HEDGE: A Concept for Low-Cost Hypersonic Flight Experiments

(Technical Paper)

The Effect of Hypersonic Research Becoming more Available

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

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Fall, 2022

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction:

CubeSats are miniaturized satellites originally from CalTech that gives university students, governments, and privately owned companies the opportunities to perform space experiments (typically low Earth orbit). Starting last year, the University of Virginia has a project with the CubeSat called the HEDGE. The HEDGE stands for Hypersonic ReEntry Deployable Glider Experiment. It aims to demonstrate the possibility of low-cost hypersonic flight experiment via CubeSats re-entering into earth's atmosphere due to natural deorbit. Technology research like HEDGE made me curious about low-cost innovations and how this potentially ground-breaking technology could affect the global balance.

Technical:

CubeSats are standardized and versatile in their use. Each CubeSat are 10 cm. cubes, but CubeSats can be combined to create 4 different CubeSat sizes: 1U (1 CubeSat), 2U, 3U, and 6U (2 x 3). The purpose of using CubeSats will vary based on the research purpose, and these are typically seen using different attachments. Stanford's 3U CubeSat, called QuakeSat, had a mission to measure ELF (Extremely Low Frequency) magnetic signal data, and they use a long AC magnetometer to achieve their mission goal. The University of Arizona's 3U CubeSat called AOSat1 uses embedded magnetorquers to become the first centrifuge spacecrafts. The HEDGE is a 3U CubeSat that only utilizes 1U for computer hardware while the rest of the length is used for creating a nose shape to achieve its goal. Common attachments all CubeSats share are antennas, solar panels, power systems, thermal systems, and attitude control.

UVA's CubeSat, the HEDGE, aims to record hypersonic data as it re-enters into earth's atmosphere to show the feasibility of low-cost hypersonic research. This could open doors for many universities with the desire to expand their aerospace department in the possible research that is now available.

How the project is achieved is by storing a CubeSat on a spacecraft's second stage. After the spacecraft has launched and the second stage has detached, the Cube Sat is then released and the onboard computer activates the nose shape to form, allowing the CubeSat to travel high speed as it orbits. When the HEDGE begins to reenter, the computer will begin to measure and send data to a satellite receiver which in turn send data back to the ground station. This process effectively achieves the low-cost aspect of the project since the HEDGE program has cost in the $100,000's, but according to the United States government, hypersonic programs cost at the minimum $10 million dollars (Sayler, 2022). Since the second stage isn't too far away from the Earth's surface, the CubeSat will naturally deorbit and re-enter into Earth's atmosphere where it will record and send hypersonic data to the Satellite Iridium which would forward those data to ground control. The CubeSat will burn entirely on entry.

This year, UVA's CubeSat is a multiyear project that is currently in its 2nd year. The process of creating a CubeSat requires high attention to detail and overall accuracy and precision primarily due to the cost of sending a CubeSat. The CubeSat this year is estimated to cost $50,000 for the launch alone. That is why although the overall team size is large, there requires subteams to work and focus on their respective department.

There are 6 subteams: Program Management, Communications, Software and Avionics, PTE (Power, Thermal and Environment), Attitude Determination and Control System and Orbits, and Structures and Integration. Each play a vital role in this project. The Program Management are the ones making sure that every other team is on pace, within budget, and within internation space law. The communications team ensures the data that is being recorded is sent via antennas. The software and avionics team takes care of the electronics and software code. PTE primarily takes into account the external environemnet of the HEDGE to ensure that it has enough power and can withstand the solar flares and radiation. Attitude and Determination team ensures that it can calculate when the HEDGE is at its optimal height for recording hypersonic data. Finally, the Structures and Integration ensures the HEDGE is structurally sound.

This year I worked with the Software and Avionics. Our overall objective is to ensure that the correct electronics are used for a cost-efficient product; that each subsystem is also integrated on the software side correctly; and that the data that is being sent is captured and sent correctly.

How we desire to approach our solution is to take inspiration from past spacecrafts since many spacecrafts have user manuals that are publicly available. Researching these spacecrafts will be necessary for picking the correct components. There are several categories for the electronics that are needed: harddrive memory, ram memory, processor, motherboard, and additional electronic to inplement other subsystems. So with each category, we will choose the best product and if there is no product that truly satifies, we will also look into producing our own product (although for time-sake, it is a last resort). The available resources that we will need are primiarily the software which in most cases have open-sources that are completely free. The anticipated outcome for this year would be devising a system that can record data and send that data is a short and efficient time since the window to send data is very short upon re-entry.

STS Portion

Technological innovation is required for a nation to advance. As globalization became prominent in the 20th century, there's been an intense transfer of technology. It led many emerging markets to grow stronger in both productivity and innovation (Asalm, 2018). But what happens when military technology also travels across borders into wrong hands? This paper will go through a case study on military innovation, more specifically, suicide bombers. Once a military innovation has been understood well enough, a government won't immediately adopt the technology, even if it provides the military edge (Horowitz, 2010). There are two things that are needed to be considered: how much financial integrity will it require and how much organizational capital will it require. The main case we will investigate today is suicide terrorism.

Terrorism occurs due to organizations and groups not having the conventional military power to challenge the government (Horowitz, 2010). Suicide terrorism achieves goals for terrorist groups in overall good success because they have small financial intensity and doesn't require much organizational capital, yet they achieve in being accurate in their targets.

Suicide bombers (the ones we know today) emerged in the 1982 during the the wake of a Lebanese civil war. The leaders intertwined religious reasoning to send civilians with bombs to attack specific targets and cause overall chaos. The main reasoning being the glorification of self-matyrs, creating both a religious and practical practice (Kramer, 1991).

Although there isn't a specific link in the transfer of technology, there are many technology that most likely inspired this idea. One could be the innovation of explosives in the 20th century that allowed them to decrease in size. Another could be the general design of carrying explosives to a designated target. The possible combination of the two created an opening for this military design to form (Horowitz, 2010).

What was the process of adopting this technology innovation? It was a low in financial intensity so on the financial side, it seemed feasible but what was needed was high organizational capital since recruiting and convincing people to do these attacks took some investment. There were mixed consensus among terrorist groups, especially the older ones who weren’t as fast in adopting new innovations and tactics, but the limited choices for innovation made the process easier for adopting such innovation (Horowitz, 2010).

What can then be said about the hypersonic research? Technology shouldn’t be just for what it can do but also how it will be used since its environment has a significant affect on how it impacts others (Winner, 1980). The primary thing is to not see HEDGE as a step into expanding hypersonic research availability for universities but also look into how it could impact other nations, but even with that being said, no innovation is guaranteed as governments and organizations must consider the cost and benefits.

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