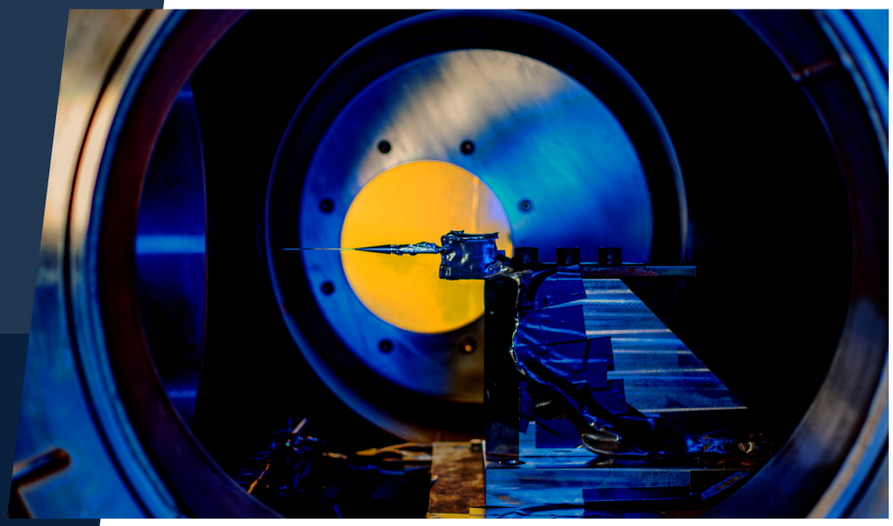
Addressing the Technical Challenges Posed by Hypersonic Flight



The Hypersonic Systems Initiative (HSI) is rooted in the University of Notre Dame's long history of aeronautical engineering. In 1882, an ambitious Notre Dame student named Albert Zahm built one of the nation's first wind tunnels to study the lift and drag of various wing shapes. Since that time, the University has led advances in aerospace research through key partnerships and major financial investments. Hypersonics represents the ultimate step in that journey: an integration of air and space that combines elements of aeronautics with astronautics.

Hypersonic vehicles have the potential to improve our world by transforming intercontinental transportation. Achieving this lofty goal will require not just new technologies but also a new approach to research. Therefore, the HSI fosters a "system of systems" approach. It recognizes the interdependence of different design elements and provides coordination where these elements interface. HSI draws on the broad expertise of its large, multidisciplinary group of affiliated faculty to perform the kind of cross-cutting research that can address the extraordinary requirements posed by hypersonic flight.

To support its work, the HSI also gathers expertise from an array of research centers and facilities across the University, including:

- The Engineering and Design Core Facility (EDCF)
- The Hessert Laboratory for Aerospace Research
- The Institute for Flow Physics and Control (FlowPAC)
- The Center for Sustainable Energy at Notre Dame (ND Energy)
- The Notre Dame Turbomachinery Laboratory (NDTL)
- The Wireless Institute (WI)

The Initiative works with peer universities, government labs, and industry partners. It has designed and is building a Mach 10 Quiet Wind Tunnel. Along with partners Hermeus and FGC Plasma Solutions, the University has also developed facilities for ram engine and high-Mach combustion testing.

Learn More

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HYPERSONICS RESEARCH CAPABILITIES

Aerodynamics

Since the early 1990s, researchers at the University have focused on predicting and controlling turbulence transitions. When fully operational, the AFOSR-ND Large Mach-6 Quiet Tunnel will be the country's preeminent facility for experiments to study and control hypersonic boundary-layer transition.

Thermal Protection

At Mach 10, aircraft surface temperatures can reach 4,400°F. To address the need for thermal protection systems, the Initiative includes a Thermal Barrier Materials and Thermal Management Focus Group and a Molecular/Nano-Scale Transport and Energy Research Laboratory that engineers materials with finely tailored thermal properties. For materials testing at hypersonic conditions, faculty use a high-enthalpy test bed ND ArcJet.

Materials

Hypersonic flight involves extreme heat transfer rates that metals and polymer-metallic matrix composites cannot withstand. The Initiative investigates new materials for hypersonic flight, including methods for joining carbon-carbon layers with dissimilar metal layers for high-temperature applications.

Structures

Hypersonic flight introduces tremendous thermal gradients. Surface temperatures may be 100x lower a short distance downstream of leading edges. The structure design team uses state-of-the-art computer-aided design and thermal-structural analysis simulations to design high-tolerance structural elements.

Manufacturing

HSI faculty affiliates, including those at the Laser Precision Manufacturing Laboratory, are investigating ways to effectively and efficiently manufacture windows, sensors, seals, and other components for hypersonic vehicles. Of particular interest are additive manufacturing and the use of artificial intelligence for niche material development.

Signatures & Long-range Diagnostics

Faculty within the Hypersonic Environment and Phenomenological Focus Group draw on expertise in long-range adaptive optics, plasma dynamics, long-range sensing, two-way communication, and sensor development to analyze the chemical reactions and heat signatures produced during hypersonic flight.

Propulsion

The Notre Dame Turbomachinery Laboratory (NDTL) supports two large-scale advanced technologies required to develop hypersonic propulsion. A supersonic testbed SBR-50 is available for short-term testing at the White Field Research Laboratory. Researchers are currently investigating plasma-assisted combustion and developing new tools to improve rotating detonation engines.

Energy Storage

Batteries for hypersonic vehicles must withstand high temperatures and high g-forces. Battery weight also affects the payload and range of hypersonic vehicles. The Initiative's Energy Storage/Capture Focus Group investigates these issues while also considering ways to harvest energy from heat transfer or from ionized air.

Communication

The flow and heating of atmospheric gas around a hypersonic vehicle form a dense layer of charged particles ("plasma sheath") that blocks the transmission of conventional communication signals. The Initiative is working to develop new methods for communicating through the plasma sheath.

Flight Control, Guidance, and Navigation

Their high velocity means that hypersonic vehicles are extremely sensitive to changes in flight conditions. The Initiative's Flight Control, Guidance, and Navigation Focus Group is working to develop adaptive controllers that make use of dynamic flight models, real-time sensors, and artificial intelligence.

Computational Science

HSI affiliates draw on the University's high-performance computing capabilities to solve some of the most complex problems in aeronautics. Faculty are currently generating models and running simulations related to hypersonic flow, hypersonic radiation, materials manufacturing, and high-Mach combustion.

Workforce Development

As the United States seeks to strengthen its hypersonics capabilities, there is a need to develop a talented and technologically prepared workforce to support hypersonic systems. Notre Dame's approach involves STEM education in hypersonic systems that reaches students at all levels from middle school to Ph.D.

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