Hypersonic Technology Research and Development at Universities

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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 hypersonic regime is flight that exceeds five times the speed of sound, or Mach 5. Numerous countries are developing missiles which fly at these speeds and can maneuver around current missile defense systems. As this type of weapon can strike targets across the world in a matter of minutes, countries have invested billions into research and development of hypersonic missiles. However, hypersonic flight is incredibly challenging, and flight testing has proven to be extremely expensive. In an effort to reduce the cost of hypersonic research and development, the US Department of Defense turned to universities, which possess the facilities, expertise, and workforce necessary to conduct foundational and applied hypersonic research to support its programs.

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? To answer the research question presented, a descriptive analysis will be in the form of a case study about the University of Virginia's hypersonic research program. Additionally, a survey of current and former UVA Aerospace Engineering students will be conducted 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 school.

This emerging technology has sparked a new arms race among Russia, China, and the US as the governments of each country are attempting to field these new weapon systems as fast as possible. While the two former nations have made significant progress towards an operational weapons system, the US has fallen behind due to various hurdles including a limited budget for hypersonic programs. Since the Department of Defense has dispersed hypersonic research and

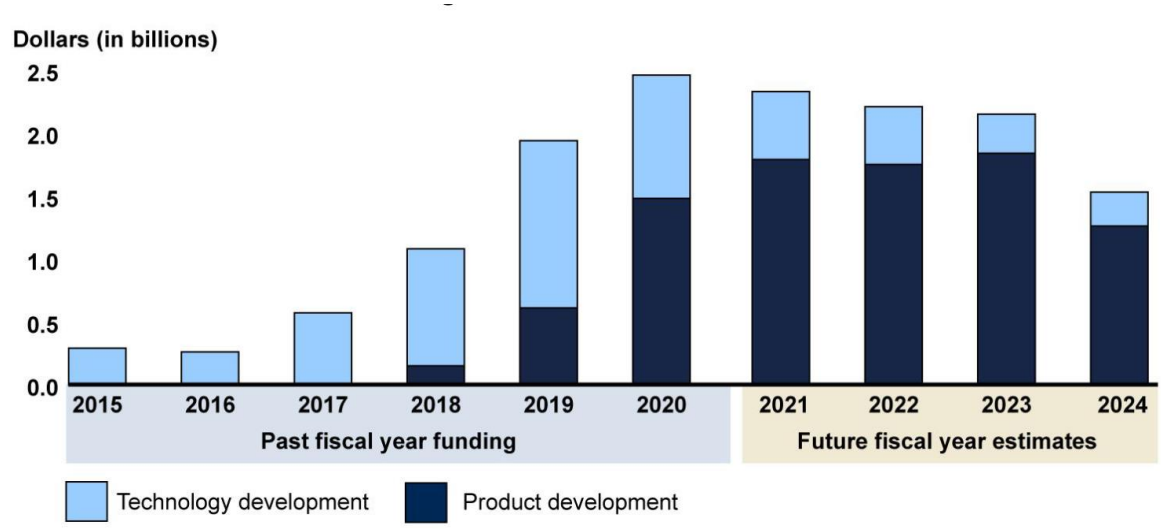
development across universities around the country, these programs at universities are critical to national defense.

Background and Significance / Motivation

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.

Figure 1

Hypersonic Weapon-related and Technology Development Total Cost



Source: GAO analysis of Department of Defense, Department of Energy, and National Aeronautics and Space Administration data. | GAO-21-378

Note. This figure demonstrates the increasing cost of hypersonic weapon development, with product development costs making up a large portion of spending after 2020.

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).

Methodology

An evidence collection method will consist of interviews of current 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. 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.

For each participant, six questions were asked. The first question was, “Why did you choose to study Aerospace Engineering?” This question is designed to build a profile of the participant by revealing their initial motivation to enter the field. The next question was “What is your senior design project?” Understanding the different senior design projects will help to determine any potential correlations between the various fields of hypersonics and results of upcoming questions. The third question was “Is there government involvement in your senior design project, and if so how?” followed by “How has your senior design project impacted any career decisions?” These two questions will reveal any government involvement in the Aerospace Engineering curriculum which may influence their career paths after graduation. The fifth question was “Do your personal morals have any influence in working in the defense industry for the US government?” Personal beliefs on developing weapons for war may dissuade some Aerospace Engineering students from working in the defense industry, so this question will reveal if the participant has objections to this career path. The sixth question was “Are you more

or less likely to work in the defense industry at this point in time compared to when you decided to study Aerospace Engineering?" Combined with the results of the previous five questions, the answer to this question will determine whether the participants' overall Aerospace Engineering education has influenced their decision to contribute to US national defense and security.

The data analysis will be in the form of case studies about the University of Virginia's hypersonic research program along with several other university programs. As the government has continuously increased funding towards universities for hypersonic research, this method will help to uncover what exactly universities are doing to contribute to hypersonic R&D in the defense industry and ultimately the purpose of government involvement in higher education. 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).

This leads into the theoretical framework of this research: techno-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 being researched.

Discussion / Results

"Leveraging University Expertise to Accelerate Hypersonics Technology Development" (DOD) is a presentation outlining the role of universities across the United States in the research and development of hypersonic technology for the Department of Defense. This slide show was created by Dr. Gillian Bussey, who is the director of the Joint Hypersonics Transition Office

(JHTO) in the Office of Undersecretary of Defense, Research, and Engineering. The mission of JHTO is to "Accelerate hypersonics technology development to enable the systems the warfighter needs through an integrated S&T strategy, allied and university engagement, and collaboration." The University Consortium for Applied Hypersonics, which consists of over 100 universities and 500 individual researchers, was created by JHTO in order to provide foundational and applied hypersonic research, development, and workforce support.

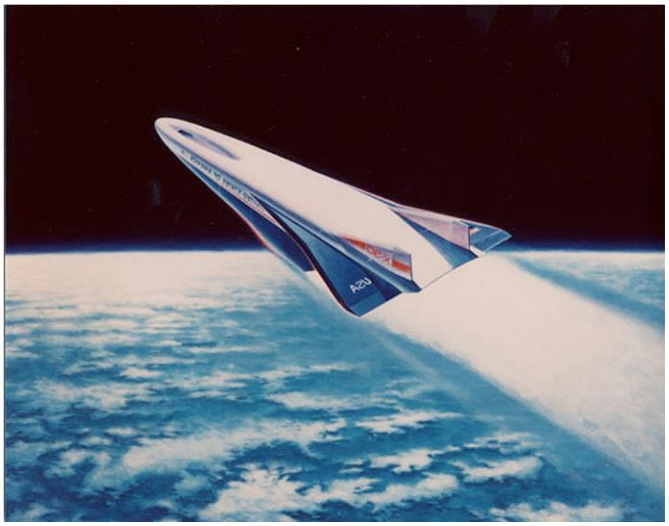
The key argument is that the non-traditional performers and partners to the Department of Defense, such as universities, are critical to accelerating hypersonic technology development. This is evident through the grants awarded to universities for research in different topic areas, from direct support of projects like scramjet propulsion to curricula development for a robust hypersonic workforce. Generous grants by the Department of Defense indicate that the US government has recognized the critical role that universities play in researching hypersonic technology in support of national defense efforts.

The University of Virginia's Hypersonic Research Complex consists of ten laboratories across 25,000 square-feet of research space housing research of 17 faculty from across several engineering departments (Goyne, 2019). The core strengths of UVA Hypersonics includes air-breathing propulsion and materials for hypersonic applications. The main research facility for the program is the Aerospace Research Laboratory, which was founded in 1986 to support basic and applied research efforts in advanced aerospace technologies ("Aerospace Research Laboratory", 2017). In 1989, the facility was endorsed by the National Space Council, a body within the Executive Office of the President of the United States, for its first hypersonic program involving a single-stage-to-orbit spacecraft and passenger spaceliner capable of achieving Mach 25. Since then, the Hypersonic Research Complex has expanded to facilitate a wide variety of research

programs, including hypersonic aerodynamics, optical diagnostic and measurement technique development, particle inertial separation, shock interaction with liquids and particles. In October 2022, the University of Virginia received $4.5 million from the Department of Defense to fund the development of a highly maneuverable scramjet engine to be used on missiles as well as manned hypersonic aircraft (DOD, 2022).

Figure 2

Rockwell X-30



Note. The Rockwell X-30 depicted above was a technology demonstrator for a single-stage-to-orbit spacecraft. The program was terminated in 1993 after 7 years of development amid budget cuts and technical issues, however research on advanced materials and hypersonic flight was completed.

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. The project is a Hypersonic Re-Entry Deployable Glider Experiment (HEDGE), a concept for low-cost hypersonic flight research using the CubeSat form factor (Goyne, 2022). The primary goals of HEDGE are to

demonstrate the feasibility of low-cost hypersonic flight experiments and to collect material data in the hypersonic environment. The Department of Defense has expressed interest in funding the program, and numerous subject matter experts in the industry have mentored the student-led team throughout development.

15 fourth year Aerospace Engineering students were interviewed in total, ten of which attend the University of Virginia while the other five attended Georgia Institute of Technology, United States Air Force Academy, University of Alabama, University of Alabama in Huntsville, and Virginia Polytechnic Institute and State University. All members of this group interned at Aerojet Rocketdyne, a space and defense manufacturer focused on rocket propulsion.

Regarding the first question about the initial motivation to study Aerospace Engineering, ten participants cited space exploration as the primary driver, two cited commercial aviation, two cited rocketry, and one cited military aviation, as this individual attended the Air Force Academy attempting to become a military transport pilot. Of the ten students interviewed from the University of Virginia, three are enrolled in the Aircraft Design capstone course, with the other seven enrolled in the Spacecraft Design capstone course. The other five non-UVA students are enrolled in capstone courses involving various fields in hypersonics, such as propulsion and aerothermodynamics. Regarding the third question about government involvement, all but the three students enrolled in Aircraft Design experienced government involvement in their senior design projects, mostly in the form of funding from the Department of Defense. The answers to the fourth question regarding career decisions based on their senior design class were mixed, as seven non-Aircraft Design students said that they would like to continue working in hypersonics, two Aircraft Design students said that they would like to continue in commercial aviation, and five students said that their respective internship experience was a greater factor due to secured

return offers. The student from the Air Force Academy was not influenced by his senior design class nor his internship and wanted to continue his path to becoming a pilot for the Air Force. While the answers to this question varied greatly, the answers to the fifth question were straightforward; the five Aircraft Design students preferred not to work in the defense industry due to personal morals, while the other ten participants did not mind at all and prioritized following their passion in Aerospace Engineering and job security. Surprisingly, all fifteen participants claimed that they were more likely to work in the defense industry, to varying degrees, compared to when they first decided to pursue Aerospace Engineering.

From the results of these interviews, it is evident that there is government involvement not just at the University of Virginia, but also at many other university hypersonic programs as well. The Department of Defense seems to be highly interested in small-scale senior design projects and have proven so through funding of each respective project. At the University of Virginia where students have the decision in their senior design course, the students who chose Aircraft Design all share the same views on working in the defense industry due to personal morals, which may have been a factor in their decision to take this course as opposed to Spacecraft Design. However, this same group claimed they were slightly more likely to work in the defense industry compared to several years earlier, although none were enthusiastic to do so. Some students in this group cited superior job security and compensation of defense jobs compared to those in the commercial aviation industry, which they discovered through networking with older students, advisors, and professionals at job fairs and internships. On the other hand, the remaining participants were more enthusiastic about working in the defense industry mostly due to an engaging internship or senior design project and no moral blockade.

This case study of the University of Virginia's Hypersonic Research Complex in addition to the results of the interviews strongly suggests that the US government, specifically the Department of Defense, is heavily involved in order to strengthen national defense and security. The entire program has been granted millions by the Department of Defense over several decades on numerous hypersonic projects, which have contributed to major breakthroughs in the development of US hypersonic vehicles. While Aerospace Engineering students at the University of Virginia have felt the influence of government within the curriculum, students at other universities share this sentiment as well, proving that the higher education system is a vital resource for the US government in regards to hypersonic research and development.

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.

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.

Conclusion

The research question which was explored in this paper is, "How does hypersonic research and development at universities align with national defense efforts and contribute to the hypersonic arm's race?" Through interviews of fourth year Aerospace Engineering students and a case study of the University of Virginia Hypersonic Research Complex, it is evident that the US government and more specifically the Department of Defense is highly involved in supporting research and development of hypersonic technology. Large research grants and funding for small-scale senior design projects are some of the main methods in which the Department of Defense relies on universities to catch up to our adversaries in this new arm's race. In understanding the relationship between government and universities from a national defense perspective, universities could further optimize research and development of hypersonic technology to increase the amount of funding received by the government, increase student engagement with defense-related research, and increase overall efficiency to boost the United States' hypersonic capabilities. Universities also should have the responsibility to inform

students of this relationship, as some are against contributing to the military-industrial complex and would prefer to avoid taking courses which align with national defense. Ultimately, it is not necessarily a negative relationship, but broader awareness will benefit all students regardless of their position on defense, as well as the university itself.

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