Thesis Project Portfolio

The Hypersonic reEntry Deployable Glider Experiment

(Technical Report)

Mach Diplomacy: Hypersonics and Global Power

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Franklin Escobar

Spring, 2025

Department of Mechanical & Aerospace Engineering

Table of Contents

Executive Summary

Hypersonic systems, characterized by their ability to travel at speeds exceeding Mach 5, are not only revolutionizing military capabilities, but also altering geopolitical interactions among nations. Hypersonic technology represents a frontier in aerospace innovation with significant implications for scientific, commercial, and defense sectors. However, access to research is constrained by the high costs and technical challenges of sustaining such high speeds, limiting accessibility for academic and smaller research institutions. This limitation in accessibility means only wealthy governments and well-funded corporations by said governments can meaningly participate in hypersonic research. As a result, the global landscape of power is shaped by those with resources to invest in and deploy these advanced systems.

My capstone, The Hypersonic ReEntry Deployable Glider Experiment (HEDGE), seeks to overcome these barriers by using a CubeSat framework to provide a cost-effective, scalable solution for gathering essential data on hypersonic reentry and flight dynamics. HEDGE aims to capture real-time telemetry on thermal and aerodynamic performance during reentry, addressing critical gaps in hypersonic research. HEDGE is composed of 3 distinct sections: the forebody, the CubeSat, and the fins. The forebody is the front-most part of HEDGE and is designed to provide an aerodynamic profile so that hypersonic speeds can be reached. The CubeSat is the central section which houses the avionics and powers the onboard telemetry. Lastly, there are 4 fins which wrap around the CubeSat and provide the aerodynamic stability needed. It will be launched as a part of NASA's RockSat-X program from Wallops Island in August 2025 on a sounding rocket. HEDGE will reach an altitude of 170km before it ejects from the rocket and begins its downward trajectory towards the Atlantic Ocean.

Through Susan Leigh Star's *Ethnography of Infrastructure* framework, there are critical infrastructural elements involved in the development and deployment of hypersonics. There is a critical interplay between how technology and infrastructure influences military strategy and national security policies to ultimately answer the question of how the development of hypersonic technologies influence global stability and power dynamics.

The emergence of offensive hypersonic weapons poses challenges for global stability, particularly concerning arm control agreements as nations race to develop and deploy these capabilities. Furthermore, the potential for hypersonic advancements to both stabilize and destabilize existing power structures. They have the possibility to enhance deterrence capabilities or risk escalating tensions and provoking arms races among competing nations. The ethnographic approach reveals that hypersonic advancements are not merely tools of warfare, but are embedded within complex networks of political, economic, and cultural factors. Ultimately, this paper highlights the important role that hypersonics play in disrupting existing power dynamics and altering the landscape of international relations.

Working on both the HEDGE Capstone and the STS project simultaneously has offered a comprehensive understanding of hypersonics as a whole. On the technical side, HEDGE allowed me to engage directly in engineering challenges, from structural considerations to figuring out a deployment mechanism, it really has me a firsthand experience in what it truly means to think and work like an engineer. At the same time, as I was working on the STS paper, I really had to take a step back and critically analyze the broad implications of such technologies, revealing their interconnectedness in power, policy, and security. Overall, this experience reinforced the importance of interdisciplinary thinking in the ability to not only build complex systems but understand their impact in a global context.