Self - Initiative Undergraduate Research

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Abstract

This paper describes an undergraduate research project conducted at a liberal arts institution during the summer of 2019. The undertaking was distinctive in that it was an engineering project conducted at a liberal arts college by undergraduate students enrolled in the college's engineering program. A multidisciplinary research team was assembled, composed of students majoring in civil, chemical and mechanical engineering.

It should be emphasized that this seven-week program was designed to serve primarily as a learning experience for the student researchers. The goals were: (1) to engage undergraduate students in the self-initiative research process; (2) to demonstrate how what they are studying and learning can be put to practical use; and (3) to teach the students the value of their chosen field and how it benefits society. It should be further emphasized that the "nuts and bolts" specifics of the project, though important, were not the primary objective; learning the value of teamwork, prioritization, time management and communication was.

In picking a research topic, the students were asked to identify areas where unmanned aerial vehicles (drones) have been underused or totally unexploited, and to select one for further detailed analysis. Unlike typical research projects, where the potential areas of research and the main topic are preselected by the research instructor, this project allowed the student researchers to make those decisions.

Several drone usage areas were identified, including: wildlife analysis, package delivery, athletic analysis, mosquito spraying, and areas in which artificial intelligence (AI) is used to enhance information gathering, such as security surveillance, storm tracking, and wildlife poaching activity. After a thorough review of these uses, mosquito spraying was selected as the focus topic. The decision was based on feasibility, time constraints (just seven weeks to complete the project), budget constraints, and capabilities of the Phantom 4 drone that was used.

The research methodology involved the following components: (1) using the team "brainstorming" process to settle on one research topic; (2) pooling the students' individual research efforts and findings to arrive at a comprehensive conclusion; (3) adapting a structured research approach to a very compressed, limited time frame; (4) coordinating a multidisciplinary team into a collaborative effort to meet specific deadlines; (5) using a high-tech mechanical device (the Phantom 4 Pro drone) to perform an untraditional assignment (spraying mosquitoes); and (6) training the students in the proper use and navigation of drones, and getting them FAA-qualified for pilot and ground observer status.

Developing the mosquito spray container and spray release mechanism, and determining the type of spray to use, required two weeks of intensive study, analysis and design, necessitating several trials before achieving satisfactory results. Despite this time-consuming process, the students were able to conduct and complete the practical aspects of the research within the seven-week time-frame, although there wasn't enough time to adequately test the final design.

Introduction

This project was conducted by four undergraduate students representing each of the major engineering disciplines: civil, chemical and mechanical. One was a sophomore majoring in civil engineering; two were juniors, one majoring in chemical engineering and the other one in mechanical engineering; and the fourth was a senior, also majoring in mechanical engineering. The project team was rounded out by an engineering instructor with expertise in structural and civil engineering. The instructor served as project director and student advisor, responsible for the day-to-day project operations.

During the course of the project, the students were introduced to a typical research process which challenged their talent, knowledge and understanding of their chosen field and taught them the logical process of selecting potential research topics, evaluating each topic, then selecting one for further detailed research and analysis. The students also learned some of the economics involved with project development, especially when it comes to the thorny issue of prying loose the purse strings of college financial support. Finally, on the technical end of the project, the students learned to evaluate the feasibility and practicality of using a high-tech mechanical device (the Phantom 4 Pro drone) to perform an untraditional assignment (spraying mosquitoes).

In short, these students got a taste of what it's like to work in the real world of engineering. They each were given assigned responsibilities through which they learned how to organize their workload, budget their time, work and communicate with others by sharing ideas and findings, lend a helping hand to others when needed, and how to present their findings in both written and oral form. It was a lot to learn in a short seven-week period, but the students more than met the challenge, gaining the confidence they will need for completing their degree, going on to graduate school, and dealing with the professional world beyond.

Literature Review

The summer research students, after deciding on the focus topic for this project, embarked on a search of the literature to avoid any duplication of identical or similar work, or as they said, "to avoid spinning their wheels." Although the search revealed some similar ideas, the students' chosen topic was unique in the sense that an affordable, readily-available commercial drone (as opposed to a more expensive, custom-made sophisticated one) would be used. And as it unexpectedly turned out, the powder insecticide container the students eventually designed and constructed (as opposed to liquid insecticide container and release mechanisms prevalent in the literature) added to the uniqueness of the project. The following are a few of the papers the students researched as part of their literature review.

- **"Design and Fabrication of Drone Based Pesticide Sprayer"** by Jeevan Gowda [1]. This paper describes a drone used in spraying pesticide for agricultural applications. It also doubles as a system for sowing seeds, with the intention of reducing human effort and labor costs while saving time and increasing the accuracy of seed sowing. The drone

is completely radio controlled via a transmitter and receiver within signal range of each other.

- **"Development of an UAV for Search and Rescue Applications"** by Naidoo, et. al [2]. This paper describes development of an unmanned aerial vehicle (UAV) used for search and rescue applications in the event of a major disaster. The platform for the UAV is a quad-rotor type helicopter, referred to as a quadrotor. A mechatronic system integration plan was developed to combine the mechanical, electronic and software elements of the research. Once the system was modelled mathematically, a control strategy was implemented to achieve stability. This was investigated by creating a MATLAB ® Simulink ® numerical model, which was used to run simulations of the system.

- **"Development of Automated Aerial Pesticide Sprayers"** by Dheepak, et. al [3]. In this paper, the authors intend to combat the pesticide poisoning occurring primarily in developing countries. According to the World Health Organization, approximately 3 million cases of pesticide poisoning occur in these countries each year, resulting in some 220,000 deaths. The authors plan on constructing an automated aerial pesticide sprayer, which is basically a combination of a blimp on a quad-copter frame. It is proposed that such a system will overcome the ill effects of manual pesticide sprayers through aerial spraying, which will cover larger areas in a shorter span of time.

- **"Agriculture Drone for Spraying Fertilizer and Pesticides"** published in the February 14, 2019 issue of *Flydragon* on the dronefromchina.com website [4]. According to this article, these drones have the ability to examine crop damage from severe storms, observe the progress of crop growth, and monitor the health of both crops and livestock herds. They also use what is called "precision agriculture" for spraying fertilizer and pesticides, and for observing, measuring and responding to crop variability.

The Project

As previously noted, this project involved evaluating the use of drones for mosquito spraying. The first major hurdle was to develop an attachable spray container for use with the Phantom 4 Pro drone. The students were tasked with coming up with a properly designed container that could be easily attached, that wasn't too big or too heavy for the drone to lift, that wouldn't interfere with the drone's maneuverability, and which would be sufficient for spraying the target area. They also had to design an efficient release mechanism that would allow a proper amount of mosquito spray in an adequate coverage pattern that would provide the best possible protection. All of this took two weeks of detailed study, analysis and design, along with several test runs of the initial design, before attaining a satisfactory final design.

The Unmanned Aerial Vehicle (UAV)

While UAV technology has existed long enough to no longer be considered as "cutting edge," it is becoming increasingly useful and valuable in many ways. Commonly referred to as drones, these vehicles remove the need for costly and sometimes dangerous ways humans conduct day-to-day routines, such as vertical structure analysis, wildlife analysis, package delivery, athletic analysis, and aerial surveying and photography, naming just a few.

Drones have also proved useful for areas in which artificial intelligence (AI) is used to enhance information gathering, such as security surveillance, storm tracking, wildlife poaching activities, and other critical and often dangerous tasks, not to mention spraying mosquitoes in heavily infested and inaccessible jungles or rainforests.

With this in mind, the mosquito-spraying concept was warmly welcomed and accepted by the research instructor, much to the pleasure of the student researchers who were excited about the topic that they had examined and selected. The time savings alone was worth the cost of the drone used for this project, not to mention the "cool" factor of having a legitimate reason to fly the vehicle.

Selection of the drone needed for this project was based on an extensive review of UAV literature [5] and products by both the students and the project instructor. The drone had to be capable of carrying up to 1.5-pounds, since the spray container and its contents were estimated to weigh almost that much. In terms of flying capabilities, weight load capacity and purchase cost, the Phantom 4 Pro (shown in Figure 1) was the most favorable drone for this project.

Figure 1: Research Drone – Phantom 4 Pro

The Mosquito Spraying Container and Release Mechanism

Since payload weight was a critical concern for the system, we decided to use a powder insecticide rather than a liquid one. After some initial testing, it was found that using liquid insecticide was not advisable. Its weight and its instability inside the container during flight (it sloshed around a lot) had an adverse effect on the Phantom 4 Pro's maneuverability. Consequently, we decided to use the powder insecticide, which was both lighter and totally stable in flight.

In regard to the release mechanism, we decided to purchase a light-weight, open/close mechanism known as the FliFli, rather than design and construct our own, as originally planned. Constructing our own would have required a motor and batteries, adding significant weight to the payload. The FliFli (shown in Figure 2) is designed for easy attachment to a Phantom 4 Pro drone (as shown in the two views in Figure 3) and allows the drone pilot to drop a light cargo from the vehicle via a remote-control system. When the pilot pushes the remote-control button, it compresses a pin which in turn releases a string attached to both the FliFli and the cargo, and drops the cargo. The photograph in Figure 4 illustrates the FliFli-string-cargo configuration, using a balloon as the cargo. Details regarding our spray container mechanism are presented next.

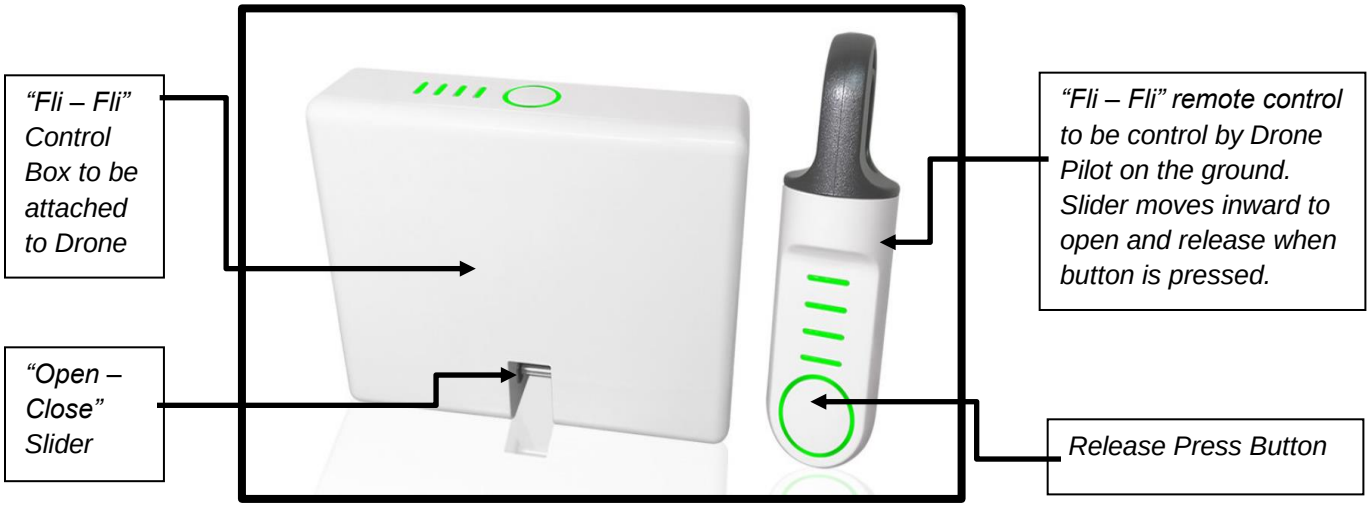

Figure 2: FliFli Release Mechanism – System Box with Slider and Remote Control

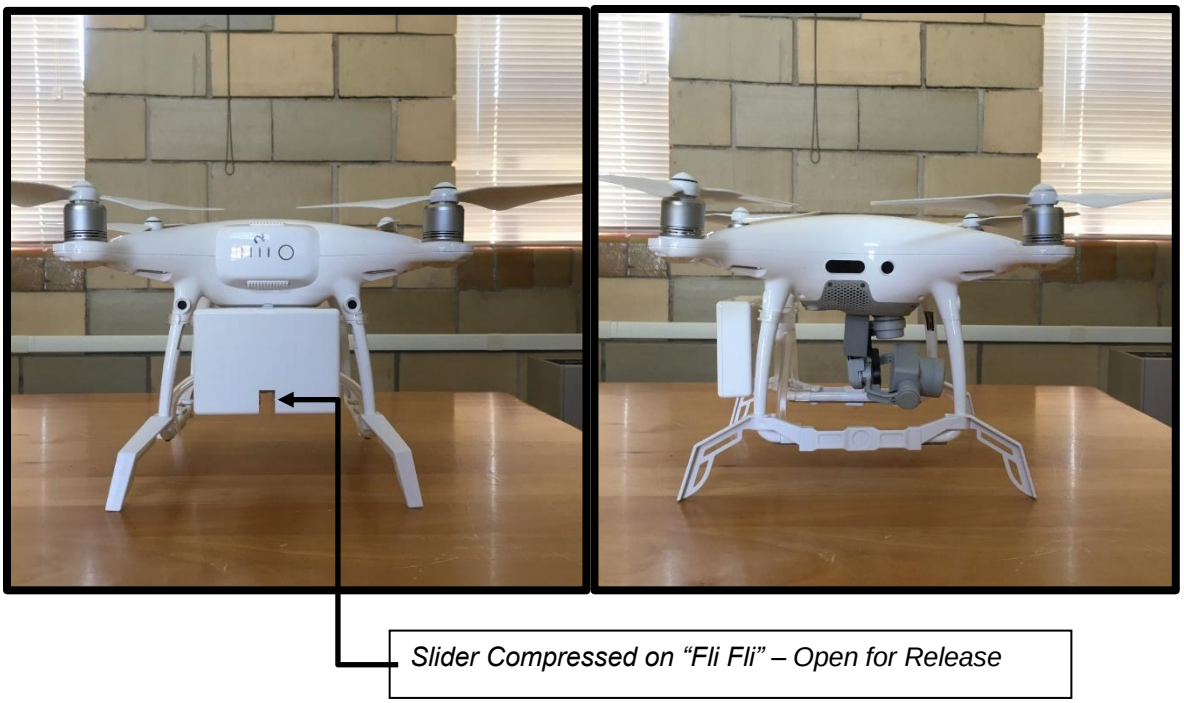

Figure 3: FliFli Box System Attached to Phantom 4 Pro Drone (Front and Side Views)

Figure 4: FliFli Attached to Drone in Mid–Air with Balloon Attached to FliFli via a String

The spray container is a 4x4-inch plastic box one inch in height, with removable top and bottom, and produced by a 3-D printer. Figure 5 shows the component parts. We first removed the bottom of the container, then reattached it with hinges on one end, creating a trap door. A kite string was attached to the other end of the trap door and to the FliFli release mechanism described above. When activated via remote control, the FliFli mechanism releases the kite string, allowing the trap door to swing open and the insecticide powder to be discharged. We then attached the container to the drone, using plastic tie wires to save on weight. Figure 6 shows a two-dimensional view of the container before and after release when all the components are in place.

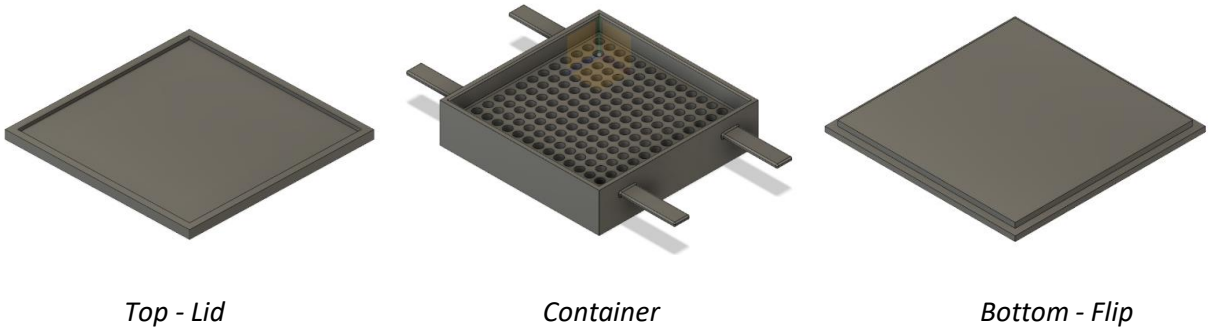

Figure 5: Mosquito Spray Container Components

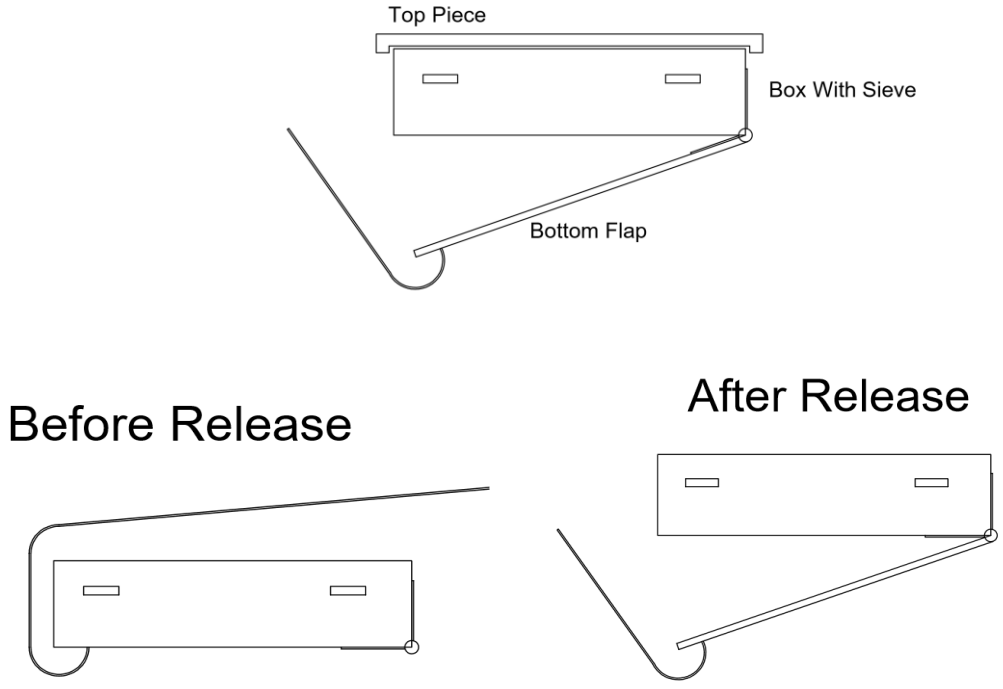

Figure 6: Mosquito Spray Container Release Illustration

Figure 7 shows the final configuration of the spray container and release mechanism attached to the drone, before and after release.

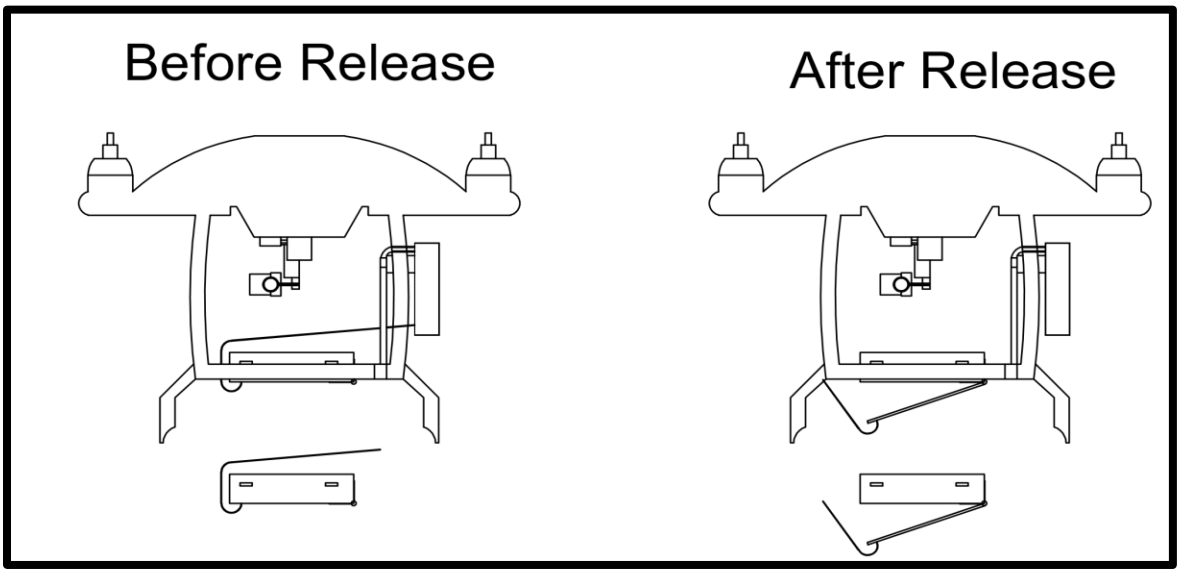

Figure 7: Final System Configuration: Container and FliFli Attached to Drone

The Mosquito Powder

As mentioned earlier, the research team decided to use a powder type insecticide versus a liquid, due to the difference in weight and stability in flight. Below are the characteristics of the Bifen IT insecticide used for this research:

- White Powder
- Very effective on mosquitoes
- Kills mosquitoes, flees, and ticks
- Weighs dramatically less than liquid alternatives
- Highly economical compared to similar products

Synopsis

The Summer 2019 Engineering Research Project (Mosquito Spraying Project) incorporated an interdisciplinary approach by involving students majoring in each of the major engineering fields: civil, chemical, and mechanical.

In conducting this research these students learned several valuable lessons regarding the realities of working in an actual professional environment. These lessons included: interdisciplinary teamwork, the sequence and phases of an engineering project, time management and scheduling,

and most importantly, the engineering concepts governing a project. In this case, they particularly learned how to assess and re-evaluate the initial project concept.

These students were given the opportunity to thoroughly explore a topic and to feel comfortable in taking the initiative in a research project. Combined with the practical lessons they learned; they consequently became more prepared to face the realities of the actual work environment they will experience when they secure employment in their chosen field.

As part of the learning process, each student was tasked with summarizing their experience during this research project, using their own words. Topics they were asked to address included: a description of the research; goals and objectives of the research; personal contributions to the research; personal expectations of the project; application of personal contributions; and overall research experience.

On the whole, they did a good job of expressing themselves, indicating that they gave a lot of thought and consideration to what they had done and how best to describe it. Due to the large volume of their responses, below is a sampling of what they said.

- *The engineering process is all about being flexible, being a critical thinker, and being a problem solver.*
- *[We]had to find a way to make this project connect with [our] chosen field. For example, I am a civil engineering student. One of the things I found particularly useful to my career path was the practice I got using AutoCAD, which is a program that most civil engineers use for creating designs. In addition to this, by working on this project, I and the other engineering students gained additional skills that we can always use later on in our respective disciplines.*
- *I definitely had to collaborate with teammates a lot and learned that sometimes you have to put your differences aside to accomplish a task.*
- *[I learned] some of the engineering concepts, such as the safest methods and approach, efficiency, cost- effectiveness, accuracy and precision that are necessary for conducting an engineering project.*
- *Through this research, I was able to learn the processes of research, ranging from creating the idea, to asking questions, to researching and testing, and ultimately to reporting on the results. I was able to learn how and what to document during research, which is everything. I also learned that ideas can always change during research, even in the middle of the project. Anything can happen.*

Analysis and Summary

A lot was accomplished on this research project during the short seven-week time frame, providing invaluable research experience to the participating students. Each student was given a specific assignment to complete, but each assignment was an integral component of the overall

picture. Each student maintained a personal portfolio documenting every aspect of his/her work and involvement on the project. At the end of the project, this information was used to compile a summary of the assignments and the lessons learned from completing them.

The students had to deal with several challenges during the project, such as: different individual expectations; varying personalities, capabilities and responsibilities; stringent deadlines; and unexpected changes and roadblocks. One of the major challenges was having to change their thinking and thought processes when it was decided to use a powder insecticide instead of a liquid insecticide. This required abandoning the liquid pump/spray container and mechanism originally planned and designed and having to come up with a totally different concept, plan and design. There was a perception among some of the students that this was a waste of time; but hopefully, when they think back on the experience, they will understand why it was important for them to endure the disappointment and frustrations, do the best they could, and persevere through to a successful conclusion.

The major overall disappointment was that there wasn't enough time to test the second design to see if it would work the way it was hoped it would, and to see if the powdered insecticide truly would be effective. If nothing else, these students accomplished the main goal of the project, which was to research and explore an area of drone usage that is either little used or not used at all. They found that it is indeed possible to use drones for mosquito spraying, given the proper equipment and system design. And in spite of their gripes and complaints, self-doubts and second thoughts, they learned the value of teamwork and doing the seemingly impossible in a very limited time frame. In short, they got a good taste of what it's like to work in the real world of engineering.

Conclusion

Enough cannot be said about the value and importance of this research project. It was a perfect fit for undergraduate research, bringing together students from three different engineering career fields who developed an organized collaborative working environment and functioned as a coordinated team in completing assigned tasks and bringing the project to a successful conclusion. Along the way, they also learned how to think logically and analytically, organize their time and efforts, work with and interact with a variety of different personalities and temperaments, and use their communication skills, both orally and written.

The students were involved in every aspect of the project, including: identifying the main focus of the research; developing a plan and methodology for achieving the research goals and objectives; operating the drone that was critical to the project; and coming up with a different concept to meet the research objective when the original concept proved infeasible.

Overall, these students came away from the project with a good working knowledge and basic understanding of many components of the self-initiative research process, which is invaluable to

graduate students when they are expected to come up with a unique research concept for a thesis or dissertation. As any grad student will tell you, coming up with such a concept and getting it approved by faculty advisors is one of the greatest challenges you will ever face as a college student.

In the final analysis, this research project was an unqualified success, despite the disappointment of not having enough time to adequately test the final design.

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