HEDGE: Hypersonic ReEntry Deployable Glider Experiment

(Technical Project)

Analysis of the Ethical Effects of Unmanned Aerial Vehicles in Modern Combat

(STS Project)

A Thesis Prospectus
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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

Warfare and the need for defense has long been a driving force in scientific discovery and engineering development. From the invention of penicillin in World War Two to the invention of the Global Positioning System (GPS), military application has furthered human understanding and capability beyond the battlefield. In as many instances as there have been great strides in communications, travel, and medicine due to these military projects, there have been cases where development of a technology has adversely affected the civilian population as well as the militaries who employ it. Since the turn of the Twenty-First Century, unmanned aerial vehicles (UAVs) have been employed in a multitude of battlefield roles. They started out and are still often used for reconnaissance, but as with many military technologies, they were developed into weapon platforms. In the years since the United States embarked on its “War on Terror” UAVs have been used to locate and eliminate targets outside of the US that are deemed to be threats (Keene, 2015, pg 1). As soon as these unmanned vehicles entered the battle space and started performing missions an ethical debate was sparked about the legality and ethical nature of the use of UAVs to carry out the nation’s strike missions. Some argue that drones are not only legal, but that their use is ethical and more effective than manned missions (Keene, 2015, pg 2). Others argue that the data from past UAV missions shows that the assurances from the US military are false and that UAVs cause more civilian casualties than manned missions and as such should not be used in combat (Barela, 2016). Furthermore, there have been studies conducted by the Air Force to research the psychological effects of the UAV missions on their remote pilots (Chappelle, 2014).

The STS portion will focus on analyzing the ethics of UAVs in combat and if they should continue to be used in their current role. This will continue beyond just the battlefield with a look into how the use of UVAs affects not just the target environment but also those who use them in combat.

The Technical portion will investigate the design and fielding of a small-scale hypersonic reentry test vehicle built upon a CubeSat chassis. Hypersonics represents the cutting edge of current aerospace research and development and is being pushed by the defense industry to catch up to foreign power's hypersonic capabilities. The CubeSat, called HEDGE, is being designed as an inexpensive and simply built unmanned satellite that will allow for cheap and repeatable hypersonic test data as it enters the atmosphere. It is very likely that all hypersonic weapons when fielded will be unmanned and thus the ethical analysis of current unmanned weapons systems will help guide the ethics of the technical project. The basic design of the HEDGE satellite will be a 3U CubeSat with an unfolding point and fin exterior for stability as it reenters the atmosphere. It will carry communications and sensory electronics so as to take and transmit data it collects at hypersonic velocities.

Technical Project

In 2019, the spacecraft design course at the University of Virginia sent a CubeSat, Libertas, to orbit on a rideshare with an Antares rocket provided by Northrop-Grumman. Contact was successfully made with the satellite until a firmware fault in the radio component of the craft made further communication impossible (Goyne, 2022). Despite this, the mission was considered a partial success and served as the first step to develop research using CubeSats. The next mission currently being considered is the HEDGE: Hypersonic Re-Entry Deployable Glider Experiment which is a concept for low-cost hypersonic flight research using the CubeSat form factor.

The primary goal of the mission is to transmit data about re-entry conditions before burning up in the atmosphere (Angeliotti et al.). After natural orbit decay, HEDGE will re-enter the atmosphere at hypersonic velocity and send telemetry to the ground. A Structures and Integration (S&I) team plans the assembly of a spacecraft, ensuring that construction is feasible and that the final design will be able to integrate with the launch vehicle (Caldwell, 2021a and Caldwell 2021b). The S&I team will also focus on the structural design of the craft for aerodynamic stability and material selection, addressing the balance between having the craft survive long enough to collect meaningful data and being able to burn up in the atmosphere for safety.

The team has developed a series of methods to ensure that the structure meets the design goals. An important approach that we are taking is to delegate specific members for inter-team communication. Our team must work with the power, thermal and environment team to select materials that will allow our vehicle to endure re-entry while preserving the viability of the hardware onboard. It is also critical that our team communicates with the Attitude Determination and Control System (ADACS) team to ensure the vehicle is oriented in the proper direction on re-entry; if the craft fails to enter nose-first, the re-entry structure will no longer be optimal for hypersonic flight, and our project would not be a success. Our team will also need to be in contact with the communications and avionics team to determine the arrangement of hardware on the vehicle, as shown in figure 1. It is important that all necessary hardware be on the vehicle, despite the 10cm x 10cm x 10cm size restriction for cubesats (Loff, 2015). To accomplish this goal, team members will be assigned to be designated liaisons to the other subsystem teams. Another approach that our team has taken on is to use finite element analysis (FEA) software and computational fluid dynamics (CFD) software to verify the structure proposed by the previous year's team, as shown in figure 2, which is critical for reducing risk during spacecraft development (Blandino et al. 2018). We will also be using Ansys Granta software to determine which materials are best for our design, taking into consideration cost, strength, temperature resistance, machinability, and commercial availability.

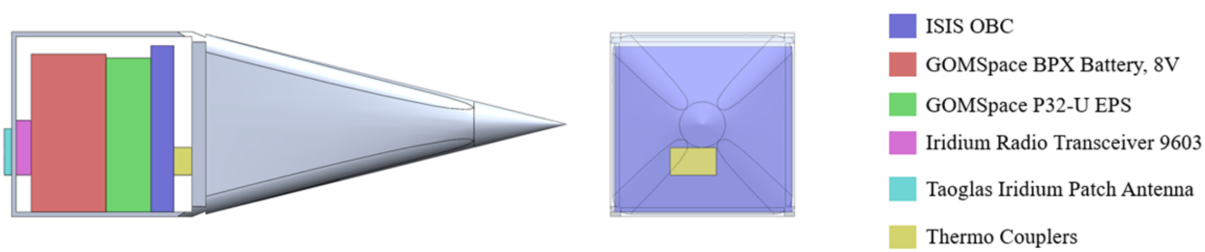

Figure 1: Approximate volume distribution of HEDGE components

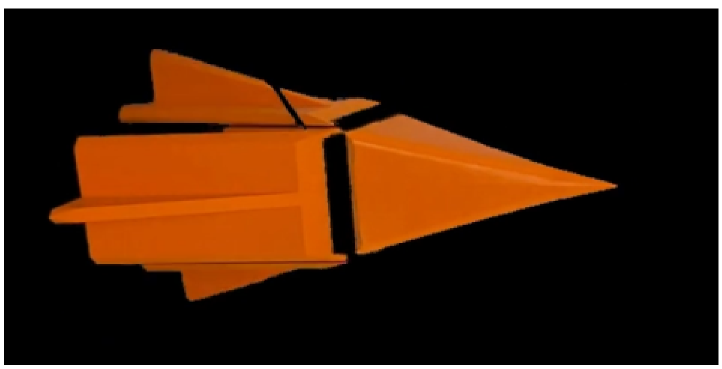

Figure 2: Mockup of HEDGE fins deployed in re-entry configuration

In the design and construction of the HEDGE spacecraft, the group will have access to the UVA Engineering Rapid Prototyping Lab and Mechanical Engineering Machine Shop, which will allow for quick and inexpensive fitment testing and design reviews. We will also have access to UVA Engineering Faculty, including our technical advisor Prof. Chris Goyne, among other subject matter experts (SME) who have experience in mission planning, structural analysis, and materials design.

The deliverable for the Fall semester will be a preliminary design review. This will be followed by a critical design review and a proposal to industry for the funding to build and launch the spacecraft in the spring semester .

STS Topic

In the modern era the newest and most debated weapon people have created to make defending themselves easier are unmanned weapons systems with precision guided weapons. The theory behind these Unmanned Aerial Vehicles (UAVs) is undoubtedly attractive to a nation's government as well as their citizens. The promise of the ability to fight foreign wars for national interest without having to send their own sons and daughters into harm's way is certainly a noble goal. However, as with all technological advancements the final product does not necessarily represent the same nobel intentions as the design was birthed with. While as previously stated the public generally agrees that sending a UAV to complete a dangerous mission is preferable to sending a human pilot into danger, the public also expects less civilian casualties and greater accuracy from UAVs than they do of humans (Walsh, 2015). This leads to a discussion of the ethics behind relying on UAVs to do a country's fighting while their citizens and soldiers are safely at home.

Research Question and Methods

Research Question: How do the ethical arguments surrounding the use of UAVs in combat affect their use by militarized nations?

To answer the research question I will explore the three main stakeholders in a country that has UAV capability and analyze their points of view. The groups being; the nation's government officials, the soldiers in charge of operating the UAVs, and the citizens of the country. The nation's government is a very obvious stakeholder as they are the ones who are paying for development of the UAV technology as well as the group in charge of ordering its use. Government officials are especially concerned with the arguments surrounding the use of UAVs as they need positive public opinion to stay in office, in democratic nations at least. This means that regardless of their personal views on the use of unmanned weapons they need to reflect to the citizens that they agree with the majority of their constituents. This makes this group hard to analyze because their position can change so rapidly based on single incidents.

The second stakeholder group I have identified to be important are the soldiers that actually operate the UAVs. This includes the pilots and the support crews for the UAVs themselves. The original theoretical benefit to the development of UAVs was to keep this group out of danger. When deployed into a battlefield the pilots are in the direct line of fire and the support crews for their aircraft are also in constant danger, even if not actively in the combat zone. However, as decades of UAV combat has occurred there have been studies that show that in fact PTSD symptoms can still occur in remote pilots, even if they never are actually in danger (Chapelle).

The third group I will be exploring is by far the largest in population size, that being the citizens. They hold up most of the ethical argument as they would like to feel safe and secure in their own homes, but also are the ones responsible for holding the government officials accountable for the ethical questions behind the use of UAVs. They are the group most focused on whether or not the use of unmanned weaponry is the right thing to do, rather than simply the convenient option.

The major stakeholders that are being left out of this analysis are the peoples who are being attacked by the UAV systems and the manufacturers of the weapons. These groups are being left out, although I acknowledge they are very important, due to them being outside the scope of the main research question. I will instead be focused on analyzing the use of UAVs by the country that possesses them.

My timeline for this research has already begun as significant base research was undertaken to produce this prospectus. Furthering my research in the next few weeks and months will be my main priority. This research will focus on analyzing the current discussions and views held by the aforementioned stakeholders. My initial research goal is to fully understand the current views of each group. After the base understanding is achieved I will shift the research towards a more technical review of UAVs actual combat effectiveness. This will include using resources published by the US Military in the public domain.

Key Texts

Barela, S. J., & Plaw, A. (2016, October 03). Are Drones Less Accurate than Piloted Aircraft? Retrieved October 15, 2020, from https://www.justsecurity.org/33333/drones-accuratepiloted-aircraft-2/

- A technical review of of UAV effectiveness compared to piloted aircraft in the same combat role
- Specifically focused of civilian casualties from strikes
- Concludes that based on US Defense Department Data that drones are roughly 33% more precise (less unintended casualties) than manned strikes in Iraq and Syria.

United States, Congress, Strategic Studies Institute, and Keene, S. D.. LETHAL AND LEGAL? THE ETHICS OF DRONE STRIKES, United States Army War College Press, 2015

- Focus on the ethics of UAV strikes as well as their legality under international laws and treaties
- Produced by the US Army, therefore may be biased in favor of past decisions made
- Weighs both sides of both legal and ethical arguments and does a good job of citing specific people and events as examples
- Provides a good baseline summary of the current environment surrounding the discussion of UAV ethics

https://www.webofscience.com/wos/woscc/full-record/WOS:000337989400008 (Chappelle, Reardon, Thompson, goodman)

- Psychological analysis of soldiers who remotely pilot UAVs
- Shows that based on analysis of a study group of USAF drone operators that PTSD symptoms are possible and 4.3% represented “severe” cases
- This number is lower than for soldiers returning from combat in theater but is higher than what is reported publicly by the DOD

Walsh, J. I. (2015, October 1). Precision Weapons, Civilian Casualties, and Support for the Use of Force. Political Psychology, 36(5)
https://onlinelibrary.wiley.com/doi/full/10.1111/pops.12175

- Analysis of population polls regarding the use of UAVs and their unintended consequences
- A great base for analyzing the perspective of the normal citizens on UAVs in combat
- Concludes that the use of precision guided munitions and UAVs make the population more sensitive to collateral damage when compared to their acceptance of damage from manned strikes.

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