National Aeronautics and Space Administration

NASAfacts

Space Technology

Game Changing Development

Entry Systems Modeling (ESM)

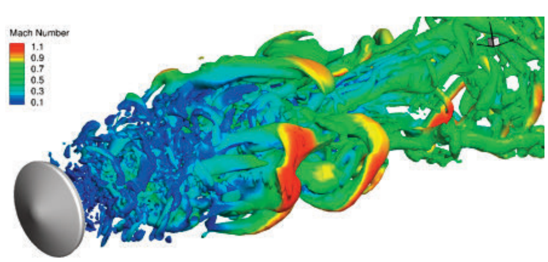
The Entry Systems Modeling (ESM) technology development project is engaged in maturation of fundamental research developing aerosciences, materials, and integrated systems products for entry, descent, and landing (EDL) technologies.

Aerosciences

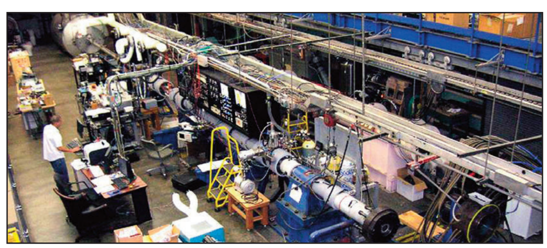
The aerosciences technical area focuses on the development and validation of simulation tools for hypersonic entry, descent and landing, making revolutionary improvements to the current state-of-the-art (SoA) in simulating reentry, with an application to increased reliability, reduced uncertainty, and enabling new technologies for reentry applications. The three core research elements within Aerosciences are Advanced Computational Fluid Dynamics (CFD), Shock Layer Radiation, and EDL Model Validation.

Advanced CFD is devoted to developing next-generation computational capabilities in order to enhance predictive accuracy of aerothermodynamics modeling software and to fill modeling gaps identified by current flight projects and the broader technical community. Two codes, US3D and FUN3D, were developed and released NASA-wide in 2014 to replace the widely-used Data Parallel Line Relaxation (DPLR) and Langley Aerothermodynamic Upwind Relaxation Algorithm (LAURA) software packages. The new codes enable greater geometric complexity and introduce many advances in physical and numerical modeling to enhance accuracy. Work also continues on the development of a new Direct Simulation Monte Carlo (DSMC) code, as well as fundamental improvements to the current SoA in DSMC modeling via a partnership with the University of Minnesota.

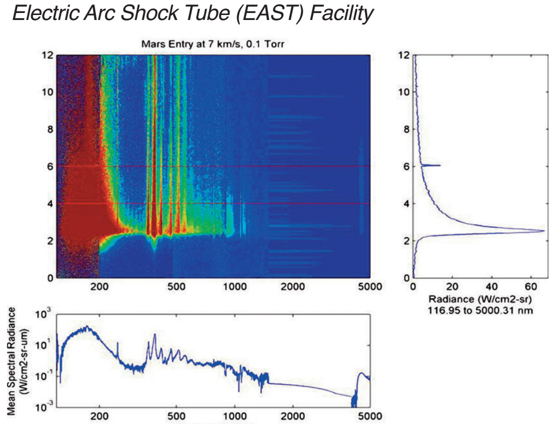
Shock Layer Radiation for many missions is a driver for thermal protection system (TPS) material selection and sizing. Experimental facilities and computational capabilities are being used to develop and validate new models and databases. The current focus is on understanding radiation for entries to Mars and Venus, as well as high-speed return to Earth. 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. One such code, NEQAIR, has been named Ames Research Center Software of the Year for 2015 and will compete for the NASA title. The tools developed are being used to better understand data returned from two radiometers flown on Exploration Flight Test 1 in December 2014, in partnership with Orion. The project is also renovating the Low Density Shock Tube, which may be able to provide unique insight into non-equilibrium radiation and environments relevant for low ballistic coefficient entry systems (such as HIAD and ADEPT), and is building international collaborations with European, Asian and Australian radiation modeling groups.



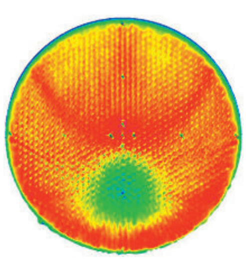
CFD—transonic wake



Electric Arc Shock Tube (EAST) Facility



Spectral radiance data

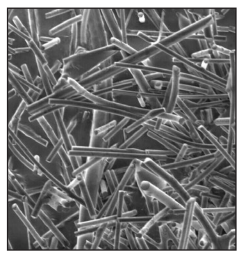


Roughness testing

EDL Model Validation is conducting focused ground testing to enable validation of aerothermal models in the other core areas. The Large Energy National Shock expansion tunnel (LENS-XX) at Calspan-University of Buffalo Research Center (CUBRC) is being used in partnership with Space Technology Research Grants (STRG) to conduct tests in high enthalpy CO2 in order to understand previously observed discrepancies in predicted shock standoff and heating in reflected shock tunnels. The High Enthalpy Tube (HET) facility at CalTech is being used in partnership with NASA Space Technology Research Fellowships to provide second source data. Heating augmentation due to distributed roughness was investigated by testing in the Langley Mach 6 wind tunnel and Ames ballistic range. The data are being used to update roughness correlations and turbulence models for blunt bodies in air and CO2.

Materials

The materials technical area focuses on developing software and hardware that will make revolutionary improvements to the current SoA and provide enabling capabilities in thermal protection materials and the high-fidelity models used in their design and analysis. The technology development effort has two elements: Advanced Ablator Thermal Models, and Advanced TPS Materials.

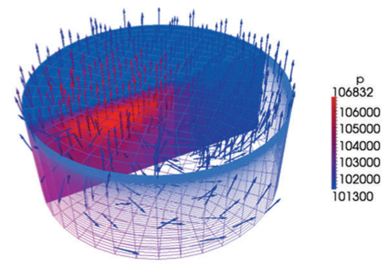


Material response

Advanced Ablator Thermal Models is focused on developing and validating a high-fidelity volumetric ablation computational capability that can be used to support materials development and uncertainty analysis through a rigorous examination of the physical and chemical processes of ablation at a fundamental level. The centerpiece of this effort is the PATO code, developed in partnership with STRG. Model validation experiments are being conducted at several universities in partnership with Early Stage Innovation (ESI), as well as within NASA and at the Lawrence Berkeley National Laboratory Advanced Light Source (cyclotron). Ablation response has also been tightly coupled with CFD, which has improved the predictive capability of NASA codes in this highly nonlinear flight regime. Finally, the lessons learned in the development of the volumetric model are being used to develop a new "greenfield" engineering design tool; the first significant change to the state of the art in more than 40 years.

Advanced TPS Materials Concepts contains three product lines. The aim of the advanced ablator development effort is to establish, through the use of fibrous felt systems and high performance charring resins, robust conformal thermal protection systems for large area heat shield applications. When matured, advanced conformal TPS systems should greatly reduce manufacturing costs and improve thermostructural reliability of ablative TPS, while simultaneously maintaining or improving the thermal performance over the current SoA. The flexible thermal protection materials (F-TPS) effort is developing high performance thermal insulators and refractory cloth systems that provide low weight and volume thermal protection solutions for inflatable decelerator designs exposed to extreme entry environment heating. ESM is extending the usable range of this material class to 75 W/cm2, making inflatable decelerators a viable architecture for a variety of robotic and human-scale entry missions. Finally, the Convective Heating Improvement for Emergency Fire Shelters (CHIEFS) effort is using materials and concepts developed under F-TPS to design and test advanced fire shelters for use by the United States Forest Service and other Agencies. Early testing indicates that F-TPS derived shelters could provide major improvements to the current SoA, a hypothesis that will be tested in Jun 2015 during set fire testing in Canada.

Advanced flexible TPS layup



3D TPS coding capability

EDL Integrated Systems

The primary technical objective of the EDL integrated systems technical area is to foster game-changing EDL or EDL enabling concepts at the system level via either subscale flight or ground testing. The primary products of this technical area are hardware, either ground test articles or flight hardware. The technical area currently consists of a single element: Exo-Brake.

The Exo-Brake is a concept for propellentless deorbit from Low Earth Orbit (LEO) via a controllable drag sail device. The concept has been previously demonstrated at the cube-sat level. The current effort intends to demonstrate control of the landing ellipse through various methodologies, including drag modulation, timed release, and predictor-corrector guidance techniques. ESM plans to fly 2 or more cubesats between FY15-17 to mature this technology for potential use in small satellite return from LEO, debris deorbit, and netlander missions to Mars or other planets.

Put it Together

Because spacecraft become extremely hot during planetary entry, ESM is exploring and developing new methods of protection. Having the capability to predict heat extremes during entry mitigates mission risk, and these predictions are made using complex codes that are validated against test data. As computer codes get better, uncertainty in predictions is reduced. Coupled with greater predictive accuracy, research and advancements in development of thermal protection capabilities are being employed to manufacture materials with increased heat resistance. These promising materials are passed to other projects to be turned into heat shields that improve reliability—or even enable new NASA missions as spacecraft become safer and lighter.

The Game Changing Development (GCD) Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

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FS-2014-10-221-LaRC