Thesis Project Portfolio

Hypersonic ReEntry Deployable Glider Experiment (HEDGE)

(Technical Report)

The Shift in Space Caused by Cube Satellite Development

(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

Owen Tuohy

Spring, 2024

Department of Mechanical Engineering

Contents of Portfolio

Executive Summary

The aerospace industry is a highly dynamic discipline with many interconnected facets. In my research into this evolving landscape, I explored two integrated subjects. Firstly, our technical project centered around engineering a Cube Satellite, or CubeSat, for hypersonic re-entry research purposes. Due to the "high priority" status of hypersonics research established by the Department of Defense, we aimed to prove that the use of CubeSats would be an advancement in the field of hypersonics testing. Concurrently, my STS research scrutinizes the transformative impact of CubeSat development on the aerospace industry, specifically how they have caused a shift in satellite design, launch, and operational frameworks. These projects revolve around an important question: "How can the aerospace industry adapt to leverage the potential of CubeSats while still addressing the challenges they introduce?" This overarching problem becomes significant when we view CubeSats as a disruptive innovation, characterized by their unorthodox conception, cost-effectiveness, and potential to democratize access to space. By highlighting the intersection between technical innovation and sociotechnical dynamics, my research strives to shed light on ways in which we can harness the potential of CubeSats while navigating the intricacy of their integration into the aerospace sector.

As part of a spacecraft design capstone project, a group of 29 undergraduate aerospace and mechanical engineering students were tasked with continuing the work done by previous classes on a Hypersonic ReEntry Deployable Glider Experiment (HEDGE). This proof of concept mission aims to demonstrate the feasibility of using CubeSats as a means of low cost sustained hypersonic flight, a materials screening method at hypersonic flight conditions, and that undergraduate students are capable of conducting these experiments with greater accessibility than traditional methods. The class was divided into six subteams, Program Management, Communications, Software and Avionics, Power Thermal and Environment,

Attitude Determination and Control Systems (ADACS) and Orbits, and Structures and Integration, were each given their own set of design requirements to be met by the end of the Spring 2024 semester. These teams collaborated amongst themselves and communicated with other groups to complete a Critical Design Review (CDR) demonstrating that the HEDGE project is ready for assembly, which will be next year's capstone class' task to complete. As a member of the Power, Thermal, and Environment subteam, my individual work centered around creating power budgets and building an auxiliary battery pack to ensure that the power system would be capable of supplying enough power for all other systems to function properly for the duration of the mission. With the exception of one issue, the system's GPS requires too much power if it is activated for the entire mission, all of our design requirements were met and we feel confident passing along our material to next year's class.

The STS research paper explores the transformative impact of CubeSat technology on the space industry, analyzing its role in facilitating a shift in the way we approach space exploration and satellite deployment. The primary research question addressed in this paper is: How have CubeSats facilitated a shift in the space industry, and how does this shift affect the diverse range of actors involved? By examining historical cases of CubeSat failures and successes, proposals for CubeSat applications, and scholarly literature on the trends seen in the industry and the democratization of access to space, this research aims to illuminate the intricate dynamics driving this shift. Based on a comprehensive literature review, the research identifies claims regarding CubeSats as a disruptive innovation. Firstly, CubeSats have democratized access to space for educational institutions, smaller nations, and startups allowing a wider range of actors to engage in space exploration and research endeavors. This is evidenced by numerous CubeSat launches and their diverse range of applications, from environmental monitoring to disaster

management. Secondly, CubeSats have altered traditional mission architectures, enabling innovative approaches such as distributed sensing networks and collaborative ventures. These unconventional mission strategies challenge typical satellite deployment and encourage flexibility in space operations. Lastly, CubeSats have sparked debates surrounding the ethical and geopolitical implications of their military applications. In response to these findings, the research concludes that CubeSats are a disruptive innovation that has fundamentally changed the landscape of the space industry, creating opportunities for a more inclusive era of space exploration.

To conclude, the work done this year brought significant value to my experience as an undergraduate student and as a prospective engineer in the mechanical or aerospace disciplines. We were able to successfully progress the work done on HEDGE, and feel confident that next year's class will be able to move the project forward into the assembly stage with the hope of achieving a launch in the Fall 2025 semester.