HYPERSONIC REENTRY DEPLOYABLE GLIDER EXPERIMENT

HOW HAS THE COMMERCIALIZATION AND INCREASE IN ACCESSIBILITY IN SPACE IMPACTED THE ENVIRONMENT?

A Thesis Prospectus
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By
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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

“Space is too important of an arena for science, humanity and the environmental movement to allow it to become a playground for competing billionaires” (Briscoe, 2022). In 2020, Virgin Galactic’s CEO divulged his long term goals for his company, to send 400 space tourist flights per year (Sheetz, 2020). Similarly, Elon Musk, tweeted that the goal of the Starship vehicle is to launch three vehicles a day (Musk, 2020). Other companies, like Blue Origin, are also participating in this billionaire space race. These space flights are possible because space is more affordable now (Coykendall, 2023). In fact, my technical project, Hypersonic ReEntry Deployable Glider Experiment (HEDGE), is a CubeSat, which is a small satellite. The mission of HEDGE is to collect hypersonic flight data during the reentry into earth’s atmosphere, allowing us to perform relatively low-cost hypersonic research. Cubesats have allowed for students to earn hands-on experience for building spacecraft, and allowed for scientists to perform low-cost experiments in space (Costa, 2023). This technical project along with the billionaire space race, has led me to ask the question, how has the commercialization/increase in accessibility of space impacted the environment? This last year, 2022, had the most successful rocket launches ever, that being 186 which is 41 more than 2021 (Coykendall, 2023). With the significant rise in rocket launches, there is bound to be some environmental effects. In this paper I will discuss my technical project, my plan for researching the environmental effects due to the rise in space commercialization, and the key texts I will be using in my research.

Technical Project

I. Problem Outline

The Hypersonic ReEntry Deployable Glider Experiment (HEDGE) is a CubeSat that will be launched into orbit and 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.

II. Objective of Research Work

The main objective of our research 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.

III. 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.

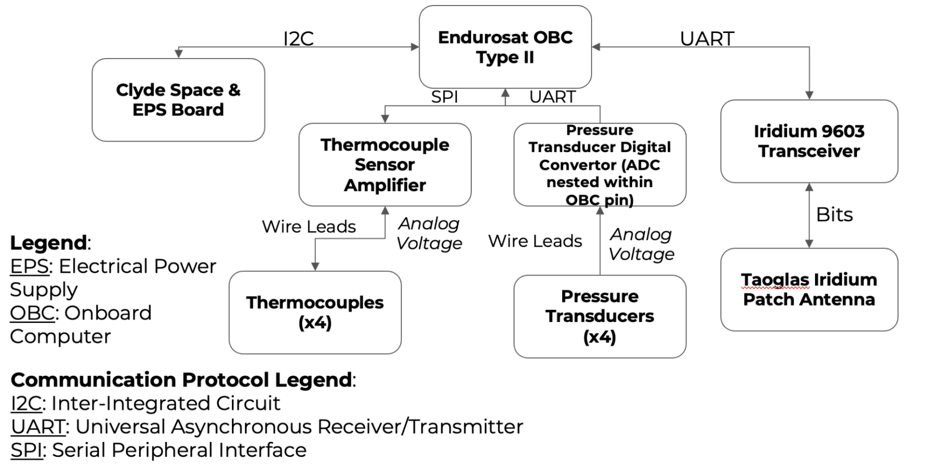

Figure 1: Hardware data flowchart (UVA MAE 4700 2023 Students, 2023)

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.

IV. Resources

For command and control, the Endurosat onboard computer will be used. The Endurosat onboard computer user manual is a great resource which 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, NASA's core flight system, a reusable software framework, will be used due to its reliability and portability (NASA). The COSMOS operating system will be used to set up the ground-based system and also run simulations software and hardware components (OpenC3, 2023). Both CFS and COMOS are open source, which allows for collaboration with others. University of Virginia professor, Mike Mcpherson, has lots of knowledge and is a great resource.

Lastly, the 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.

V. Objectives for Spring Semester

By the end of the Fall 2023 semester, the Software and Avionics team plans to deliver the hardware components for the MSP300 pressure transducer and the RockBLOCK9603 Iridium transceiver module for hardware. Because the OBC will not be in person for testing until the Spring, the software that the team plans 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. In order to be certain that components are working properly, a testbench for both hardware and software will be created. OpenC3 COSMOS provides a framework for cubesat testing that the team plans to utilize to create an exhaustive set of tests that accurately simulate the working environment of the satellite (OpenC3, 2023). Alongside these objectives, the team plans 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, the software and avionics team 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.

STS Topic

The space industry has changed dramatically since the start of the Space Race. In the past, the space industry was focused on providing national security for the government mostly run by NASA (Twiss, 2022). Now, there is a large private space industry that is looking to capitalize off of space. The specific technology I will discuss are spacecraft. As stated in the introduction, my question is, how has the commercialization/increase in accessibility of space impacted the environment? This is an important question because the space industry is growing rapidly with companies like Starlink planning on launching 42,000 satellites (Clark, 2022).

There are a couple of relevant social groups involved in this research question. There are the companies that are creating these space tourism and commercial space technologies like SpaceX, Starlink, Virgin Galactic, and more. They are the ones who are profiting off of space technology. The governments and policy makers are another social group. They create regulations for space technology and monitor the impact they have on the earth. Examples of this social group are the United Nations, the Federal Aviation Administration, Environmental Protection and Agency, and other countries' governments and policy groups. The scientific community is another and they perform the research on the environmental impacts of modern space technology. The consumer is also a social group. They are who will use these technologies directly or indirectly. They are being left out of this paper because they are not central to the argument. The social groups will help paint a picture of how space technology affects not only the environment but the impact on everyone. Space technology in the past focused on learning more about how the universe works, or studying the climate patterns on earth to help with climate change (Dunbar, 2023). Now, modern space technology has different purposes, to make money.

In order to research this topic effectively, I will be using the Actor Network Theory (ANT) STS framework. This framework identifies the actors of a system and holds them all at the same level, so that essentially each actor can affect the network (Sismondo, 2009). The actors in my paper are the companies, governments, spacecraft, environment, and the scientists researching this problem. Companies like SpaceX, Starlink, and Virgin Galactic, are looking to make money with these space technologies, whereas the scientists' goals are to increase knowledge about how space technology impacts the environment. The government's goal should be to protect people, but can also be to help companies thrive. To summarize the connection between these actors; companies are creating these space technologies to make money with little or no regard to how it impacts the environment, scientists are researching how these technologies impact the environment so that government/policy makers can create policies based on the knowledge they find. Companies can also influence the government to prohibit the creation of restrictions on space commercialization, which is something that I am planning on researching more for the thesis. My next steps will be looking into previous cases where technology has caused environmental harm and how government bodies reacted, as well as identifying different government bodies that have different motives in space commercialization. I will use scientific research papers and reviews to have quantitative evidence of exactly how and how much modern space technology is impacting the environment. I will also use policy and regulation documents to show how the lack of policies are allowing companies to launch as much as they want without concern for the environment. In order to answer the question in full, the next step is to understand the current research of the environmental impact of past space technology, then move into understanding the current research of modern space technology, the policies and government bodies associated with both.

Key Texts

This section will discuss the main sources that will help answer the research question.

- "Environmental Limits to the Space Sector's Growth" by Loïs Miraux.

- This review talks in detail about the main environmental impacts of space technology, including space debris, night sky pollution, rocket emissions, and stratospheric ozone depletion. This text argues that the limits of space technology are not only of a technological and economical type, but there also exists an environmental limit. This is an important argument because as technology progresses and as the economics of space technology works itself out, the companies pursuing commercial space will not factor in the environmental impact their technology has.

- "Potential climate impact of black carbon emitted by rockets" by Ross, Mills, and Toohey.
    - This study investigates the new type of hydrocarbon rocket engine, and its environmental impact. The research included a 40-year climate simulation that shows how the hydrocarbon rocket launches planned by space tourism will impact the earth's atmosphere. Their results show that there is a major impact of space tourism's future use of hydrocarbon engines on the environment. This is an important text because it quantifies how space tourism might impact the atmosphere, and gives reason to government agencies to create regulations on rocket engines.
- "The Policy and Science of Rocket Emissions" by James A. Vedda and Martin Ross.
    - This paper speaks about the environmental concerns of the combustion emissions from rocket engines, and lays out current policies in the aerospace industry. This paper also argues that there should be more research in launch emissions so that there can be regulations created regarding rocket launch emissions. This is an

interesting paper because an aerospace company that helps to create space technology published it. This paper is important because it not only educates on the different ways rocket launches impact the environment, it also highlights the public perception of these rocket launches and their environmental effects and how the perception has led to no motivation to create policies and regulations. This paper will help to connect the different actors and stakeholders in the thesis project.

- "Impact of Rocket Launch and Space Debris Air Pollutant Emissions on Stratospheric Ozone and Global Climate" by Ryan, Marais, Balhatchet, and Eastham.
    - This is a research article on the impact of rising space tourism on the earth's atmosphere. It specifically discusses the impact that space debris has on the earth's atmosphere. This article is important for answering the research question posed in this prospectus because it provides quantitative measurements of space debris on the environment. With an ever increasing number of spacecraft orbiting in space, there is an ever increasing space debris problem. This key text will help declare the level of impact space debris causes.

Resources

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