Senior Capstone Spacecraft Design: How to Build a Rocket

The Ethics and Ubiquity of Defense Careers for Aerospace Engineers

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

The aim of my technical senior design capstone, Spacecraft Design I and II, is to design, fabricate, test, and deploy a rocket to deliver an experimental payload to an altitude of 5,000 feet. This design project originated within the confines of Spaceport America's Intercollegiate Rocket competition but has since expanded beyond the requirements for the competition to allow for student experimentation within the course. In addition to serving as the lead for the Aerodynamics and Structures team, I am also the project manager of the design capstone. This position has offered many managerial challenges but has also provided a keen perspective on the topic holistically. This specific senior design capstone has never been offered in the past, and therefore much of my work has been centered around developing a framework for future students to follow. I aim to offer three unique perspectives of the project: the project from the managerial perspective and the work required to facilitate current and future student engagement; the project from my perspective as the aero-structures team lead and the decision-making vital to this team's success; and finally, a holistic view of the entire project as someone interfacing with every team and the development they have made.

Senior design courses such as this one are integral to the engineering curriculum as a whole, and offer a direct expression of the academic interest fundamental courses do not have the freedom to allow for. The work "What We Learned, When We Learned It, and How We Learned It: Takeaways from an Institution's Aerospace Engineering Capstone Experience" [1] further articulates these claims and posits the importance of physically fabricating a product to complete this sort of curriculum. My position as the project manager has offered considerable insight both into why the capstone is vital to the individual engineer, and how students express their career interests in this work. It is this expression of interest and its intersection with the ethics of pursuing an aerospace engineering career which will serve as the point of intersection between my technical focus and my sociotechnical focus. Particularly, I aim to identify the discrepancy between the career interests students express within their senior design capstone and the ubiquitousness of defense careers in aerospace. My goal is to place this question into a larger framework, such as the framework expressed by Lin, P. in his "Ethical Blowback from Emerging Technologies" [2], which describes the unforeseen consequences of defense innovation.

The senior design capstone serves as the final point of passage from student to engineer for many. The unique agency it provides the student both in the chosen topic and how the student approaches the problem is largely representative of the freedom graduates find in the careers they are able to pursue. However, the discrepancy between what captivates many early engineering students and the commonality of defense and military careers for aerospace engineers demands investigation. Moreover, the ethical ramifications of pursuing this sort of career are evident even in the coursework taught to aerospace engineers. In this work, I will address why these careers are so common and why students are not adequately provided an ethical framework through which to consider these careers; I will examine the interplay of this issue with my senior design capstone, which largely prepares students to enter this workforce.

Building a Rocket Now and In the Future

The goal of the senior design capstone is to produce a rocket to deliver a payload to an altitude of 5,000 feet. This ostensibly simple goal has undergone a series of changes already during the capstone, as the project has taken shape. Initially, the goal was to compete in Spaceport America's IREC competition, although it was quickly realized that since the UVA

Rocketry Club plans to compete in this competition, the UVA capstone cannot also send a rocket, since only one rocket is allowed from each university. As the project manager for the capstone, much of my work has been focused on resolving these sorts of issues. The project has now shifted away from the competition, allowing for student experimentation, although we have maintained certain requirements from the competition.

Outlining our requirements has been vital to the success of the capstone. Particularly in this ambiguous space, having well-defined constraints is necessary to ensure the rocket performs as expected. For instance, we maintained the target altitude of 5,000 feet, but removed the requirement that the payload must be of the dimensions 10cm x 10cm x 30cm. These decisions allow for the course to focus on what the students find most interesting and have largely been a cross-team effort.

The capstone is broken into three teams, and each of these teams are further broken down into sub-teams. The breakdown is shown below.

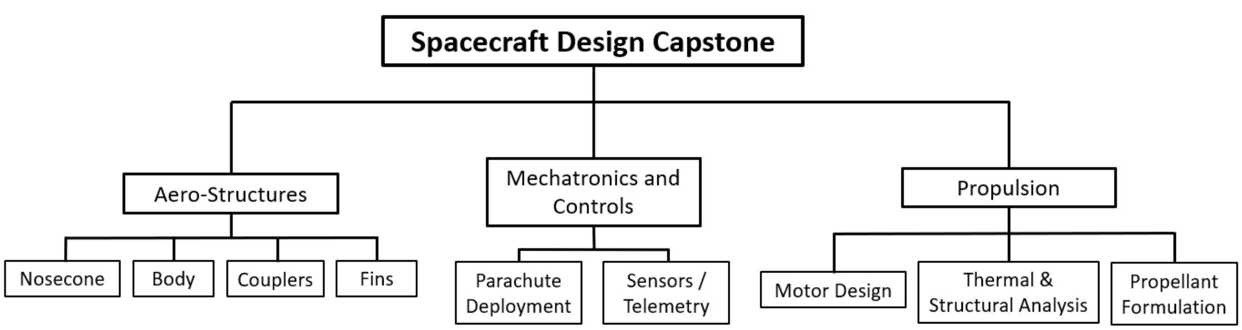

Fig. 1. Capstone Teams and Sub-Teams

Because the capstone consists of 32 students, having well defined roles and groups has been vital to our success. My team, Aero-structures, has been broken down by the physical components of these rockets. It was difficult to anticipate the workload required for each sub-team—and therefore the required team size—but cross-team communication has minimized this effect.

In addition to assigning action items across teams, documentation has been a large part of my role. This documentation both facilitates the work students are currently doing, and also allows future students to expand on our work. This has consisted of project schedules, action item lists, work breakdown structures, validation and verification matrices, risk assessment, decision matrices, and finally our design reviews. The four design reviews allow the class to communicate their progress to the professors and advisors overseeing the capstone. The Design Specification Review refined our project guidelines and allowed for each individual sub-team to explain the decisions they have made. Documenting these decisions is particularly important to future senior engineers; this documentation allows students to revise the choices we have made, or better understand why these decisions are important.

In my role as the Aero-Structure team lead, one of the largest decisions we have made is the layout of our subcomponents. This decision was made in large part with the mechatronics team, as their avionics coupler and payload will have vital thermal and shock requirements. We conducted several trade studies, anticipating issues each might have, as shown below:

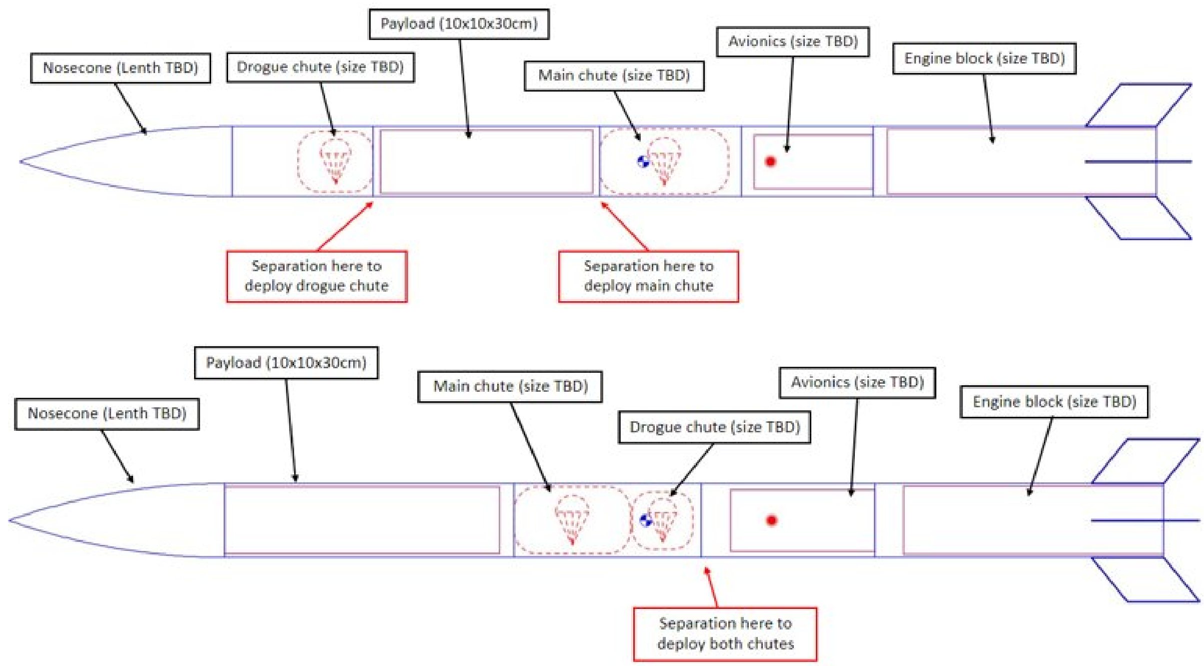

Fig. 2. Two Example Rocket Component Layouts

To make our final decision, we compared what other universities had elected to do during their IREC design review presentations. This also required us to fully define the functionality of our payload, so that we could determine its location in the rocket. Ultimately, we decided on the final layout, shown below. This allowed for dual separation, where the nosecone would initially separate, deploying the payload and then the drogue chute. Afterwards, the avionics coupler would separate, deploying the main chute.

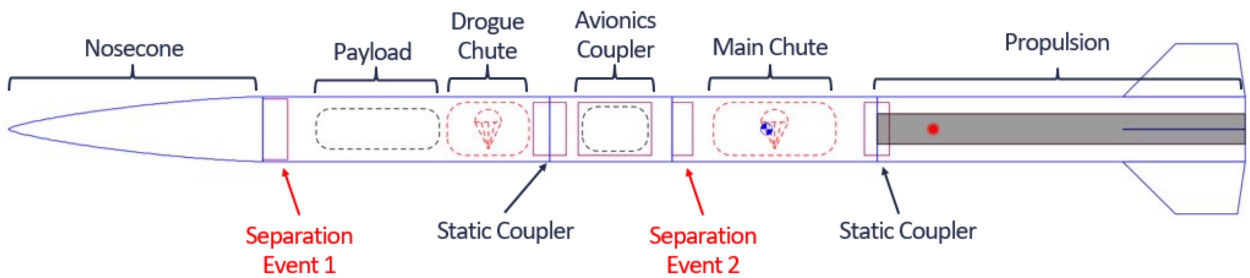

Fig. 3. Final Rocket Component Layout Decision

To exemplify the primary connection to my STS topic, I aim to introduce the work "Linking personal and professional social responsibility development to microethics and macroethics: Observations from early undergraduate education" [3], which highlights the ethical ramifications of engineering coursework. The literature also explains the interplay between social responsibility and professional responsibility, and how engineering ethics education fails to bridge that gap.

The Ethics of Aerospace Engineering

I am working on the topic of the ubiquitousness of defense related careers for aerospace engineering students because I want to find out why such a large portion of aerospace students pursue such roles in the military industrial complex despite how students express their academic interests and the morality of such a choice. This is important because of the discrepancy between perceived career opportunities within aerospace and the reality of the job market; furthermore, the rationalization of such choices seems to alleviate the individual of any responsibility given the scale of the United States's defense industry.

This topic must be approached through several unique frameworks to identify such a multifaceted issue. First, through work such as "A Model for Student-led Development and Implementation of a Required Graduate-level Course on History, Ethics, and Identity in Aerospace Engineering" [4], I will identify the absence of ethical considerations within many aerospace curriculums. It is this absence which seems to have permitted the growth of many of these ethical concerns. These concerns are further articulated by Taylor, I. in "Who Is Responsible for Killer Robots? Autonomous Weapons, Group Agency, and the Military-Industrial Complex" [5], where many issues broached by militaristic innovation are acutely analyzed. The complexity of the field evidently garners many of these questions, and yet the curriculum does not seem to prepare the student to deeply consider their ramifications.

However, it is evident that this issue is contingent upon a larger system: the military industrial complex. To approach the issue from this perspective, I plan to introduce work such as "Speaking Out Against Socially Destructive Technologies: Norbert Wiener and the Call for Ethical Engagement" [6]. This work considers the societal implications of this way of developing technology, which directly highlights the importance of the topic I plan to discuss. As a source of a quantitative measure of militaristic trends, "Trends in World Military Expenditure" [7] offers a reliable set of data to draw from. Understanding this growing presence is vital to my argument. "An Aerospace Nation" [8] expands on the popularity of the field, and how it has grown into the massive force it is known to be in the United States. This historic perspective augments the established militaristic framework, and recharacterizes how this ubiquitousness came to be.

To understand this issue from the perspective of the student, I aim to introduce the work "Design-build-launch: a hybrid project-based laboratory course for aerospace engineering education" [9], which reframes the importance of these capstone projects and their connections to the work aerospace engineers perform. Furthermore, “Common elements of capstone projects in the world’s top-ranked engineering universities” [10] importantly describes commonplace attribute of the design capstone. With these two works, I plan to compare the work students are able to perform in their capstone to the sort of work in these aforementioned aerospace fields.

Conclusion

In conclusion, my work aims to explain the commonality of defense careers for aerospace engineering students, and their appeal to early professionals. It also aims to describe the impact the senior design capstone can have on these students, and how vital the capacity to express academic interest in this way is. The societal implications of this topic are overtly expressed in how militaristic innovation affects our world, and the sort of aerospace engineers required for these innovations. These monolithic systems—such as the military industrial complex—are not without their own ethical considerations and moral questions. It is integral that we first posit these questions, so that they may be broached and answered. The defense industry asks many of these ethical questions, and yet it appears so far that the aerospace engineering curriculum has yet to educate its students on how to answer them.

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