NASA**facts**

Space Technology

Game Changing Development

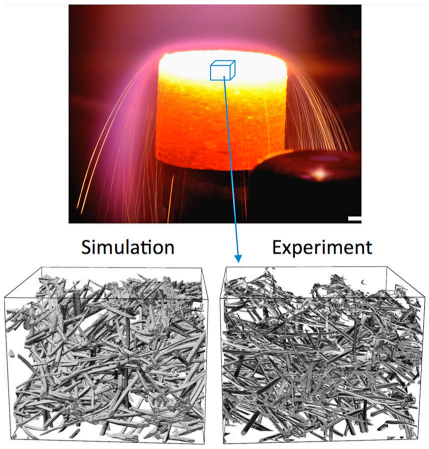
Entry Systems Modeling (ESM)

The Entry Systems Modeling (ESM) technology development project is engaged in maturation of fundamental research, with the aim of developing and validating better models for entry, descent and landing (EDL) missions. Investments are divided into four technical areas, described below.

Predictive Materials Modeling

The Predictive Materials Modeling (PMM) technical area focuses on developing and validating a high-fidelity volumetric ablation modeling capability that can be used to support thermal protection system (TPS) development and uncertainty analysis through a rigorous examination of the physical and chemical processes of ablation at a fundamental level.

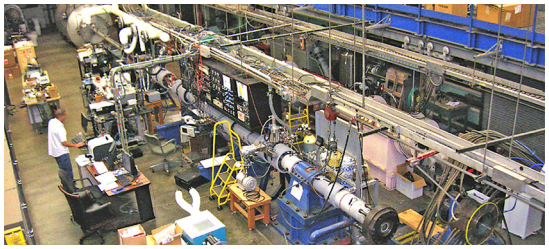
The primary materials under investigation are Avcoat, Phenolic Impregnated Carbon Ablator (PICA), and PICA coated with a silicone called NuSil, which is the material flown on the Mars Science Laboratory slated to fly again on Mars 2020. The physical models developed are implemented primarily in three Agency ablation modeling codes. First is PATOx, which has recently demonstrated the first-ever material response simulation of an entire tiled entry aeroshell. PuMA was developed to better understand porous materials at the microstructural level and has evolved into a powerful tool that can directly predict key material properties from first-principles and tomography data. PuMA and PATOx form the basis of a planned revolutionary TPS computational design environment (DAO-TPM) that could radically reduce the time and cost of bringing new materials to flight maturity. Finally, Icarus is poised to become the Agency workhorse tool for engineering design and analysis of ablating TPS, combining the speed of an engineering tool with unprecedented physical accuracy. Model validation experiments are being conducted at several universities in partnership with Early Stage Innovation, as well as within NASA and at the Lawrence Berkeley National Laboratory Advanced Light Source.



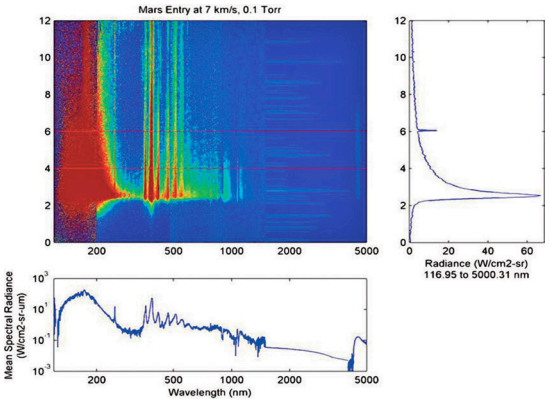
Comparison of microscale TPS simulations with experiment.

Shock Layer Kinetics and Radiation

The Shock Layer Kinetics and Radiation technical area focuses on developing and validating accurate models for the radiation produced behind the shock wave of an entry vehicle. Shock layer radiation for many missions is a driver for



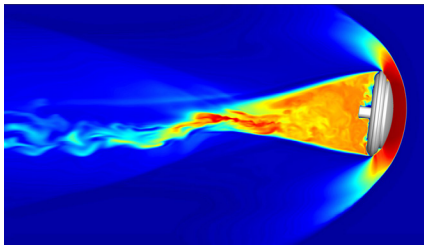
Electric Arc Shock Tube (EAST) Facility.



Spectral radiance data.

TPS material selection and sizing. Experimental facilities and computational capabilities are being used to develop and validate new models and databases. The current focus is on understanding radiation for high-speed return to Earth, as well as entries to Mars and Venus. The most detailed spectroscopic databases in the world are being assembled from fundamental measurements obtained in the Electric Arc Shock Tube (EAST) coupled with quantum calculations that give unprecedented insight into nonequilibrium processes. The new databases feed directly into production radiation codes, substantially improving their accuracy. The tools developed are being used to design and position radiometers to fly on the Mars 2020 mission as well as the Orion EM-1 flight test in 2019. The project is also renovating the Low Density Shock Tube to provide unique insight into nonequilibrium radiation and is upgrading the EAST to add an expanding flow section that will provide the first-ever validation data relevant to predicting the radiation environment in the wake of an entry body. Theoretical models for predicting wake radiation are under development in partnership with the University of Illinois and have already been used to estimate the heating environment for Mars 2020, InSight, and Orion.

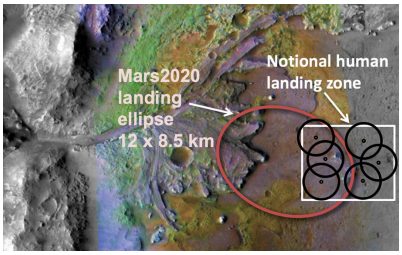
Computational and Experimental Aerosciences



CFD simulation of entry wake flow.

The Computational and Experimental Aerosciences (CEA) technical area focuses on the development and validation of aerodynamic and aerothermodynamic tools for hypersonic entry, descent and landing, making revolutionary improvements to the current state-of-the-art (SoA) in simulating reentry with an eye toward increased reliability, reduced uncertainty, and enabling new technologies for entry applications. Key near-term investments include the development of parachute fluid-structure interaction models for inflation and descent (in partnership with Stanford and the University of Illinois), as well as computational models for predicting the dynamic behavior of blunt entry bodies as they decelerate. In addition, ESM is investing in the development of a new experimental capability, magnetic suspension, that may revolutionize the way in which free-flight stability data are obtained for future entry systems. Another area of investigation is on the impact that TPS roughness has on aeroheating and turbulent transition. For the first time, experiments will be conducted in two different facilities on models with flight-relevant roughness patterns, and the resulting augmented heating will be measured and used to guide computational model development. Finally, the CEA element is working to develop next-generation numerical aerothermal modeling capability using discontinuous Galerkin methods, which hold promise to finally eliminate the extreme grid sensitivity that plagues current aerothermal modeling codes.

Guidance, Navigation and Control



Comparison of landing accuracy required for human Mars with current state of the art.

Advancement of guidance, navigation and control (GNC) techniques for planetary entry has been slowed by the limited number of flight opportunities and a preference by flight programs to limit risk by adapting legacy approaches to mission-specific requirements. However, the landing accuracy requirements for eventual crewed missions to Mars will require a more than three order-of-magnitude improvement to the current SoA (from 6.5-km to 50-m precision), likely necessitating entirely new approaches during the entry and descent phases of the mission. The GNC technical area focuses on developing and testing improved entry guidance methods. The effort is a close partnership with the Safe and Precise Landing Integrated Capabilities project, which is developing descent GNC, to enable an end-to-end GNC approach for the spectrum of potential vehicle architectures for human Mars exploration missions.

Put It Together

The EDL segment is one of the riskiest parts of any landed mission, and is an area where key systems are reliant on computational design because they cannot be adequately tested prior to use. This in turn drives the need for high-fidelity EDL modeling using complex codes that must be carefully validated against test data. As these computer codes get better, uncertainty in predictions is reduced, which translates into increased reliability and/or performance.

The Game Changing Development (GCD) program is part of NASA's Space Technology Mission Directorate. The GCD program aims to advance exploratory concepts and deliver technology solutions that enable new capabilities or radically alter current approaches.

For more information about GCD, please visit
http://gameon.nasa.gov/

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