Program Management for Hypersonic Reentry Deployable Glider Experiment (HEDGE)

(Technical Paper)

Analysis and Impact of US Hypersonic Spending

(STS Paper)

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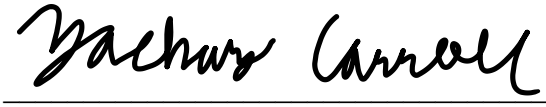
On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature  Date 11/28/2022
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Introduction

The United States Department of Defense (DOD) lists hypersonic innovation as a "high priority." (Wasserbly, 2022) Hypersonic flight is flight within the atmosphere above Mach 5. However, hypersonic development is expensive. Developing and finding inexpensive new ways to evaluate hypersonics will allow the DOD to catch up to Russia and China in terms of hypersonics without wasting substantial amounts of money. Lowering the cost of hypersonics testing also allows University Students to get firsthand experience in an area important to many defense contractors where they would potentially work. For my capstone and technical prospectus, I will discuss the Hypersonic Reentry Deployable Glider Experiment (HEDGE) we are building in class. HEDGE will attempt to address the current problems in hypersonics and offer low-cost hypersonic testing while also allowing university students to get firsthand experience. HEDGE uses low-cost Cube Satellites (CubeSats) small 10x10x10 centimeter cubes to demonstrate hypersonic flight. After being launched into extreme low earth orbit HEDGE will naturally deorbit within a week and reenter the atmosphere reaching hypersonic speeds while transmitting relevant data. The craft will then burn up in the atmosphere to easily comply with regulations.

My science technology and society (STS) prospectus discusses the department of defense funding regarding hypersonics. Currently, we are behind Russia and China in terms of hypersonic weapons but spend billions of dollars a year on research for not yet operational weapon developments. In this section I will discuss why DOD spends so much on hypersonics relative to the civilian sector and then justify or discredit the current DOD budget for hypersonics.

Technical Prospectus

Introduction

There are six different functional teams in our class working together to design HEDGE. Communication between six different teams and thirty different people poses inherent challenges. To successfully complete our project, we will have to ensure that the teams are communicating effectively. On top of that, the program management team also manages the financial and compliance aspects of HEDGE. As a university program, we will need to secure funding to build and launch HEDGE and make sure our vehicle complies with all current regulations.

Objective of Research Work

Overall HEDGE has three primary objectives and two secondary objectives. The primary objectives are as follows: demonstrate the feasibility of affordable CubeSats as a platform for hypersonic glider flight research, demonstrate an extremely low-cost materials screening method for hypersonic flight conditions, and show that undergraduate students can conduct hypersonic glider flight experiments at lower cost and with greater accessibility than traditional programs. The secondary objectives of HEDGE are as follows: integrate undergraduates into industry, government, and university partnerships evolving complex system engineering and program management with multiple stakeholders and to help with STEM and hypersonic outreach to community and potential engineering students. The objectives are less focused on the technical data collected from HEDGE and more concerned with demonstrating the feasibility of a new type of hypersonic vehicle. This year, as the program management team, we will lead the functional teams to a successful and accurate critical design proposal at the end of the school

year. After completion we will ask for funding from the DOD for future year's capstone students to evaluate and launch the experiment.

Technical Approach

Program management at its heart is "managing a group of projects or a program in a way that the final delivery is aligned with the strategic goals" (Brown, 2022). Our program management team is unique in that it has three specific functions that are all intertwined. The first function is the management of the capstone class, working as the leader of the functional teams ensuring everything is on track. The second function is compliance, or space law, working to ensure that we are within federal and DOD CubeSat regulations. The third function is finance, working to track and ensure everything related to money. This section will break down the approach, resources, and individual outcomes for each section of our functional team.

The management aspect has two main functions: to ensure functional teams have well defined goals and to help functional teams communicate efficiently and effectively to accomplish those goals. Currently there are several measures taken by our team to accomplish this. First, we are implementing class-wide discussions, including all functional teams, each week to track progress from each team and help all teams stay up to date with other teams. These discussions will be brief and informal, discussing what each team has been working on, their progress on goals, any questions they have, and what teams they need to communicate with. Utilizing this will help limit communication breakdowns between functional teams because every week all teams will be up to date with any changes other teams make and on what they are working. We are also implementing class-wide communication software in the form of Discord to help communication between teams. Discord is an instant messaging social platform used by many school clubs. It allows easy communication between all members and lets users set up channels

that let each functional team communicate with each other. Throughout the semester we will monitor the efficacy of Discord and may change our primary form of inter-team communication. We are fortunate that the entire class meets in person twice every week, which allows for frequent in-person communication between all the teams.

Compliance for HEDGE has a few main goals: communicate the necessary licensure and regulations to the functional team leads where applicable, be available to answer all questions from anyone on the project about compliance, check designs against current regulations and suggest improvements, begin the licensure process, and create a list of resources available for the project team to access. Completing these tasks involves research by the program management functional team as well as effectively communicating both verbally and in established channels to the other members of the project. In the design and brainstorming process, the compliance officer will be available as a resource for other groups to use so hopefully they design with project compliance in mind. One of the main things the compliance officer wants the rest of the class to know is the basics of the CubeSat standard and to have looked over it at least once. Below are the standard CubeSat sizes, one of the many CubeSat regulations we will consider when designing HEDGE. We will use the 3U as our size constraint.

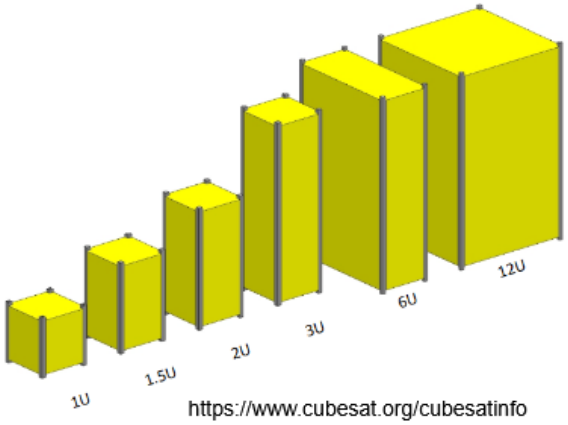

Figure 1. Size comparison of the standard CubeSat sizes, from the CubeSat Standard document (Cal Poly, 2022).

Lastly, the project management team will have a Chief Financial Officer (CFO) that will be responsible for the finance of HEDGE, including tracking cash flow, financial planning, providing strategic recommendations, identifying, and addressing risks, and keeping up with financial records and documentation. To produce an estimated cost for our mission, we will first establish assumptions and ground rules to develop the overall scope of the project. Once the ground rules have been identified, we will build a Work Breakdown Structure (WBS) diagram which starts with the broadest scope and branches out into many subsections until every aspect of the mission has been acknowledged (NASA, 2015). We can then use cost estimating models provided by the Spacecraft Design textbook to estimate each of the elements in the lowest layer of the WBS, and then can roll each layer upward to reach a final overall cost estimate (Wertz et al., 2011). We will then document all findings in a financial report which will be submitted to the DoD for funding approval.

Available Resources

Regarding the program management team, the University of Virginia's Aerospace Engineering department has given us approximately $4000 which can be budgeted to support any of the other functional teams in their research and development. This funding can be used for instrument testing, lab or facility use, or prototyping. As far as communication, we have the privilege of using excellent free software that can easily link members together in an organized manner. Applications such as Discord will be crucial in organizing the communication of each team in one organized server. Google Drive will help us organize our files so that the program management team can track the progress of each functional team.

STS Prospectus

Throughout history supersonic flight has been reserved exclusively for government use. Only two commercial planes have gone faster than the speed of sound, and only one was consistently flown throughout its lifetime. (Heppenheimer, 2007) Today there are no commercially available supersonic aircraft for civilian use, but there are several companies working on bringing supersonic flight back to the public. However, when the conversation moves to hypersonic civilian aircraft the scene drastically changes. There are no civilian applications of hypersonics. This is due to two things, money, and size. Hypersonic flight has historically been extremely expensive and large-scale hypersonic flight will continue to stay that way. (Lofgren, 2022) Secondly, hypersonic aircraft must be small and streamlined to reduce drag. This reduces the number of people or cargo that can be transported. Combined these two factors make civilian hypersonic flight a horrible business strategy.

Alternatively, there are numerous applications of hypersonics in the military. One major driving force behind the use of hypersonics missiles is their ability to avoid detection and interception. Hypersonic missiles travel low enough to avoid early detection and fast enough to render missile defense systems obsolete. Globally, many of the United States main adversaries are investing in hypersonic research. (Sayler, 2022) Tong Zhao, a Fellow at the Carnegie-Tsinghua Center for Global Policy, “China’s pursuit of hypersonic weapons, like Russia’s, reflects a concern that U.S. hypersonic weapons could enable the United States to conduct a preemptive, decapitating strike on China’s nuclear arsenal and supporting infrastructure. U.S. missile defense deployments could then limit China’s ability to conduct a retaliatory strike against the United States.” (Sayler, 2022) Clearly China recognizes the strategic power of hypersonic missiles. However, they also understand that by developing their own hypersonic

program they can practically bypass US missile defense, forcing the United States to protect itself under the concept of mutually assured destruction rather than superior technology. If both China and the US have reliable hypersonic weapons both sides are deterred from attacking under the concept of mutually assured destruction as hypersonics all but guarantee that missile defense systems would be irrelevant. However, the US is currently behind Russia and China regarding hypersonic weapons (Johansen, 2022). This shifts the balance of power to China and raises concerns that China may be able to defend against US missile attacks but not the other way around. Missiles are not the only aspect of our large military, or nuclear triad, and the United States can deter China in other ways. The US has strong allies, the ability to implement harsh sanctions, and a strong conventional and nuclear military. Combined these aspects deter China from a first strike against the US. However, is this enough to deter China from invading Taiwan? But matching China's hypersonic technology and arsenal would only help the US and its allies achieve their goals.

In 2023 the US will spend 4.7 billion dollars on hypersonic research, development, testing, and evaluation, up from 3.8 billion in 2022. The pentagon has also called hypersonics a "high priority" for the DOD. (Wasserbly, 2022) With the total budget for the DOD being around 770 billion dollars (Department of Defense, 2022) it would make sense that the US military is spending billions on something with high implications such as hypersonics. Based on their importance, but especially the fact that the US is behind Chinese and Russian developments, it is crucial to continue to invest in hypersonics research and the current increase in US hypersonics expenditure is more than justified.

Conclusion

This year for HEDGE we hope to complete a critical design review as well as submit design proposals to the Department of Defense and other contractors to gain funding and support for next year's HEDGE team. Our goal as the project management group is to help other groups communicate effectively and work together to achieve these goals on time and within budget. We want to make the next year of the project run as smoothly as possible and support the future engineers in their continuation of the project.

Currently the Department of Defense is the only US entity investing heavily in hypersonics research. Due to the increasing technological advancements from adversaries such as Russia and China, it is important that the US continues to gain the technical edge. However, it is important to consider the financial implications of hypersonics research and seek to develop low-cost ways to innovate, such as HEDGE.

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