Hypersonic ReEntry Deployable Glider Experiment

Analysis of the March 2023 Hypersonic Missile Test Failure by the United States Air Force

A Thesis Prospectus
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By
Emmanuel Kenscoff

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Technical Project Team Members:
Temidayo Akinbi, Tyler Spittle, Sean Jolly, Idriss Shively, Kate Wilkins

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.

ADVISORS

Benjamin Laugelli, Department of Engineering and Society
Chris Goyne, Department of Aerospace Engineering

Introduction

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Although major global powers such as the United States, Russia, and China are investing billions of dollars over the recent years towards the development and testing of hypersonic weapons (especially hypersonic missiles), the United States is nearly a decade behind in researching hypersonic technology and is currently trying to match pace with other global powers in order to ensure the best national defense with global tensions having a significant uptick in the past five years. Michael Horowitz, director of the Pentagon's emerging capabilities policy office, talks about how the two options for the United States at this point is to either expand the range of weapon options or to deter conflict (Grady, 2023).

In order to address how the United States government can match the levels of innovation and research to other leading global powers, I propose the development of a hypersonic flight vehicle that aims to collect valuable data while in orbit at a much reduced cost compared to traditional methods that we currently use. As this project is heavily influenced by social, political, and economic factors, understanding how these factors played a role in the U.S. lack of research in hypersonics is critical to the success of this project. To examine these factors, I will use the STS framework of actor-network theory to analyze the United States Air Force's failed second test flight of Lockheed Martin's hypersonic missile. I will more specifically talk about how foreign powers such as China and Russia have pushed the U.S. to rushing the development of their hypersonics research, leading to multiple failures in their testing phases and delaying their progress in being updated to the latest hypersonics research.

If the United States government chooses to neglect making technological improvements to their hypersonic weapons as well as refuse to understand the social, political, and economic factors

that prevent them from making valuable progress in the hypersonic field, they are at risk of being vulnerable to attacks from foreign powers due to technology that is outdated and putting innocent civilians in unnecessary risk. Because redesigning the U.S. hypersonic technology requires a socio-technical understanding, both the technical and social aspects must be addressed. I will outline a technical project that uses current small-form satellite technology to gain the same data at hypersonic speeds at a more affordable rate. I will also talk about a STS project that uses actor network theory to analyze how the U.S. Air Force failed test on Lockheed Martin's hypersonic rocket is a result of the technological momentum by foreign powers such as China and Russia in the advancement of hypersonic weapons. Using the insights from both will allow me to design a technical upgrade that will help the United States to be able to compete in the advancement of hypersonics.

Technical Project Proposal

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While I have previously mentioned how a major issue is that the United States is greatly behind in hypersonic technology research amongst other global powers, the issue that plagues the United States speeding up research is how we can be able to do that without spending excessive amounts of money like our current research methods. This is where Cube Satellites (or CubeSats) come in: squared-shaped miniature satellites that weigh about a kilogram that can be used as one unit (1u) or multiple units depending on the experiment's requirements (Goyne, 2023). The advantage to CubeSats over traditional commercial satellites is that they have the same capabilities of testing instruments, conducting science experiments, and opening doors for commercial applications and educational projects at a significantly reduced cost. CubeSats have

been around for a little more than two decades with its first concept being developed in 1999 and first launched in 2003. As of today, over 500 CubeSats have been launched by over fifty countries (Canadian Space Agency, 2023). In our case, we are using the concept of CubeSats to design HEDGE. Attached below in Table 1 are the primary and secondary objectives of HEDGE (Goyne, 2023).

Primary Mission Objectives	
O1	Demonstrate the feasibility of affordable CubeSats as a platform for hypersonic glider flight research.
O2	Demonstrate a materials screening method for hypersonic flight conditions at an extremely low cost.
O3	Show that undergraduate students can conduct hypersonic glider flight experiments at lower cost and with greater accessibility than traditional programs.
Secondary Mission Objectives	
O4	Integrate undergraduates into an industry, government, and university partnership involving complex systems engineering and program management with multiple stakeholders.
O5	Conduct STEM and hypersonics outreach to community and potential engineering students.

Table 1: Primary and Secondary Objectives for HEDGE

My technical project group focuses on the communications subsystem of HEDGE, both on the ground and while the glider is in orbit. We are tasked with establishing a method of reliably transmitting data between the ground station and the glider throughout its mission up until it completely dissolved by burning up, which is done by communicating with the on-board antenna on the CubeSat and recovering the data using an Iridium relay satellite. This data will be

used to observe how hypersonic speed conditions during the reentry phase affect the materials used on HEDGE. In order to achieve this mission, we need to be able to collect four measurements per second. This can be done through four thermocouples and transducers that produce 2 bytes of data per measurement transmission. We need to ensure that we have full transmission coverage throughout the entirety of HEDGE's journey so that we do not lose valuable data while HEDGE is in operation.

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However, we run into two potential major issues that can essentially ruin getting the essential data needed to complete our mission and would set us back both financially and operationally. The first is the thermal heating of the antenna; if burned too early during re-entry, we risk not getting the essential data that we need on the effects of hypersonic speeds on the HEDGE's material composition. The second is keeping a constant communication between the relay satellite and HEDGE. Since the beams are cone-shaped, a sizable gap between the relay satellites could result in less overall coverage during the initial part of re-entry. Since HEDGE has no propulsion system, its orbital path has to be considered in order to see where it's best to start re-entry while having a strong connection to the relay satellites.

As we start to get into the more technical and hands-on portion of HEDGE, the goal by the end of next semester is to eventually have a physical model that is capable of being tested for space conditions. For our technical, our objectives require collaboration with the other subsystems. With the Software and Avionics team, we need to know if our transceiver is able to connect and transmit with the Iridium satellites and still provide constant communication with the ground station during re-entry conditions. This also includes ensuring that our on-board computer (OBC) and our communication protocols don't provide redundant instructions, which

will be ensured using error-correcting memory/code. We will also be working with the Power, Thermal, and Environmental team to figure out the placement of the antenna so it can resist hypersonic speed temperatures long enough to get the essential data while still maintaining the omni-directional feature and that's along with the other parts that we need to assemble onto HEDGE for our subsystem.

STS Project Proposal

On March 13, 2023, the United States Air Force carried out its second test flight of Lockheed Martin's hypersonic missile prototype (Capaccio, 2023). The prototype was projected to reach speeds up to Mach 8 for up to a thousand miles. When they released the hypersonic missile missile from a B-52H bomber off the southern California coast, there was a successful separation of the warhead from the rocket booster and a good flight path. However, the warhead failed on the communications end when there was a failure of transmitting telemetry data that showed its in-flight performance and the weapon's flight characteristics. Lockheed Martin is currently working on a failure analysis to determine the root cause, which will determine the fate of the ARRW program by the U.S. Air Force (Losey, 2023). (Removed rest of paragraph)

While there were certainly technical factors that contributed to the failed test flight, the pressures from global foreign powers such as China and Russia as well as from other officials within the government to protect the country in such a hurry have gone neglected. If we continue to only consider the technical aspects of the failed U.S. Air Force test flight and other future test flights, the United States will almost surely put itself in a position where it will not be able to protect itself from foreign attacks from hypersonic technology and will not be able to retaliate as well. This comes as the U.S. Air Force plans to conduct two more test flights before the end of

2023 (Honrada, 2023). I argue that a lack of newer hypersonic technology in conjunction with the pressure to protect to boost national defense and societal pressures from foreign powers as well as U.S. officials led to the failure of the second test flight conducted by the U.S. Air Force. Actor-Network Theory takes the idea that there's a network builder that combines the work of human and non-human factors to complete a goal, which is called translation (Laugelli, 2023). The goal of ANT is to help expose the complexity of a failure or crisis, delving into science and technology and tracing the complex relationships between governments, technologies, knowledge, and money upon other factors (Cressman, 2009) through the five overlapping stages: problematization, interessement (or interposition), enrollment, mobilization, and black-box (Callon, 2023). Using translation, I will talk about how the U.S. hypersonics research network was created and the process by which the network failed to understand what human and non-human factors are to blame for the failed test flight. This analysis will require me to take evidence from articles surrounding past test flights that have either progressed or hindered U.S. hypersonics research, any public statements from U.S. officials, and statements from other foreign powers regarding U.S. hypersonics.

Conclusion

The deliverable for this technical problem will be a 1 unit CubeSat that will glide in Low Earth Orbit and collect data on how hypersonic speed temperatures affect the materials used on HEDGE. The STS Research Paper will focus on why societal pressure from global powers such as China and Russia in their advancements in hypersonic missile technology is responsible for the failure of the United States Air Force Test of Lockheed Martin's hypersonic missile for collecting in-flight data. This will be accomplished using actor-network theory to discuss how

society's shaping of the hypersonic missile has ultimately shaped how the United States government responds to rising global tensions with the use of hypersonic missiles that are able to circumnavigate successfully and stay undetectable. The combined results of this technical report will help to understand the socio-technical aspect of the breakthrough and advancements of hypersonic technology and implementing CubeSat as a way for the United States to advance their hypersonics research while not having to waste millions of dollars as well as spend less time having to create new parts.

Word Count: 1,765

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