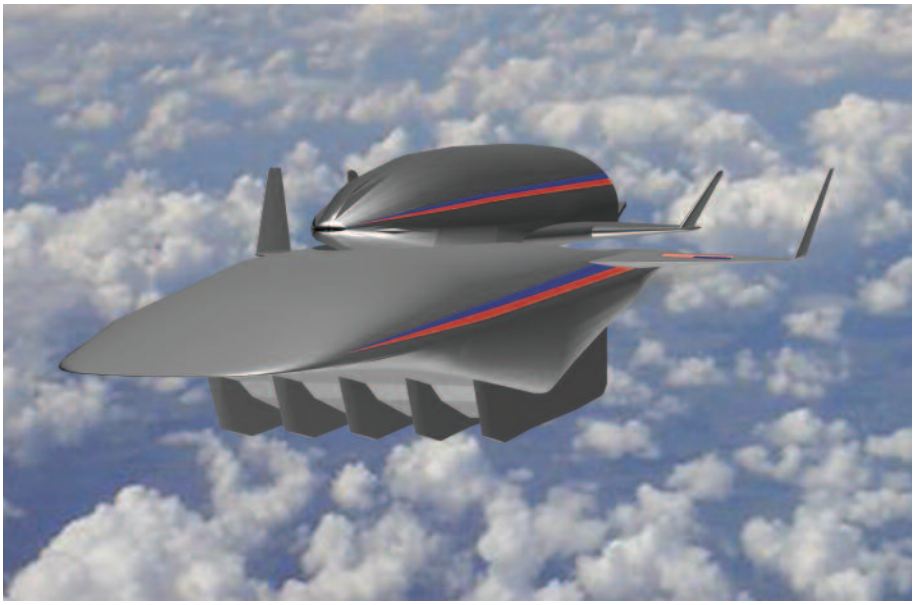
Hypersonics Research

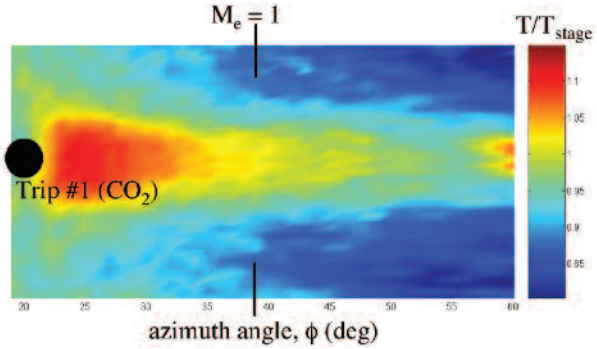
The Hypersonics Project, part of NASA's Fundamental Aeronautics Program, is committed to mastering the science of hypersonic airbreathing flight in Earth's atmosphere and of planetary atmospheric entry in support of NASA's mission: to pioneer the future in space exploration, scientific discovery, and aeronautics research.

Research in the Hypersonics Project focuses on solving some of the most difficult challenges in hypersonic flight, such as the development of:

- Materials and structures for airframe and air-breathing propulsion systems that can withstand repeated cycles of severe temperatures
- Predictive models for compressible flow, turbulence, heating, ablation, and combustion
- Advanced control techniques for vehicles that fly in the hypersonic flow regime
- A new generation of experimental instrumentation based on lasers that can be used to validate theoretical and computational models
- New types of airbreathing propulsion systems that integrate either high-speed turbine engines or rockets with scramjet engines



NASA's airbreathing-powered, Two-Stage-to-Orbit reference concept is shown in flight.



High-fidelity simulation tools are being developed to investigate the effect of different planetary atmospheres on boundary layer-transition.

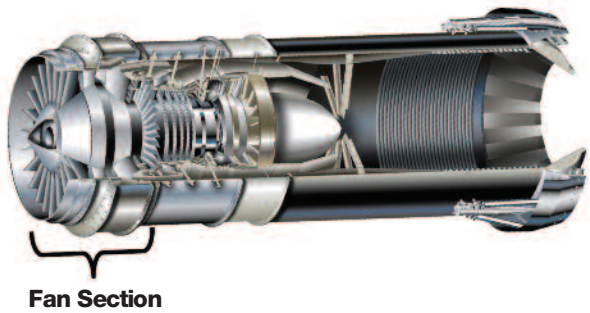
- Integrated physics-based design tools that simultaneously design the airframe and propulsion systems

Technology developed under the Hypersonics Project also may help the Department of Defense achieve its goal of global range at high speeds with persistence and significant payload.

Research Overview

The Hypersonics Project focuses on the development and validation of enabling foundational tools and technologies for two hypersonic system classes: Reusable Airbreathing Launch Vehicles (RALV) and the Planetary Atmospheric Entry System (PAES), a large vehicle focused on transporting humans and scientific payloads to and from Mars. There is a critical need for dramatic improvements in our current capability to enable the landing of large payloads with or without humans safely on Mars.

At the present time, rocket-powered, expendable launch vehicles reach hypersonic speeds in the upper atmosphere while transporting payloads to



The Mach 4 variable-cycle turbofan ramjet is a turbine-based combined cycle (TBCC) propulsion system designed for Mach 0-4 operation.

orbit. Humans are transported to orbit and back by the space shuttle, a semi-reusable system based on 40-year-old technology. Unpowered hypersonic entry vehicles return to Earth from near-Earth and interplanetary orbits. Probes transit the atmospheres of other planets and land robotic exploration systems. While these are extraordinary accomplishments, the extreme heating of hypersonic flight requires designers to incorporate large design margins to cover uncertainties in design predictions, resulting in reduced mission capabilities and increased costs.

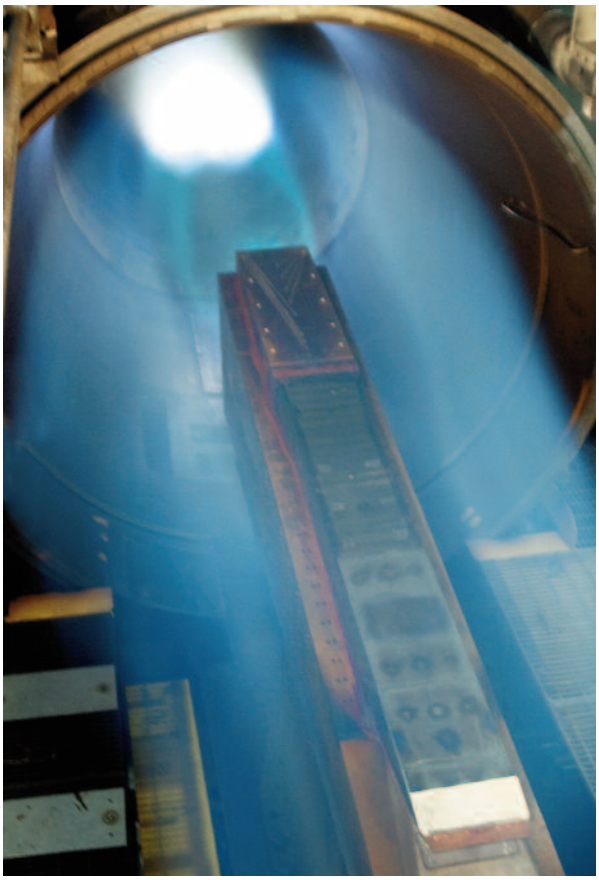
A key objective of the Hypersonics Project is to develop design and analysis methods and tools that adequately model fundamental physics and allow credible, physics-based optimization for future operational hypersonic vehicle systems of the two classes identified above. This research will enable more efficient and safer hypersonic systems to emerge. A stable, long-term commitment to investment in foundational hypersonic research should lead to sufficient understanding of the underlying physics. Then design methods can achieve the level of certainty required to fully utilize the possibilities of hypersonic airbreathing flight and enable it to become routine.

Technical Disciplines

Hypersonics Project research is organized within technical disciplines, each focusing on the enabling technologies in its own area:

- Materials and Structures
- Airbreathing Propulsion
- Aerodynamics, Aerothermodynamics, and Plasma-dynamics
- Guidance, Navigation, and Control

Pratt & Whitney Rocketdyne X-51A WaveRider Scramjet Engine Demonstrator readied for world's first hypersonic, hydrocarbon-fueled scramjet flight test—The SJX61-2 engine, which will power the Boeing X-51A WaveRider test vehicle, recently successfully demonstrated key flight clearance objectives in ground tests simulating Mach 5 flight conditions at Langley Research Center. Credit: PWR

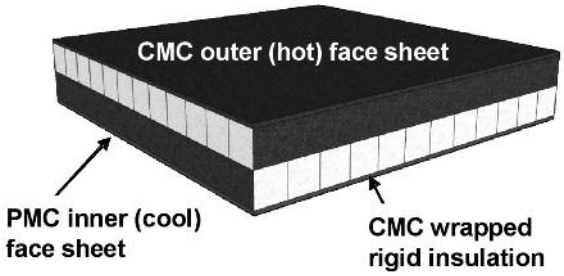


Workers from ILC Dover and NASA Langley inflated and tested the Inflatable Re-Entry Vehicle Experiment (IRVE) in preparation for testing at NASA's Wallops Flight Facility on the Eastern Shore of Virginia. Credit: NASA/Sean Smith

- Experimental Capabilities
- Physics-Based Multi-Disciplinary Analysis and Optimization
- Atmospheric Entry Decelerator Technology

Reliable Airbreathing Launch Vehicles (RALV)

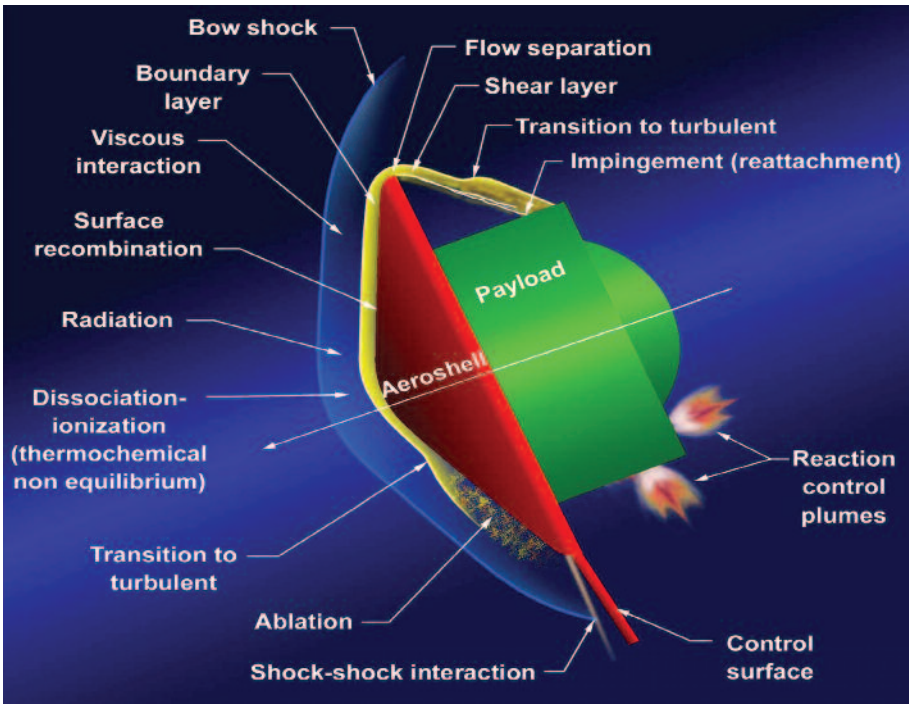
Leading-edge hypersonic research on airbreathing vehicles seeks to enable sustained hypersonic flight through Earth's atmosphere with the ultimate goal of routine, airline-type access to space.



Integrated hot structures offer the potential for significant weight reduction for the airframe structure.

For reusable, airbreathing, access-to-space technologies, the project is aligned with the goal defined in the 2007 National Plan for Aeronautics Research; namely, to demonstrate sustained, controlled, hypersonic flight. Successfully meeting this goal will require continued research and development in all areas of high-speed atmospheric flight, including integrated vehicle design, aerodynamics, aerothermodynamics, high-temperature structures and materials, lightweight and durable thermal-protection systems, supersonic combustion, and airbreathing propulsion concepts that operate from subsonic speeds into the hypersonic regime.

Hypersonics Project research and development goals include extending the use temperature and life of high-temperature materials and structures, reducing component mass, and developing airbreathing propulsion technology for Two-Stage-To-Orbit Turbine-Based Combined Cycle (TSTO/TBCC) vehicles.



Physics-based, high-fidelity computational models are being developed to model complex physical and chemical processes during planetary entry.

Planetary Atmospheric Entry System (PAES)

Future science and human exploration missions to Mars and other planets will require dramatic improvements in our current capability to land large payloads safely on these worlds.

The state of the art for successfully landing payloads on Mars is less than 1 metric ton in weight with a landing accuracy of approximately 100 km of the desired landing site. Technologies to enable delivery of higher masses to higher altitudes with greater accuracy are being developed.

Plans for human and large science missions to Mars require a nearly two-orders-of-magnitude increase in landed mass. The main challenge is that the Mars atmosphere causes significant thermal heating but is too thin to enable deceleration to manageable terminal velocities. These factors are daunting challenges for the system designer, as is the requirement for precise targeting at landing points of scientific interest, rendezvous with pre-positioned landed assets, or both.

Solving the problem of safely landing large payloads on the surface of Mars requires analysis of a number of technology options over the entire re-entry speed range (from high hypersonic to subsonic). The Hypersonics Project is a joint sponsor with the Exploration Systems Mission Directorate (ESMD) and the Science Mission Directorate (SMD) of a multi-year systems

analysis trade study aimed at identifying promising technologies for hypersonic entry and supersonic descent through the Mars atmosphere.

The Hypersonics Project in turn uses this and other studies to guide its investments in technologies, computational tools, and physics modeling for PAES applications. The technical scope of the disciplines ranges from foundational research to multi-disciplinary analysis and optimization:

- Materials and Structures
  - Advanced high-temperature ablators
  - High-fidelity ablation models
  - Flexible TPS

Research into planetary atmospheric entry supports NASA's mission to pioneer the future in space exploration, scientific discovery, and aeronautics research.

- Aero-, Aerothermo-, and Plasmadynamics
  - Advanced CFD methods
  - Physics-based chemical kinetics models
  - Advanced radiation models
- Atmospheric Entry Decelerator Systems
  - Hypersonic inflatable aerodynamic decelerators
  - Supersonic inflatable aerodynamic decelerators
  - Supersonic retro-propulsion

The Fundamental Aeronautics Program is addressing two key aeronautics challenges related to space exploration: access to space and entry into planetary atmospheres.