ASME IAM3D U.M.A.R.C.V. Competition Design Report and Implementation Memo

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CAD Drawings of Additively Manufactured Components

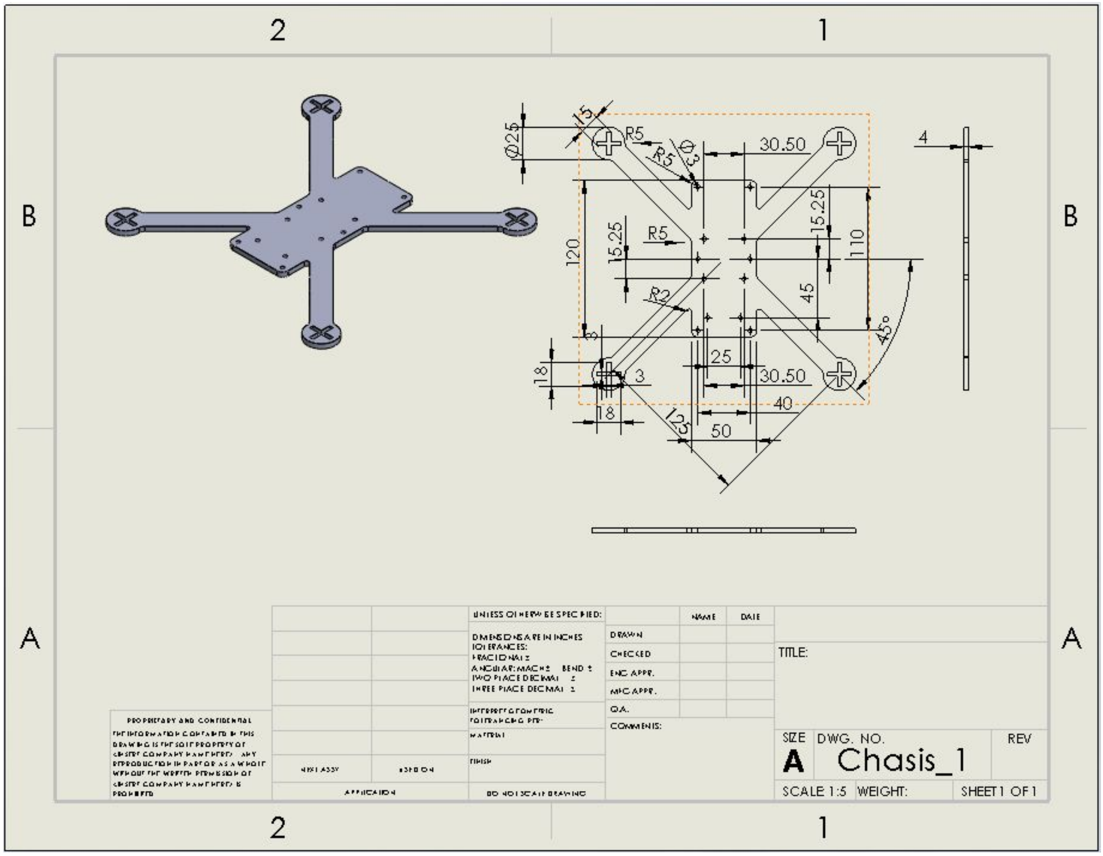

Figure 1: Chassis

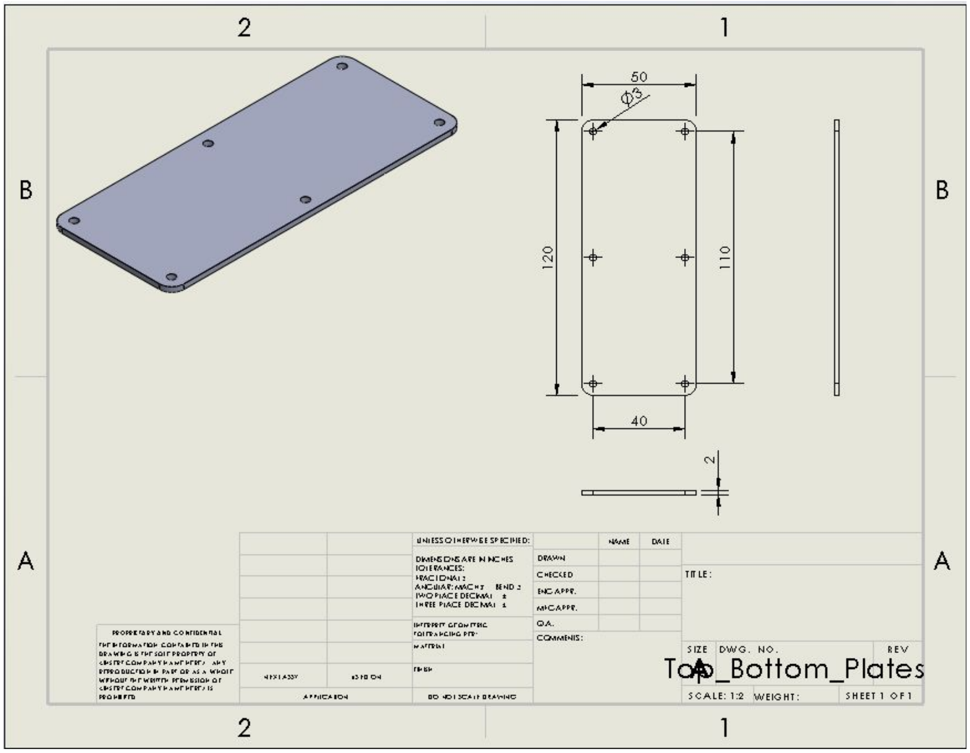

Figure 2: Top and Bottom plates

The following images are the CAD model and the Exploded CAD assembly drawing of all parts created using additive manufacturing. The cylindrical standoffs are placeholders for purchased hardware.

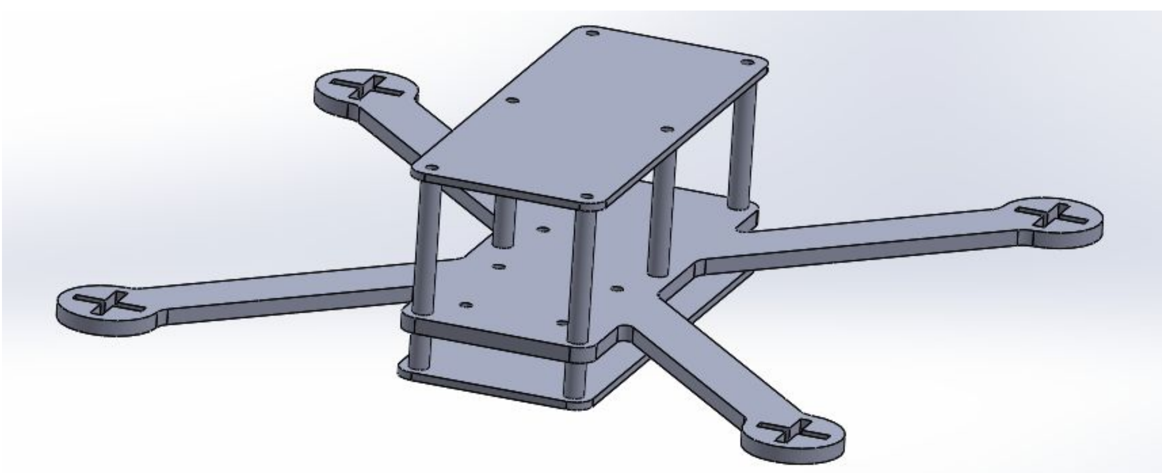

Figure 3: Frame Rendering

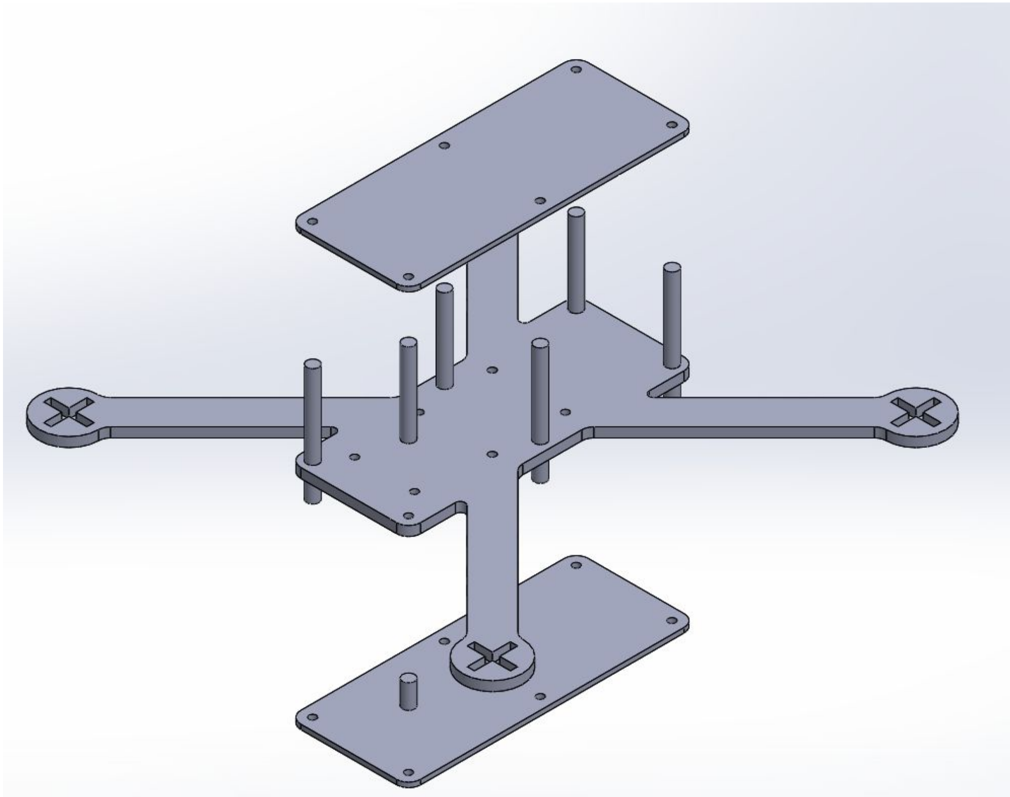

Figure 4: Exploded View

Vehicle Performance and Specifications

The team has several criteria to evaluate vehicle performance. These include flight time, mode of grabber operation, and quality of video signal. The team expects the vehicle to have a flight time of 7 to 10 minutes, a grabbing mechanism that can be freely and quickly toggled for ease of use, and a video system that will remain largely static free.

Below is a specification table for all major components purchased and used in the system.

Table 1: Component Specifications

Component	Specification	Units
Motors	2700	KV
Electronic Speed Controllers	45	A
Cameras	2	Number
Radio	8 or 16	Channels
Wireless Video System	32	Channels
Video Transmitter	25	mW
Battery	3400	mAh
Propellor	6	in
Magnet	50	N
Frame Size	250	mm

The device uses 2700 KV motors. KV is a rating of revolutions per minute per volt input (RPM/Volt). 2700 KV is a balanced value for quadcopters of this size, and provides sufficient power while remaining relatively efficient. Also used are 45 amp electronic speed controllers (ESC's). These ESC's are capable of fully supplying the motors' power needs. The video system uses two switchable cameras that face forward and down respectively. The pilot has access to a switch on their radio to toggle between the cameras. An on screen display is added to the video feed by the flight controller, showing information like flight time and battery voltage. This feed is then transmitted by the 25 milliwatt video transmitter. This signal is then received by a video receiver and provided to the pilot through goggles. While 25 milliwatts is a relatively low transmission power, it is adequate for the short ranges present in the competition. The radio system can support a maximum of 16 channels, which is more than enough to support the vehicle's equipment. The propellers used are 6 inches in diameter. The Magnet used in the pickup system outputs a force of 50 newtons, more than enough to pick up and hold the payload. The magnet system will allow the pilot to toggle the pickup of the object quickly and repeatedly if needed.

Structural Analysis

In order to ensure the structural integrity of the vehicle, analysis must be conducted. The team created a structural simulation intended to emulate the real world loading of the frame. This was done using Ansys Workbench. The team's frame design has a chassis component that provides structure for the drone. The simulation was conducted on this structural subframe. Below is a picture showing the subframe.

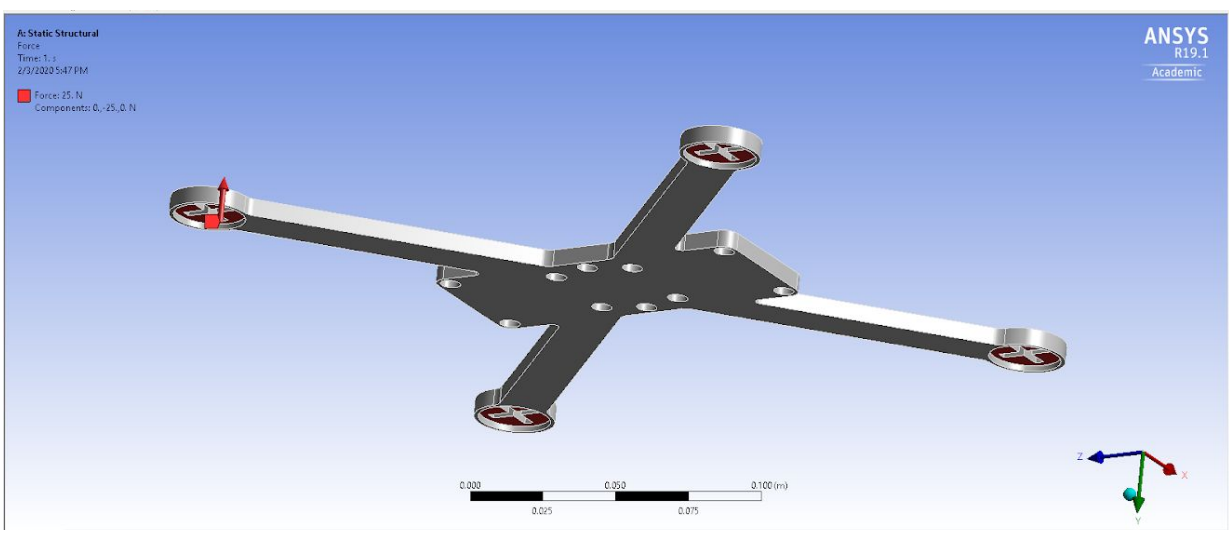

Figure 5: Force Loading

This component mounts most of the hardware used in the system, and will withstand the majority of the forces of normal operation. Simulated forces were applied to the motor mounts, emulating thrust from the propellers. These are shown by the red faces in the picture above. A force of 25 newtons was distributed evenly across these faces. This quantity was chosen due to expected worst case thrust values during normal operation.

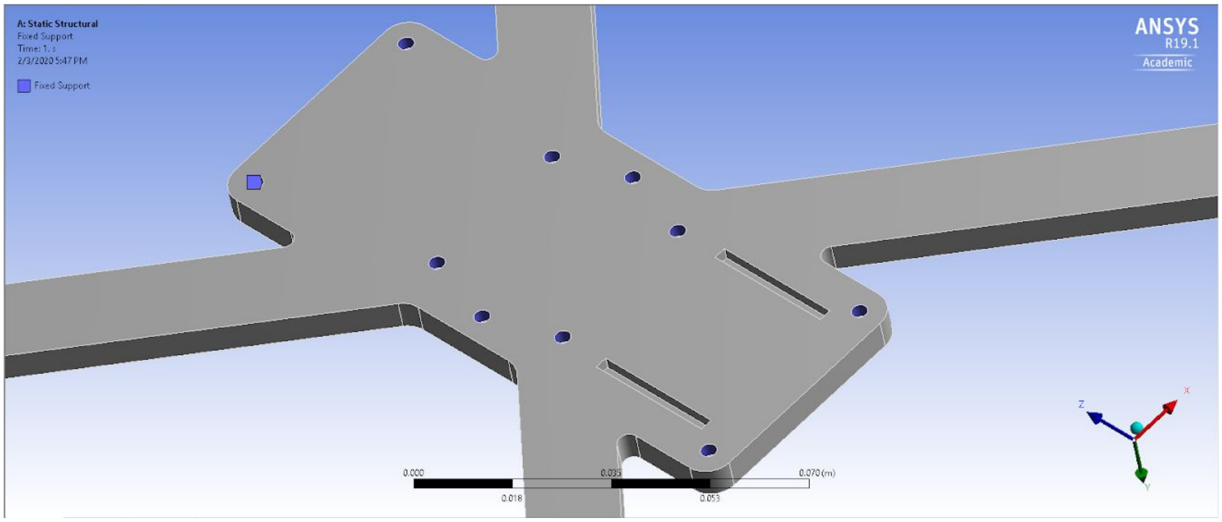

Figure 6: Support Scheme

Next, fixed points were assigned. Fastener holes were assumed fixed due to the rigidity that other components of the frame and the fasteners themselves will provide to the structural subframe. The fixed points are shown above in blue. Material properties for Polylactic Acid (PLA) plastic were then added. At this point a mesh was created and results were generated.

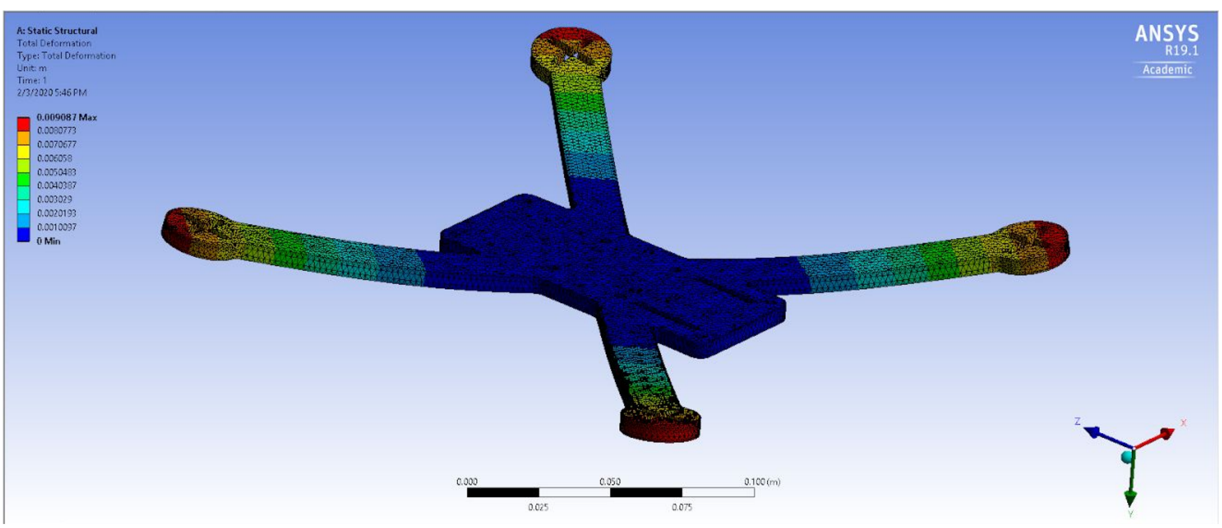

Figure 7: Displacement Data

The figure above shows the expected deflection of the model. The maximum deflection experienced is 9 millimeters.

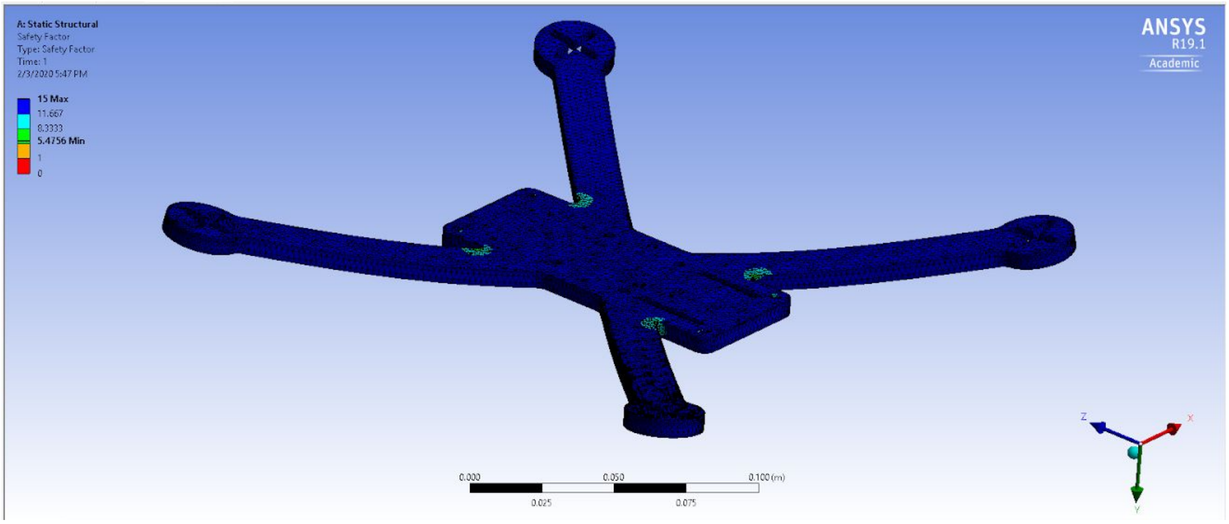

Figure 8: Safety Factor Data

The figure above shows safety factors throughout the chassis. The lowest value found in the component is around 5, meaning the model is more than capable of withstanding the forces applied.

Design for Manufacture and Assembly Analysis (DFMA)

Our IAM3D project focuses on ease of manufacture and efficiency of assembly via simplifying our product design efficiently, in the minimum time and at a lower cost. From the beginning of the project, one of our main goals was to minimize product cost through design and process improvements. We combined several parts into one piece by 3D printing frame which has a base that carries electronics and on the right and left side there are four wings with four motors on each side, all of them are one coherent piece. Moreover, there is a top plate attached to the base that protects the electronics from above. Therefore, only a few screws are needed in our design while no adhesives are in use.

On the other hand, we haven't turned blind eyes to the enhancement of quality of the product and efficiency at each stage. In fact, we increased reliability via minimizing the number of parts and fasteners, which decreases the chance of failure. There is nothing to take away to make the device more simple, parts are already at minimum.

Design for Additive Manufacturing Analysis

Based on our analysis, we found several ways to make our design easy to print. First, we established the bottom surface of the top and bottom plate so that printing can result in the least amount of errors, the bottom surface is the most flat and the holes develop in printing. In order to use the screw to connect all the plates, we leave the holes on the printed pieces. As we know, the parts are printed layer by layer. The components are designed to minimize overhangs when printing. The chassis component has a narrow rectangular overhang, but due to this being very thin and supported on each side of it there are no issues with printing. These help us reduce the failure of printing the frame, and improve the reliability.

Design Iterations

The design iterations include integrating the grabbing mechanism to our device. The team does have a goal to integrate the frame to make it easier during competition so that if failures occur, our biggest stress points in our device in the arms of the drone can be easily replaced. This may result in increasing the thickness of the arms.

Testing

This outlines the testing procedures the team will complete to validate the design. These testing procedures will be based on the team's engineering requirements. The engineering requirements to be tested are battery capacity, altitude, compatibility, and agility. The remaining engineering requirements have been validated through adhering to design constraints. The general durability and reliability of the design has been verified through the completion of the structural analyses testing. While there is no "crash test" or "drop test" the system will be subjected to harsh landings and most likely minor crashes throughout the testing procedures and pilot training. These events will constitute the team's durability testing.

The Maneuverability Test aims to validate the agility, altitude, and compatibility engineering requirements. The agility and altitude engineering requirements will be validated through this flight test. The flight hardware has been designed to be compatible but will be verified by this test. This test will take around 2 hours to complete and will be the first test conducted. The objective of this test is to verify that the craft can complete extreme maneuvers predictably without unexpected behavior. This test allows the craft control system to be tuned if failed. The aircraft will be subjected to 10 tests of each maneuver. The maneuvers to be tested are full throttle, full yaw while stationary, fast turn while at speed, and slowing from high speed to hover. The last 2 maneuvers are to be conducted under the 10-foot altitude limit. Successful completion of a maneuver counts as a pass, while unexpected behavior or failure to complete the maneuver counts as a failure. Each category must have an 80% pass rate to be considered a success. This relatively low rate was selected as a good balance because maneuverability tests can be affected by pilot skill and error. Upon failure of a category, qualitative information will be used to tune the control system. This test is needed to ensure flyability and reliability of the aircraft.

The Battery Drain Test aims to validate the battery capacity engineering requirement. The output of this test is the expected flight time of the vehicle. If this flight time is longer than needed or too short, the battery capacity can be updated to better match the devices needs.This test will verify the battery capacity chosen by the team. The aircraft will be flown for three trials with the magnet disabled, and three with the magnet enables for a total of 6 trials. The time for the battery to be drained from charged to empty will be timed. The times recorded will be averaged to get the expected flight time of the vehicle. This time will allow the team to validate the battery capacity chosen by comparing the expected flight time with the needed flight time.

The Payload Pickup Test aims to validate the compatibility, agility, and altitude engineering requirements. The compatibility of the electromagnet pickup system will be tested by validating its functionality. The maneuverability of the system while picking up the payload will validate the agility engineering requirement. The altitude engineering requirement will be tested by using the system while observing the craft to ensure it remains below the limit.This test will time the aircraft while it picks up a payload. The aircraft will start in a hover, pick up a payload, and return to a hover. This process will be completed 20 times. The time required to complete this process will be timed, recorded, and averaged. This will provide an expected time for the pilot to complete this process in competition, as well as validate the usability and flyability of the aircraft.

Changes Made

This section details the changes made since the submission of the competition design report. The team has thickened the chassis section of the frame from 6 millimeters to 10 millimeters, as well as increasing its infil from 70% to 95%. This will significantly decrease the deflection and increase the stiffness of the frame. The team has also begun work on a modularized version of the frame in order to improve the lead times on frame components. The grabbing mechanism circuit has been designed, and will use a relay in order to control the electromagnet's function. The control software has been edited to allow the magnet control to be implemented once the relay's functionality has been tested by the team.

Moving forward, the team's focus is on the repair of the electrical and frame system. All components are accounted for except for the chassis subsection of the frame. This component has been experiencing warping when manufactured, and the team plans to implement the modular frame in order to manufacture the frame on a team member's printer, rather than the Makerlab printers. Once the system is flyable, the magnet system is planned to be added to the system, completing the first full system iteration.