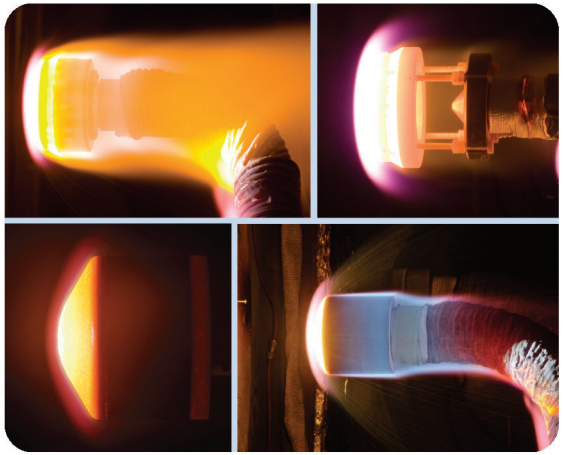
ENTRY SYSTEMS & TECHNOLOGY DIVISION

Every NASA flown thermal protection system (TPS) has been tested in some capacity in the Ames Arc-jet Complex



Arc-Jet Complex

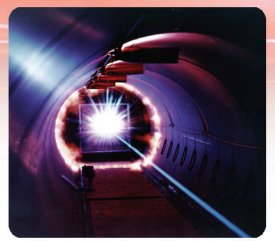
POC: george.a.raiche@nasa.gov

Unique high enthalpy environmental simulation capability that serves customer-driven aero-thermal response requirements in support of NASA missions and other National programs

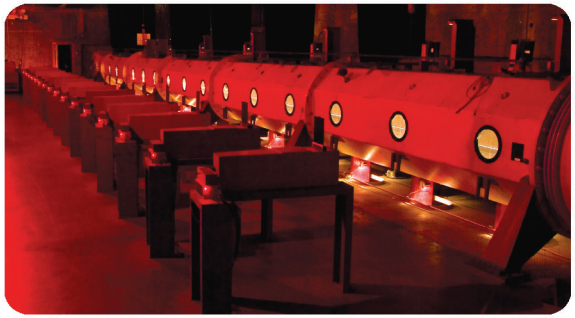
- Nation's highest powered (150 MW DC) arc-heated hyper-thermal test facility
- Unique capabilities enable development of advanced TPS concepts and materials
- Large test articles (up to 60 x 60 cm)
- Pre-mixed test gas with continuous high enthalpy flows (2 - 40 MJ/kg in air)
- Plasma flow expands through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

Ballistic Range Complex

POC: charles.j.conerlison@nasa.gov



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



Electric Arc Shock Tube (EAST) Facility

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

Instrumentation Flight Hardware

- Designed to capture flight entry data in order to improve heat shield design, fidelity of aerothermal modeling tools, and planetary atmospheric models
- Successfully flown during the MSL Mars entry (2012)
- Scheduled to fly on Orion's first flight test (Dec 2014) and DARPA's Falcon hypersonic test vehicle

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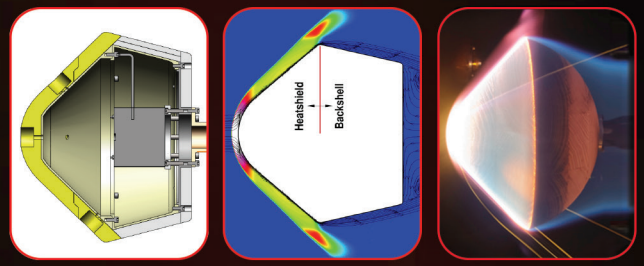
National Aeronautics and Space Administration

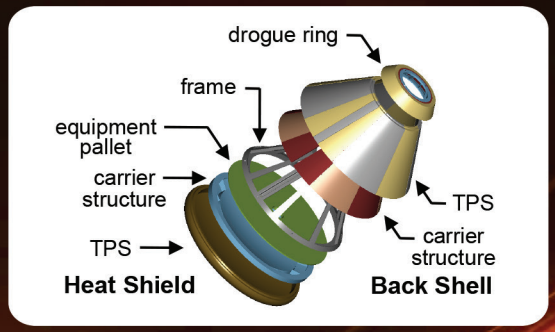
ENTRY SYSTEMS & TECHNOLOGY DIVISION

ENTRY SYSTEMS TECHNOLOGY

Providing state-of-the-art entry system technologies for 5+ decades - ranging from initial concepts through design, analysis, and testing-culminating in successful flight missions

INNOVATE ⇔ DESIGN ⇔ ANALYZE ⇔ TEST





EXPLORE!

ENTRY SYSTEMS & TECHNOLOGY DIVISION

Providing atmospheric entry technologies and expertise for over 50 years

Ames Research Center

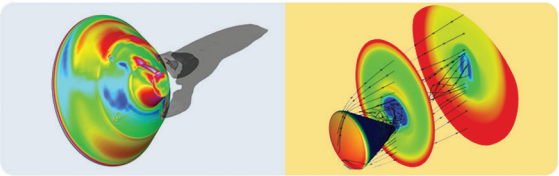
Located in the heart of Silicon Valley, the ES&T Division offers state-of-the-art aeroshell design and development; high enthalpy aero-thermal modeling and testing; high temperature material modeling, development, and characterization; Thermal Protection Systems (TPS) sizing, integration, and post-flight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

Aerothermal Modeling & Analysis

POC: david.b.hash@nasa.gov

Navier-Stokes Solver for Hypersonic Flows

- High fidelity computational fluid dynamics (CFD) codes for modeling reacting, non-equilibrium flows
- DPLR and US3D codes enable prediction of aerothermal environments to establish TPS material requirements for atmospheric entry spacecraft

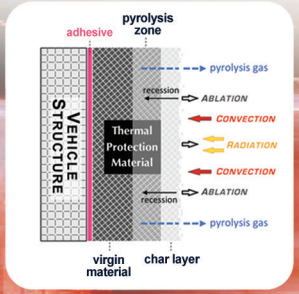


NEQAIR - Nonequilibrium Air Reduction

- 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 giant planet entries

TPS Material Modeling & Analysis

FIAT - Fully Implicit Ablation, Thermal-Response



- Ablative material response modeling tool with surface ablation, internal pyrolysis, and multi-layer material stack
- Provides time accurate solutions of thermal diffusion

Flight Proven Heritage TPS Materials

POC: joe.conley@nasa.gov

PICA - Phenolic Impregnated Carbon Ablator

- Stardust: fastest Earth entry (12.9 km/s, 2006)
- SpaceX's Dragon: 1st successful commercial reentry from low Earth orbit (LEO) (2012)
- Mars Science Laboratory: Mars entry (2012)

SIRCA - Silicone Impregnated Reusable Ceramic Ablator

- Backshell TPS for Mars Pathfinder, MER, and Mars '03 probes

TUFROC

- Light weight, low cost, reusable TPS for 1650°C
- X-37b: USAF reusable spacecraft (2010, 2012)
- SNC Dream Chaser: commercial reusable spacecraft

Space Shuttle TPS Materials

- FRCI, LI-2200, TUFI, RCG coating, gap filler

Materials Research & Development

POCs: margaret.m.stackpoole@nasa.gov, john.w.lawson@nasa.gov

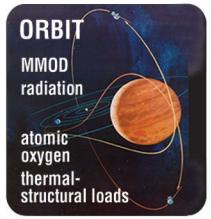
- **Woven TPS:** Leverages US textile sector to provide tailorable, higher performance, lower cost TPS for Venus, Giant planets, and high speed Earth re-entry
- **Conformal TPS:** Reduces part count, eliminates gap issues, simplifies system integration
- **Reusable TPS:** Enables lower cost, lighter weight, higher performance re-entry from Earth orbit
- **Computational Modeling:** Pioneering atomistic scale modeling in support of real world applications
- **Material Characterizaton:** Understanding thermal, mechanical, chemical properties and microstructure

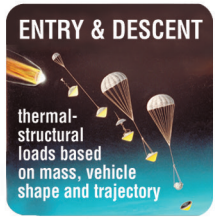
Systems Engineering & Analysis

POCs: donald.t.ellerby@nasa.gov, mary.livingston@nasa.gov, robin.a.beck@nasa.gov

REQUIREMENTS

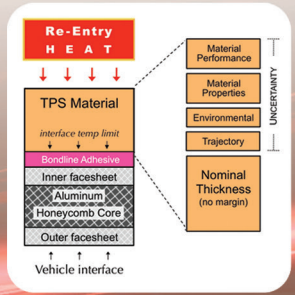
- Defining the design space by understanding the requirements





DETAILED DESIGN

- Relevant environments
- Thermal-mechanical loads
- Interface constraints
- Multi-disciplinary optimization

HEAT SHIELD SIZING & MARGINS

- TPS material thickness based on temperature constraint at vehicle interface
- Extra margin added due to uncertainties in
  - *materials*
  - *environment*
  - *trajectory*