HYPERSONIC REENTRY DEPLOYABLE GLIDER EXPERIMENT (HEDGE)

HYPERSONIC TRANSPORT VEHICLES FOR COMMERCIAL APPLICATIONS

A Thesis Prospectus
In STS 4500
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The Faculty of the
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Bachelor of Science in Aerospace Engineering

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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Introduction

Hypersonics is currently a very compelling area of research in the aerospace sector, with the potential to significantly advance the technological infrastructure of the military, space, and airline industry. The US military can employ hypersonic missiles for both offensive and defensive applications in regards to foreign affairs. Space organizations can use hypersonics research to develop reentry vehicles that can adequately withstand the harsh environment, allowing for the reuse of spacecraft for space missions. The emergence of a hypersonic airplane can enable the airline industry to offer flights at unprecedented speeds. While these technological advancements would be revolutionary, hypersonics, especially in the US, is unfortunately still in its primitive state. There is simply not enough known about hypersonics to integrate it into a product that can fulfill the requirements necessary for these applications.

My technical capstone topic addresses this problem by developing a flight vehicle that can be launched by NASA as a CubeSat but then reconfigures itself as a hypersonic flight vehicle for reentry into the atmosphere. The success of this mission would demonstrate the feasibility of using CubeSats for low-cost, hypersonic flight experiments. Additionally, this mission would provide an affordable method to analyze materials for spacecraft reentry conditions. My STS topic more specifically focuses on a hypersonic transport vehicle for commercial applications. Hypersonic transport vehicles would drastically reduce flight times for passengers, which can be useful for both professionals who need to make an urgent meeting, as well as passengers who have a very difficult experience with long flights. My STS research paper will delve into the societal impacts of a hypersonic transport vehicle, specifically regarding the economic, environmental, and ethical concerns.

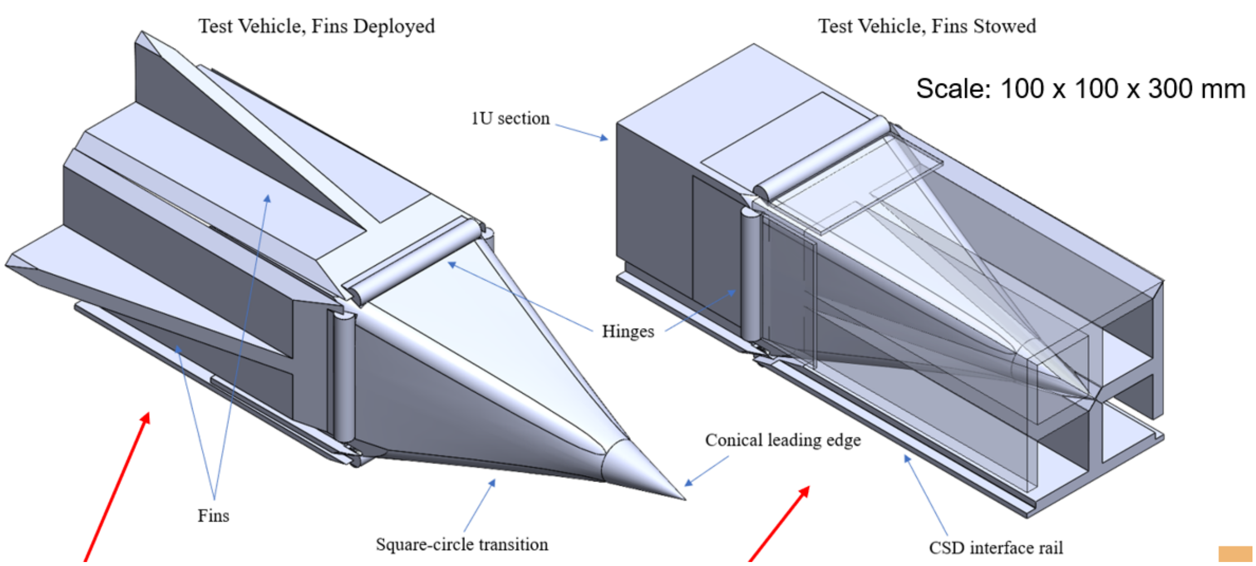
While my technical topic and STS topic address two different problems in the realm of hypersonics research, they are related in that both topics will teach UVA students about how flight vehicles behave in a hypersonic environment. In my technical topic, the glider will give valuable data about the temperature, pressure, and air density on the surface of the vehicle. In my STS topic, I will delve into how a hypersonic plane will function in order to evaluate its economic and environmental effects. These two papers will combine into one portfolio to give a comprehensive review of a hypersonics mission proposal from UVA as well as a look into industry's progress on hypersonic transport vehicles.

Technical Topic

When spacecraft in low earth orbit (LEO) deorbit, they re-enter the atmosphere at hypersonic speeds, which is over five times the speed of sound. Currently, more research is needed to understand how to design a reentry vehicle that is aerodynamically efficient for these high speeds, especially in the maneuverability of the vehicle in the upper atmosphere, the ability for thermo-structural components to withstand high temperatures, and to produce flowfield characteristics that resemble computational simulations (Pezzella, 2013). I strongly agree with Pezzella because material selection is a highly debated topic in my capstone class and that a thorough analysis of a material in a hypersonic environment could help scientists choose a material for future space missions involving reentry. Learning about hypersonic reentry is highly important for future space missions that desire a controlled vehicle in the upper atmosphere to extend the mission duration and/or to collect more data. Currently, there is limited research about the flow properties surrounding a hypersonic vehicle re-entering the atmosphere, mainly due to its high complexity and, as a result, its cost. Moss and Bird (2003) attempted to use the Direct Simulation Monte Carlo (DSMC) method to predict the flow and heating characteristics of the

Space Shuttle Orbiter, one of the few existing spacecraft to ever re-enter the atmosphere in a relatively controlled manner. They were able to create an accurate model at their lowest altitude range, but their predicted results diverged significantly as they increased in altitude. Moss and Bird are two very established researchers from NASA Langley Research Center, and their paper strengthens my argument that we need more hypersonic data so that we can improve models that will try to predict a hypersonic flight vehicle's condition and status.

In order to affordably obtain more data on controlled hypersonic reentry, my capstone class is working on developing a CubeSat, or a small cubic satellite of ten centimeters in each dimension, that would launch into extreme low earth orbit (ELEO) for seven days until it naturally orbits and enters the atmosphere hypersonically. During reentry, the CubeSat will release hinged flaps to change the geometry of the spacecraft from a cube to a more streamlined vehicle. In this way, we can attempt to model a larger hypersonic vehicle and retrieve data that can help us improve existing hypersonic vehicle designs. This proof-of-concept mission would confirm the possibility of affordable hypersonic experiments.



Over the course of the year, my capstone class will work in 6 distinct teams to complete different aspects of the mission: Program Management, Communications, Avionics and Software, Power/Thermal/Electric, Attitude Determination and Control Systems, and Structures and Integration. Under Professor Goyne's supervision, we as a class hope to finalize the design of the spacecraft and create a working prototype by the end of the year. Personally, I was assigned into the Program Management team as the Chief Financial Officer for the project, and my goal is to obtain a stakeholder willing to provide funding for the mission as well as to produce a cost estimate of the mission.

STS Topic

Commercial flights across the world can easily take more than twenty-four hours to reach their destination, not to mention layovers that can add hours to a passenger's trip. Hypersonic transportation is fascinating to me because it can potentially change the way that we view the airline industry. For example, a typical hypersonic aircraft is estimated to "travel from Tokyo to Los Angeles in only 110 min[utes]" (Smith & Sziroczak, 2016). Smith and Sziroczak, a professor and a PhD student, discuss environmental effects, sustainability, aerodynamic characteristics, stability, propulsions, and structures of a hypersonic transport vehicle in their journal published in *Progress in Aerospace Sciences*. Hypersonic transport vehicles are also interesting because of their technical complexity. Hypersonic aircraft are very difficult to design, and thus are very expensive to build (Bertin & Cummings, 2003). I agree with Bertin and Cummings that great strides have been made to get to this point, but much more progress is necessary to achieve the overall goal of an easy access to space.

A large emphasis of the STS research paper will be put into environmental impacts because the engine necessary to get the vehicle up to hypersonic speeds requires significant fuel consumption. Peterson and Waters (1972) compared hypersonic effects to supersonic states and claimed that "the environmental problems connected with a [Hypersonic Transport] seem potentially less severe than those of a [Supersonic Transport] vehicle". This is a positive sign that we are not further damaging our environment, but it is notable that supersonic and hypersonic flight is much more damaging to the environment than subsonic flight. Another source noted that the Space Transfer Shuttle produced a wake with a nitric oxide concentration eight hundred times greater than the surrounding nitric oxide concentration. In total, about five thousand kilograms of nitric oxide was produced for each shuttle descent (Stuhler & Frohn, 1998). Furthermore, Harris (1992) recognized the environmental concern of hypersonic transport vehicles, but asserted that it should not be treated as a top priority. As you can see from previous literature, the effect of hypersonics on the environment is heavily debated and has shifted over time. Many sources argue that the impact is negligible while others argue that it is a concern but not significant enough to consider it as a design driver. The purpose of my STS research is to thoroughly analyze the environmental impacts to come up with an informed conclusion on the severity of a hypersonic transport vehicle, especially when compared to existing infrastructure.

My STS research paper will be guided by the Actor-Network Theory (ANT), a theoretical framework that suggests that both human and nonhuman entities play a role in influencing the sociotechnical system of society. Looking at my STS topic, there are several human actors that should be considered under ANT, including engineers, scientists, the general public, the military, space industry, airline industry, and all the actors that fall under the umbrella of these large actors. Nonhuman actors include the environment, societal impact, economic impact, cultural shifts, and the current technological state of hypersonics. All of these actors influence each other simultaneously and shift fluidly. In order to learn more about the societal effects of hypersonic commercial aircraft, I will need to find more recent literature to better understand the state of hypersonics today. I think it is important to research how the engine works to see how it affects the environment. I believe that Chris Goyne and Mike Smayda can be valuable subject matter experts to help me with my research. Professor Goyne is a professor in the aerospace engineering department at UVA and much of his research involves hypersonics. Mike Smayda is the Chief Product Officer for Hermeus, a company with the mission to develop a commercial hypersonic transport vehicle by 2029, and has an industry perspective which can be valuable in understanding the economic effects of hypersonics. I will consult with Professor Goyne and Mr. Smayda to find the best literature for my research.

Conclusion

While studied for decades, hypersonics is still very much in its early stages of development. There are many actors in this sociotechnical issue, yet the research and industry sectors are clearly more focused on improving the technology as a top priority, while dismissing the rest of the actors such as environmental impact, economic impact, social impact, and ethical concerns. The goal of these two research projects is for me to learn deeply about the science and societal application of hypersonics, to spread knowledge to colleagues, and to contribute to a project that can help research institutions obtain valuable and unprecedented data. I hope to find knowledge that provides a more holistic evaluation of hypersonic vehicles, taking into consideration all of the actors involved. With this evaluation, the aerospace industry will have a comprehensive understanding of hypersonics not just as a technology, but as a sociotechnical system.

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