



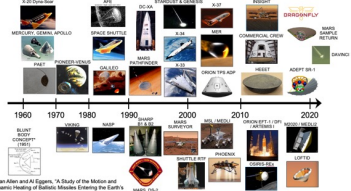
Thermal Protection Systems and Materials

Matt Gasch, Mairead Stackpoole, Jay Feldman, Ethiraj Venkatapathy
NASA Ames Research Center, Moffett Field, CA 94035

Thermal protection systems protect space vehicles from aerodynamic heating during entry into planetary atmospheres. The Thermal Protection Materials Branch combines experiment, fabrication, characterization, evaluation, analysis and modeling to support NASA missions and collaborates externally to technology transfer thermal protection materials and tools to commercial or other agency partners.

NASA Ames Thermal Protection Materials Branch

- 70 years of experience in ablative and reusable TPS development, testing, modeling, instrumentation and mission support including providing one-of-a-kind flight hardware, for both human and robotic missions.
- Enabling commercial space companies through technology transfer and support of TPS needs to facilitate their long-term success.
- Continuously working on advanced TPS development for improved mission cadence and lower cost with minimized supply chain issues.
- Enabling successful arc jet testing by providing test design consultation and support to external customers.



NASA Entry Projects supported by Ames

Flight and Developmental Ablative Thermal Protection Systems

PICA (Phenolic Impregnated Carbon Ablator) successfully flown on Stardust, Mars Science Lab, OSIRIS REx, Mars 2020, Space-X's Dragon return and will be used on the Dragonfly mission to Saturn's Moon Titan

SIRCA (Silicone Impregnated Reusable Ceramic Ablator) flown on the Transverse Impulse Rocket System cover TPS on Mars Pathfinder and Mars Exploration Rover and recently by commercial space companies (Inversion)

3D MAT - extremely strong 3D woven quartz cyanate ester ablator invented for Orion's lunar return compression pad.

HEEET (Heatshield for Extreme Entry Environments) is a TRL 6 dual layer 3D woven carbon phenolic for very high entry heating environments. This material is suited to Venus probes and landers; Saturn and Uranus probes - all missions recommended by the NRC's Planetary Science Decadal that NASA seeks to pursue in the near future.

3MDCP - 3D Mid Density Carbon Phenolic TPS baseline for the Mars Sample Return Earth Entry System - single piece heatshield that avoids the manufacturing / certification challenges associated with tiled configurations

Conformal PICA - more efficient TPS than heritage PICA, reduces part count and gap issues, simplified integration - successfully transferred to commercial space companies

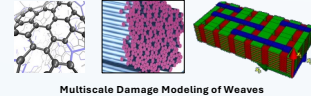


TPS material modeling and analysis

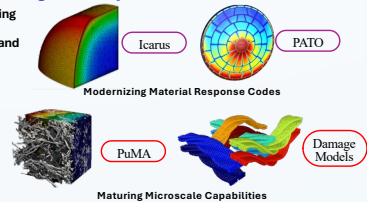
Develop material response models to predict TPS ablation during entry and establish sizing.

Apply predictive modeling to characterize material properties and behavior over multiple scales

Characterize vehicle and component thermal structural performance during entry



Multiscale Damage Modeling of Weaves



Modernizing Material Response Codes

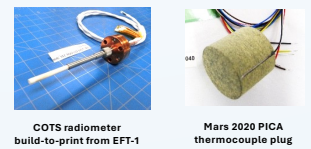


Maturing Microscale Capabilities

TPS Instrumentation

The Entry Systems and Technology division is a leader in entry system and test instrumentation with expertise in technology maturation and integration of sensors into TPS high enthalpy flow applications. Flight instrumentation captures data during atmospheric entry for validation of modeling tools and reduces risk on future missions. Instrumentation expertise includes manufacturing, characterization, testing and integration of instruments; advancement of thermocouple design innovation; implementing high reliability thermocouple technologies; addressing anomalies seen in flight and ground tests; TPS and aerothermal reconstruction efforts

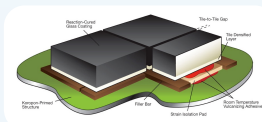
- Notable flight instrumentation and reconstruction efforts:
- Mars science laboratory (2012)
 - Orion Exploration Flight Test (2014)
 - Mars 2020
 - Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)
- Upcoming Flight Instrumentation Opportunities:
- Artemis missions
 - DREAM instrumentation suite on the Dragonfly mission
 - VISTA instrumentation suite on the DAVINCI mission



COTS radiometer build-to-print from EFT-1 Mars 2020 PICA thermocouple plug

Reusable Thermal Protection Systems

Reusable TPS materials developed by NASA have flight heritage with the Space Shuttle, X-37B and Orion Multipurpose Crew Vehicle. Similar systems are used or under development on SpaceX Starship, Stratolaunch Talon-A, Sierra Space DreamChaser, and others.



Many reusable TPS are tiled, as shown above, with high emissivity glass coatings that reject heat and also reduce exothermic atom recombination reactions that would otherwise raise the TPS temperature during entry.

TUFROC is the state-of-the-art in high temperature reusable TPS based on low density ceramic and carbon fiber materials with high performance coatings. TUFROC is a two-piece tile system that can be made into blunt or sharp wing leading edges (WLE), nose caps or acreage tiles. Photos below show pre- and during-test images of various TUFROC geometries.

