Hypersonic Reentry Deployable Glider Experiment (HEDGE)

The Change in Global Response to Anti-Satellite Weapons Testing in Recent Decades

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By
Griffin Dewey

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Technical Sub-Team Members: Brett Schriever, Owen Solomon, Najarie Williams

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

M.C. Forelle, Department of Engineering and Society

Chris Goyne, Department of Aerospace Engineering

Introduction:

There is a prominent and growing issue that might imperil all of humanity: trash. I'm not referring to the trash that fills our landfills and, more alarmingly, oceans. I'm not even referring to trash here on earth at all but rather trash in space, more commonly referred to as space debris. Since the first satellite reached space in 1957, those responsible for these missions have been careless about leaving rocket and satellite remnants in space. Even the first satellite, Sputnik 1, was left in orbit after its battery died and ceased transmitting (*Sputnik 1*). Although leaving a satellite in space without a plan to remove it is inherently problematic, it's the small pieces of junk that are the real concern, as they are just as lethal and harder to avoid.

In 1968, the Soviet Union performed the first anti-satellite (ASAT) weapons test, intentionally blowing up a satellite and creating a large cloud of debris. Since then, China, India, and the United States have followed suit, each government blowing up its own satellites in a show of force, creating much more debris (*Space Debris from Anti-Satellite Weapons* 2008). When a debris hits a satellite, it can cause the satellite to explode, sending more debris going in all directions. In fact, this has already happened multiple times, but most notably in 2009 when an old Soviet satellite collided with an operational communication satellite, blowing it up (Pultarova, 2023).

The growing international concern for the safety of space has been evident in recent decades, leading to a shifting attitude toward ASAT testing. Comprehending the impact of this changing attitude on the prevalence of ASAT tests is the first step in fully understanding the approach that can be taken to protect space. This has inspired my STS research question: How have international attitudes toward ASAT testing changed as space debris has become a growing concern? I will approach this question by first elaborating on the importance of space as a resource. Next, I will discuss the threat that debris poses on space and the impact of ASAT testing on it. Finally, I will go over the methods that I will use to research this topic.

ASAT testing is not the only way that space has been used by militaries; space is the latest battleground. In fact, for my team's project as the UVA Class of 2024 Spacecraft Design Capstone, we are studying the effects of hypersonic reentry into the atmosphere. Hypersonic research is one of the highest priorities of the defense industry right now, as international tensions climb and the United States seeks to catch up to Russia and China in this field, as it can be applied to create missiles traveling up to ten-times the speed of sound, or Mach 20. These missiles travel through the atmosphere rather than in space, allowing for real-time navigation and control of the missile and less time for defensive measures to be taken by the target. Understanding the behavior of materials travelling hypersonic speeds is crucial for national security, as we are incredibly vulnerable to foreign attacks without this technology. Our CubeSat, a small satellite that we are using to conduct this research, will be launched into low Earth orbit (LEO), and will reenter the atmosphere at hypersonic speeds, transmitting crucial data back to us before it burns up.

Technical Topic:

The fiscal year 2023 DoD budget request lists hypersonics as a defense-specific critical technology; technologies that require prioritized research, experimentation, and prototyping to ensure homeland defense and project power to our adversaries (Comptroller, Office of The Under Secretary of Defense, 2022). As global relations continue to deteriorate, and the threat of a larger conflict becomes ever more probable, the United States Government (USG) recognizes the national security implications in our lack of technological maturation in the field of hypersonics, and the threats these weapons pose to the US homeland (Sayler, 2023). As Kelley Sayler and collaborators argue, "[t]he maneuverability and low flight altitude of hypersonic weapons could challenge existing detection and defense systems" (Sayler et al., 2020), hypersonic missiles have become a serious national security concern in the past decade due to China's hypersonics weapons program testing, and the operationalization of these missile systems by Russia in their war with Ukraine.

Unlike Intercontinental Ballistic Missiles (ICBMs), hypersonic missiles travel through the atmosphere rather than a suborbital flight. This allows for near real-time navigation and control of the missile while also hindering early missile warning defenses. Understanding the behavior of materials traveling at hypersonic speeds is crucial to successfully develop and field a weapons system that can deter our adversaries. A major issue the USG has in developing these systems is the length of time a major acquisition program takes; the typical timeline takes roughly 10 to 20 years to operationalize. Figure 1 illustrates the bulk of the DoD's acquisition process for major acquisition programs, which has many bureaucratic "go/no-go" decision points that can often add months to years to the expected program delivery timeline.

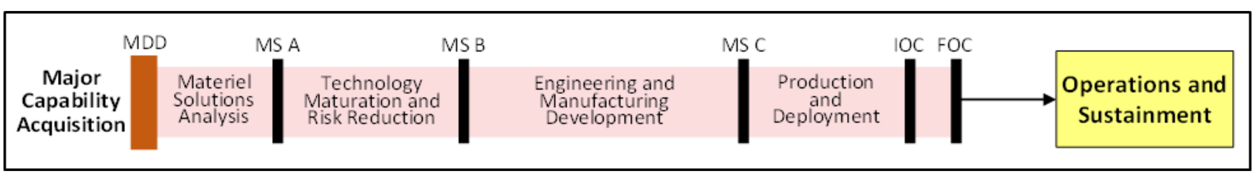

Figure 1. DoD Acquisition Process for Major Acquisition Programs (Department of Defense, 2020).

Since our nation's adversaries have a significant lead in the development of this technology, it is imperative that the USG places significant importance on development of these weapons systems. A common research and development technique is to test technologies using CubeSats. The Hypersonic Reentry Deployable Glider Experiment (HEDGE) program will help bridge some of the gap related to hypersonic glide research and development.

There are three primary mission objectives for HEDGE: demonstrate the feasibility utilizing low-cost CubeSat technology for defense research and development, where HEDGE supports hypersonic glide research; demonstrate low-cost material screening methodology for hypersonic flight conditions; demonstrate that undergraduate university students can contribute national security research and development goals, in which HEDGE is a low-cost, accessible hypersonic glide experiment.

The goal with HEDGE is studying the effects of hypersonic reentry through the atmosphere, and as the Project Management Team, our job is to make sure it happens by helping organize the other functional teams to assure program timelines are being met. Unlike most CubeSats, HEDGE requires an atmospheric reentry to conduct its mission, and thus it will be launched into very Low Earth Orbit (LEO), below 400 km in altitude, so that it reenters the atmosphere soon after launch. The goal of this experiment is to transmit crucial scientific data back for analysis on conditions HEDGE experienced as it reentered the atmosphere at hypersonic speed.

Our leadership team will use an Open Source Project Management Software, Open Project, to monitor progress and assign tasks to the specific subgroups, in addition to bi-weekly meetings via Zoom. Using these tools, we will prepare materials for a Technical Interchange Meeting (TIM) at the end of the Fall semester. We will then further our work into the Spring semester continuing to ensure efficient communication across groups, keeping the project on schedule and budget, and keeping a record of tasks across the class. This will lead up to the completion of a System Integration Review (SIR) at the end of the Spring semester. The completion of this meeting will demonstrate that the HEDGE project is ready for assembly, which will be a task that next year's HEDGE capstone class will take on.

When our CubeSat is launched and released into the upper atmosphere at a speed exceeding Mach 5, assuming HEDGE is successful, we will gain a better understanding of hypersonic travel and how materials respond under that stress. This is crucial information to help our military stay competitive with other global superpowers, so we are less vulnerable to attacks. Nothing is more important than safety, and without missions such as this being performed to gather the data to allow the creation of the most advanced technology and weaponry in the world, the United States would not be able to remain safe.

STS Topic:

Most people don't think about space often, and if they do it is probably in the context of NASA and science fiction; they might wonder "who cares if we can't go to space anymore?" The fact of the matter, though, is that nearly everybody is impacted by space technology far more than they might realize. Yes, one of the allures of space is the great beyond. Recently, many governments have been considering colonizing the moon even Mars. (Kamin, 2023). NASA spent $10 billion on the James Webb Space Telescope alone to help us understand the history of the universe. (USAFacts, 2023). I understand that pursuing questions about the nature of the universe doesn't immediately benefit the economy or livelihood of most people and may seem like a ludicrous investment, but beyond the scientific and explorational allure of space, its utility in everyday life for most people is often underappreciated. Without satellites, we would not have cellphones, GPS, accurate weather predictions, and so much more. Inaccurate weather predictions alone would lead to thousands of deaths each year and billions of dollars in damages (Shrader et al., 2023). The terrifying part of space debris is that, if it gets out of control, not only will it cut us off from learning more about and exploring space, but it will also destroy technology that many people have become accustomed to. I will investigate these ideas through a lens of technological determinism, as understanding the way that technology reliant on space impacts our lives is crucial in understanding the true impact of space debris (Smith, 1994).

Currently, there are millions of pieces of debris in space, and by some estimates over half of it is a direct result of ASAT testing. The 22,000 pieces of debris larger than a softball are currently being tracked by the Department of Defense, but the estimated 150 million pieces smaller than 10 cm are not (*Space Debris from Anti-Satellite Weapons* 2008). To date, there have been four satellite collisions with space debris (*Space Environment Statistics* 2023). Thousands more have been avoided with evasive maneuvers (Alamalhodaei, 2023). The snowballing effect of this debris is worrying, especially as more and more satellites are launched, increasing the risk of collisions which leads to more debris and so on.

Not only is space a new frontier for research and commercial markets, but it has also become the most recent battleground. Most military satellites are used for early warnings for things like missile launches, navigation, communications, and surveillance, like spy satellites (Fox et al., 2013). Because spacecraft have become so crucial to military action in the past few decades, many countries have developed anti-satellite weapons, or missiles that are used to destroy satellites. When countries test these weapons, they typically blow up their own satellites in orbit, causing massive clouds of debris. With growing international concern over this, some countries have changed their perspective on the allowance of these practices. For instance, championed by the United States to curb the arms race in space, the United Nations addressed the issue in 2022. This motion was passed by a wide margin, but it should be noted that among the countries that opposed it were India, China, and Russia: the three countries besides the United States that have performed successful ASAT testing (Foye & Hernandez, 2022).

To further investigate this shifting attitude toward ASAT testing, I will find primary and secondary sources online that discuss these topics, focusing primarily on how Russia, China, and India have dealt with the issue and how it has impacted their foreign relations. I will further research the proceedings from the United Nations conference on the matter to understand the way that various countries approach this issue. Additionally, I will investigate the difference in attitudes of these tests from NASA and the United Space Department of Defense, and the equivalent organizations in China, Russia, and India. To find better and a wider variety of resources, I also plan to interview someone who works directly with this issue, trying to influence the United States government to increase regulations on debris-causing activities in space. A company called Astroscale seeks to do just this, and I will speak with multiple people there in both the lobbying and engineering departments.

Conclusion:

The United States has always been a leader in both space and defense, but other countries are passing us in many areas. My technical project, HEDGE, not only provides us with the privilege of working on a satellite that will go to space, but it also gives us the opportunity to help our military to stay competitive with other countries to keep our country safe. Space can be used responsibly even when it comes to military purposes, but it often isn't, namely with ASAT testing. It is important to understand international attitudes toward ASAT tests and how they have changed over the years to fully understand this issue and steps that can be taken to protect space. If space debris is not mitigated and controlled, people run the risk of losing access to space entirely. This means a world without cellphones, GPS, accurate weather predictions, space-based telescopes that provide valuable insight into our universe, and so much more. We must ensure that future generations are able to look at the sky and see endless possibilities rather than prison bars.

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