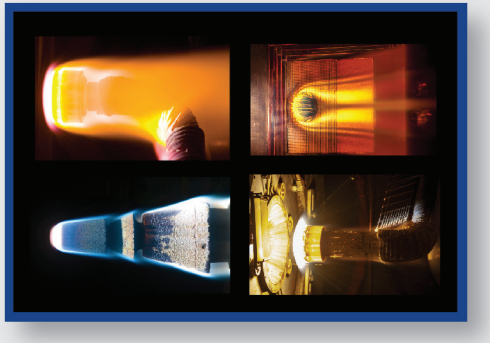
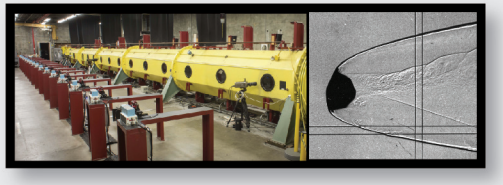
Arc Jet Complex



Unique high enthalpy environmental simulation capability that serves customer-driven material performance requirements in support of NASA missions and other National programs.

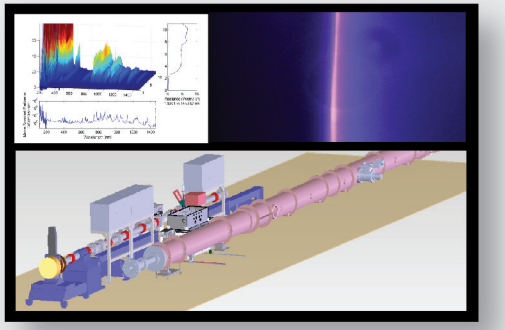
- Nation's highest powered (150 MW DC) arc-heated hyper-thermal test facility
- Unique capabilities enable development of advanced TPS concepts and materials
- Large test articles (up to 60 x 60 cm)
- Pre-mixed test gas with continuous high enthalpy flows (2 – 40 MJ/kg in air)
- Plasma flow expands through conical, semi-elliptical, channel nozzles to hypersonic speeds
- Enthalpies similar to planetary entries
- Spectroscopic / Laser Induced Fluorescence diagnostic capability

Ballistic Range Complex



- NASA's sole remaining aero-ballistic range
- Utilizes an arsenal of model-launching guns to accelerate small-scale models of various size, shape, and materials to velocities > 8 km/sec
- Investigates the aerodynamics, aerothermodynamics, gas-dynamics of hypervelocity flight

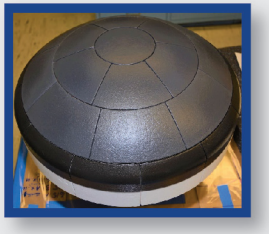
Electric Arc Shock Tube Facility



- Creates shock-heated, high enthalpy gas environments similar to those encountered by atmospheric entry vehicles
- Capable of simulating velocities from 1 km/sec to 46 km/sec at pressures between 1 Pa to 100 MPa in a variety of planetary-like atmospheres

STAR Labs

The Sensors & TPS Advanced Research (STAR) Labs at NASA Ames Research Center specializes in engineering, design, and fabrication of test articles from a variety of thermal protection materials as well as sensors and instrumentation. All lab spaces fall under ITAR controls. STAR Labs is certified to AS9100 per the Ames Quality Management System and follows NASA ASTM and industry standards.



20-inch diameter Advanced TUFROC nose concept model with AETB/TUFI outer ring.

NASA Ames Research Center
Moffett Field. California 94035-1000
www.nasa.gov/centers/ames/entry-systems-and-technology

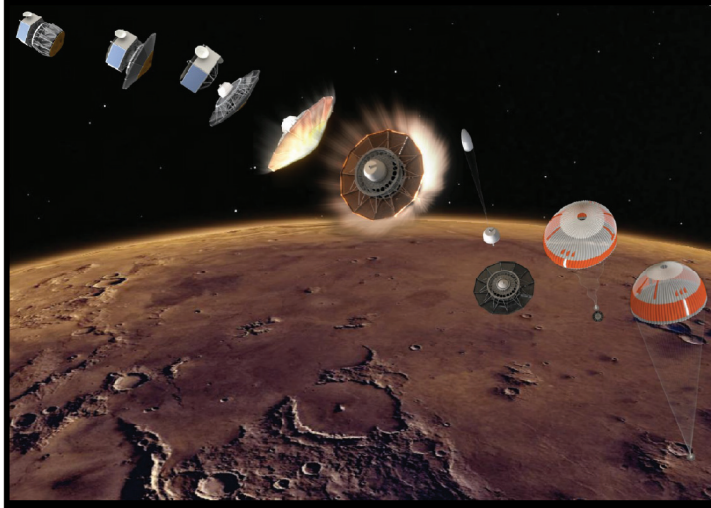
For more information contact david.b.hash@nasa.gov

National Aeronautics and Space Administration

ENTRY SYSTEMS & TECHNOLOGY DIVISION

Located in the heart of Silicon Valley, the Entry Systems & Technology Division offers state-of-the-art aeroshell design and development; high enthalpy aerothermal modeling and testing; high temperature material modeling, development, and characterization; Thermal Protection Systems (TPS) sizing, integration, and post-flight evaluation.

Innovate – Design – Analyze – Test



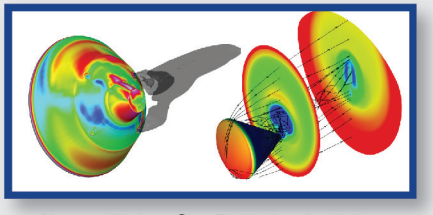
www.nasa.gov/centers/ames/entry-systems-and-technology

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

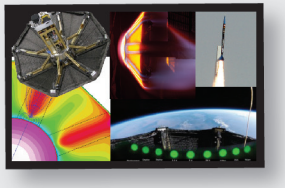
- Develop and employ the DPLR and US3D computational fluid dynamics (CFD) codes for high-fidelity modeling of reacting, non-equilibrium flows
- Predict aerothermal environments to establish TPS material requirements for atmospheric entry vehicles



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



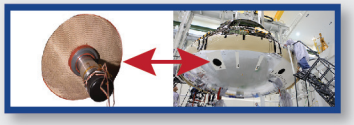
Perform/coordinate systems level integration for entry vehicles, including the direct application of new technologies and capabilities to analyze, design, develop, test, evaluate, manufacture, integrate, certify, and operate entry vehicles and systems.

- 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, 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

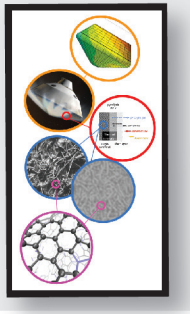
HEEET – Heatshield for Extreme Entry Environments is a TRL 6 dual-layer 3D woven carbon phenolic for very high entry heating environments

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

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

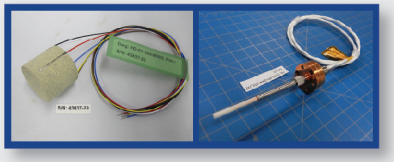


Instrumentation

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:

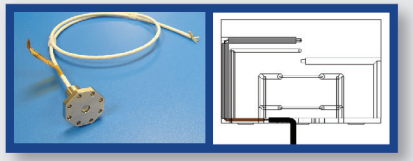
- Mars Science Laboratory (2012)
- Orion Exploration Flight Test-1 (2014)
- Mars 2020

Upcoming flight instrumentation opportunities:

- Artemis missions
- New Frontiers 4 Dragonfly mission
- Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)

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*