Hypersonic ReEntry Deployable Glide Experiment (HEDGE) Communications, Ground and Space

The Consequences of Cooperation and Competition between Nations and their Goals in the Space Domain

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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

In the past century, we have seen some of the greatest advances in technology, especially in the field of aerospace. This progress is epitomized by the span between the Wright brothers' groundbreaking flight to humanity's first steps on the moon. The time between these two significant historical events is only 66 years. In this short time they have been able to make the tremendous leap of barely getting off the ground to then entirely leaving the atmosphere and getting a man on the moon and back. But what is driving these feats of innovation? There can be many reasons to want to push the boundaries of what is possible, but the manner in which you go about advancing technology can change the speed of the progress. There can be the motivation of competition that increases innovation and growth or there can be the cooperation factor. The goals of nations are also a very important part to look at when seeing the impacts of cooperation and competition. My paper will answer whether cooperation or competition is the better way to advance space research and human progress. In this paper, there will be a look into how competition impacted technology during the space race, and how cooperation nurtured progress such as with the ISS, as well as the factors that drove these different strategies of development due to the goals of the nations involved.

The technical project that I will be working on this semester and the next, is HEDGE. HEDGE stands for Hypersonic re-Entry Deployable Glider Experiment, and is, most simply, a CubeSat. A CubeSat is a small satellite that can be cheaply sent into the atmosphere due to its small size. It can be used for a variety of purposes. Our CubeSat however, will be deployed and sent through the atmosphere in an hypersonic reentry maneuver. This CubeSat will begin collecting data about its reentry, sending that information back down to the Earth, and then disintegrating in the atmosphere. I am part of a team working on the communications side of the project. I am the team lead that will help design and put together the system of components required to translate data into a radio frequency signal, send it to an Iridium satellite, which then relays it back to the ground station for data analysis. When looking at what would cause us to speed up our development of the design, one can see how if we were actually competing with another CubeSat team, we would work much faster than we are doing now. One could also see how if we were to work with another university, progress could also be sped up and our design could be better.

My STS project focuses on that very idea from the previous paragraph's last few lines. The STS project looks at it at a much larger scale and looks at real events that happened in history. The driving factors and goals for the nations involved are also much more complex and elaborate than doing a school project. We will specifically look at the Space Race, between the United States and the USSR, for effects of competition, and compare them to the effects due to cooperation and look to the ISS as an example. When deciding what is a better motivator for driving innovation, we should also look at what each nation wants to accomplish during that time. This is important because realizing a clear better option can help shape relations between nations and decide what is best for technological innovation.

Technical Project

The United States is quickly trying to catch up to years of advancements of other world powers such as China and Russia in hypersonic technology, especially in the field of international warfare. According to Air Force General Glen D. VanHerck, "hypersonic weapons are extremely difficult to detect and counter given the weapons' speed and maneuverability, low flight paths and unpredictable trajectories." (Vergun, 2023)[1] Hypersonic weapons, as defined by the Voice of America, are weapons that, "fly at speeds of at least Mach 5" (Seldin, 2022)[2]. These weapons can be used for defense and offensive capability and can provide the country that welds them a significant advantage as they are extremely hard to detect. Because of the staggering difference in the progression of hypersonic technology between us and other foreign countries, the question becomes *what can be done to catch up within the next decade*. CubeSats have become an emerging technology over the past few decades for their ability to put cutting-edge experiments into space for a reduced price by creating a standard form factor for these experiments and reducing the costs for new parts for each experiment.

For our technical project, we will be working with Professor Goyne on the Hypersonic ReEntry Deployable Glider Experiment (HEDGE). This is a CubeSat that will test new materials and their ability to re-enter the atmosphere. Our role within the project is working on the communications subteam to ensure that the data collected from the experiment can be received on the ground.

The focus of our project is to get the CubeSat to reenter into Earth's atmosphere at hypersonic speeds, which will then allow us to collect data on how hypersonic speed conditions on reentry affect different materials. We will collect data as the CubeSat is speeding through the atmosphere and send it up to an Iridium satellite. This satellite will send the information collected back down to us on the ground for processing and analysis.

Our more specific role in this project entails working on the communications aspect of this CubeSat. We are working on data transmission through an antenna on the satellite and working to set up a successful way to recover this data using an Iridium relay satellite. We are exploring and enhancing the communication systems of the CubeSat, ensuring reliable data transmission and reception during the crucial phases of re-entry, thereby contributing to the overall understanding of material behavior and enabling more efficient data acquisition for future space exploration missions. Some of the challenges of this include the design of the circuit boards and on board computer for data translation, placement of the antenna on the CubeSat for optimal signal directing, data collection on the ground, and the external factors such as heat that could affect the mission.

Our initial approach involves the precise calculation of the required data transmission rate that aligns with the functional objectives of the communication team, collecting 8 measurements, compiling them, and sending them out every ten seconds. The first step of the process consists of reviewing the previous class's determination. It was found that 4 thermocouples and 4 pressure transducers on the spacecraft would provide readings, each measurement being 2 bytes. After calculations, they got a total of 53 kbytes transmitted over a period of 16 days. We can use this information to then start our process of proving that all requirements are met.

The next approach we will take is to ensure a 100% transmission coverage. However, there are a few issues that we will need to address first. The base design of the cubesat currently has the antenna facing behind the cubesat. The Iridium Communications Satellite that we will be using though has satellites in orbit that are facing straight down as they are optimized for complete coverage of the surface of the Earth (Maine et al., 1995)[3]. The beams on the satellites spread out as they get closer to the surface which means that the closer to the satellite, the less area the beams cover. When the cubesat is first launched into space, it will be in a fairly circular orbit resulting in the antenna facing behind the satellite. An image of the one example Iridium satellite and HEDGE after initial deployment can be seen in Figure 1. While the antenna being used is fairly omnidirectional, which means that it should be able to send a signal in any direction, the fins of

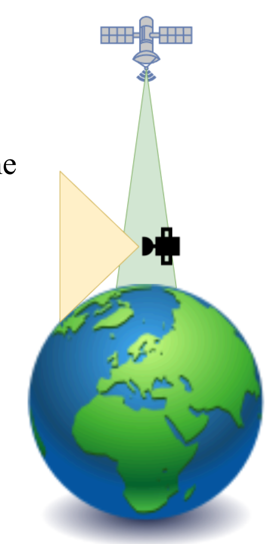

Figure 1: (Draw.io)

HEDGE are made out of inconel which means testing needs to be completed to see if the signal will be able to penetrate through it. The second main challenge is to ensure that HEGE will be able to stay in contact with Iridium Satellites while it is re-entering through the atmosphere. Some challenges associated with this include thermal heating of the antenna and transceiver and also keeping line of sight with the Iridium Satellites. Figure 2 shows the difficulty with keeping in contact with the relay satellites as their beams are cone shaped meaning that they cover less area closer to the satellites and there are larger gaps in the network as discussed above.

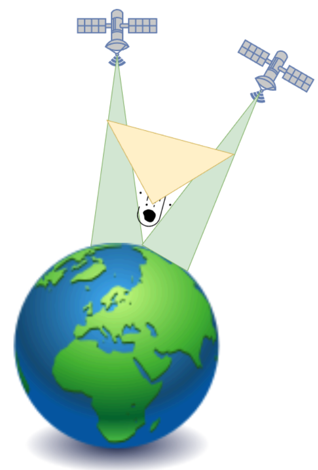

Figure 2: (Draw.io)

To enable a functioning communication system, the Iridium 9603 Transceiver needs to be linked with both the motherboard and an antenna. During the prototype phase, we'll integrate a custom communication circuit board from ECE students, enabling the antenna to link with the transceiver. As a backup, we'll employ the RockBLOCK 9603, combining the Iridium 9603 transceiver and a patch antenna in one unit. This RockBLOCK 9603 will establish a connection with the Raspberry Pi using a 10-pin Molex-style cable.

This connection to the Raspberry Pi facilitates the transceiver's ability to receive commands and access power. For the actual in-flight mission, we will affix the Taoglas IP.1621.25.4.A.02 patch antenna to a PCB board that incorporates a built-in ground plane. This will be accompanied by a U.fl cable that connects to the transceiver. The Iridium 9603 Transceiver is equipped with a Samtec low-profile header connector, which is designed to be attached to a Samtec header female socket. This configuration allows for the transceiver to be soldered onto a PCB, creating a connection with the on-board computer for the in-flight mission.

Some resources that are available for the capstone include both Professor Goyne and Professor McPherson. The cubesat design lab is also available and there are parts purchased last year including an Iridium 9603 and the Taoglas Patch Antenna. Also the team is fortunate to have four electrical engineering students working with the class this semester on the design and manufacturing of the boards and some basic software that will interface with the Iridium transceiver. This semester we will be working on finalizing placement of the antenna and working on testing to ensure the antenna will be able to connect with the Iridium constellation. Further components will be purchased once funding for the project is finalized and the team is cleared to proceed with integration.

Our Spring semester objectives focus sharply on the testing, assembly, and integration of the communications subsystem. The first primary focus on integration is with the Software and Avionics team, as we need to be able to test our transceiver for two conditions : the ability to connect with and transmit through the atmosphere to an Iridium satellite, and the ability to ensure reliable communications in a simulation of re-entry conditions. A vital part of this integration process is programming the OBC to automatically encode and send both our spacecraft vitals and sensor data. Additionally, we must ensure our OBC and communications protocols have layered redundancy through the implementation of error-correcting memory or error-correcting code. Successful tests of the above will demonstrate the ability to reliably communicate with HEDGE via the Iridium network. Additionally, we need to work alongside the Power, Thermal, and Environment team for the integration and placement of communication components and mounting. The antenna placement is of high importance here, as it needs to be able to resist the high temperatures while maintaining strong omni-directional broadcast characteristics.

STS Project

The question I will answer, with regards to competition and cooperation, is which style of motivation seems to be the most beneficial to research and advances in technology. These motivations varied based on the context, goals, and challenges of each approach. Firstly, I will research the competition motivator component. The competition between the US and the USSR had both positive and negative impacts on the development of space technology and the advancement of human knowledge. I will look deeply into the specific case of the US versus the USSR around the 1960s in the great space race. For the cooperation side of my research, I will look at all the contributions and advances made in the time of the ISS, as well as how cooperation limited progress.

When doing research on the Space race, I will look into the two main actors, the US and USSR. I will read different works to help myself better understand the history and their relationship at this time and how that developed into the Space Race. I chose this case study because they were in a cold war with each other, leading to a clearer and greater emphasis on competition. A non-human actor I will touch on is Sputnik. Sputnik scared the US about how advanced the USSR was. Khan Academy says that, "in response to perceptions of Soviet technological success, the National Aeronautics and Space Administration (NASA) was established on October 1, 1958" (Getchell)[4]. This means that the Sputnik actor affected the US and contributed to the creation of NASA. My research questions for this competition section include looking at how much money was spent, the timeframe of development, and what was developed. I will look at what exactly competition did to drive these certain factors.

I will also look briefly at what drove competition. People will go to work for the company that promises the most exciting and innovative technologies. So a big reason to be the first to the moon for example, was for recruiting. The promise of NASA and its goals are things that seem fulfilling and better to work on then something that another weaker or poorer country would not be able to spend the resources to do. Even before the space race there was competition between nations to produce missiles for the purpose of war. The U.S recruited many scientists from Germany after World War 2. The U.S wanted these scientists to help them develop nuclear arms. Michael Neufeld says that, "The aerospace specialists, who constituted most of the Paperclip program, were here to help the United States in the rapidly developing arms race with the Soviet Union" (Smithsonian, 2023)[5] . The driving factors of competition are important to look at but my main question is how did competition between the US and the USSR affect the development of space technology and the advancement of human knowledge? After answering this question, I will then talk about how progress of the human race was hindered during this competition phase. Such as how there was separate research and development between the US and USSR.

After talking about the benefits and drawbacks of competition, I will look at the side of cooperation and collaboration. The specific case to look at in space is going to be the International Space Station. There are many countries that have worked on it and in it. NASA says that, "The largest space station ever constructed, the ISS continues to be assembled in orbit. It has been visited by astronauts from 18 countries—and counting" (NASA, 2023)[6]. These 18 will be the main actors. I will talk about the main benefits such as the fact that research and development is done along with other nations rather than against them. There are benefits to this as well as negatives. One positive is the resources saved from having one ISS for all the countries that use it, rather than each country making and sending up their own research stations. One negative is that there is less urgency. There's no threat of another country beating yours if you are all working together. This causes a much more relaxed environment. The calmer nature of cooperation also leads to less mistakes as scientists are not rushed to complete projects or do calculations. I will try to find information to include on the amount of failed tests or operations during cooperation of the ISS and compare it to the amount during competition like with the Space Race. This will help look at the efficiency of each motivator. I will also do research to see all that has been discovered and created from the ISS and compare that to the inventions during the Space Race.

When looking to compare competition and cooperation, to see which is better, I will focus on different aspects. I will look at what is best for the nation and what is better for the human race. One could argue that competition can better the human race as both sides of the conflict are progressing fast and pushing forward innovation. Cooperation saves resources and promotes peace, which is also good for the human race. What is good for the human race, many may think, are things that do not necessarily include ideas of sending out things to space, and may think the money is better used elsewhere. However, many technological advances in space lead to gains for humans on Earth. Space exploration could also lead to major advancements for humans in the future when space travel is cheaper and space mines can be affordable and attainable.

My timeline for my paper is that I will find resources for the STS project throughout this semester and have a good understanding by the spring to write the final version. An effective method of writing I am going to use is compare and contrast. I will also use actor network theory. This is a good theory for my paper because I will look at the human actors, such as US's and USSR's governments, to see how they were driven to advance technology through competition. Then I can evaluate the non-human actors, Sputnik and the ISS, and see how they contribute to society and the advancements of technology.

Key Texts

International Cooperation & Space Exploration | Baker Institute. (n.d.). Baker Institute. https://www.bakerinstitute.org/research/international-cooperation-and-continuing-exploration-space

- This resource discusses the significant contributions made by various countries to the success of the ISS and how it serves as a model for international cooperation. This article also speaks more broadly about the effects of cooperation and why it is important. This will help me explain the benefits of cooperation.

International Space Station Cooperation - NASA. (n.d.). NASA. https://www.nasa.gov/international-space-station/space-station-international-cooperation/

- This article provides an overview of the international partnership that operates the ISS, highlighting the complexity and success of this cooperative endeavor. It talks about how the ISS is one of the most politically complex space exploration programs ever undertaken. I can use this to explain how cooperation can be done even if it is very complex.

Project Paperclip and American Rocketry after World War II. (n.d.). National Air and Space Museum. https://airandspace.si.edu/stories/editorial/project-paperclip-and-american-rocketry-after-world-war-ii

- This article helps show how scientists are recruited and used to advance one's own goals. It also explains how these scientists were used in the space race and how we wanted the

German rocket scientist so that other countries did not have them. It also touches on the USSR and the space race which is useful for my paper.

Space race timeline. (n.d.). Royal Museums Greenwich. https://www.rmg.co.uk/stories/topics/space-race-timeline

- This article documents the space race and gives good information of the timeline of events. This is important to help pace the development of technology and how far humans progressed during this time of competition rather than cooperation.

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