Hypersonic Re-Entry Deployable Glider Experiment

A New Arm's Race Involving University Students

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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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The New Arm's Race

The development of hypersonic missiles has sparked a new arms race among Russia, China, and the United States as the governments of each country are attempting to field these new weapon systems as fast as possible. Unlike conventional subsonic and supersonic missiles, hypersonic missiles have the ability to strike targets from very long distances very quickly, thus rendering conventional missile defense systems obsolete (Stone, 2020). While the two former nations have made significant progress towards an operational weapon system, the United States has fallen behind due to various hurdles, including extremely high costs for testing of these systems and a limited budget for hypersonic programs. Each year, Congress has steadily increased funding towards the Department of Defense for hypersonic research to catch up to Russia and China, with a total budget of $4.7 billion requested for FY2023 up from $3.8 billion, however these programs are still not well funded compared to our adversaries (Sayler, 2022). As hypersonic missiles may cost up to $100 million per unit, compared to cruise missiles which cost $5 million, the United States has not been able to conduct many tests and collect real experimental data (Stone, 2021). Therefore, there is a real need for a low-cost method for hypersonic flight experiments in order to conduct more testing of these systems.

In an effort to reduce the research and development cost of hypersonic weapons, the Department of Defense turned to non-traditional performers and partners (DOD). Universities across the United States possessed the facilities, expertise, and workforce necessary to conduct foundational and applied hypersonic research to support DOD programs, thus the University Consortium of Applied Hypersonics (UCAH) was founded. Consisting of over 100 universities and 500 individual researchers, UCAH aims to advance hypersonic flight systems through delivering innovation and workforce in support of national defense. The focus of UCAH's

research spans six critical topics of hypersonic flight: materials, structures and thermal protection systems, guidance, navigation and control (GNC), air-breathing propulsion, hypersonic environments and phenomenology, applied aerodynamics and hypersonic systems, and lethality and energetics (ibed).

The University of Virginia is one of many universities funded by the Department of Defense to conduct hypersonic research and train students for the workforce (DOD, 2022). Fourth year undergraduate Aerospace Engineering students have the option of enrolling in either Aircraft Design or Spacecraft Design courses, the latter of which is currently focused on hypersonic technology through a year-long capstone project. From a technical perspective, the overarching goal of this year's project is to create a solution to expensive hypersonic experiments (Goyne, 2022). However, there exists an even greater goal embedded within this project: to leverage university students and researchers to assist the United States Department of Defense in developing hypersonic weapons to regain ground in the hypersonic arm's race.

HEDGE: UVA's Undergraduate Hypersonic Entry

In an effort to facilitate access to space for university students, the CubeSat standard was created by California Polytechnic State University (Howell, 2018). A CubeSat is a class of miniature satellites which are based around 10 centimeter cubes which have a maximum weight of around four and a half pounds each. The benefits of CubeSats are derived from its simplicity and small form factor, which ultimately lowers the cost of space missions and justifies higher risk research.

Figure 1. UVA Libertas CubeSat (Samarrai, 2019)

In 2019, the spacecraft design course at the University of Virginia sent a CubeSat, Libertas, to orbit on a rideshare with an Antares rocket provided by Northrop-Grumman (Frick, 2020). Contact was successfully made with the satellite until a firmware fault in the radio component of the craft made further communication impossible (Goyne, 2022). Despite this, the mission was considered a partial success and served as the first step to develop research using CubeSats. The next mission currently being considered is HEDGE: Hypersonic Re-Entry Deployable Glider Experiment which is a concept for low-cost hypersonic flight research using the CubeSat form factor.

After natural orbit decay, HEDGE will re-enter the atmosphere at hypersonic velocity and send telemetry to the ground. A Structures and Integration (S&I) team plans the assembly of a spacecraft, ensuring that construction is feasible and that the final design will be able to integrate with the launch vehicle (Caldwell, 2021). The S&I team will also focus on the structural design of the spacecraft for aerodynamic stability and material selection (Caldwell, 2021), addressing

the balance between having the craft survive long enough (Park et al., 2021) to collect meaningful data and being able to burn up in the atmosphere for safety (Blandino et al., 2018).

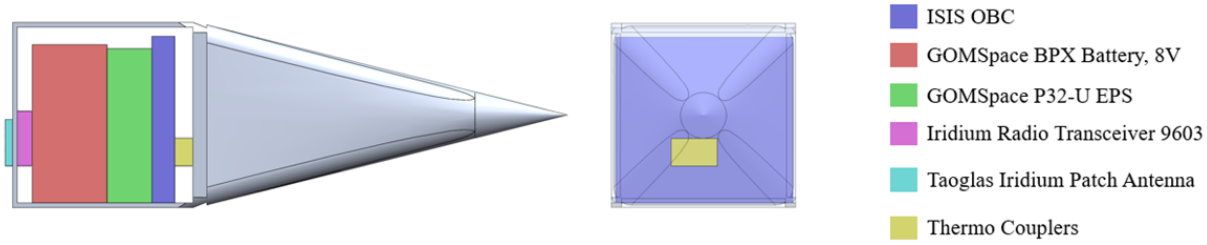

Figure 2: Approximate volume distribution of HEDGE components (Goyne, 2022)

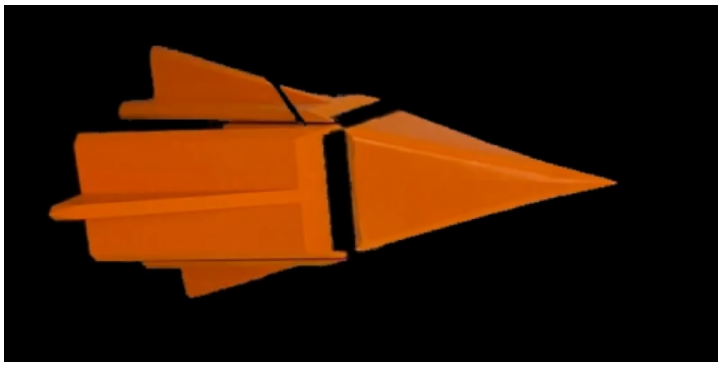

Figure 3: Mockup of HEDGE fins deployed in re-entry configuration (Angeliotti et al., 2022)

The second, more broad goal of this mission is to demonstrate the feasibility of a low-cost hypersonic flight experiment. As hypersonic flight is an expensive endeavor, the team will attempt to solve this issue by taking advantage of the low cost of CubeSats and Earth's natural gravitational force to accelerate a vehicle to hypersonic speeds. The most recent hypersonic missile test, the AGM-183 ARRW, was developed by Lockheed Martin under a $480 million contract (Pawlyk, 2019). Comparatively, the estimated cost for HEDGE is $68 thousand (Angelotti et al., 2022). While a full-scale hypersonic missile test may provide more high quality

flight data, HEDGE will allow for higher risk experiments due to the much lower cost of replacement in the event of a failed test (Spence, 2022). If the HEDGE re-entry vehicle is able to successfully collect and transmit flight data, we will have proven that hypersonic flight tests do not have to be hundreds of thousands of dollars.

While HEDGE may seem like a completely harmless vehicle designed as part of a school project, there are deeper implications to consider. This project will be closely tied to US hypersonic development efforts, with the Department of Defense's UCAH being a major source of funding and the US Navy being a potential customer for this technology. While HEDGE is not a missile designed to strike a designated target, the applicability to hypersonic weapons and the US Government's influence on this seemingly civil hypersonic experiment means this technology may have inherently political qualities.

Techno-politics of Hypersonics

While there has been a large focus on the defense application of hypersonic technology, there also exists a civil application consisting of research in the civil aeronautical and astronautical fields. However, much of the research done in the civil space has also been applied to the development of missiles, which begs the question of whether hypersonic technology, even in the civil space, is inherently political.

The framework which is most useful to analyze this research question is techno-politics as laid out by Langdon Winner (1980) in "Do Artifacts Have Politics?" Hundreds of public higher education institutions have conducted research in civil hypersonics, but due to the dual-purpose nature of this technology, there may be underlying power and authoritarian intentions embedded in the technology. According to Winner, artifacts can contain political properties in one of two ways: technical arrangements as a form of order or inherently political

technologies. In both cases, certain groups utilize technology to increase their power, while other groups are typically marginalized by the technology (ibid).

Most, if not all technological developments in the defense industry fall under the category of technical arrangements as forms of order. In general, a nation's defense complex has a goal to protect the nation and win its wars against foreign groups (Mattis, 2018). From a social framework, the technologies developed for war attempt to promote freedom, human quality of living, and justice for its users while oppressing groups that the technology is used on. On the other hand, research on civil applications of hypersonic technology falls under the category of being inherently political. While these applications may seem non-political, hypersonic technology is dual-purpose and the main focus currently is on defense applications. Almost all hypersonic research, whether civil or defense related, will see first action on a hypersonic missile. The HEDGE project, for instance, has no direct applications or purpose in the defense industry, but the data collected from this experiment and the concept of a hypersonic CubeSat vehicle may be used to aid the development of hypersonic vehicles meant for the military. Additionally, power and authority are implicitly embedded in many civil hypersonic technologies, as the research and development efforts are often funded by the US government through UCAH. Providing a financial incentive to universities to conduct hypersonic research further reinforces the government's indirect influence on this technology. So this technology, used for a completely peaceful purpose will still be inherently political, as it is directly compatible with a political relationship that is the weapon that uses this technology.

Research Question and Methods

The question that will guide the research will be: How does research and development of hypersonic technology for civil applications at universities align with national defense efforts

and the new international arms race involving hypersonic weapons? Students who are studying Aerospace Engineering in colleges across the US often have no intention of pursuing a career in the defense industry due to various reasons including personal morals and views on the United States military complex, and rather intend to focus on contributing to peaceful aerospace solutions throughout their college experience and career. However, hypersonic technologies span both civil and defense spaces, often without any clear and explicit boundaries. Students and their families should be informed about their tuition and time at college contributing to not only a well-rounded education, but possible government programs which may one day be used to oppress and kill social groups. This question will attempt to determine if studying civil hypersonics in college is a contribution to the US's arm's race efforts.

To answer the research question presented, a descriptive analysis method and two evidence collection methods will be utilized. The descriptive analysis will be in the form of case studies about the University of Virginia's hypersonic research program along with several other university programs. Within the case study, the five types of guiding questions will be "when" questions to address relevant temporal context, "where" questions to address jurisdiction and relevant location, "what" questions to uncover facts and data, "who" questions to identify the participants involved with the case, and "how" questions to determine the relationship between the past and current situation (Foley, 2022).

An evidence collection method will consist of a survey of current and former UVA Aerospace Engineering students in an attempt to determine how the engineering education has influenced their willingness to contribute to national defense efforts and their views on government influence on hypersonic research at the school. Lastly, agency reports from the DOD will be used as a secondary source to determine the extent of the government's influence on

hypersonics at universities. Grants by the DOD towards hypersonic research are strong evidence of the government attempting to align universities with national defense efforts, so these agency reports will help to quantify the magnitude of the DOD's contributions (DOD).

Future Implications of This Research

Hypersonic technology is expensive, and the Department of Defense is looking to universities to research and develop the technology at a lower cost in order to catch up to our adversaries of this new arm's race. The technical deliverable, HEDGE, will attempt to be a low-cost solution to hypersonic flight experiments. The research paper, once successfully completed, will reveal how much these types of projects are contributing to national defense efforts. This deliverable is not attempting to make an argument about the morality of student contributions to the hypersonic arm's race, but rather the effectiveness of the DOD's efforts to leverage alternative resources in its mission to protect the United States. It is critical that the US is able to keep up with Russia and China's hypersonic programs because a power imbalance can lead to aggression on not just the US, but allied nations who rely on us to deter attacks.

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