Thesis Project Portfolio

Hypersonic ReEntry Deployable Glider Experiment (HEDGE): A CubeSAT Approach to Low-Cost Hypersonic Research

(Technical Report)

Risk, Reform, and Innovation: The Impact of Major Accidents on Sports Safety Technologies

(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

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Spring, 2025

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Executive Summary

Engineering innovations hold extraordinary potential to save lives—yet the systems designed to protect us often lag in adopting these very technologies. Whether slowed by institutional inertia, cultural resistance, or fears of legal and reputational fallout, a persistent gap exists between what engineers can build and what society will accept. This disconnect is especially visible in high-speed, high-risk environments where decisions around safety carry profound consequences. My thesis portfolio explores this dilemma from two intertwined perspectives: first, by leading a technical project to democratize access to hypersonic research, and second, by investigating why life-saving safety innovations in professional sports are often delayed until after tragedy strikes. Together, these works ask: how can engineers ethically navigate the space between innovation and implementation, and what responsibilities do they bear when lives are on the line?

The technical project, titled Hypersonic ReEntry Deployable Glider Experiment (HEDGE), aims to expand access to hypersonic research by creating a low-cost CubeSAT platform capable of collecting atmospheric reentry data. Traditional hypersonic testing remains prohibitively expensive, typically requiring full-scale infrastructure and military-grade vehicles. HEDGE addresses this barrier by leveraging a 3U CubeSAT launched on a NASA sounding rocket through the RockSat-X program, enabling student teams to collect hypersonic data at a fraction of the cost. Designed to reach Mach 4.88 at altitudes of 150–170 km, the satellite features deployable fins, onboard sensors, and real-time telemetry via the Iridium satellite network. Our objectives included verifying fin deployment, capturing video of aerodynamic behavior, and demonstrating data downlink from free-flight conditions. Throughout the year, our team operated as an integrated system of specialized subgroups—including structures, avionics,

software, and systems integration—iteratively improving designs, running aerodynamic simulations, and coordinating testing logistics. This project not only demonstrated the technical feasibility of small-scale hypersonic testing but also showcased the power of resource-limited teams to meaningfully contribute to research spaces typically dominated by large government or industry entities.

In parallel, my STS research paper, *Risk, Reform, and Innovation: The Impact of Major Accidents on Sports Safety Technologies*, examines why protective equipment in professional sports is so often mandated only after a public tragedy. Using a qualitative comparative case study approach, the paper analyzes six examples of delayed safety innovation, including the HANS device in NASCAR, the Halo in Formula 1, Guardian Caps in the NFL, neck guards in hockey, batting helmets in Major League Baseball, and safety modifications to the Olympic luge track. Drawing on the reactionary model of safety governance, the study argues that reform is not typically proactive but reactive—spurred by tipping points like high-profile deaths, lawsuits, or reputational crises rather than by scientific evidence alone. Across these cases, the research identifies common forces delaying reform: athlete resistance rooted in performance and tradition; institutional inertia driven by legal, financial, and reputational concerns; and public backlash over aesthetics or perceptions of weakness. Even when safety technologies are validated and available, they often remain optional or resisted until the cost of inaction surpasses the risks of adoption. The paper concludes that engineers must not only design effective protective technologies but also act as advocates for their implementation—using communication, collaboration, and ethical foresight to build public trust and institutional accountability before tragedy necessitates change.

Together, these projects offer a multidimensional view of the ethical and practical challenges engineers face when designing technologies intended to protect human life. From my technical work, I learned how strategic design, interdisciplinary collaboration, and iterative problem-solving can empower even small, resource-constrained teams to contribute meaningfully to high-stakes fields like hypersonics. From my STS research, I gained insight into the non-technical forces—cultural narratives, institutional hesitancy, legal fears—that determine whether protective innovations ever reach the people they are meant to safeguard. Both projects deepened my understanding of engineering as not just a technical practice but an inherently sociotechnical one, where success depends on navigating human, institutional, and ethical landscapes as much as solving mechanical or computational challenges.

Looking ahead, I recommend that future research continue exploring the intersection of engineering, ethics, and communication, particularly in fields where delayed implementation carries life-or-death consequences. Improving safety outcomes requires more than technical excellence; it demands proactive governance structures, stakeholder engagement, and cultural shifts that prioritize prevention over reaction. As engineers, we must embrace a broader vision of responsibility—one that extends beyond the lab or the drawing board to the real-world systems and communities we aim to protect.

I extend my deepest gratitude to my capstone advisor, Professor Christopher Goyne, for his invaluable mentorship and commitment to our team's success; to my STS advisor, Professor Kent Wayland, for guiding me through the complex ethical and sociotechnical dimensions of this research; and to my family and friends, whose unwavering support carried me through every challenge along the way.