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Hybrid senior project courses in engineering education during the pandemic challenge

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Hybrid Senior Project Courses in Engineering Education During The Pandemic Challenge

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Abstract

EGR 4810, 4820, and 4830, are a series of required Project Design Principles and Applications- "Capstone" Senior Project courses. This Senior Project is comprised of multidisciplinary majors with multiple faculty advisors from Aerospace Engineering, Electrical and Computer Engineering, Chemistry, and Mechanical Engineering. Students taking these courses are highly dependent on on-campus labs and off-campus test sites. However, the COVID-19 restrictions challenge the academic environment and restrict the students' ability to access the manufacturing facilities and to work together. In this paper, we present the design, implementation, and outcomes of the senior project courses during the pandemic. The project includes investigation of novel technologies for increasing the endurance of UAVs, mainly by increasing power-to-weight ratio through parasitic weight reduction of structural and power systems and generating/harvesting energy mid-flight. These courses are a mixture of virtual Zoom weekly entire team meetings, sub-team with industry partner meetings, students' garage manufacturing, and in-person meetings. The courses aim to motivate students to apply engineering knowledge for new product development of engineering systems. Students can access the tutoring, supplemental instruction, and to store their assignments and other documents through the project team OneDrive and emails of co-advisors. The weekly virtual Zoom meetings give supplemental instruction and lets the project manager coordinate and assign which students will participate in at home and limited on-campus laboratory activities. Campus-visit compliance training for COVID-19 social distancing and hygiene requirements was defined and conducted before each week's Lab sign-in used by the students. The courses proved to be exciting learning experiences for the college students. They applied critical thinking skills and creativeness in developing a quadcopter / airplane hybrid payload delivery/surveillance UAV, making presentations, and implementation of the garage manufacturing. Overall, the experiences have motivated the students doing a great job to learn and approach engineering even with the pandemic challenge.

Index Terms **—** Hybrid, virtual, challenge the academic environment, senior project capstone course, endurance, UAV, solar panels, battery, supercapacitor, structures, wireless.

1. Introduction

The hybrid multidisciplinary senior project course curriculum and hardware enable students that are not allowed on campus to experience laboratory build and test experiences at home in a virtual team environment. This curriculum will include training, hybrid communication protocols, design of testing methods and test rigs that can be performed at a student's residence, purchase of hand tools, small lab equipment and test article materials suitable to be checked-out or mailed to a student's home for test article manufacture and testing. As stated in L.B. Nilson and L.A. Goodson's book [1], "*Distance is no barrier to a great education; what do stand in the way are inadequate online course design and implementation and deficient faculty training and support…*" This pedagogy will be applied not only during the COVID-19 pandemic campus laboratory shutdown, but also for future course applications where current on-campus laboratories are not available due to over-crowding or other constraints such as lab maintenance or equipment shutdown. This expands the inclusiveness of a senior project to include students that do not have home access to hand tools, electrical and structural assembly and testing equipment, nor have access or cannot afford to purchase materials for making the project test articles and test fixtures at home. In L.D. Fink's book, the effective teaching should help student "*…develop skill in thinking or problem solving*" [2]. This is a pedagogical approach for developing project design courses / experiments and the curriculum in virtual/remote environments.

This is an ongoing and repeatable project. The student engineering teams have been working on this multi-year, multidisciplinary project to integrate a complex variety of technologies into a new RC aircraft design; this complexity and new approaches requires multi-year development time.

This project provides a better learning modality for around 55 Aerospace Engineering (ARO)/Electrical and Computer Engineering (ECE)/Mechanical Engineering (ME) senior students every academic year. The organization chart of the student team is shown in Figure 1. Students are divided into sub teams that contribute toward the final UAV concept explained later in the paper. The senior students will be graduated with completing senior project courses. It also benefits junior undergraduate student and graduate students who do research under co-advisors' supervision. Our university is a federally designated as a Hispanic Serving Institution (HSI) by the U.S. Department of Education. As a state university located in a multi-cultural urban metropolis, this project will provide access to research project for a large number of students from low-income and underrepresented minorities.

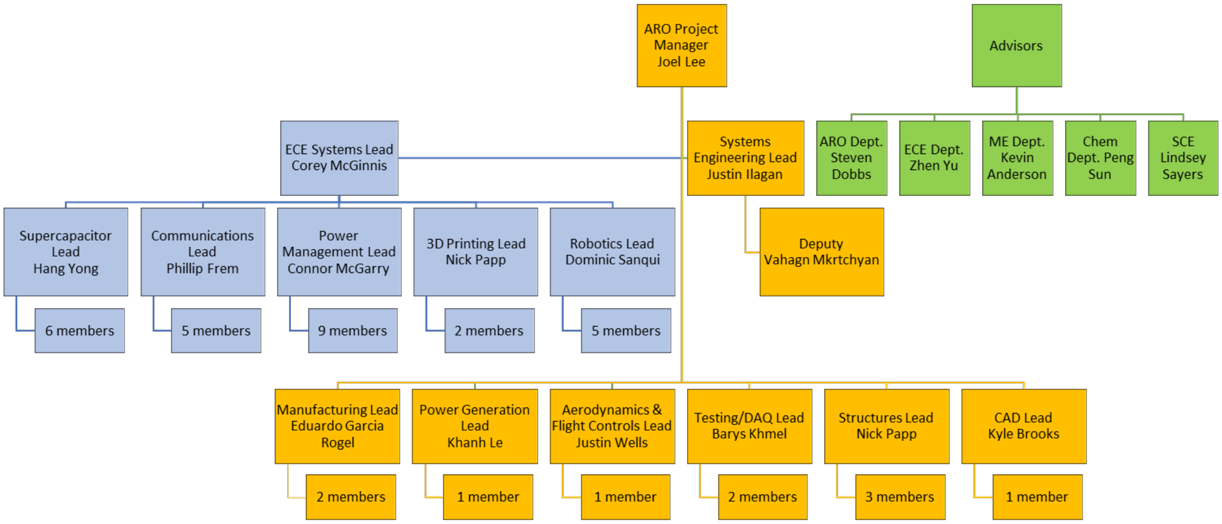

Fig. 1 Senior Project Team Org Chart

This project involves maximizing the power/weight ratio of a fixed-wing UAV, as well as using mid-flight charging via powerlines to at least double the flight endurance [3-4]. Weight optimization is done by repurposing structural elements to either generate or store power. For example, structural solar panels replace simple fiberglass wing skins to charge during the day. Also, rather than using a discrete battery pack located within the UAV's fuselage, the aluminum wing spars are replaced with carbon fiber battery spars to store the UAV's power. The key novel technology still in development include an induction coil receiver located in the aircraft's lower wing skin. This increases stiffness due to copper coils supporting the skin, and this enables the aircraft to wirelessly charge from powerlines within 6 feet. This requires precise autonomous control to ensure optimum charge rates, as well as maintaining a safe distance from powerlines to avoid damage. The team is also collaborating with Southern California Edison for guidance regarding the specifications of powerlines as well as ensuring we are flying within the safe distance from them. This wireless charging drone concept also serves Edison's interest in a technology that can inspect damaged powerlines. The final product will be a package delivery/payload carrying drone called the "Solar Induction Charging Drone" or Sinchdrone, which is shown in Figure 2.

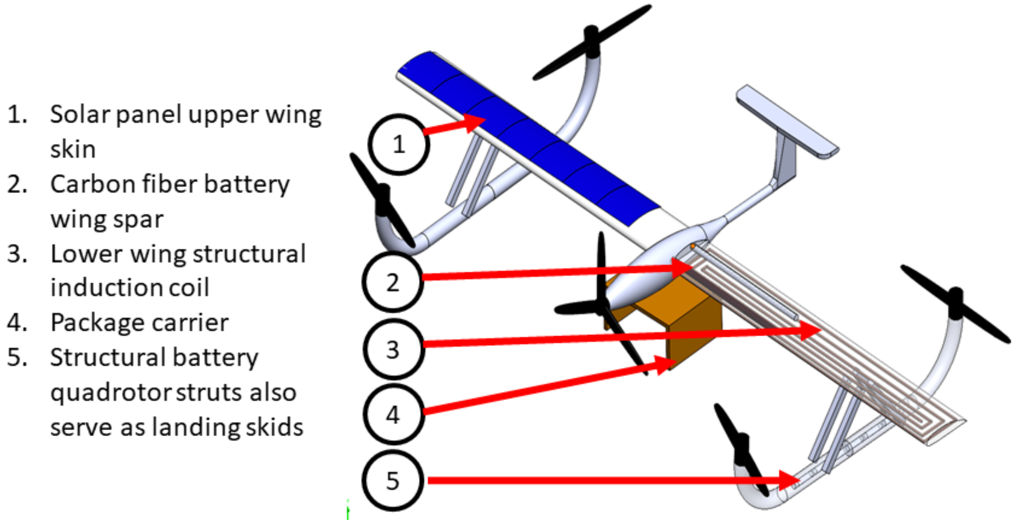

Fig. 2 CAD sketch of Sinchdrone concept with key technologies labeled

The Sinchdrone has applications in both civilian and military sectors. In the civilian sector, it would be designed for long range package delivery while charging along powerlines and a series of ground charging networks. In the military sector, 24/7 surveillance can be supplied when it is infeasible to deploy existing larger scale UAVs. A diagram of the Sinchdrone's concept of operations is shown in Figure 3.

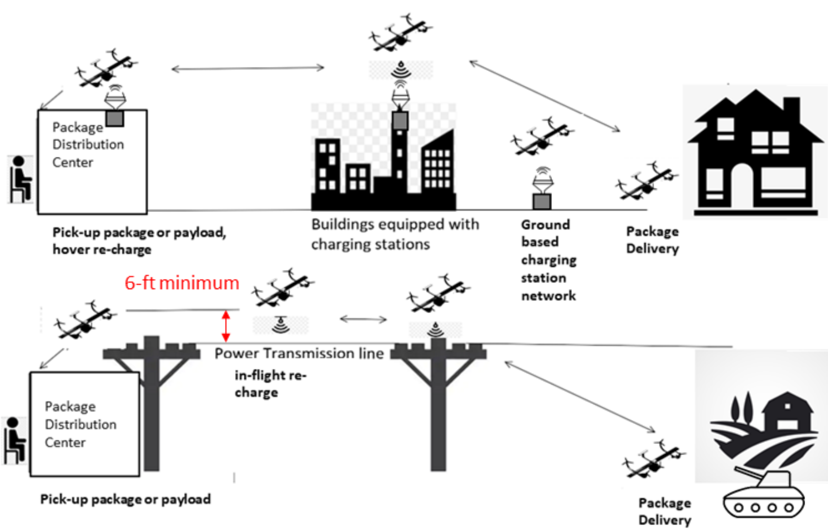

Fig. 3 Sinchdrone concept of operations

Other novel technologies that do not bring significant benefits to the UAV at the moment include: supercapacitor wing skins, gust vibration induced power generators, and thermoelectric generators. Supercapacitor wing skins replace the lower wing skin of the aircraft to store power, but current supercapacitor technology holds a negligible amount of power for the project's purposes. Gust vibration induced power generators use wing vibrations to convert kinetic energy into electrical energy, but it weighs too much to provide any benefit for increasing UAV endurance.

Because this UAV will rely on several power sources that produce both alternating and direct current, a power management system is needed to ensure that a steady direct current is fed to the batteries. The team has also developed an intelligent charging scheme that alternates between two battery packs to increase charge rate compared to charging a single battery until it is full.

It is essential that students be able to access the widely used equipment: digital multimeter, power supply, function generator and oscilloscope at home, and the project is able to afford all the materials to develop and test a working model of our UAV, so the project has applied for an innovative approach to instruction, the Special Projects For Improving The Classroom Experience (SPICE) funding. Such fund will be used in purchasing of hand tools, hardware and software required to validate project system-level requirements. Students will develop the system integration designs by following a systems engineering process, and will be able to mentor and hand-off these skills to the junior students on the team for next academic year.

The project has been funded at $3,000 per year via a Lockheed Martin funded student fund through the Aerospace Engineering Department (AY 2019-20 and AY 2020-21). With the help of the SPICE funds, we can accelerate the project development via developing hybrid "garage-manufacturing and testing" capabilities and hybrid sub-team communication processes toward meeting the flight testing milestone in 2021-2022. This would help the team catch up to the original schedule commitment shown to Lockheed Martin, but was delayed by the COVID-19 campus shutdown. We plan to repeat our funding request to Lockheed Martin in 2021-2022 to progress to the first flight test concept feasibility milestone.

2. Senior project course technical description

Students are required to fabricate, test and demonstrate the baseline bench test in students' home or garage during the COVID-19 Campus Shutdown through a broad array of fabrication methods. The details are discussed below. Some portions of fabrication/testing have already been performed, while others are planned for the future.

2.1 Battery wing spar (in progress)

How we are manufacturing the circuit

In terms of electrical wiring, the battery wing spar design is similar to many other Li-ion battery packs [5]. Currently, the battery size selected is two packs of three cells wired in series to create two 12.6V packs. Since the batteries must be placed end to end, and the UAV is utilizing the intelligent power management system, the batteries cannot be one uniform pack. Therefore, each set of three cells will have its own Battery Management System (BMS). This is connected to the power management system.

Since the team is working on manufacturing this at home rather than at school, some adjustments were made. The team had to buy a spot welder, nickel strips, and Kapton tape as well as the components for the system. Some of these tools may have been available had there been access to campus supplies. Shipping was also more difficult as parts had to be sent to specific members rather than to a centralized location. Since the members designing the wing spar and the ones building the components are not close together, communication is more difficult since any clarifications must be described verbally or made in a graphic rather than being shown in person.

The person manufacturing the battery spar has no prior experience operating spot welder, but is familiar with soldering, and general electric circuit design. As much as it would be desirable to engage all team members for the battery spar design and manufacturing, social distancing prevented many students from participating effectively past the initial design phase, especially since many aspects of battery spar design had to be modified on the spot during the manufacturing process.

How we are manufacturing the wing spar

To manufacture the battery spar, we have designed a cylindrical spar that is able to fit all the batteries and its circuitry as well as provide the proper strength to have a successful flight. We will be replacing the aluminum casing of the batteries with Kapton tape and stuffing this configuration within our carbon fiber spar to add the required strength.

We purchased two different size carbon fiber tubes for the forward and aft spars. We decided to buy these items rather than build it ourselves for two main reasons. First, COVID-19 has restricted our team from working together on campus. Because of this, the team did not have the proper equipment at home to build or test these spars. The second reason we purchased these tubes was because the company has a guarantee on their products. This meant that we could use accurate material properties for the spar analysis, and we would not have to worry about any other failures that may have occurred if we manufactured the spars ourselves. If we were able to build these at school, we would make extra spars to test at the Structures Laboratory. This Lab would have given the team the ability to find material properties the spars that we personally manufactured.

The person working with the carbon fiber spar has no prior experience working with composite materials, and a limited knowledge of general manufacturing techniques. That, combined with the need for specific tools to work with carbon fiber (hardened drill bits, high power drill, etc.) has made it challenging to achieve the manufacturing goals at initial deadlines. Since the budget is somewhat restricted and there are other team members who have more experience and tools to work with composites, it was decided to delay the final carbon fiber spar assembly before an opportunity arises to work with more experienced members of other teams in person. Similar to the battery circuit design process, there is a lot of collaboration across various teams (Testing, Manufacturing, Structural, Electrical) during the design and manufacturing process, but due to remote work process and not being able to work in person together, it takes significantly more time to refine the design and overcome challenges that inevitably arise.

2.2 Thermoelectric power generation (in progress)

Thermoelectric power generation is a technology that the team has been experimenting with for multiple years to determine its viability for possible installation on our aircraft. This technology, if successful, would extract heat from the motor driving the UAV propeller, convert the heat into electricity, and dissipate any remaining waste heat. While the effects of COVID-19 slowed progress, fortunately most preliminary testing was accomplished prior to the closure of campus facilities, leaving us with data to work with to continue testing. While in a remote learning environment, we have managed to accomplish more workbench testing of the thermoelectric generator using supplies available at home and components that were ordered online, which is illustrated in Figure 4. We have run tests to determine if a small electric fan and voltage boosting circuit would be viable to cool the generator, and we have also designed, ordered, and received a custom-made aluminum part to complete the thermoelectric generator assembly so that it can soon be put through final bench tests to determine power output. The completed generator assembly in Figure 5 now consists of a DC propeller motor, a milled aluminum heat shroud, a thermoelectric generator, and a heat sink. All testing required was conducted individually, with prior experience in operating equipment such as the power supply and multimeter, and previous exposure to the creation and measurement of electrical circuits.

The thermoelectric generator has been deemed a "novel technology" as it is not viable for implementation on our aircraft, which was confirmed much in part due to beneficial research and experimentation accomplished during COVID-19. We hope to accomplish final ground tests of the unit this semester to report our ultimate power output data.

Fig. 4 Home workbench testing of the thermoelectric generator

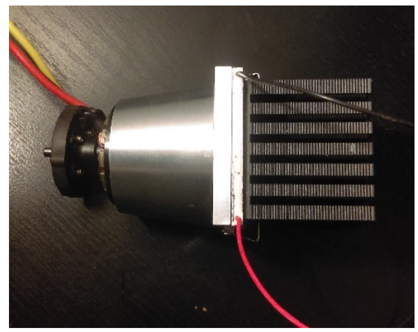

Fig. 5 Completed thermoelectric generator assembly

2.3 Autonomous flight control, communication, and collision avoidance (in progress)

For the Communications sub team, we were tasked with creating a system that allowed our UAV to fly autonomously without the need of manual ground control. Due to COVD-19, we had the disadvantage of not being able to experiment with different ideas in the lab, but this set back did not stop our team. We were able to do literature research that showed us a system that is affordable and efficient for our team's prospects [6]. The pandemic allowed our team to fast track our goals due to meeting more frequently in Zoom, which allowed us to get more research done with the assistance of the research papers. After the initial research, our team was then divided into two different smaller teams, one which focused on the practical building of the system while the other focused on more research. For the team focusing on building the system, we were able to effectively find the necessary parts online (shown in Figures 6-8) to be shipped to our homes as we work remotely. The research team is then able to continue to develop potential ideas that can help the overall reliability of the system.

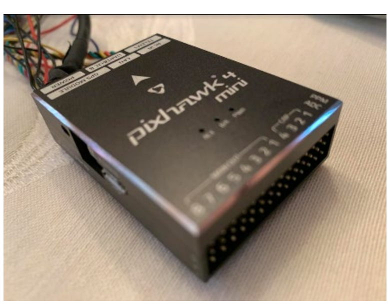

Fig. 6 Pixhawk 4 Mini **Fig. 7** GPS Chip **Fig. 8** LIDAR Sensor

Our system is separated into two main parts. One part is the drone system while the other is the ground control station. These two are connected via a cloud Linux server to help with wireless feedback transmission between the two. The drone is connected to a flight controller using the Ardupilot software, a Raspberry Pi 0W to allow wireless connection, and a camera connected to the Raspberry Pi to transmit live footage from the drone to our ground control station. A GPS and Lidar chip is integrated into the system for future use that mainly includes a Collision Avoidance System. Our drone then connects to a wireless cloud Linux server using a Mavlink router, which then connects to our ground control station. Our ground control station consists of a computer running windows 10 with mission planner software to transmit data between the drone and computer. This is our initial setup for our autonomous flight system that can be built remotely with members working safely at home.

Although our project focuses on autonomous flying and transmission through a network of drones using internet, we are going to start this project by using radio transmission over a short distance combined with manual flight control to get our drone up and running. After this we will implement our autonomous flying research to our drone to allow for autonomous flying and collision avoidance as well as being able to transmit video data from the drone to our ground control station. To do this we split up our team into software and hardware sub-teams. The hardware team focuses on getting the proper equipment for our drone to collect data as well as researching how to use the flight controllers and the raspberry pi together. The software team focuses on research and implementation of OpenCV Tensor Flow as well as the use of Convolutional Neural Networks in order to train our drone in image recognition and autonomous flight. We are able to do this research individually within the safety of our homes.

2.4 Wing manufacturing (in progress)

Our Manufacturing team is working with both the structures and the testing team to be produce developmental wings with different configurations to analyze and compare structural properties. Our different configurations are listed below in table 1 and lists the top skin, bottom skin, and core material. As the phases are developed, they will become more complex in design to reduce overall weight and add technologies to improve the aircraft's endurance. Technologies include replacing the top skin with a structural solar array. Methods to manufacture each phase is described below. Note that working with any composites is not a difficult task, but does require attention to detail, practice, and lots of patience. This can be challenging for someone learning for the first time, but it's not impossible. It's highly recommended to do plenty of research ahead of time and to try methods on small samples before tackling bigger layups.

Table 1 List of wing configurations

Phase	Top Skin	Bottom Skin	Core
Phase 1	Fiberglass	Fiberglass	Form
Phase 2	Fiberglass + Solar Cells	Fiberglass	Foam
Phase 3	Solar Cell	Fiberglass	Foam or spar/rib

Phase 4	Solar Cell	Fiberglass w/ copper induction coil	Foam or spar/rib
Phase 5	Solar Cell w/ supercapacitor	Fiberglass w/ copper induction coil	Foam or spar/rib

a) Phase 1

The foam core is cut out of EPO or XPS foam using a wire cutter. A 3D printed rib with the proper chord length is used as a guide to get the desired wing profile. Figure 9 shows a foam block 4 inches in height, which is used to minimize the profile cut-out error. Four blocks are cut out to produce a 16-inch span wing. The foam blocks are put together using Beacon Foam Tac Adhesive Foam Glue. Fiberglass with epoxy resin is applied around the wing to form a uniform skin, which is shown in Figure 10. In an ideal situation, the composite wing is placed under a vacuum to put pressure on the resin and fabric for better adhesion. In this case, the foam would collapse under vacuum pressure and therefore had to air dry.

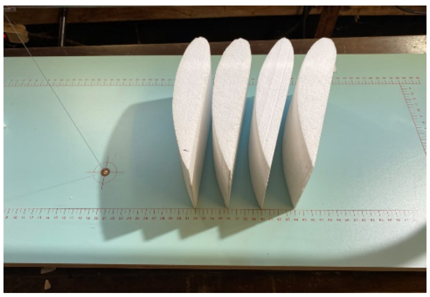

Fig. 9 Foam core segments

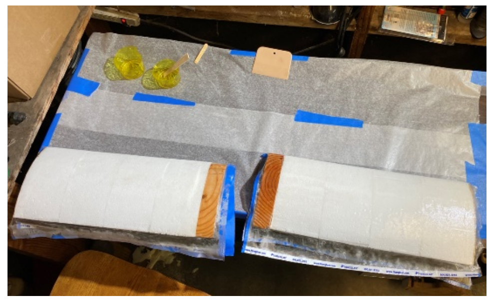

Fig. 10 Attached foam core segments

Another alternative that is being implanted is to lay up the skins on female molds of the top and bottom surface profiles. This allows a full vacuum to take place and squeeze out any unnecessary resin resulting a lighter part. The top and bottom skins are then popped off the molds and glued onto the foam core.

b) Phase 2

Phase 2 has very similar manufacturing techniques to phase 1 in producing the core, the top skin, and bottom skin. For this phase, we have thought of two methods to mount the solar panels to the top surface. The first method is just to adhere the solar cell array to the top skin. The second method is to sandwich the solar panels between two plies of fiberglass and layup on the male molds mentioned above.

c) Phase 3

Phase 3 will repeat the same manufacturing steps for the lower skin. This time the upper skin will only be the solar cells and will be mounted either to a foam core or a traditional spar and rib structure. Details on manufacturing the upper skin still needs to be discussed.

d) Phase 4

Phase 4 will be an exact replica of phase 3 except for the bottom skin which will a copper induction coil. The coil will be sandwiched in-between two fiberglass plies. The coil will serve as an induction charger and as a wing stiffener, similar to stringers on aircraft.

e) Phase 5

Phase 5 will be a phase 4 wing as well but this time the upper skin will be a solar cell array attached to supercapacitors. Details on manufacturing the upper skin still needs to be discussed.

2.5 At-home structural wing bending test (in progress)

The testing team had planned to perform a wing bending test back in Fall of 2020 but because of COVID-19 all classes and teaching methods had to be strictly online. The original plan was to test a section of the wing with about 1/4th of the actual wing span. There had been calculations done on how much the anticipated maximum load that the wing could take so the load being applied could easily be multiplied to this test wing as if it were a full-size replica of the wing.

In the campus structures lab, there is lab equipment where we could easily put the wing test section under a load to mimic the anticipated aerodynamic loads that the UAV experiences during flight, typically in the vertical direction. The lab has great measuring devices to accurately measure the deflection throughout the wing. These instruments would allow us to predict the maximum load of the wing for the UAV. There are also apparatuses available in the aerospace lab to be able to quickly test the strength of certain materials as this project concerns using different materials to be as light weight as possible. Some of these materials have not been used for UAV applications so testing them is a high importance. Because there is no lab access for any of the members of the testing team, we have had to attempt to perform this test at home. We have had to do this without any type of physical meetings due to the stay-at-home orders that were in place during the time. On-campus, we would perform the test, hopefully in one session, collect the data then go home and analyze it. But because we cannot meet up and perform a test, we have had to re-adjust and perform the test at home.

We have had to think how we can perform this test at home and get accurate results as if we were using the school's lab. We concluded that it was best that we use water as a load to apply to the wing that will be used for the UAV. In lab, this load would be a mechanical load (physical weights), at home we can weigh the water (by using the volume of the water) to use the water as load and be able to perform the test. For the deflection of the wing, we will use a laser range finder due to its high accuracy to be able to accurately predict the maximum load of the wing. In the lab, we would use a vertical ruler along the wing.

Fig. 11 Wing bending test setup

The test was carried out by mounting the wing sections to the end of a table on the wooden rib. 3d printed clamps are added at the tip and the midspan to mount the buckets and scales to measure applied load. Water was added in equal increments and the deflection at the midspan and tip leading and trailing edges was measured from the ground. A load vs. deflection plot was produced to identify the bending failure point. The foam itself is not structural rather it acts as a way for the skin to keep its shape and stiffen the fiberglass. Therefore, we predicted a buckling failure. Figure 12 below shows a test piece after failure and figure 13 shows the load vs deflection curve.

Fig. 12 Buckling Failure

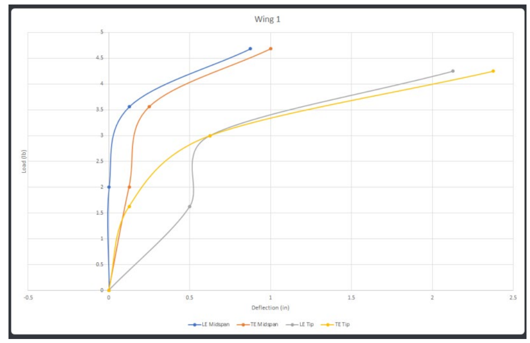

Fig. 13 Load vs Deflection Curve

The load vs deflection curve identified key flaws in our test setup. The biggest issue was that are weight increments were too large. Failure begins to become identifiable as low as 1.6 pounds on the trailing edge tip (yellow curve). We will use smaller buckets and smaller weight increments of ¼ of a pound to acquire more data points in future tests. Our test plan will change. Instead of just adding loads incrementally and measuring deflection, we are going to measure the unloaded wing in between each increments to see if the wing is coming back from deformation or if it is yielding.

2.6 Fresnel lens testing on solar cells (completed)

The goal of the Fresnel test is to help us determine the feasibility of utilizing a Fresnel lens as the upper surface of the airfoil. In theory, a Fresnel lens helps collect and focus light rays on the solar cell area, boosting its performance. Testing is required to analyze the power benefit vs weight penalty in close to real life situations. For that, a variable load circuit consisting of parallel resistor-transistors was designed.

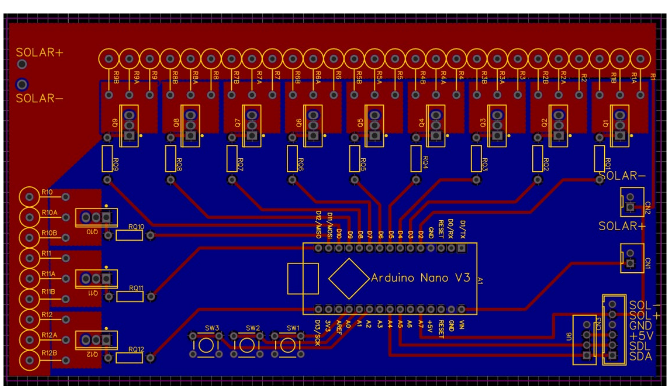

Fig. 14 Variable Load Transistor-Resistor Circuit

Fig. 15 Test Setup

Figure 14 illustrates this circuit and within that circuit, a programmable microcontroller (Arduino Nano v3) is used to measure 256 different voltage drops. The capability for such a wide range of measurements is provided by eight transistors in parallel, giving us 256 different combinations. The data is then transferred from the circuit to a laptop via USB. The airfoil shape was designed in Solidworks and printed using a 3D printer, show in Figure 15. There were several challenges during designing and performing this experiment. In light of the COVID-19 pandemic, students were denied access to labs on campus. To overcome this obstacle, students had to communicate and find possible testing locations in public places. Russian Ridge Preserve in Redwood City was chosen to test the system, since it was a convenient location roughly in between Supercapacitor and Testing Team Leads locations, who were responsible for running the test. Another obstacle was designing and manufacturing the test circuit without access to labs and equipment. For that, we had to rely on members who had access to tools (soldering iron, multimeters, etc.) and equipment (resistors, transistors, Arduino) at their place of residence.

Unfortunately, due to poor weather conditions, the Fresnel lens test data didn't converge. The weather during the testing was cloudy, wet, and late in the day (4PM). Due to that, the measured light output was about 10% of expected brightness during a sunny day. As a result, the effectiveness of the Fresnel lens decreased by 10% and below, giving unreliable data and noisy readings. Once the weather clears, we can repeat the test to get more reliable data.

2.7 Endurance testing (in progress)

Due to the COVID-19 pandemic, the testing of our batteries had to be done from home. We acclimated to this situation by mailing and purchasing the proper materials and equipment for our team, which includes: a power meter, a DC bench power supply, Samsung INR 35E 18650 3500 mAh Lithium-Ion Battery, and a 150 W adjustable electronic current load. We chose to use an adjustable electronic current load because a constant current load is required to accurately calculate the capacitance of our batteries. Our group is working in a small group to design the testing process. We are working together remotely to design a testing procedure and we will meet up on campus to conduct the testing. In terms of training, no one from the group has any experience doing battery testing. We are striving to learn the theory as best as we can and implement it through our testing. The first step to obtaining the battery's capacitance value is to charge up our Lithium-Ion battery by setting our power supply to output 4.2 V and a maximum current draw of 1 A; we will know our battery is done charging when the current draw is close to zero. After that, we are going to set the constant current load to draw around 700 mA, connect the power meter to the end of the leads, and start a timer to document the time it takes for the battery to completely discharge. We will know when the battery is completely discharged once the power meter displays a voltage of 2.65 V, which is the discharge cut-off voltage. Lastly, we can take the time it took for the battery to discharge and multiply it by the constant current load of 700 mA to determine the true capacitance of our Lithium-Ion battery. Alternatively, we can use another method to obtain the capacitance in which we take the data obtained to create a Current (mA) vs. Time (Hours) graph and by calculating the area under this graph we will be able to determine the true capacitance of our Lithium-Ion battery.

2.8 Induction charging (in progress)

In order to increase the longevity of the aircraft's in-flight time, the Power Management Systems (PMS) team has identified various forms of wireless charging technologies to experiment with [7-

[9]. As the Induction Charging Manufacturing sub team, we have currently been pursuing Induction-Based Wireless technologies, which utilizes electromagnetic energy to induce a charge in the device. The objective is to outfit the aircraft with a receiver coil, and a subsequent ground station with a transmitter coil. As the aircraft comes into close proximity with the ground station, the station will be able to transmit power via magnetic resonance. As the aircraft is in flight, the proposed idea is to harness the electromagnetic energy that resonates from distribution power lines to continuously charge the aircraft. While the aircraft is in close proximity to the power lines, the same principle of magnetic resonance will allow power to transfer to the aircraft. The Induction-Based Wireless charging technology is designed to utilize a 28VAC power supply, which will first be tested with a STORM Drone 4 unit, and could potentially be applied on the BANSHEE UAV to optimize the efficiency and endurance. While the project is under the manufacturing state, our team is responsible to figure the balance point between payload and endurance. Using LTSpice we were able to model the circuit schematic for both the transmitter and receiver designs.

Due to the ongoing pandemic, the progress on experimentally testing our design has been drastically slowed. With no access to a laboratory, we have been unable to effectively test any of the designs we have laid out. Increased wait times on components has delayed us as well. Lastly, trouble getting in contact with members from other teams on the project has been greatly exasperated.

Before this project, the members of the Power Management team had a very limited understanding of how wireless charging systems were designed. Most understanding came primarily from previous courses related to electromagnetic fields and circuit design. The Power Management Team consists of fourteen undergraduate students and one graduate student, with the undergraduate students working in three teams, one of which is the manufacturing team for the wireless charging circuit.

3. Course learning outcomes and grading procedure

This senior project course prepared our college students with engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

Students are evaluated according to course learning outcomes (CLO) based on 100-percent (100-point) grading scale. The CLO and the respective grade credits are defined in Table 2.

Table 2 Course learning outcome and credits

#	Course learning outcomes	Credit, %
1	Project design	25
2	Baseline UAV wing garage manufacturing	20
3	Demonstration the bench test	25
4	Final project and report	30
	Total	**100**

The senior projects are a series of required courses, normally start on fall semester and continued on spring semester. Due to the COVID-19 situation, we changed to virtual mode of instruction for all classes in spring 2020, fall 2020 and spring 2021 semesters. At the end of the fall 2020 semester, we assessed the students who completed their senior projects on critical thinking skills, written communication skills, information literacy and, most importantly summarizing the work the individual accomplished on the senior project team during fall 2020 to aid in assessing a course grade. One of the students was the ECE system engineering lead, serving as a liaison between the Advisors, Project Manager, and Aero system leads. Two of the students are sub-team leads. During the first semester on the project, the students played a small role as a member of the sub-teams to familiar the project. On the second semester, students were able to take the leads position and made major contributions. The students completed and submitted the final project report. An IEEE paper was written based on the senior project research and has been accepted to publish.

4. Outcomes

The AY 2020-21 senior project course proved to be exciting learning experiences for the students even with limited design, build and testing capabilities at home. These limited at-home experiences identified needed tools, equipment and building materials that if were available, could have progressed the project much further and the hands-on and experimental experiences would have been greatly enhanced.

Typical learning outcomes addressed by this paper include ability to apply critical thinking skills, hands-on "garage manufacturing" skills, design of experiments using home-built structural and electrical testing methods, and innovation in developing a quadcopter / airplane hybrid payload delivery/surveillance UAV design. Also, making oral presentations to industry sponsors (Lockheed Martin) including showing novel methods for effective hands-on activities conducted at home enhance communication skills. Figure 16 shows the progress and status report presented to Lockheed Martin via Zoom. Overall, the experiences will motivate the students to produce professional results even with the pandemic restriction challenges.

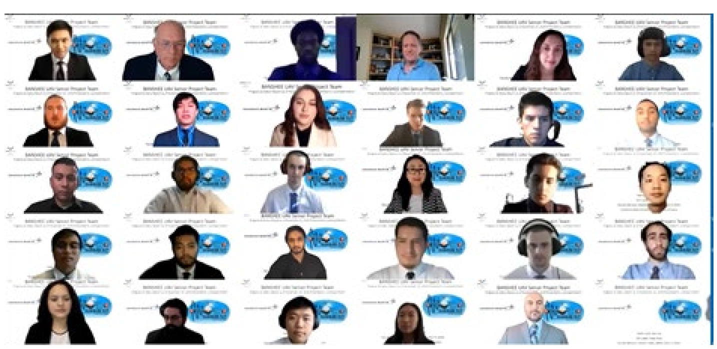

Fig. 16 Progress and Status Report Presented to Lockheed Martin

There is no specific data at the moment that indicates any changes in student performance due to the pandemic. However, student performance/progress is negatively impacted by the inability for students to meet every week to use campus manufacturing/testing facilities.

5. Conclusion

In terms of achievements, this is the first virtual mode course based on capstone senior design. Even though the team was unable to physically meet and collaborate on building certain technologies related to the project, everyone was able to meet virtually and make improvised building/testing setups without major hindrance to the project schedule. Funding, especially from Lockheed Martin, has enabled the team to purchase the tools necessary for the fabrication of UAV components as well as prototypes for power generation/storage technologies. In addition, when some students are done manufacturing a certain item, the budget will help with shipping costs to send the item to whichever student/team needs them for testing/further manufacturing. Lastly, all tools belong to the project and will eventually be returned to the project locker on campus for future use. The team still plans to attend professional virtual conferences to present work to industry professionals.

6. Acknowledgement

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