Entry Systems Modeling and Ground Testing: Enabling Flight Performance and Risk Reduction

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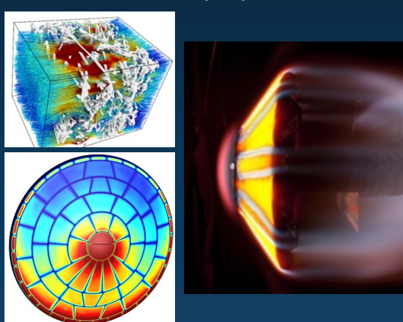
Science Impact: ***Entry, Descent, and Landing (EDL) comprises a relatively small portion of a mission's timeline, however, it is typically among the largest risks. Flying through a body's atmosphere reliably and accurately – from orbit to ground or via aerocapture – is a critical step toward successful in situ exploration.***

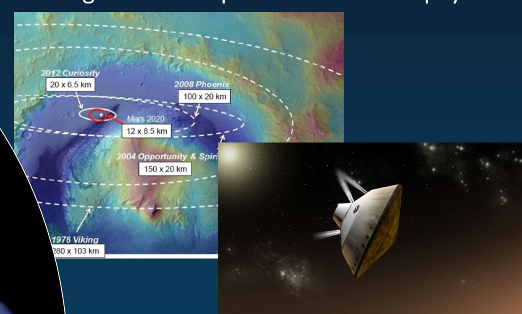
TPS Materials Modeling

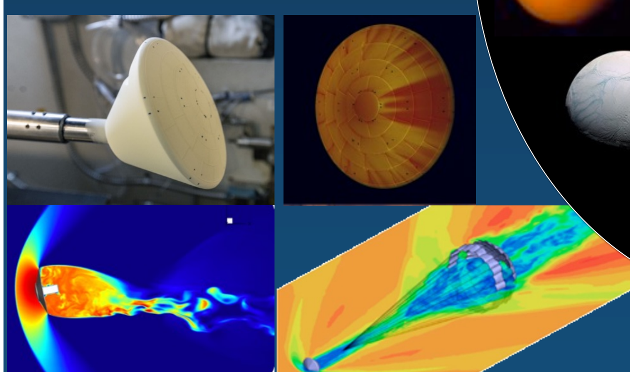
Advanced material response models for HEEET and other next-gen woven composites; Arc jet testing for TPS performance qualification; Lab capabilities to characterize material properties



Guidance, Navigation, and Control

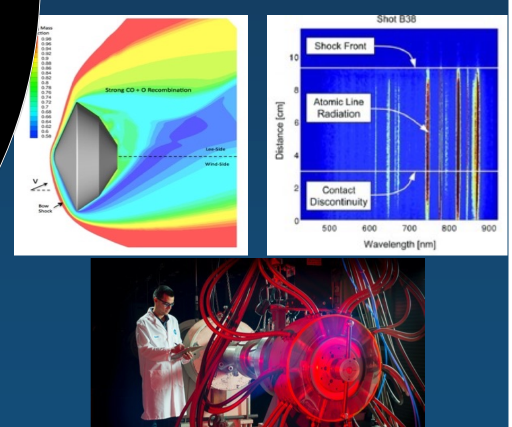
Guidance, Navigation, and Control models enable precision landing and aerocapture for scientific payloads





Aerodynamic Modeling

Free-flight CFD for vehicle dynamics and aerocapture; Turbulent heating models; Parachute modeling; Wind tunnels to characterize aerodynamic performance and heating environments



Shock Layer Kinetics and Radiation

High-fidelity aerothermal simulation for Mars, Gas Giants, Venus, and sample return to Earth; Electric Arc Shock Tube facility measures flight-similar radiative emission

Entry Systems Modeling and Test Capabilities Applied to Planetary Science Missions

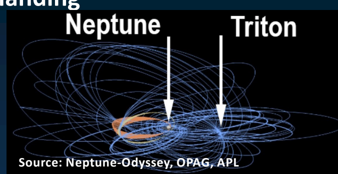
***Entry, Descent, and Landing (EDL)* modeling and testing are critical components of a mission's lifecycle, from concept through execution.**

Elements of Spacecraft Flight:

ARRIVAL: Trajectory Analysis

(*POST2, Genesis*)

- Advanced guidance and control algorithms for precision aerocapture and landing
- Launch-to-land guidance



Multi-destination mission concepts

ENTRY: Aerothermodynamics

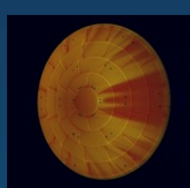
(*Shock tube, Ballistic range, Hypersonic wind tunnels, NEQAIR, HARA*)

Thermal Protection System (TPS) Modeling

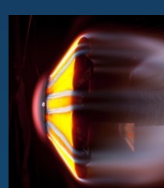
(*Icarus, PATO, PuMA, Hydra*)

- Shock layer radiation for all destinations
- Aeroheating environment test & simulation
- Thermal protection system sizing
- Aeroshell reliability, reduced TPS margins / mission risk

Electric Arc Shock Tube



Hypersonic Wind Tunnels

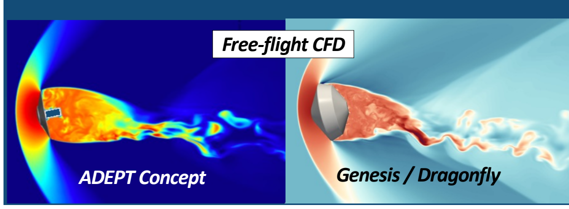


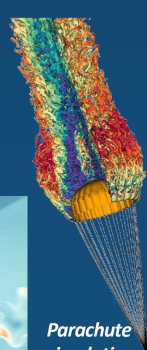
Arc Jets

DESCENT: Aerodynamics

(*Wind tunnels, Ballistic range, US3D, LAVA*)

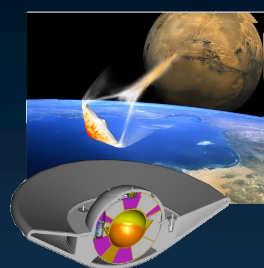
- Entry vehicle dynamics test & simulation
- Parachute inflation & descent dynamics
- Ground-to-flight traceability





Parachute simulation

Planetary Science Mission Infusion:



Small Bodies / Sample Return

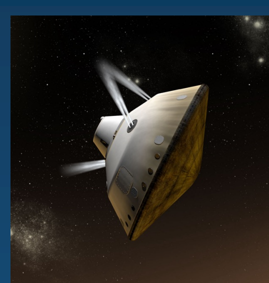
Advanced models are necessary to meet stringent reliability requirements:

- Extreme aeroheating environments
- High-fidelity woven TPS modeling
- Quantify TPS failure & reliability
- Simulation & testing of entry vehicle dynamics

Outer Planets

New EDL challenges:

- Unique H_2-He-CH_4 aerothermochemistry
- Aerodynamics, guidance, and control for aerocapture at Ice Giants
- High-fidelity woven TPS modeling



Mars Exploration

Expanding the performance envelope:

- Reduce TPS mass margins to accommodate greater scientific payloads
- Aero, guidance, and control for precision landing to higher latitude, elevation

Venus Exploration

Extreme conditions:

- High-speed aerothermodynamics for dense CO_2/N_2 atmosphere
- High-fidelity woven TPS modeling
- Simulation & testing of entry vehicle dynamics
- Simulation of parachute & separation dynamics