Undergraduate Thesis Prospectus

Future of Hypersonic Flight Experiments: The Convenience of CubeSats

(technical research project in Aerospace Engineering)

The Balance of National Security, Commercial Interests, and Individual Privacy

(sociotechnical research project)

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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General research problem

How can satellites best serve long-term social and environmental needs?

Starting in 1957, space technology has continued evolving both in infrastructure and in technology. Today, thousands of satellites orbit around Earth monitoring our planet. On one hand, satellites provide critical data for weather forecasting, global positioning systems (GPS), and environmental preservation. On the other hand, the Department of Defense invests in satellites for strategic advantages, protecting national security interests, and supporting the interconnected world. In the modern world, satellites play a pivotal role in all aspects of our daily lives and have a profound impact on global connectivity (Yu, 2022).

Future of Hypersonic Flight Experiments: The Convenience of CubeSats

What is the optimum design of a working mockup of a CubeSat to serve as a research platform for hypersonic glider flight?

In Spacecraft Design I, my capstone project is to develop a CubeSat to demonstrate the feasibility of using CubeSats in low-cost hypersonic glider flight experiments. With the help of my capstone advisor, Professor Chris Goyne, and the aerospace department, I will be collaborating with Idriss Shively, Tyler Spittle, Temidayo Akinbi, and Emmanuel Kenscoff to work on the communications of the satellite.

The United States is making rapid efforts to bridge the gap with other global powers in hypersonic technology, so a big question is posed: *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 to test and collect data on hypersonic technology performance. A CubeSat collects data when it reaches hypersonic speeds

during reentry into the Earth's atmosphere without the need for a propulsion system. (Poghosyan & Golkar, 2017). The University of Virginia's Hypersonic ReEntry Deployable Glider Experiment (HEDGE) uses CubeSats to collect data on how hypersonic speed conditions on reentry affect different materials. Communication systems are essential in this project to gather the collected data from the CubeSat. As the CubeSat is speeding through the atmosphere, the data collected will be sent to an Iridium satellite and then the information will be sent down to Earth for processing and analysis. The HEDGE mission depends on the successful transfer of the data.

We are working on data transmission through an antenna on the satellite and to set up a successful way to recover this data using an Iridium relay satellite. After exploring and enhancing the communication systems of the CubeSat, we will ensure reliable data transmission and reception during the crucial phases of reentry. The focus is to contribute to the overall understanding of material behavior and enabling more efficient data acquisition for future space exploration missions.

The class is split into 6 subgroups: Program Management; Software and Avionics; Power, Thermal, and Environment; Attitude Determination and Control System; ADACS and Orbits; Structures and Integration; and Communications. The project faces pressures because of the various teams working on different aspects, which raises concern about whether the other groups can successfully complete their respective sections.

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 will utilize the RockBLOCK 9603, which combines the Iridium 9603 transceiver and a patch antenna in one unit. The RockBLOCK 9603 will then establish a connection with the Raspberry Pi via 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.

By the Spring semester, our objectives focus sharply on the testing, assembly, and integration of the communication subsystem created in the Fall. The first primary 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 reentry conditions. A vital part of this integration process is programming the on-board computer (OBC) to automatically encode and send both our spacecraft vitals and sensor data. Successful tests of the above demonstrates the ability to reliably communicate with HEDGE via the Iridium network.

The Balance of National Security, Commercial Interests, and Individual Privacy

In the U.S., how have governments and privacy advocates competed to draw the line between legitimate and improper data collection via satellite?

The competition between privacy advocates and governments is an ongoing struggle to "align a legacy regulatory system with an increasingly diverse space environment" (Goessler, 2022). It involves ongoing discussions, legal battles, and regulatory efforts about the ethics of the new digital age. With the US government arguing that satellite data collection is crucial for

security, there is a growing concern that the government cannot protect individuals' civil liberties. The issue of government surveillance through satellites is complex and divisive with the numerous benefits it provides accompanied with many risks (Frąckiewicz, 2023).

Forms of Research

Former IBM Chairman and CEO Lou Gerstner once said, "What are the implications for individual privacy in a world where millions of people are driving Internet-enabled cars that have their movements monitored at all times?" Renenger (2002) investigated this quote and the newly developed GPS systems to understand the risks of satellite tracking and the right to privacy. He highlights a fundamental concern that relates to our modern, digitally connected world. It is concluded that there is a need of careful consideration of the implications of satellite-based tracking as Renenger (2002) contends that "only if a public trusts a technology can they truly come to rely on it."

Wasowski (1991) studied the historical aspects of international satellite remote sensing, looking at underlying concerns that rooted in the early military applications. The political, legal, and ethical issues surrounding international satellite remote sensing have a long a complex history. Wasowski (1991) states that in the early days of satellite launches, there were no notable objections over the potential violation of territorial sovereignty. However, the lack of protest about space activities should not be interpreted as a lack of serious concern. It should, instead, be interpreted as a lack of public knowledge on the relevant facts. In the end, Wasowski (1991) concludes that technology is ethically neutral, yet ethically significant due to the limitless opportunities it provides.

Goessler (2022) investigates employees of U.S. Space companies to understand the U.S. Space policy and law. One interviewee highlighted that the government's duty is to set the

standards and the operational side should be left to the private sector. However, another interviewee notes that, "Government policy is incapable of moving fast enough to stay in front of where investment is leading us." Two companies specializing in on-orbit servicing raised concerns about the governments capacity to effectively oversee their operations, given their involvement in niche, emerging technologies. Space is the future, and we must begin addressing the tough policy issues.

Participants

U.S. companies and research institutions that seek to launch private satellites must secure a license from the federal government, and with the increasing prominence of satellite technology, satellite companies are pushing the government to streamline the licensing process. Electric Frontier Foundation (EFF), an international non-profit digital rights group, works to urge agencies to take privacy into consideration when they issue satellite licenses. EFF believes that government access to sensitive information from satellites raises concern for the violation of the Fourth Amendment. To solve this problem, EFF suggests several changes to Department of Commerce's proposed rule of licensing to increase transparency and reduce potential privacy risks (Li & Lynch, 2019).

TS2 SPACE, a telecommunication service that offers the public use of satellites to send data, further explains the debate of the ethical implications versus the necessity of surveillance for public safety. TS2 Space believes that allowing governments to use satellites to track citizens is necessary for public safety and national security. To uphold public privacy, "it is important for citizens to be aware of their rights and understand how governments are using satellite technology to observe and collect data about them." With public understanding of satellite

technology, the advantages of satellite surveillance surpass the associated risks (Frąckiewicz, 2023).

The Brookings Institution is a nonprofit organization that works to improve policy and governance with the use of nonbiased research on the most important issues in the world. When it comes to privacy, it often seems like an uphill battle, but Brookings is dedicated to pioneering innovative strategies to alter this dynamic. Data about each of us is getting generated faster and faster, and we cannot keep up. Brookings believes that "we need an American answer – a more common law approach adaptable to changes in technology – to enable data-driven knowledge and innovation while laying out guardrails to protect privacy." The answer to privacy concerns lies in establishing the trust that data about individuals is handled in a moral way.

Finally, we have the Foundation for Defense Democracies (FDD), a nonpartisan institute focused on national security and foreign policy. FDD investigates proponents of defense innovation and the risks of information getting leaked to America's adversaries. Defense intellectuals have been promoting bringing "dynamism" back to US industrial base. However, the FDD believes that "even the most promising and well-intentioned efforts risk building on a foundation controlled by the adversary" (La Bruyère & Picarsic, 2023).

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