HEDGE: Hypersonic reEntry Deployable Glider Experiment

Hypersonic Companies and their Ethical Decisions

A Thesis Prospectus
In STS 4500
Presented to
The faculty of the
School of Engineering and Applied Sciences
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Aerospace Engineering

By
Amy Paz Cuervo

October 11, 2023

Technical Team Members: Morgan Myers, William Plunkett, Timothee Kambouris, Brandol Garcia

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

ADVISORS

Joshua Earle, Department of Engineering and Society

Chris Goyne, Department of Mechanical and Aerospace Engineering

I. Introduction

The development of hypersonic technologies for both civilian and military use has grown significantly in the past few years. Hypersonic flight is when mach 5 is exceeded (*Definition of HYPERSONIC*, 2023). The mach number is calculated by dividing an object's speed by the speed of sound. Hypersonic flight has various complex effects such as dissociation of air molecules, creation of plasma, changes in chemical reaction, etc. Therefore, there is a need for extensive testing to design and create flight vehicles that are capable of withstanding the effects of reaching hypersonic conditions. Methods of testing in hypersonic conditions are typically very costly. For example, the use of hypersonic wind tunnels, which are ground based facilities that generate flows of air and accelerate the stream with nozzles and diffusers, are expensive and require a lot of time to set up (Woodford, 2021). Although hypersonic wind tunnels can be insightful, they are not economical and also have a limit as to what can be tested in terms of size.

Currently there is a race to develop hypersonic technologies particularly in two areas; hypersonic missiles for the world militaries and civilian space travel. This race adds to the need for a new, cost-effective method for hypersonic testing. The Mechanical and Aerospace Department at the University of Virginia is working towards developing a solution to this problem with the HEDGE project, my technical project. HEDGE is a great technological advancement, however the ethical implication of such a technology is not so clear. Cube-sat's immense potential and significance makes them valuable tools for collecting vital data on hypersonic reentry. However, deploying CubeSats in this role is not without political implications. According to Winner, "…we examined ways in which the intractable properties of certain kinds of technology are strongly, perhaps unavoidably, linked to particular institutionalized patterns of power and authority" (Winner, 1980, p. 134). In order to determine these political implications, I will conduct an analysis of how

ethics plays a role in hypersonic technologies, specifically within Raytheon technologies. The aim of my STS project is to answer the following research question: *How effectively can companies involved in hypersonic technologies incorporate ethical principles into their corporate policies regarding potentially life-threatening technology?*

My thesis prospectus will cover my technical project, STS project and key texts. In the technical portion I will discuss the specifics of my technical project and my plans for the following semester. In the STS portion, I will talk about my research question, why it is important, the relevant social groups, frameworks/methods that will be used, and finally a timeline for completing this research. Finally, for the key texts section I will be listing 4 primary sources that I have found for my STS project and providing a description of their arguments.

II. Technical Project

Problem Outline

The Hypersonic ReEntry Deployable Glider Experiment (HEDGE) is a CubeSat that will be launched into orbit to reenter the Earth's atmosphere at hypersonic speeds to collect data. A CubeSat is a small satellite that uses standard size and form factor (Caldwell, 2023). The Software and Avionics subteam, has the responsibility of designing the hardware and software system of HEDGE so that it can collect, store, and transmit data during the mission. More specifically, our subteam will be connecting the onboard computer (OBC) to the rest of the hardware components. This is important because the other subteams have components that need to connect, interact, and communicate with the OBC.

Objective of Research Work

Our main objective this year is to construct and test a prototype that embodies both essential hardware and software components for the HEDGE mission. Our duties include furthering the

advancements of last year's team who selected the critical electronics: the pressure transducer, the Endurosat onboard computer, and the thermocouple. The challenge lies in ensuring seamless communication amongst these components and guaranteeing that the data is effectively transmitted through the Iridium transceiver module back to Earth.

Building upon the existing groundwork, our responsibilities extend to developing the required software that facilitates real-time data acquisition, processing, and transmission during the CubeSat's operational phases. Once the prototype construction is finalized and the software is comprehensively developed, it will need to be tested. The tests must validate both the software's functionality and the hardware's resilience for the conditions of hypersonic re-entry.

Approach and Methods

The first step is integrating the selected components. The team will collaborate with the electrical engineering students to design and fabricate circuit boards that can connect the thermocouple, pressure transducer, and receiver. These circuit boards will be based on the data flowchart as seen in data flowchart in Figure 1.

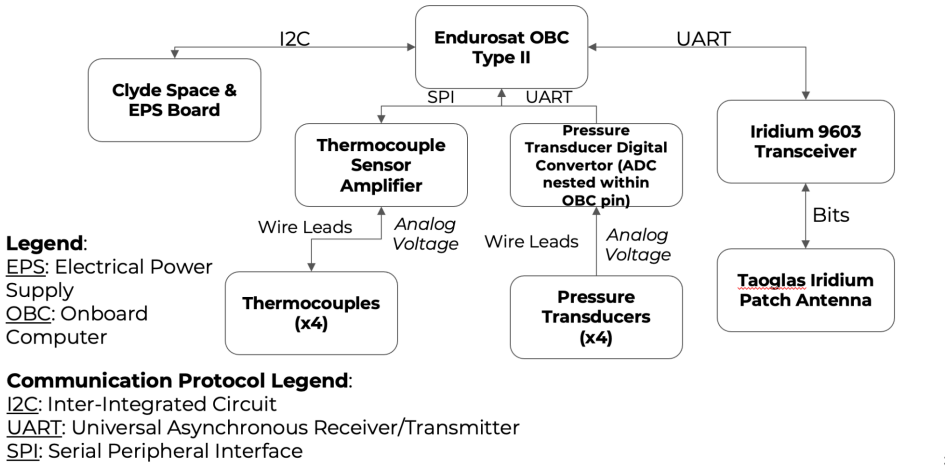

Figure 1: Hardware data flowchart (UVA MAE 4700 2023 Students, 2023)

The software, which consists of freeRTOS, COSMOS, and CFS, will be developed to work alongside the hardware. Then, multimeters and microcontrollers will test the hardware and software to ensure the OBC communicates well with all components. The team will show and discuss the final design with other subsystem teams to streamline the integration process for the final HEDGE prototype.

Resources

For command and control, we will use the Endurosat onboard computer. The Endurosat onboard computer user manual has key information about hardware and software integration, application programming information documentation, initial configuration procedures, troubleshooting, and safety guidelines (Endurosat, 2018). To manage onboard processing, we will use NASA's core flight system, a reusable software framework, due to its reliability and portability (NASA).We chose COSMOS operating system to set up the ground-based system and also run simulations software and hardware components (OpenC3, 2023). Lastly, UVA electrical and computer engineers are collaborating with our subteam and will be a great help in designing the circuit boards and initial software set up.

Objectives for Spring Semester

By the end of the Fall 2023 semester, we, the software and avionics team, plan to deliver the hardware components for the MSP300 pressure transducer and the RockBLOCK9603 Iridium transceiver module for hardware. The OBC will not be in person for testing until the Spring, therefore the software that we plan to deliver contains CFS programs corresponding to both the pressure/temperature and communication hardware components on a Raspberry Pi 4b running FreeRTOS (TImada). The biggest objective of the Spring 2024 semester is to port the CFS software to the endurosat OBC, and ensure that input/output (IO) between the software subsystems and their

respective hardware components functions correctly. To be certain that components are working properly, we will use a testbench for both hardware and software. OpenC3 COSMOS provides a framework for cubesat testing that we plan to utilize to create an exhaustive set of tests that accurately simulate the working environment of the satellite (OpenC3, 2023). Additionally, we plan to update the CFS project ported to the OBC to align directly with the information transfer/data storage mechanisms described in the HEDGE documentation. For the fall semester, we will work together to prepare for a Technical Interchange Meeting (TIM) with the rest of the subteams. For the second semester, all the subteams will collaborate to make a System Integration Report (SIR) and one technical thesis.

III. STS Project

I am examining hypersonic technologies that can be developed with the help of HEDGE. Brey writes, "External means serve to extend the range of actions or tasks that someone is capable of, either by enhancing existing capacities or by adding genuinely novel capacities. They may then help one realize intentions that could not be realized with just one's faculties" (Brey, 2000, Pages 9-10). CubeSats fall into the second category that Brey mentions; technologies that introduce entirely new capabilities. Hypersonic missiles are just one of several technologies that can be developed from the HEDGE project.

For my STS project, I will examine hypersonic technologies, such as hypersonic missiles, in context of company guidelines and the effect on society, specifically for Raytheon Technologies. I am posing the following question: *How effectively can companies involved in hypersonic technologies incorporate ethical principles into their corporate policies regarding potentially life-threatening technology?* This question is important to consider because hypersonic technologies are new and developing at a rapid pace. It is important to establish a foundation of ethical

guidelines before technology disperses through society. My research question will be answered in two main parts. The first one being what ethics statements Raytheon Technologies has made and what those statements are trying to do. The second part is looking at how well Raytheon Technologies actually follows those ethical statements.

Relevant social groups include the general public, hypersonic companies, and governments. General public is simply the general civilian population all around the world. The hypersonic companies are companies like Raytheon technologies which are working to develop hypersonic technologies. Governments are the various governments around the world, but there is a large focus on those with more influence and power. Military members and researchers are social groups which are relevant, however I will not be considering these social groups due to their lack of control on how hypersonics are used. Enlisted soldiers are assigned tasks and cannot do much if they are assigned to work with hypersonic missiles. Those researching hypersonics can have good intentions by looking for how to advance hypersonic technologies, however they do not have full control over how their findings are used.

The method that I will be using to explore my research question is tracing networks of relationships, otherwise known as Actor Network Theory (ANT). This will involve identifying the actors involved, how they connect with each other, where power flows, what actors are considered necessary, who is left out of the network. Due to the technology being relatively new this is a good method/ framework because it explores all the moving parts, both human and non human. Actor network theory allows for a greater understanding of the technology and the effect it has on society. Identifying obligatory passage points is also crucial, although sometimes it can be challenging. Obligatory passage points are actors that must be in the network for it to function. The real power lies in how these actors are interconnected (Sismondo, 2009). I will be able to use the network to

define the roles that these actors play. Lastly, I will consider how to mobilize the points in the network to overcome challenges from other networks.

As discussed, I have established a research plan for my STS project. Currently, I have found primary sources which will help me answer my research question. Four of these primary sources and their arguments will be analyzed in the following section. Moving forward my goal is to gain additional sources to further support my findings so far and also begin to incorporate the method and frameworks that I discussed.

IV. Key Texts

In this section I will cover four primary sources, their arguments made, and why they are important to my STS project. These four sources are not the only ones that I will use for my STS project, but they are essential to begin to explore my research question.

The first key text is an article by the Harvard business review, which includes an interview with Gregory Hayes, the Raytheon CEO. In this interview Gregory Hayes speaks on the role of Raytheon technologies in the Ukraine war. This article makes it clear that Raytheon technologies is an important player in the missile distribution for the Ukraine war. This text is important to my STS project because it established that Raytheon Technologies is involved in global conflict around the world that have ethical impacts. Ultimately, this text provides information that supports the decision of analyzing Raytheon Technologies.

The second key text is a technical report written by the Naval Postgraduate School and Raytheon Technologies. This technical report is about an investigation of the current impacts and limitations of ethical policies on design , development and deployment of unmanned undersea weapons. Although this report focuses on undersea unmanned systems there are ethical principles that Raytheon technologies explores. Toward the end of the report there are recommendations made

to gain ethical control. This report is important to my STS project because it provides insight into how raytheon technologies views ethical issues with new technologies that have life threatening impacts.

Next, I chose a chapter from the book, "*Research Handbook on the Arms trade"* written by Andrew T.H. Tan. A section in this chapter evaluates how the character and conduct of warfare will change as a result of the increasing pace of military operations with key importance placed on emerging threats posed by hypersonics. As stated by the Raytheon Technologies CEO in the first source, Raytheon plays a big role in current global conflicts. This source will help me explore the effects of Raytheon Technology supplying hypersonic missiles. This is important for my STS project because it is important to consider the future impacts of decisions made by raytheon technologies in the present day.

Lastly, the Raytheon ethics and compliance website plays a vital role in my STS project research. The website includes their 5 company values, resources and initiative, enterprise risk, and anticorruption policies.This text provides information straight from Raytheon Technologies about their company values. In the global trade section of the website, there is a statement on their operations with Russia due to the Ukraine war. This will fit in well with the first text that was listed because it will provide more background as to how and why Raytheon is involved in the Ukraine war.

References

Brutzman, D. P., Blais, C. L., & Wu, H.-F. (2020). *Ethical Control of Unmanned Systems: Lifesaving/Lethal Scenarios for Naval Operations* (p. 104) [Technical]. https://apps.dtic.mil/sti/pdfs/AD1118298.pdf

Caldwell, S. (Ed.). (2023, August 23). *What are SmallSats and CubeSats?*. NASA. https://www.nasa.gov/what-are-smallsats-and-cubesats/

Davis, M., & Tan, A. T. H. (2020). Technological change, future wars and the arms trade. In *Research Handbook on the Arms Trade* (p. 456). Edward Elgar Publishing.

Definition of HYPERSONIC. (2023, October 19). Merriam Webster. https://www.merriam-webster.com/dictionary/hypersonic

Endurosat. (2018, June 20). *Endurosat User's Manual.*

Ethics and Compliance. (n.d.). Retrieved October 28, 2023, from https://www.rtx.com/who-we-are/ethics-and-compliance

NASA. (n.d.). *Core flight system*. NASA. https://cfs.gsfc.nasa.gov/

OpenC3. (2023). https://openc3.com/

Raytheon CEO Gregory Hayes: How Ukraine Has Highlighted Gaps in US Defense Technologies. (2022, March 25). https://hbr.org/2022/03/raytheon-ceo-gregory-hayes-how-ukraine-has-highlighted-gaps-in-us-defense-technologies

Sismondo, S. (2009). Actor Network Theory. In *An introduction to science and technology studies* (2nd ed., pp. 81–92). Wiley.

TImada. (n.d.). *Timada/raspi4_freertos: FreeRTOS UART sample porting to Raspberry Pi 4b.* GitHub. https://github.com/TImada/raspi4_freertos

UVA MAE 4700 2023 Students. (2023). *HEDGE Critical Design Review*.

Winner, L. (2009). Do artifacts have politics. *Readings in the Philosophy of Technology*, *251*.

Woodford, C. (2021, August 19). How does a wind tunnel work? Retrieved from https://www.explainthatstuff.com/windtunnel.html