HEDGE, Hypersonic ReEntry Deployable Glider Experiment
(Technical Paper)

How CubeSats Represents a Paradigm Shift in the Space Industry
(STS Paper)

A Thesis Prospectus
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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

The earliest satellites launched into space could be lifted on the tops of rockets by hand. As spacecraft technology developed, satellites grew. Now, 65 years since the launch of Sputnik I, thousands of satellites launched into orbit are significantly smaller and significantly more powerful. The space race was one of the most widely followed scientific and engineering ventures in the 1960's. Since the moon landing at the end of that decade, spaceflight languished from the public eye. 50 years of technological innovation has not been widely covered, all the while our everyday lives are significantly affected by the presence of satellite technology. Most people have little to no knowledge of modern-day satellite technology, and certainly not what forces brought about the advent of the wide adoption of CubeSats and microsatellites and their uses as inexpensive research tools. For large space missions with very large budgets CubeSats have the potential to be used as inexpensive base research tools to effectively screen materials and methods for possible future deployment. The proposed STS research paper seeks to explore the paradigm shift in why CubeSats and microsatellites are widely used today as research tools.

The proposed technical report is a project using a CubeSat to cheaply research hypersonic glide characteristics and my team's role as the program managers.

Right now, there is not an affordable method for testing a vehicle in hypersonic conditions. Hypersonic conditions mean the fluid flow around the vehicle is higher than Mach 5. Typically, these conditions are seen on reentry from orbit and in hypersonic weapons (Anderson, 2012). More testing is needed in hypersonics to better devise models for how materials and structures will operate in these conditions. Better models will help develop next generation orbital reentry vehicles.

Technical topic

The United States Department of Defense (DOD) lists hypersonic innovation as a “high priority”. (Wasserbly, 2022) However hypersonic development is extremely expensive. Russia and China have already included hypersonic missiles, carrying nuclear and conventional warheads, in their arsenals for over 5 years. (Acton, 2015) Developing and finding inexpensive new ways to test hypersonics will allow the DOD to catch up to Russia and China in terms of hypersonic weapon technology without wasting large amounts of money on testing. Lowering the cost of hypersonic testing also allows University Students to get hands-on experience in an area important to many defense contractors where they would potentially work. HEDGE will attempt to address these problems and offer low-cost hypersonic testing while also allowing university students to get hands-on experience with a previously out of reach technology. HEDGE utilizes low cost, standardized Cube Satellites (CubeSats) which are10x10x10 centimeter cubes that will demonstrate hypersonic flight upon reentry to Earth's atmosphere. 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 comply with federal space regulations.

There are six different functional teams in MAE 4690 Spacecraft Design I working together to design HEDGE. Each team focusses on a different set of components for the spacecraft. The teams are: Structures and integration; Attitude Determination and Controls; Power, Thermal and Environment; Communications; Software and Avionics, and Program Management. This proposal is being written by the members of the Program Management team, whose role is to manage the 5 other functional teams and deliver a compliant product on time and under budget.

Communication between six different teams and 30 different people poses inherent challenges. To successfully complete our project, we will have to ensure that the teams are communicating effectively. The program management team also works to set and define the goals and technical objectives of HEDGE. On top of that the program management team also manages the financial and legal 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. The program management team is responsible for working directly with the professor to begin the process of pitching the project to industry and securing approximately $75,000 in funding.

STS Topic

Background

Sputnik I was launched in October of 1957, it was the size of a beach ball and was only capable of sending out beeps on radio waves telling the people on earth that it was in fact in space and flying above their heads (Rogers, 2019). That launch was soon followed by Sputnik II and then the US's Explorer I and Vanguard I. The launches after Sputnik I could take atmospheric measurements and relay them back to Earth. Their primary goals were to gather more data about the earth's elusive upper atmosphere. In the 10 years, NASA and the USSR's Soviet Space Program (SSP) sent dozens of man-made satellites into earth orbit. All the while building a body of knowledge and an industry to support it. These efforts by the United State and the USSR were the beginnings of the space industry.

In the US, rockets were designed by NASA engineers as well as contractors from major companies like Rocketdyne, IBM, and General Motors (Kluger, 2019).

After Apollo, the United States saw a boom in satellites launched into space as a result the development of rocket technology from the previous decade (Heyman, 2009). The United States Department of Defense was one of the largest organizations putting satellites in the sky with things like spy satellites, communication satellites, and GPS (Heyman, 2009). Only large companies could possibly afford to put something into orbit, like AT&T with the Telstar 1 (Smith, 2010). Satellites of this era were large and expensive. The cost per pound to put something into orbit in the 1970's was between 20 and 50 thousand dollars (Roberts, 2022). In the 1980's and 1990's many of the satellites the US took to orbit were done so in the cargo hold of the Space Shuttle. The space shuttle was an incredibly expensive method of getting into space but due to political pressures and promises that it will get cheaper over time, the United States continued to use the space shuttle are their primary space launch system. Satellites like the Hubble Space telescope were taken to their orbits this way and many sections of the International Space Station took rides on the Space Shuttle. However, due to the high cost of a launch, mainly large satellites could fly on the shuttle, and small computer components just were not powerful enough yet to be made practical for a mission to space.

How have CubeSats and microsatellites facilitated a paradigm shift in the aerospace industry? I plan to analyze this research question using the theory of Paradigm Shift. This theory will help the reader understand the actors and stakeholders relevant to this problem and show how they have changed over time to become what they are now. There have been large changes to the space industry since its inception, many that have brought paradigm shifts to how engineers create and launch satellites. I will look at the development of CubeSats in the late 90's and track the subsequent change and adoption of CubeSat satellite technology and show how they have drastically changed the satellite industry. Standardization of CubeSats have allowed

for the cost of developing a basic satellite to decrease greatly, opening access to space to more companies and universities. The rapid decrease in the cost of going to space with technologies like the SpaceX self-landing first stage rocket has made it cheaper than ever to send something into space. (Humphery, 2010)

I think that paradigm shift works well for analyzing CubeSats and how they have disrupted the aerospace industry because they were a technology that was developed well into the maturity of the industry, and they have seen huge growth in the last two decades.

I think that paradigm shift works for understanding how one technology has changed and shaped an industry but is limited in the perspective on the entire industry. If the reader is trying to understand how the satellite and space industry work, paradigm shift doesn't provide enough information to understand.

Research Question and Methods

Research Question: How have CubeSats and microsatellites facilitated a paradigm shift in the aerospace industry?

First, I will introduce the background of the space industry from its beginnings to when the CubeSat was first developed. I will track the development of the CubeSat and the number of launches. This is to understand how the contents of space launches have shifted over time. It will also be important to know the cost per pound to go into space each year and to understand how the size and weight of computer components affects the size of satellites launched. I will also get the data on number satellites launched each year. This will help inform what is going to space and who is sending it, as access to space is a very important change to analyze with paradigm shift. As well as the number of CubeSats and microsatellites launched each year. I

will also then show what organizations are launching these CubeSats and what they do with them. I will show that these are new uses for space technology by finding the novel things that organizations are doing with CubeSats. I will then show that these things would have not been possible with previous satellite technology.

Conclusion

The name the technical capstone project is HEDGE, which stands for Hypersonic ReEntry Deployable Glider Experiment. We are developing a platform to study hypersonic reentry based around an inexpensive CubeSat that will hopefully bring the cost of base research in hypersonics down tremendously. When HEDGE launches, we will demonstrate that a group of university undergraduates are capable of working a hypersonic technology and gathering data in an extremely harsh environment.

For the STS research paper, I am writing about how CubeSats have represented a paradigm shift in the larger space industry. At the end of the thesis it should be clear as to why so many universities and companies use the standardized CubeSat designs and why large satellite missions are becoming more and more rare.

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