Technical Paper:
AIAA Austere Field Light Attack Aircraft RFP

STS Paper:
Evaluating the Societal Impact of Future Commercial Hypersonic Flight Technologies

A Thesis Prospectus Submitted to the
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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:

Since the successful development of human flight over a century ago, the aerospace industry has become involved in and shaped many aspects of human interaction around the world. Aviation is a constantly evolving and advancing field-- the modern planes we fly today would have been unimaginable to early aircraft designers and they will only continue to be innovated upon into the future. However, as with any evolving system, new technology often brings about change, both intentionally and unintentionally. It is the role of the designer to consider these impacts in the context of greater societal and ethical implications and strive to prevent any negative manifestations their technology may take on during its lifetime. This task becomes quite challenging when the engineering assignment itself has an inherently evil nature. How can one contemplate the ethics of a design if its intended usage is immoral?

My technical project revolved around the American Institute of Aeronautics and Astronautics (AIAA) "Austere Field Light Attack Aircraft" request for proposal (RFP). My group was tasked with designing a comprehensive close-support attack aircraft with the intent it is to be used by the United States military. There are many ethical aspects to my technical project, the most pressing being it's obvious involvement in war. The aircraft we design has the express purpose of participating in active combat and, if developed, will inevitably lead to the death of many people. Though we ourselves are not engaging in these killings, we are enabling others, such as the United States military, or even unknowingly, the militaries of other countries, to do so. For our design, there exists the morbid duality that the more effective our design is, ultimately the more enemy forces will be neutralized in its service lifetime. It is a very gruesome concept but it speaks to the reality many engineers, of all fields, face when working for their nation's military. As an aerospace engineer, it is important to contemplate what ethical design of this nature would consist of. It was summarized, that engineers of military technology must prioritize the lives and safety of their own countrymen, both military and civilian, and strive to mitigate the total loss of human life where possible, through their designs and involvements; they should also understand the necessity of a nation's military and the considerable implications the military, as an economic industry, has on a nation's survival (University of Sheffield, 2016). In the case of the technical project, these societal and ethical frames were considered by the team: the main priority of our designed light attack aircraft is survivability, the need to protect the crew above all else transcends all aspects of our design. This project speaks to the role of engineering as a force for evil instead of good, but an essential one nonetheless.

The technical subject of the STS prospectus and the technical topic for the Department of Mechanical and Aerospace Engineering are not related. For the STS Prospectus, I will instead focus on the rapidly approaching possibility of commercial hypersonic flight, and will explore both the positive, social and economic outcomes of the technology's introduction as well as investigate the unintended consequences that may occur as result of the technological system's usage. Hypersonic aircraft systems present massive opportunities for better connecting populations around the globe and improving international human networks, again another example of aviation technology impacting all aspects of human interaction and becoming a critical institution for the development of a global society.

Technical Topic:

The 2020-2021 University of Virginia Mechanical and Aerospace Engineering Department's senior design project, my technical project, revolved around the American Institute of Aeronautics and Astronautics (AIAA) "Austere Field Light Attack Aircraft" request for proposal (RFP). The class was split into three teams of seven members, which worked on three unique solutions for the AIAA design challenge to be submitted in May 2021. The objective of the RFP was to develop a light attack aircraft that can provide close air support to ground forces, similar to that of an attack helicopter, which also focused on affordability, survivability, and functionality. The aircraft had to meet a strict set of performance specifications for two pre-designed flight missions-- these missions dictated payload capacities, climb rates, service ceilings, take-off and landing distances, and projected service life(s). One unique focus of the request for proposal was the requirement to operate on austere fields which presented several technological and structural design challenges. There were very few limitations on the appearance or shape of the aircraft, leaving a large design space for engineers to imagine creative solutions to. The proposed design's performance would need to be justified using known and projected performance capabilities and flight specifications for both existing technologies and technologies that are deemed to be functionally feasible by 2025 (AIAA, 2020).

During the fall of 2020 semester, the teams analyzed a myriad of domestic and foriegn aircraft that filled this light attack/fighter role, discovering both current and historical examples. Many of the individual team members' initial designs would incorporate elements of previously successful light attack aircraft. The initial aircraft concepts, designed with NASA's OpenVSP software, were rated and ranked in a design matrix based on their perceived performance as it related to the RFP's objectives. Once a collaborative design was selected, each of the seven team members became a subject field expert (SFE) on a different aspect of the aircraft's design. State-of-the-art technologies were researched and their performance capabilities were used to justify early design decisions and generate initial performance parameters. These parameters, such as take off gross weight (TOGW), were used to determine what aspects of the aircraft would need to be modified to make the conceptual design feasible.

The goal for the spring semester (February to May of 2021) is to iterate the generated conceptual design (completed in the fall semester) and establish a final feasible design that will meet the RFP requirements. Each SFE will focus on softwares and design tools to optimize their individual aspect's aircraft components and designs. The group will work to integrate these individual contributions to a completed aircraft structure and collaborate on a final dimensioned model of the aircraft design. The individual SFE's will contribute their optimized component's researched and modelled performance parameters to determine the aircraft's final flight capabilities. Ultimately, the team will be required to produce several deliverables for the AIAA submission in May of 2021 to conclusively prove the feasibility and performance of the proposed design; these include a fully dimensioned 3D model of the aircraft, basic aerodynamic analysis of the vehicle, weight and moment calculations for the general aircraft design, a description and performance analysis of the proposed propulsion system, vehicle performance diagrams (based on the vehicle's velocity, loads, mission profiles, and maneuverability), and a cost analysis of the final design.

STS Prospectus Introduction:

One of the most recent advancements in the aviation industry was the development of hypersonic vehicles, aircraft capable of exceeding Mach 5. The first hypersonic aircraft to exceed this velocity was the single-seated Northrop Grumman X-15 in 1967, this program only consisted of some 200 total flights (Dunbar, 2014). New advancements in propulsion systems, computers, and high performance aerospace materials may allow for these vehicles to be larger, functional, and more efficient in the near future, allowing them to become a major part of the commercial aerospace industry for applications beyond research and defense. This is significant because a larger quantity of humans are becoming fiercely dependent on international systems to provide their lifestyle, leading to a new demand for faster transportation. In my STS prospectus, I will explore the potential implications, both intentional and not, commercial hypersonic vehicles may have on the global community with their earliest industry introduction in as early as five years from now. Commercial hypersonic travel does not simply involve a new generation of vehicles, there will be massive infrastructural changes as a result of taking this next step in aviation. My research will have two main focuses, the first being an analysis of the technical aspects of the hypersonic vehicle system, specifically, quantifying the vehicles' expected needs and performance capabilities. The second focus will be to evaluate the societal, political, economic, and environmental impacts this technological system may have, noting several historical implementations of similarly motivated technologies. Hypersonic flight is typically viewed as a technological achievement rather than a significant aerospace system. In this comprehensive study, I strive to fill this gap in knowledge and obtain a multi-disciplinary analysis of the hypersonic system as a whole. Commercial hypersonic systems would be greatly benefited by an STS study, given their complexity, global scale, and ability to impact all aspects of international human interaction. STS analysis could provide a more complete insight into how this technology will be implemented, function, and how it will both shape and be shaped by the participants in this global system.

Research Question:

As stated, the main objective of the STS prospectus is to provide a complete, multidisciplinary perspective on the greater societal impact of commercial hypersonic transportation systems and evaluate any potential ethical conflicts that may arise as the system enters global human networks in the near future.The research strategy for quantifying the impact of this technology will be separated into smaller more defined questions:

1) How have researchers and designers quantified the hypersonic vehicle's potential performance improvements and promised technological advancements?
2) What social, political, economical, and environmental infrastructures are needed to support this technology?
3) Which global networks and groups of people will be directly or indirectly benefited or hindered by the introduction of commercial hypersonic flight systems?
4) How has the introduction and evolution of historical transportation paradigms and their infrastructures, specifically those focused on increased speed and efficiency, impacted society and led to ethically polarized outcomes?

Literature Review:

Existing studies of hypersonic vehicles tend to focus on the feasibility of the technology and the economic needs and impacts of faster transportation. One very thorough study on the technological impact of hypersonic vehicles is by Kevin Bowcutt, Boeing's chief scientist of hypersonics, who compiled a vast array of predictions and models for current hypersonic research. After consideration of several in-development commercial hypersonic vehicles, Bowcutt deemed the technology as functionally feasible and obtainable in the near future given a variety of technological milestones are achieved. Bowcutt predicted important factors like vehicle sizing, focus on trans-pacific routes, and an “optimum speed/altitude combination” will be required for the system to be profitable. Bowcutt indicates that he does not expect the technology to be immediately more available than a comparable “premium travel” means, such as business or first class, based on the business model: “money traded for major improvements in time as opposed to money traded for comfort”. As far as societal impact is concerned, he only highlighted that low altitude sonic booms would impact local populations and high-altitude environmental pollution would be a major concern (Bowcutt, 2020).

Another source, hints at some social implications of the technology but again tends to focus on economic impacts. The author suggests the primary usage of hypersonic vehicles will be to “propel us boldly into a new era of flight”, mainly that of commercial space travel. The article highlights the potential for a “reusable hypersonic vehicle” that could “serve the future needs of space and research industries, while simultaneously providing a significant increase in the pace of business and commercial transport”. The author highlights that the introduction of these vehicles will trigger massive financial growth for a variety of businesses that “has not been seen in the past 40 years” and the potential for new industries such as space tourism. The argument is made that functional hypersonic vehicles will more than outweigh the cost of development if they are implemented in the correct industries (Sanders, 2012).

Again, an existing hypersonic research source was limited to the context of economic and technological achievements; Virgin Galactic describes that “supersonic jets [can] hold potential for civil applications” and that new technologies like NASA’s X-59 Quiet SuperSonic Technology (QueSST) can make it feasible for “point-to-point hypersonic travel” which could be "transformational for transit and tourism" (Brandi, 2020). Virgin emphasizes the need for focus on "customer experience and environmental responsibility" (Brandi, 2020).

Another literature source regarding supersonic (not hypersonic) travel was analyzed, it showcased the importance of socially and environmentally conscientious design on a company based level. The supersonic aircraft development project, Aerion's AS2 and the theoretically successive ASX aircraft, are being "designed specifically around noise and emissions" to both appeal to consumers and ease regulatory difficulties. To do this Aerion first developed "the "boomless cruise", which allows the plane to fly supersonically without the boom striking the ground", and designed a propulsion system that "could operate on 100% synthetic fuels". The company also plans to offset any carbon emissions through a reforestation effort and eventually wants to create an aircraft that will be hybrid electric and achieve carbon neutrality. Aerion predicts, for consistent business travel, "every person who flies on their airplane, AS2 will save them 142 hours a year" (Sillers, 2020). This source was very insightful for this study.

Many of the explored hypersonic flight sources failed to elaborate on the infrastructure required by the systems, this source provides one historical transportation system that has a massive similarity to the development of hypersonic travel. The Chinese bullet train system is extremely relevant to the implementation of hypersonic technology given their near identical design motivation. The Chinese high speed rail system (HSR) was developed in response to the national need to connect high population centers, encourage tourism, and ease congestion in existing transportation systems. On the surface, China's implementation of this technology, that impacts over 1.7 billion passengers, appears to be successful, however there are some underlying consequences of its development: the Chinese government has incurred a massive financial debt from the construction of this infrastructure project, the HSR heavily burdens local electricity grids, and the HSR is noted, in some instances, to function only at partial capacity or at an ineffective schedule (Davies, 2019).

A similar infrastructural level impact hypersonic travel may have can be foreshadowed by documents from the United States Department of Transportation. The DoT states "[air traffic] congestion is expected to be an increasing problem as the population swells and more and more people take to the skies" (Baggaley, 2019). The DoT argues air traffic congestion directly costs the "U.S. economy over $40 billion" and indirectly costs airlines "lost revenues and taxes of over $26 billion". The DoT also highlighted the fact that increasing airport infrastructure and systems would be ineffective given the nature of government projects as having massive "physical, economic, and political constraints", promoting that an external entity should seize "short-term opportunities to utilize existing [airport] capacity". The article stated that the potential for better airspace systems that can reduce delays could save consumers and airlines "200,000 hours annually" (Sturgill, 2007).

STS Framework and Method:

The proposed research questions will be answered by forming two STS frameworks, developed using the main method of archival study of both quantitative and qualitative sources. Since commercial hypersonic vehicles are still in development, their impact has yet to be seen and direct studies cannot be performed nor can an investigation involving those impacted by the technology take place. Further, most resources directly involving the technology, likely from the manufacturers and researchers of the vehicles, may have inherent biases in how they address the positive and negative aspects of the design, which must be highly scrutinized during the creation of the STS frameworks. It is worth noting that, of the already complete research, many of the corporate manufacturing companies, like Boeing, tended to down-play some potential negative effects of the technology including large preventative challenges that may inhibit or delay the successful development of the vehicles and they often oversold positive potential outcomes, in some cases emphasizing technologies that appeared vastly underdeveloped.

Moving forward, two STS frameworks were utilized to comprehend the societal impact of this technology during the course of this project, the Social Construction Of Technology (SCOT) theory and the Actor Network Theory (ANT). SCOT would be used to evaluate which human networks would be affected with the introduction of the technology, specifically how the technology could change how we interact with each other, while also inferring how the users and designers of the technology could influence aspects of the technology's design, usage, and objectives. SCOT will be used to analyze how the technology will be received by the public and how its users could invent ways to utilize it. Conversely, ANT will explore how equally contributing 'actors', including both human and non-human entities, will impact how the technological system is able to be implemented and utilized. This theory will excel at highlighting factors and actors that could negatively impact the system or even prevent it's successful development.

Project Timeline:

Fall Semester:

- Define research question **- September 13th**
- Explore how the technology works **- September 20th**
- Learn STS frameworks(ANT and SCOT) **- October 14th**
- Peer review of prospectus**- November 23rd**

Spring Semester:

- Evaluate historical transportation paradigms **- February**
- Examine what infrastructure would be needed for hypersonic travel **- March**
- Apply STS frameworks to researched technology **- April**
- Conclude STS study of hypersonics **- May**

Conclusion:

Hypersonic transportation, though a thought provoking and awe-inspiring technology, has the potential to make significant changes in many very important global systems, the likes of which could impact millions of people in all aspects of their life, from health care to online consumerism. To truly quantify the impact of this aerospace system, first, new knowledge about the system's technological capabilities must be evaluated and quantified. Next, it is important to perform an in-depth STS study regarding the societal, political, environmental, and economical infrastructure needed to support such a cutting edge aerospace system. This societal and ethical analysis is what is currently missing in most literature that already exists around the technology, making it my goal, using the STS frameworks of ANT and SCOT, to capture the global, societal impacts of hypersonic transportation from a multidisciplinary perspective.

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