Undergraduate Thesis Prospectus

CubeSat Prototype Development for Hypersonic Glider Research

(technical research project in Mechanical and Aerospace Engineering)

Rallying the Troops: How the United States Government and Big Defense Spread Love for Missiles

(sociotechnical research project)

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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General Research Problem

How does the United States promote research and development in the Aerospace industry?

The United States Department of Defense (DoD), among other government agencies, sees the aerospace industry as a catalyst for achieving global leadership. One of the DoD's obstacles toward acting on its agenda is garnering public support for aerospace research and development. The Cold War global aerospace boom is a relevant case study. President John F. Kennedy praised the Space Race in his 1961 address, declaring, "I believe that this nation should commit itself to achieving the goal… of landing a man on the Moon and returning him safely to the Earth. No single space project...will be more exciting, or more impressive to mankind, or more important..." (Smithsonian, 2023). Space advocates leaned on the emotional aspect of achieving the "impossible" and the threat of Soviet advancement to accelerate industry growth. After the war, it was difficult to maintain momentum. The industry consolidated from over 70 suppliers to 5 prime contractors (Walker, 2002). These contractors require significant capital investment for manpower and technology development. According to 2022 data, the defense industry employs 2.2 million people across all US states, providing $240 billion in total compensation (Aerospace, 2023). In 2023, NASA pledged $24.38 billion of its $33.09 billion budget in obligations (USAspending, 2023). The US government and prime contractors utilize Cold War-era social techniques, fund university research, employ a mammoth workforce, and push unlikely boundaries in efforts to promote their agendas.

CubeSat Prototype Development for Hypersonic Glider Research

Can CubeSats serve as a feasible platform for hypersonic glider flight research?

CubeSats were developed in 1999 by professors at California Polytechnic State University and Stanford University, enabling students to design and execute satellite missions. They are classified by number of units (1U, 2U, or 3U), and a 1U CubeSat has a volume of 10 cm^3 (Government of Canada, 2022). Our capstone, *Hypersonic ReEntry Deployable Glide Experiment* (HEDGE), aims to demonstrate the viability of CubeSats as an affordable platform for conducting hypersonic glider research. A rocket will launch our 3U CubeSat into low earth orbit (LEO). After release, HEDGE will deploy fins, morphing into a hypersonic glide vehicle that will live in LEO until naturally deorbiting (Goyne, 2023). To simulate a real mission planning scenario, the capstone is split into various sub-teams: program management; communications; software and avionics; attitude determination; power, thermal, and environment (PTE); structures and integration. Our group has been assigned to PTE.

The power subsystem has the main objective of supplying electrical power to all other subsystems in the CubeSat, and power produced must exceed power required. The thermal subsystem's objective is to tailor the design of HEDGE to expected thermal conditions. Considerations include thermal protection in LEO and reentry and complete burnup of the CubeSat after data collection. The environment team's objective is to calculate the mechanical loads experienced by the spacecraft during launch and reentry, and to determine the potential space debris or radiation HEDGE will encounter based on the timing and location of its launch.

The power team will combine previous work with information from industry to estimate power generation, collaborating with other teams to determine system requirements and optimal products. The thermal team will run tests and simulations to examine previously selected

structures and materials. We will use CFD and FEA to analyze reentry conditions and thermal loads, ensuring that HEDGE can collect data before burnup. The environment team will conduct research to find values needed for load calculations as well as debris and radiation trajectories.

To determine the power budget, we will use the documented hardware specifications for the components and previous calculations. For thermal analysis, we will use Ansys Fluent and Mechanical to carry out CFD and FEA on an existing CAD model of HEDGE. Prior teams identified Niobium Alloys as the best high temperature material and Teflon as the best ablative material for the hypersonic nose cone, and we will work to predict performance. The environment team will use loads and testing parameters found within the NASA Sounding Rockets User Handbook and the SpaceX's Falcon User Guide to perform structural tests using the aforementioned resources. Online databases will be used to track orbital debris and radiation.

In the spring semester, the power team will recalculate the power budget and power flow chart with new EnduroSat components (Figure 1).

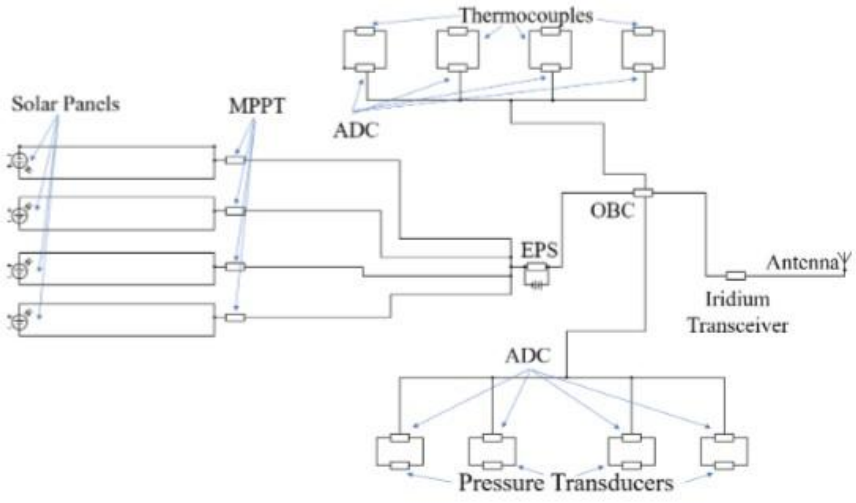

Fig. 1. HEDGE Power subsystem circuit diagram (Source: 2022-2023 *HEDGE* Thesis)

Components must generate and store more power than the maximum power draw (MPD). Also, the team will configure a battery pack to fit in the nose cone and power the CubeSat when solar panels aren't producing power. The primary goal of the thermal team is to analyze HEDGE performance under a variety of conditions. We will review completed CFD analysis, modify the CAD model and CFD parameters to meet current objectives, and run several iterations of CFD and FEA testing. Our work will include predicting the reentry burnup time for the final design. The environment team aims to find the mechanical and vibrational loads during launch and reentry and determine any protections against radiation or space debris.

The fall semester of MAE 4690 will conclude with a Technical Interchange Meeting (TIM), where sub-teams will merge work into one Critical Design Review (CDR) and present completed research and future design plans.

Rallying the Troops: How the US Government and Big Defense Spread Love for Missiles

In the US, how have defense contractors and policymakers managed moral concerns regarding substantial defense spending and the development of advanced weapons?

The United States defense industry grows despite controversy regarding the ethics of investing in advanced weapons. Corporations from all fields influence the federal government, but defense contractors collect unprecedented funding. President Eisenhower warned of this influence in his 1961 farewell address, coining the term “military-industrial complex” (MIC) to describe the relationship between government and prime contractors (National Archives, 2023). Gordon Adams built on Eisenhower’s concern in the 1980s, framing the contractor-government relationship as an “iron triangle”, where the federal government is both a regulating body and a customer (Adams, 1981). Nearly 50% of the Pentagon budget goes to the primes each year– in

return for the $10.2 million invested by these companies in campaigns for members of the Armed Services Committees (Wooten, 2022). The paper trail is public, and the implications of these transactions are clear, yet Americans have been divided for decades on whether defense is worth billions. According to Ronald Reagan Presidential Foundation and Institute polls, two thirds of Americans disagree with defense budget increases (Harper, 2022).

Research exists from an array of lenses on financial and ethical concerns with defense. The budget has moral implications itself, as money might otherwise address social welfare issues. Wang and Miguel (2012) quantified the excess profits of prime contractors, using "industry-year-size" matched measures to show that defense company profits far surpass peers in other industries. However, defense work is technically demanding, and earning profit is not only expected, but required. Kantian Nonideal Theory and Just War Theory apply to weapons development and profiting from war-related goods. Doyle (2010) uses nonideal moral theory to examine whether nuclear proliferation should be permissible in Iran, despite the Treaty on the Non-Proliferation of Nuclear Weapon. He writes, "Unfortunately, the fact of nonideal conditions makes it impossible to sometimes avoid putting humanity's rights at risk in the pursuit of legitimate self-defense." Forge (2009) adopts the perspective of the engineer behind a weapon, writing about uncertainty on future use. He claims Just War Theory cannot be used in preparation for war, since the blueprints for weapons might one day serve an immoral customer. While grappling with moral dilemmas is not at the forefront of MIC daily operations, understanding why people question the industry can protect future growth. Gallup (1942) explores the power of public opinion, citing instances of the government implementing policies that the public supported for months prior. In November 1935, 80% of Americans favored a larger Air Force. Military experts disagreed on the importance of air power as Hilter's regime conquered Europe,

long after the public had recognized its relevance for future warfare. Public opinion matters, and lawmakers and defense contractors today constantly work to earn the support of voters.

Spheres of influence on the defense industry include advocacies and defense engineers, in addition to the aforementioned government agencies and prime contractors. Some groups support defense, while others challenge American foreign policy and the use of warfare as a whole. According to the DoD's website, "[The DoD's] mission is to provide the military forces needed to deter war and ensure our nation's security" (U.S. Department, n.d.). The DoD "ensures" responsible use of controversial weapons by updating policies such as DoD Directive 3000.09, which "maintains the requirement that commanders and operators who authorize the use of, direct the use of, or operate autonomous and semi-autonomous weapon systems do so with appropriate care and in accordance with the law of war…" (Garamone, 2023). All prime contractors are vested in the problem of reputation management alongside the DoD, and Raytheon provides an example of collective goals. Their website frames offensive weapons as part of the defensive and preaches a patriotic message of protecting freedom. "At Raytheon, the foundation of everything we do is rooted in our values and a higher calling – to help our nation and allies defend freedoms and deter aggression…" (RTX, n.d.). A blogger by the alias "pomjuice" started a Reddit thread for engineers at defense contractors to discuss how they rationalize the fact that their product might harm people ([pomjuice], 2013). "Pomjuice" introduces the notion that not all MIC products are purely war-related: "GPS technology was made popular by the Navy. The Apollo program was based on the rocket program" ([pomjuice], 2013). One engineer responded, "...if there was a conflict, I wanted to make sure that my country's troops won and with that in mind I'm going to do my utmost to make the best items that I can..." ([rhombomere], 2013). Republicans generally endorse defense spending more than

Democrats, but the Blue Dog Coalition is an exception. In its bylaws, the coalition affirms its commitment to the "financial stability and national security of the country" (Mission Statement, 2017). They voted in favor of the National Defense Spending Act, which freed up over $800 billion for the DoD (Blue Dog, 2022). The side opposing the DoD, contractors, and politicians has a wide base, despite its quieter voice. Win Without War is one of many advocacies that criticize the Pentagon. They believe in peaceful foreign policy, calling out "redundant" and "dangerous" new weapons of mass destruction as well as "mismanagement" and "profiteering" at the Pentagon (Win, 2021). Defense may have a pile of money to stand on in Fiscal Year 2023, but its proponents will continue to face moral questions in the future. How the government and contractors will face such questions demands further analysis of the participants and existing research in this section.

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