D woven quartz / cyanate ester ablative invented for Orion's lunar return compression pad

Reusable TPS: TUFROC & Space Shuttle Materials

Lightweight, low cost, reusable TPS for use up to 3000+°F TUFROC flown on USAF X-37b

Research & Development TPS Materials

HEEET – Heatshield for Extreme Entry Environments is a TRL 6 dual-layer 3D woven carbon phenolic for very high entry heating environments

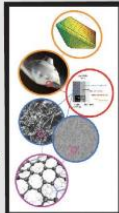


3MDCP – 3D mid-density carbon phenolic TPS baselined for the Mars Sample Return Earth Entry System

Conformal PICA – more efficient TPS than heritage PICA, reduces part count & gap issues, simplified integration

TPS Material Modeling & Analysis

- Develop material response models to predict TPS ablation during entry and establish sizing
- Apply predictive modeling to characterize material properties and behavior over multiple scales
- Characterize vehicle and component thermal structural performance during entry



Instrumentation

The TS Division is a leader in entry system and test instrumentation, with expertise in technology maturation and integration of sensors into TPS for high enthalpy flow applications.

The value of flight instrumentation is evident:

- Captures data during atmospheric entry for validation of modeling tools
- Reduces risk on future missions



Notable flight instrumentation and reconstruction efforts:

- Mars Science Laboratory (2012)
- Orion Exploration Flight Test-1 (2014)
- Mars 2020
- Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)

Upcoming flight instrumentation opportunities:

- Artemis missions
- New Frontiers 4 Dragonfly mission

Experience includes:

- Manufacturing, characterization, testing, and integration of instruments
- Continued advancement of thermocouple design innovation
- Implementing highly-reliable thermocouple technologies
- Addressing anomalies seen in flight and ground tests
- TPS and aerothermal reconstruction efforts, Non-Destructive Evaluation (NDE) analyses, and science return



Optical Recession Sensor for Artemis

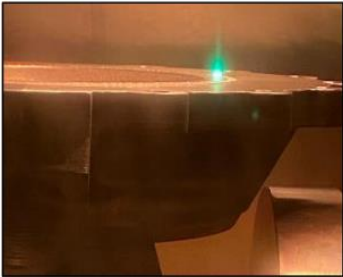
Thermocouple Design Improvements



Additive Manufacturing



Composite Manufacturing



Advanced Welding



Large-Scale 3D Printing for Rocket Engines



NDE and Process Development



Plasma Torch Testbed & Solid Fuel Torch

Materials

- [Damage Tolerance/Fracture Mechanics](#)
- Debris & Weather Encounter Impact Testing
- Space Environmental Effects Testing
 - [High Intensity Solar Environment Testing](#)
 - [Ionizing Radiation and UV Radiation Testing](#)
 - Plasma and Charging Testing
- Biological and Physical Sciences - Flight Experiments
- [Mechanical, Tribological, and Chemical Materials Testing](#)
 - Hydrogen Testing
- [Electrostatic Levitation Laboratory](#)

Processes

- [Materials Diagnostics & Failure Analysis](#)
- [Advanced Metal Joining](#)
- Cryogenic Insulation & TPS Process Development

Manufacturing

- Additive manufacturing and welding of refractory materials
- [Digital Manufacturing](#)
- Large Scale Process Development, Tooling & Manufacturing

Data Management

- MAPTIS (Agency asset) & Database Management
- Physical Sciences Informatics

SCANNING ELECTRON MICROSCOPE (SEM)

- ★ Zeiss GeminiSEM 560
 - ✧ Resolution: 0.4 to 1 nm
 - ✧ Magnification: 10³ general use, 2 x 10⁶ max
 - ✧ EDS (energy dispersive X-ray spectroscopy) and EBSD (electron backscatter diffraction) modes
 - ✧ Variable pressure mode for nonconductive samples
 - ✧ Large samples possible (up to 12"x12"x12")
 - ★ Zeiss Supra 55VP
 - ✧ Resolution: 1 to 4 nm
 - ✧ Magnification: 10³ general use
 - ✧ EDS and TKD (Transmission Kikuchi diffraction) modes
 - ✧ Variable pressure mode for nonconductive samples
 - ★ Two sputter coaters
 - ✧ Metal: Pt, Ir, Au, Pb
 - ✧ Carbon coater
- EDS provides elemental composition and mapping
EBSD and TKD provide grain structure, grain orientation, and phase at microscale



LOAD FRAME

- ★ MTS Insight Electromechanical Load Frame
- ★ Outputs:
 - ✧ Force
 - ✧ Displacement (via crosshead and/or extensometer)
- ★ Useful for:
 - ✧ Mechanical properties as function of strain, temperature, time, etc.
- ★ Instrument:
 - ✧ Load Capacity: 35,000 lb,
 - ✧ Fixtures: tensile, compression, lap shear, flexure
 - ✧ Temperature limits: -180 to 425 °C



ADDITIONAL ANALYSIS AND SERVICES

- ★ Chemical analysis
 - ✧ Gas Chromatography / Mass Spectroscopy (GC-MS)
 - ✧ Fourier Transform Infrared Spectroscopy (FTIR)
 - ✧ UV-Vis-NIR Spectrophotometry
- ★ Thermal properties
 - ✧ Solar absorptivity
 - ✧ IR emissivity
- ★ Optical microscopy
 - ✧ Digital microscope
 - ✧ Stereo microscope
- ★ Hardness
 - ✧ Rockwell hardness
 - ✧ Micro hardness
- ★ Sample preparation
 - ✧ Cutting
 - ✧ Polishing
 - ✧ Etching



MATERIAL CHARACTERIZATION TEST CAPABILITIES AT NASA JSC

Leslie Schaschl – leslie.j.schaschl@nasa.gov
Shakira Morera-felix – shakira.morera-felix-1@nasa.gov

National Aeronautics and
Space Administration



MATERIAL CHARACTERIZATION TEST CAPABILITIES



METALLURGY LAB - JSC