A2 Aero Micro - 20F12

Final Proposal

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EXECUTIVE SUMMARY

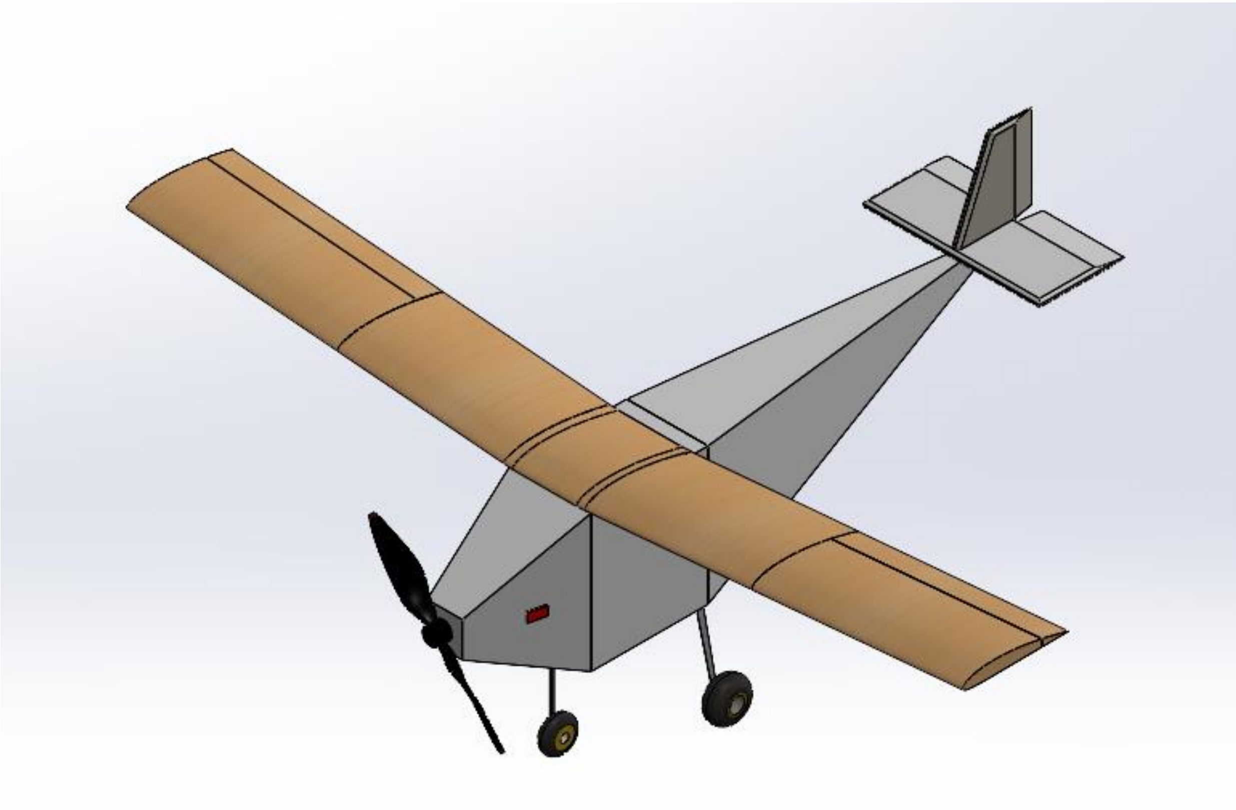
This team was tasked with designing and constructing a micro airplane to compete in the 2021 SAE Aero Micro competition. The design must be original work by the team with minimal interaction from people outside of the group.

The competition itself has several requirements that the team must obey, or the team will be docked points or even disqualified. There are many basic requirements the team has to follow, such as using one of the official competition 450W power limiters, using propellers that are not made of metal, have a red power plug, have the team's number be easily visible on the plane, and clearly labeling the planes center of gravity with the classic center of gravity (CG) label. However, there are specific rules that the team must follow for the micro class portion of the competition. The team must not exceed a wingspan of 48". This maximum wingspan replaces the previous year's rule of being able to fit within the competition container, so the plane is still limited in size. The plane must also use electric motor propulsion, utilize no more than a 4-cell Lithium Polymer battery and be able to completely enclose the payload plates. The team will be scored on the amount of cargo they can carry (including any bonus payload), as well as the time it takes for the plane to complete one flight circuit.

The airplane must first be broken down into major components to conduct research on each and develop an innovative design. The wings and airfoil are one of the most important aspects to any plane, and if this is not designed properly, the plane could fail to ever fly. It was determined that the wings are going to be made using a rib and spar design because of the low weight and high strength that can be achieved. The ribs are made from the Clark-Y airfoil laser cut from ⅛" balsa wood sheets. After the ribs are cut and separated approximately 2" apart, wooden spars are placed in the designated cuts in the ribs. A leading edge is also cut from balsa wood to match the same profile as the airfoil itself. Once the aileron is cut and put into place, the team wrapped the wings with MonoKote (a lightweight and clear plastic shrink-wrap). These wings are then connected at the center of the airplane and are secured to the fuselage. The fuselage is made from foam board to maintain focus on being both rigid and lightweight. The tail of the airplane is made of foam board for the same reasons, and it utilizes a conventional tail design. This conventional tail design has both vertical and horizontal stabilizers, and each has a servo-controlled elevator or rudder to maintain control during flight. The airplane has other major components, such as utilizing a carbon fiber rod to connect the fuselage and tail, a tricycle landing gear that allows for movement on the ground not reliant on aerodynamics, and several to-be-determined propulsion components such as the battery, propeller, and controller.

Several technical analyses were performed for the aircraft with these components to determine the engineering integrity of them. The wings were analyzed for any risk of sag or bending moment, and adjustments were made based on this analysis. The wings were determined to still be made of ⅛" balsa wood, but the spacing between them needs to be 2-2.5" to avoid adding unnecessary weight and creating sag. The fuselage also underwent an analysis to determine if the material selection of foam board was feasible, or if the cargo requirement and attachment requirement was too great for the foam board to withstand. The results of this analysis are that the foam board is sufficient, assuming the walls are thick enough to support all of the weight while also not causing unnecessary drag. Several other analyses were done to support the tentative final design of the plane, and any necessary adjustments have been made.

The team is in the process of building the plane and hopes to be close to completion by the start of the 2nd semester of capstone. Once the team can conduct test flights, the iterative design process will continue, and the team will make necessary changes to ensure the plane flies properly and can perform well at the competition.



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1.0 Background

1.1 Introduction

The SAE Aero Micro competition is a competition where teams are tasked with constructing a micro airplane with several constraints. Some of these constraints stated in the 2021 competition rules include a maximum wingspan of 48”, implementing a 450-watt power limiter, launching the plane from a 4’x8’ platform, and having the payload stored in a cargo bay. Upon learning of the new rules released for the 2021 competition, we were also made aware that the timed assembly of the craft was no longer a component in the scoring in the competition and that the teams craft will not have to fit in a container with specified dimensions. The main objective of the competition is to carry the largest amount of payload, through a flight circuit course, while having the fastest time to the first turn. The 2021 competition will have teams be scored on the weight of the payload carried, flight time, technical reports, and many other factors. This project is of interest to the sponsor because the ideas developed in this competition can be applied to full scale aircraft. This project addresses the issues seen in real-life airplanes where the payload is limited for smaller planes. If the team is successful, the sponsor and stakeholders will benefit in the idea of NAU gaining respect in the aerospace education industry, as well as being supplied more money in the future for the teams to have a better chance of winning the competition.

1.2 Project Description

Following is the original project description provided by SAE International:

The SAE Aero Design competition is intended to provide undergraduate and graduate engineering students with a real-life engineering challenge. The competition has been designed to provide exposure to the kinds of situations that engineers face in their real-life work environment. First and foremost a design competition, students will find themselves performing trade studies and making compromises to arrive at a design solution that will optimally meet the mission requirements while still conforming to the configuration limitations. Micro Class teams are required to make trades between two potentially conflicting requirements, carrying the highest payload fraction possible, while simultaneously pursuing the lowest empty weight possible. [1]

2.0 Requirements

The following section discusses the requirements of the aircraft being designed by the team. This includes, the customer requirements that were derived from the SAE competition rules, the engineering requirements that were established using the customer requirements, a functional decomposition of the aircraft system, a house of quality, and the standards, codes, and regulations applicable to the project. Because the team experienced a shift in the rules and regulations, much of this information has been altered from that of the preliminary report.

2.1 Customer Requirements

For the SAE Aero Micro team, customer requirements were presented in the form of SAE Aero design rules. The SAE competition provides a detailed description of what is expected and what functionalities of the design are required. In short, a competition will be conducted where speed and payload weight/size capacity are contributing scoring factors. Flights and landings must be successful for the score to count. The aircraft must take off from a 4’x8’ platform and land within a designated 200-foot landing strip. A complete list of the customer requirements derived from the competition rules is presented below along with a brief description. Additional requirements listed are due to limiting factors such as the budget provided by Northern Arizona University.

1. Wingspan Dimension (The wingspan cannot exceed 48”)
2. Electric Motor (Only electric Motors are allowed for the propulsion)
3. Battery Limited to 4 Cell (The maximum battery size is limited to a 4-cell battery)
4. Power Limiter (The aircraft must incorporate a power limiter in the electrical circuit)
5. Carries Metal Payload Plates (Part of the flight score includes the weight of payload plates)
6. Carries Payload Boxes (For each flight attempt at least one delivery box must be carried)
7. Carries Payload Plates in Cargo Bay (Payload plates must be fully enclosed in the fuselage)
8. One Fully Enclosed Cargo Bay (the number of cargo bays for the payload plates is limited to one)
9. Securable Payload Plates (Payload plates must be secured using an approved method)
10. Quick Payload Removal (Both payloads must be uninstalled within one minute)
11. Short Take-Off Distance (The aircraft must takeoff from a 4’x8’ platform raised 1 foot)
12. Aircraft Range (The aircraft flight is scored based on the ability to complete the whole course)
13. Controllable in Flight (The pilot must be able to maintain control of the aircraft at all times)
14. Fast Aircraft (The aircraft flight is scored partially on the time it takes to complete the first leg)
15. Can Carry A Lot of Weight (The aircraft flight is scored partially on the additional weight carried)
16. Short Landing Distance (The aircraft must be able to land within the 200-foot landing strip)
17. Red Arming Plug (the aircraft must be equipped with a red arming plug to ensure safety)
18. Empty CG Markings (The aircraft must display the empty center of gravity location)
19. Gross Weight Limit (The aircraft cannot exceed 55 pounds)
20. 2.4 GHz Radio Control System (The aircraft must use a 2.4 GHz radio controller)
21. Spinners or Safety Nuts (The propeller must be properly secured to ensure safety)
22. No Metal Propeller (Metal propellers are prohibited for the competition)
23. No Lead (The material lead is prohibited from the competition)
24. No Structural Support from Payload (The installed payloads must not help support the structure)
25. Metal Payload Plate securing Hardware (Payload plates must be fastened with metal hardware)
26. Low Cost Build (The team is limited to a $1500 budget which includes registration fees)
27. Durable Design (The design and construction must be durable and reliable)

2.2 Engineering Requirements

Using the customer requirements listed and discussed above, the engineering requirements that will help determine the final design of the aircraft can be derived. Engineering requirements are quantifiable and measurable. Therefore, the derived engineering requirements also include a goal or target value that the design aims to meet, along with a tolerance of that goal’s value. The list of engineering requirements that the team derived, and the tolerances is presented next.

1. Wingspan Length (48” -1/16”)
2. Battery (4 Cells -3 Cells)
3. Power Limiter (45 Watts +/-0 Watts)
4. Cargo Bay Volume (36 Inches cubed +/-10 Inches Cubed)
5. Quick Payload Removal (1 Minute -0.5 Minutes)
6. Short Take-Off Distance (8 Feet -2 Feet)
7. Aircraft Range (350 Feet +/-25 Feet)

8. Fast Aircraft (40 MPH +/-15 MPH)
9. Can Carry A Lot of Weight (10 Pounds +/-5 Pounds)
10. Short Landing Distance (200 Feet -100 Feet)
11. Gross Weight Limit (25 Pounds +/-10 Pounds)
12. Radio Control System (2.4 GHz +/-0 GHz)
13. Cost (300 US Dollars +/-200 US Dollars)
14. Lift (30 pounds +/-5 Pounds)
15. Thrust (15 Pounds +/-3 Pounds)
16. Drag (5 Pounds +/- 1 Pound)
17. Ground Control Turn Radius (2 Feet +/-1 Foot)
18. Reliability (95 Percent +/- 5 Percent)
19. Crashes Before Major Repair (1.5 Crashes +/- 0.5 Crashes)

2.3 Functional Decomposition

Creating a functional decomposition is a key component in taking the overwhelming task of capstone and breaking it into components that are easier to understand and complete. This section discusses the black box and functional models the team created to dissect the process of building a micro airplane into a workable and viewable processes.

2.3.1 Black Bod Model

The team created a black box model of a flying airplane to begin decomposing the larger problem of designing and constructing a full micro airplane. This black box model accepts inputs on the left side and transforms them through the "black box" into appropriate outputs. The functions that occur inside the black box can then be detailed further in a function model to decompose the problem into smaller, simpler problems that the team can address one at a time.

The black box shown in Figure 1 shows the relevant energy, material, and signal inputs and outputs for a flying airplane. The inputs of highest importance are power, the airplane components (wings, landing gear, etc.), and the RC controls. The important outputs are a full RC plane, movement, and appropriate signal indicators.

The black box model shown in Figure 1 is very similar to the preliminary report but has been updated to account for the cargo and a power limiter. These material inputs were not considered on the original figure, as the team did not know they needed a power limiter or to carry a new cargo (the 2021 rules had not been distributed yet). The team also added the red arming plug to the model as it seemed like an important material component that had been left out. Otherwise, the black box model has remained unchanged from the original, and Figure 1 is the black box model the team will likely use for the remainder of the project.

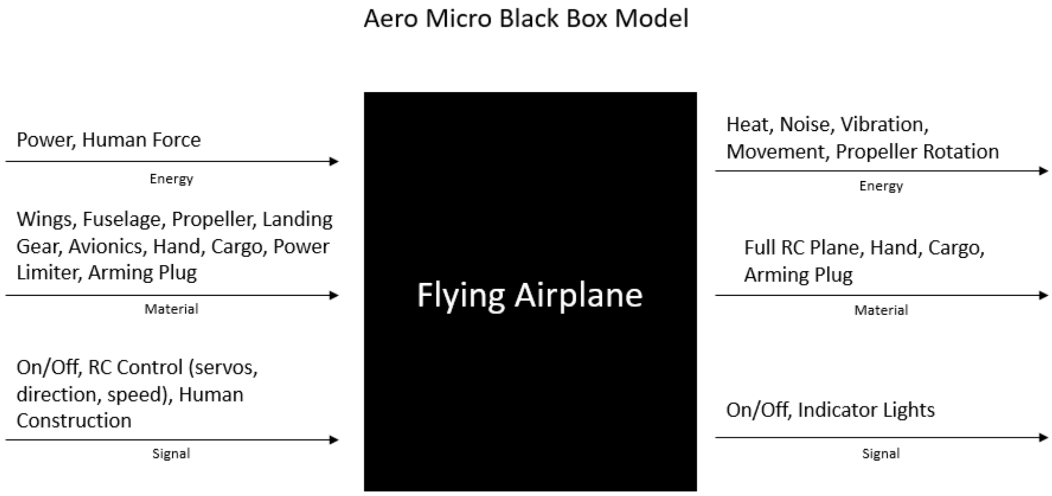

Figure 1: Black Box Model for a Flying Plane

2.3.2 Functional Model

After completing the black box model detailed above, the team took the relevant inputs and outputs and began creating a functional model to describe the functions that were occurring within the "black box". This model takes the inputs of energy, material, and signal and describes with arrows how these signals transform to become our outputs. An updated version of this functional model for the team's current progress is shown in Figure 2.

The functional model of a micro airplane (shown in Figure 2) shows the inputs to the system on the left side and the system outputs at various points on the right side. The figure uses orange, green, and blue arrows to show energy, material, and signal inputs respectively and the arrows describe how those inputs move through the system. The team had a pretty comprehensive model created a month ago, however relevant updates to the model include the introduction of the arming plug, power limiter, and cargo described earlier. These material inputs affect the system import power, power delivery, and add a new function of accepting the cargo, which are all shown in Figure 2.

The functional model shown in Figure 2 helped the team dissect the problem down into further, more simplistic, components for design and construction. Specifically, it helped to show what systems need to be developed in what order, as certain subsystems and processes will not function without their predecessors. For example, the entire airplane must be assembled before the plane can accept cargo, and the plane must import and store power before beginning to deliver it to necessary subsystems. Additionally, the functional model served as a way of dividing the project into smaller tasks so that each team member could work on a relevant and important subsystem. By creating this model, team members could see what subsystems and tasks were important to work, and how their work contributed to the overall system. In summary, the functional model divided up the intensive task of designing and constructing a micro airplane into specific, measurable, and achievable subtasks.

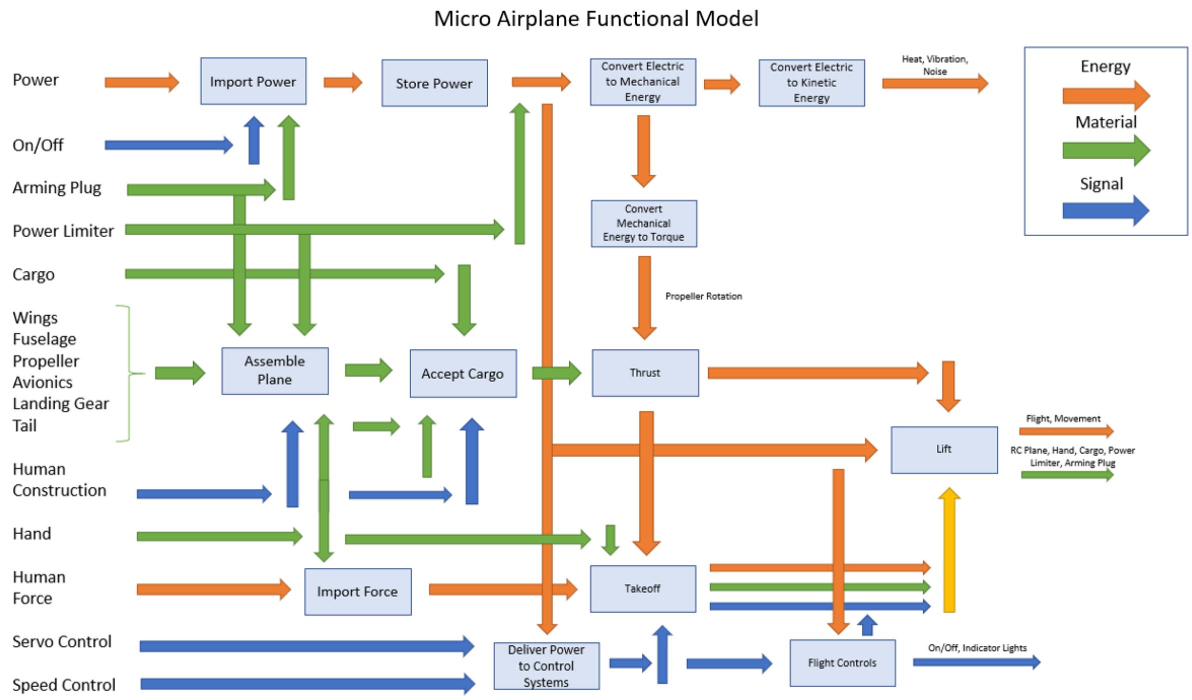

Figure 2: Function Model for the Team's Aircraft

2.4 Quality Function Deployment (QFD) and House of Quality (HoQ)

Using the customer needs along with the derived engineering requirements, a QFD with a HoQ was completed in order to better understand the relationship between the customer needs and the engineering requirements (Appendix A and B).

This house of quality provides the team with an absolute importance rating for each of the engineering requirements listed. This helps the team better understand what components and requirements must be more heavily focused on. This also helps the team understand how the engineering requirements relate to each other. The house of quality has shown the team that the most important engineering requirement is the speed of the aircraft. This is due to the speed aspect of the competition scoring system. Other important engineering requirements include the cargo bay volume, quick payload removal, and the ability to carry a large amount of weight. While this helps the team better understand the engineering requirements, many of the customer needs are requirements specified by the competition rules and must be adhered to regardless of the HoQ results. The team must keep in mind all requirements of the competition to ensure that the submitted design is compliant with the rules and regulations. Also included in the HoQ are the specified testing procedures that are discussed in further detail in the Testing Procedures section of this report.

2.5 Standards, Codes, and Regulations

In order to maintain the safety of everyone present during flight, as well as ensure the engineering integrity of the plane is maintained, there are numerous standards and codes of practice the team must follow. These standards and codes can include rules that the team must abide by, as well as engineering standards that ensure the structural integrity of the plane. Table 1 is a list of some standards and codes the team is applying to this project.

Table 1: Standards of Practice as Applied to this Project

Standard Number or Code	**Title of Standard**	**How it applies to Project**
ASTM F2910 [2]	Standard Specification for Design and Construction of a Small Unmanned Aircraft System	Establishes all the basic rules to be followed when designing an unmanned aircraft of 55lbs. or less. It will ensure the team does not pose any risk to themselves and those around during flight.
ASME Y14.5 [3]	Dimensioning and Tolerancing	Ensures all proper dimensioning and tolerancing are performed on drawings and production of airplane parts. Parts will be guaranteed to be within some tolerance zone to ensure construction of the airplane has minimal issues.
LPR 1710.15J [4]	NASA Wind Tunnel Model Systems	Ensures wind tunnel testing for aerodynamics will be conducted in a safe manner. A certified tester will either be present during the test, or will teach a team member how to properly do so.
ASME B18.2.1 [5]	Bolts and Screws	All bolts and screws used in the system are guaranteed to be up to standard and do not face the risk of prematurely fracturing. The thread pitch and diameter of each are sure to be within the appropriate tolerance and will always fit with the proper nuts, etc.
2021 Collegiate Design [1]	2021 SAE Aero Design Rules	Ensures all competition rules will be followed to avoid any risk of disqualification. All competition-specific safety requirements are to be added to the plane, and the team will also be aware of how the scoring will take place.
IEEE 128-1976 [6]	Guide for Aircraft Electric Systems	Clearly lays out the standards on properly wiring the electric components of the plane. Will prevent any risk of shorting or causing a fire when current is delivered through the wires. Also ensures the team will have proper radio communication to control the servos and propeller speed.

Table 1 lays out each of the basic standards and codes the team is applying to this project. In general, it will ensure the team is kept safe, as well as ensure the structural integrity of the airplane is maintained. These standards will prevent any risk of fire or shorting any wires when focusing on the electrical systems. It will also ensure that each fastener and part being used is produced within the proper tolerance zone. This will make sure that the team never has an issue with securing the plane together and risking the plane falling apart during flight. Overall, these standards and codes will ensure the safety of everyone present during flight, as well as ensure all parts being produced are not at risk of early failure.

3.0 Testing Procedures

The team plans on conducting three different tests on the design to evaluate if it satisfies key engineering requirements. The first procedure is to test if it satisfies both the weight and speed requirement for the design because the goal is to maximize the weight being carried while maintaining higher airspeed. The second test is designed to test whether the airplane can handle multiple takeoffs and landings, as a proper takeoff and landing is required to earn points. Finally, the third test is designed to test durability, quality, and reliability throughout the entire system by taking it through multiple intensive flights. These tests will help the team determine if they have met their engineering requirements.

3.1 Testing Procedure #1: Flight Test

The objective of this test is to assess the overall weight that our aircraft can carry while still maintaining the capabilities to complete the flight path of the competition. The team will conduct test flights while increasing the weight after each successful flight. This will demonstrate that the craft can meet the requirements of carrying weight while completing the designated flight path set forth by the competition in a timely manner. The schedule for this testing will begin around January, and the full duration of this testing is unknown. It is unknown because of the potential for crashes during this kind of testing. In the event of a crash, the aircraft will need to be repaired and the duration of repair time ranges depending on the scope of the damage.

3.1.1 Testing Procedure #1: Performance of Aircraft

The team will begin by testing if the aircraft can carry the delivery packages. After the aircraft has completed this portion, the team will begin testing the metal plates. The metal plates pose the greatest challenge due to the weight they add to the craft. This will have an impact on the overall center of gravity (CG) and the speed at which the aircraft can travel. This testing will verify that even with added weight, the aircraft overall CG has not shifted. If the center of gravity is shifted by weight, the team will need to adjust the design because a shift in CG could lead to a crash depending on how drastic the shift is.

3.1.2 Testing Procedure #1: Resources Required

The team will use the Flagstaff Flyers airfield to conduct these tests. Other resources included the delivery packages and the metal plates. The competition left the design of the metal plates up to the team. The team will require multiple plates in order to fully evaluate the capability of the plane. The team's overall goal is to find a balance between weight and speed since both criteria play a major role in the overall scoring of the flight.

3.1.3 Testing Procedure #1: Schedule

The team will first make a prototype aircraft to use in these tests. The goal is to begin testing by January since there is the potential to crash during this kind of testing. The objective by beginning testing as soon as possible is to allow for as much time as possible for repair and redesigning of the craft.

3.2 Testing Procedure #2: Takeoff and Landing

A second important test for the aircraft will be repetitive takeoff and landing tests to ensure the airplane can take off and land without issue as both a proper takeoff and landing are required to earn any points on a flight.

3.2.1 Testing Procedure #1: Repetitive Takeoff and Landing Tests

The test will be performed by completing repetitive takeoff and landing cycles. Each cycle will be performed a minimum of ten times using the required rules of takeoff and landing given by the project rules:

Takeoff Requirements from SAE [1]:

1. The Micro Class aircraft must accomplish a take-off from a designated 4-foot by 8-foot takeoff platform that is elevated a minimum of 24-inches above the ground. The take-off area will be approximately level.
2. The pilot and one (1) team member may be at the take-off area.
3. The aircraft must be only held and released by one (1) team member. Release of the aircraft by the pilot is prohibited.
4. The weight of the aircraft must be supported by the landing gear while on the platform. All landing gear, and aircraft ground contact points must be in contact with the surface of the platform. The rear of the aircraft may *overhang the platform.*

Landing Requirements from SAE [1]:

1. Land within the 200-ft designated landing zone. Micro Class aircraft must be prepared to land on either a paved or unpaved landing zone.

One cycle of testing will be considered to be a takeoff and a landing on both paved and paved ground (30 data points in total). The number of failures and successes will be recorded in order to determine the success rate of flights. This success rate needs to be extremely high, as any failure within this test would result in a total loss of points during competition.

3.2.2 Testing Procedure #1: Resources Required

The required resources for this test are:

1. Complete and flyable aircraft.
2. Data recorder.
3. Competition Pilot (Zachary Kayser)
4. Takeoff Platform as defined by the competition.
5. 200-foot runway of either paved surface or unpaved landing zone.
6. Proper/legal zone for flying.

3.2.3 Testing Procedure #1: Schedule

In order to run this test, the entire airplane must be complete and ready to fly. The team intends to have a flyable aircraft ready by the end of winter break. The team hopes to run this test as soon as they have determined the aircraft is indeed flyable, which will likely happen two weeks into the semester.

The entire testing time will take approximately 3 hours in order to record the data points required but may take longer if multiple failures occur. If takeoff and landing become a major failure point, the test may be scrapped in order to preserve components for a new design.

3.3 Testing Procedure #3: Durability and Quality Testing

Finally, durability testing is another important test for the team, as the design must be able to withstand travel to competition, preflight checks, and three successful flights during competition with minimal re-construction.

3.3.1 Testing Procedure #1: Repeated Stress and Durability Tests

This test will be performed as follows:

1. Transport the aircraft to designated locations, and perform any construction required.
2. Perform pre-flight checks.
3. Successfully launch the airplane
4. Fly the airplane through an extended circuit to ensure it can handle the competition circuit.
5. Land the airplane
6. Perform steps 2-5 a minimum of three more times to ensure the aircraft can complete the required number of flight tests (3) at competition.

This procedure will test the durability and quality of the build, ensuring it can withstand the stresses it will experience at competition. Launch and flight will test the construction of the fuselage and wings, as well as the quality of the motor, propeller and avionics. Additionally, landing will test whether the aircraft and landing gear can withstand the stresses of multiple and possibly suboptimal landings at competition. This test is important as the aircraft must complete three flights at competition with very little repair, or the team could lose significant points.

3.3.2 Testing Procedure #1: Resources Required

The required resources for this test are:

1. Complete and flyable aircraft.
2. Data recorder.
3. Competition Pilot (Zachary Kayser)
4. Takeoff Platform as defined by the competition.
5. 200-foot runway of either paved surface or unpaved landing zone.
6. Proper/legal zone for flying.
7. Repair parts that would be available at the competition.
8. Proper pre-flight testing materials.

3.3.3 Testing Procedure #1: Schedule

As with all tests, the team must ensure they have a complete and flyable airplane before this test can be completed. As noted, the team intends to have a complete airplane by the end of winter break, so this should not present an issue in completing this test.

This test is likely the last test the team will perform, as durability and the insurance of completing multiple flights comes after the insurance of one proper flight as defined by out flight testing and landing/takeoff testing. This test will likely be performed approximately a month into the new semester, ensuring that the plane is competition ready well before the competition begins, leaving time to complete improvements.

4.0 Design Selected

After completing a rigorous review of various aircraft designs and their own unique set of pros and cons, the team has decided to proceed with the implementation of a standard, single-engine monoplane design. The team selected this design as it is relatively simple in design and has a vast amount of information regarding the design. These factors allow the manufacturing process to be much more simplistic and efficient. Furthermore, the success of other teams using the same design in the competition of previous years is further evidence that this design is highly effective. However, our initial design had to be altered in the past few weeks as the rules for the upcoming competition in 2021 were only recently released and are different in a few areas, compared to the 2020 competition rules. Due to the rules not being released earlier in the semester, as they usually are, our initial design was made to adhere to the rules of the 2020 competition and as a result of the 2021 competition rules late release, the team was forced to change the initial design to comply with these new set of rules [1].

4.1 Design Description

The new set of rules for the 2021 SAE Aero Micro competition were only just recently released in the days following the submission of the preliminary report [1]. Consequently, the team had to immediately implement an array of design changes that would conform to these new rules. Some major changes to the rules that forced the team to make design changes to some of the systems were assembly time not being counted towards the overall score, the implementation of a 450-watt power limiter, cargo bay for the payload, and time it takes for the craft to complete the first 180 degree turn in the course [1]. In order for our design to align with these rules and make our craft more effective in scoring points within the new scoring system, the team created new CAD models of the proposed redesigns as well as simulations of their performance in order to gauge how they will perform once they have been manufactured.

4.1.1 Wing Specifications

The wings are a crucial component of the craft as they are used to generate lift for the craft and control the pitch. With the standard monoplane design and overall goal of the competition, the team has chosen to utilize a traditional rectangular wing set. The wingspan of the wings for the craft are set at 48”, within the competition limit of 48”. The wings of the craft are constructed out of lightweight balsa wood and are internally fitted with ribs and spars to give it increased strength and resilience, while still maintaining an overall lightweight design. Due to a timed assembly no longer being a factor in the scoring of the competition, the design for the wings attached to the fuselage has changed in order to create a more secure, stronger, and more sturdy fit. This was achieved by having the spars of the wings extend beyond the wings and fit into slots on the side of the body of the fuselage. The wings will be controlled by servo motors which will allow the plane to control its pitch and perform turns. The simulation in figure 3 below shows that the wing created can generate upwards of 20N of lift at an angle of attack at 10 degrees. While this is not an idea angle of attack, it would suffice for the team’s application, and proves that using this airfoil is possible. Additionally, the team believes that the SolidWorks simulation is less than optimal, and the airfoil will actually produce more lift than the simulation states due to the simulation being performed at a very low Reynold’s number where SolidWorks simulation tend to fall apart [7].

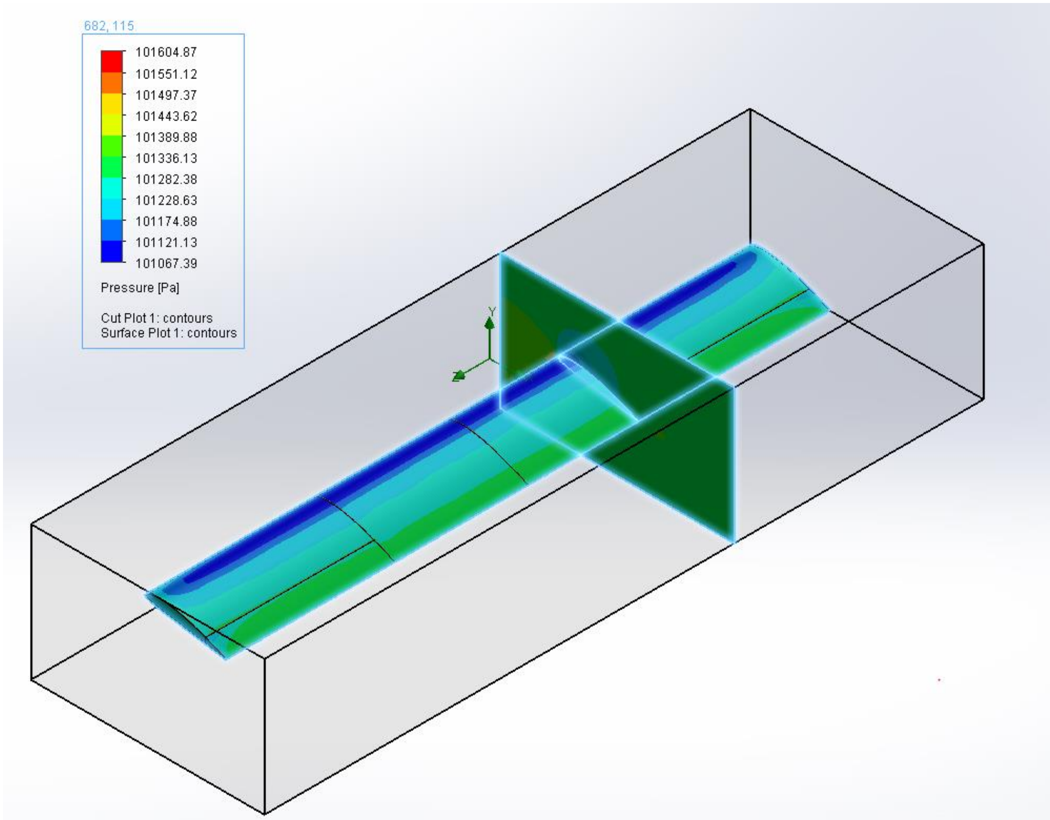

Figure 4: Complete Fuselage of Craft.

4.1.2 Fuselage

The fuselage is the main body of the craft where the drive system and the cargo bay are fitted. The fuselage is also the portion of the craft where the wings and the tail portion of the craft will be attached. The rules for the 2021 competition state that the payload must be stored within a cargo bay and points may be subtracted from the overall score if any of the cargo suffers damage. Therefore, the team has designed a cargo bay constructed out of foam board that is light in weight and will provide ample protection for the payload and avionics that it holds. The payload that the craft will carry will be stored in a cargo bay, located in between the nose and tail portions of the craft. It will have a hinged door that will allow for the box-shaped payload to be easily inserted and secured in this area. The front portion of the fuselage is the nose, which is the location where the motor, battery, and electric speed control of the drive system will be stored, along with other avionic components. The propeller of the drive component will be fitted on the frontal exterior of the nose. The tail of the craft will provide it with stabilization and the horizontal flaps help control the pitch of the craft and the vertical flap assists the plane in completing turns. The tail that the team has designed is to be constructed out of a lightweight foam board. The nose and the tail portion have also been made into sleek geometry in order to allow for reduced drag and enhanced aerodynamic efficiency.

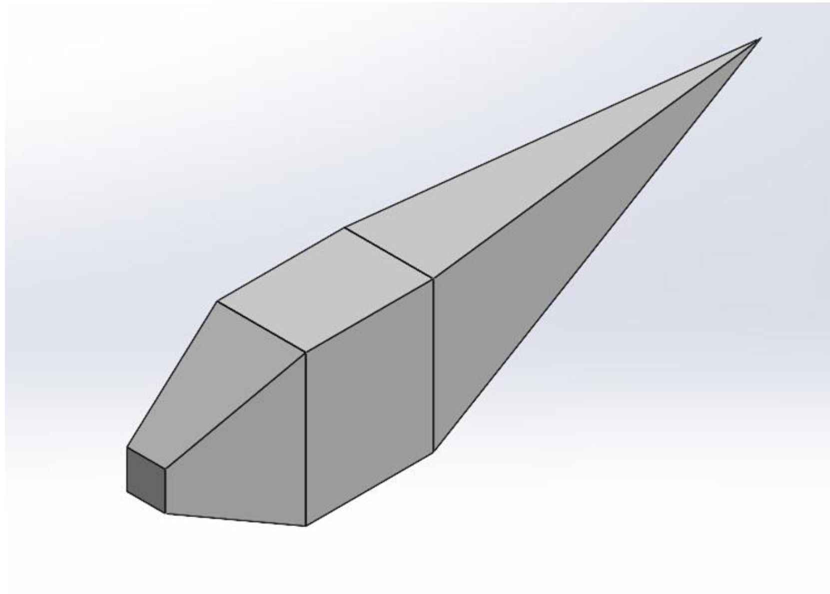

Figure 4: Complete Fuselage of Craft.

4.1.3 Drive System

The drive system of the craft is arguably the most important as without, the craft itself will not be able to achieve any sort of self-propelled motion and it will not be able to fly. The set-up of the drive consists of a motor, a battery, a propeller, and an electric speed controller. From the new set of rules released for the 2021 competition, the drive will have to be fitted with a 450-watt power limiter, which will prevent the motor from operating at its maximum continuous power at 800 watts, or just above any power level over 450 watts. Although this severely limits the potential performance of the current motor that the team has, it is not their interest to obtain a different motor. For the drive component we are using a Scorpion HK 2520-1880 motor, which is an incredibly powerful and weighs in at only 3.64 ounces, perfect for the type of competition that the team will compete in [8]. The propeller is an APC 9" diameter with a 4.7" pitch that is ideal for generating a large amount of thrust and also allowing the plane to travel at a faster rate of speed compared to propellers with a larger diameter [9] . With the flight time being another new factor in the scoring of the competition, the team has decided to use this propeller as it will allow the craft to carry a significant payload, while also being fast enough to complete the course in a short amount of time. With all of these components already in the team's possession from the previous team leaving them over, the team was able to save about $160. As shown in Appendix C [10], the drive system will be capable of generating a weight-thrust ratio of 1.30 and flying at a speed of 45 MPH. These numbers are encouraging as they demonstrate that the craft will be able to carry a sizable payload, while flying at a speed that will be much easier to control, which is crucial when performing turns and conducting a controlled landing, without damaging any of the payload.

4.1.4 Landing Gear

The landing gear is crafted out of lightweight aluminum that will have the sufficient strength to withstand a landing with a weighted payload, while also adding a minimal amount of weight to the craft itself. The landing gear has been designed to utilize a tricycle system which will provide it with better balance and greater chance of a successful landing. This is due to the rear two wheels being set under the payload, where the center of gravity of the craft is located, and where the possible shifting of the payload would likely occur. The height of the landing gears has also been designed to allow for at least an inch of clearance for the tip of the propellers to the ground. Since the propellers have been selected to be 9" in diameter, the landing gear will have a height length of at 5.5” to give at least an inch clearance from the tip of the propeller to the ground. Lastly, the landing gears will have controlled steering using DC motors, so that the team may conduct a stable landing on the runway and not lose any points for having the craft run off of the runway.

Figure 5: Rear Joint Landing Gear [11]

4.1.5 Prototype

Construction of the prototype of the craft has just recently begun as we plan on completing most of the build over the six weeklong winter break. However, with the recent news that the NAU machine shop had just recently obtained a laser cutter, the team was able to laser cut portions of the ribs for the wings. The original plan for the team was to begin the construction of the prototype in the time following the completion of the preliminary report. However, the new rules for the 2021 competition were released at this same time and work had to be prioritized for the new designs that would comply with these new rules and be most effective in the scoring system. As a result, the construction of the prototype had to be pushed back for some amount of time and the team has planned where the prototype will be constructed and improved upon over the upcoming winter break.

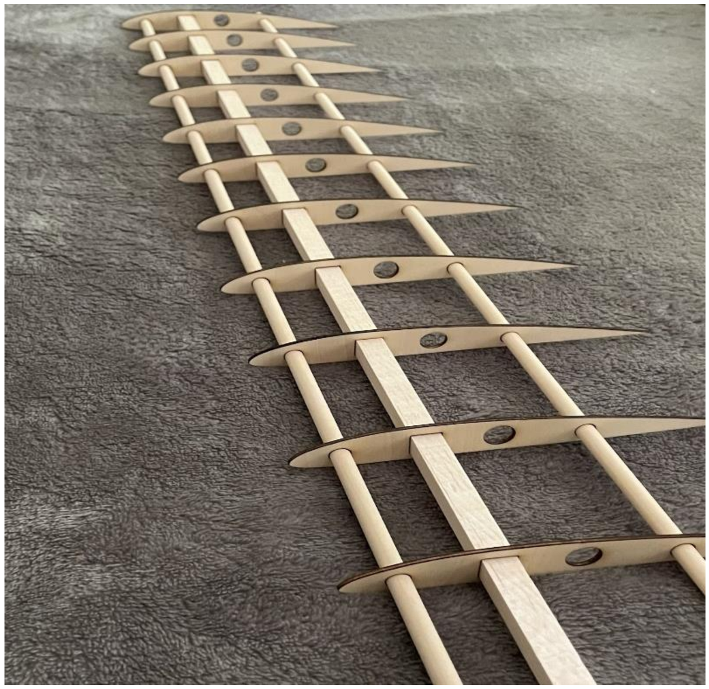

Figure 6: Balsa Wood Skeleton Prototype of the Wing

4.2 Implementation Plan

The team's plan is to continue construction of the prototype during winter break. After this, the team can begin conducting flight tests in January. The plan is to build the aircraft out of foam board and balsa wood. These materials are relatively inexpensive which will allow for multiple prototypes to be constructed. The team will use the laser cutting to manufacture the fuselage, airfoils, and tail of the aircraft. The team currently has $400 dollars left in the budget, and the bill of materials seen in Appendix D shows a projected cost of $335.11. The cost shown accounts for buying materials to build multiple aircrafts seeing as how the team project potential crashes or damage to the craft during the testing that'll begin in January. This is seen in Figure 7, the exploded view of the aircraft. The plan for the airfoils is to wrap the balsa wood ribs and spars in foam board. Given the dimensions for the fuselage, multiple pieces will be laser cut and joined by using hot glue. An issue the team has run into is the power limiter that is required by the competition rules is not yet available. The team is currently in contact with the supplier Neumotors to see when this component will be made available for purchase. Following the testing in January, the team has until mid-March to finalize the design. After this, the team will need to divert attention to the proof of tech inspection video due April 2nd, as well as the proof of flight video due April 9th. The validation event for the micro class will be held in Van Nuys, CA from April 9th to the 11th.

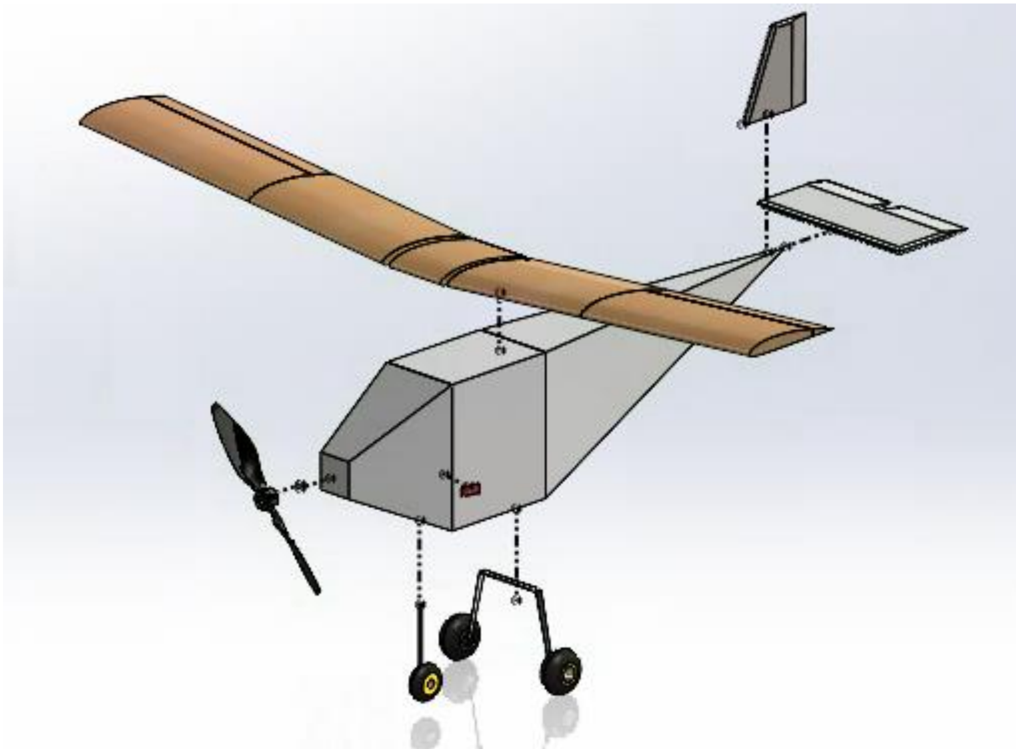

Figure 7: Exploded View of the Teams Aircraft

5.0 Conclusion

Summary Outline

Overview of the project + critical requirements

Work Performed During semester.

Final Design Solution

Future Work

Overall Warp up

6.0 References

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7.0 Appendices

7.1 Appendix A: Quality Function Deployment (QFD)

	Customer Needs	Customer Weights	Wingspan Length	Battery	Power Limiter	Cargo Bay Volume	Quick Payload Removal	Short Take-Off Distance	Aircraft Range	Fast Aircraft	Can Carry A Lot of Weight	Short Landing Distance	Gross Weight Limit	Radio Control System	Cost	Lift	Thrust	Drag	Ground Control Turn Radius	Reliability	Crashes Before Major Repair
			Technical Requirements																		
1	Wingspan Dimension	9	9			3		9	1	9	9					9		1	1		3
2	Electric Motor	3		9	9			9		9	3		3		3	3	9				
3	Battery Limited to 4 Cell	9		9	9	3		3	9	3	3		3	3	3		3		1	1	
4	Power Limiter	9	3	3	9	3		3		3				1	3	3	3			1	
5	Carries Metal Payload Plates	3	1			3	3	3	3	3	9	1	9			9	9	3			
6	Carries Payload Boxes	9	1			9	3	1		3	3	1	3			3	1	9			
7	Carries Payload Plates In Cargo Bay	9				9	3			3											
8	One Fully Enclosed Cargo Bay	9				1	1				1							1			
9	Securable Payload Plates	9				1	9												1	1	
10	Quick Payload Removal	3				1	9													3	
11	Short Take-Off Distance	3	3	3	1	3		9		3	3		1			9	9	3	1	3	3
12	Aircraft Range	3		9	3				9	3	3							3		3	
13	Controllable in Flight	9	3					3	3	3		3		9		3	3			3	3
14	Fast Aircraft	3	1	3	3			3		9		3					9				3
15	Can Carry A Lot of Weight	3	9					3			9		3			9	3	1			3
16	Short Landing Distance	9								3	3	9							9	3	1
17	Red Arming Plug	9		3	3																
18	Empty CG Markings	9					1				1		1		3						
19	Gross Weight Limit	3		1		1					3		9		1						
20	2.4 GHz Radio Control System	9												9					9	1	
21	Spinners Or Safety Nuts	9													1					3	
22	No Metal Propellor	9															3				3
23	No Lead	9											3								
24	No Structural Support From Payload	9				3															3
25	Metal Payload Plate securing Hardware	9				1	9													3	3
26	Low Cost Build	3			3										9						1
27	Durable Design	3	1				1	1		3					1				1	1	9
	Technical Requirement Targets		48	4	450	180	1	8	350	40	2	200	5	2.4	300	7.5	5	0.25	2	95	1.5
	Units		Inches	Cells	Watts	Inches Cubed	Minute	Feet	Feet	Miles Per Hour	Pounds	Feet	Pounds	GHz	US Dollars	Pounds	Pounds	Pounds	Feet	Percent	Crashes
	Tolerances of Ers		- 1/16	-3	+/- 0	+/- 25	-0.5	-2	+/- 25	+/- 15	+/- 1	-100	+/- 2	+/- 0	+/- 200	+/- 5	+/- 2.5	+/- 0.1	+/- 1	+/- 5	+/- 0.5
	Absolute Technical Importance		189	210	246	321	273	255	153	333	270	129	165	198	132	252	234	129	195	174	201
	Relative Technical Importance		5%	5%	6%	8%	7%	6%	4%	8%	7%	3%	4%	5%	3%	6%	6%	3%	5%	4%	5%
	Testing Procedure (TP#)		N/A	1	1	N/A	1	2	1	1	1	2	1	1	N/A	2	1	1	2	1/2	1/2

*QFD and HoQ excel document available upon request

7.2 Appendix B: House of Quality

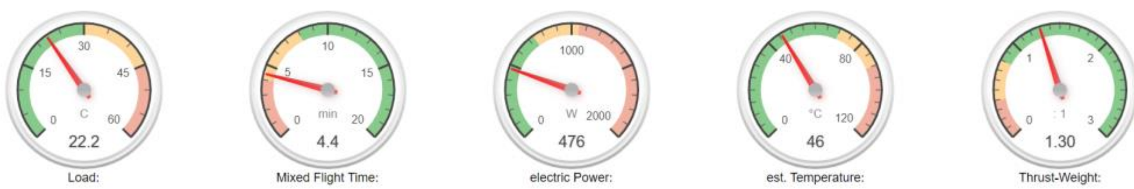
Project: **SAE Micro 20F12**
Date: 11/10/2020

Crashes Before Major Repair	C					C		A			C	C	C				A	A	
Reliability					A	C	A			A		B	A						
Ground Control Turn Radius										A		B							
Drag	B			A				B						A	A				
Thrust		B	A					A	B		C			A					
Lift	A		B					A	A		A								
Cost		C	A				A					A							
Radio Control System		C				A				A									
Gross Weight Limit			C	B					A	C									
Short Landing Distance						A		A	B										
Can Carry A Lot of Weight				A	C		C	A											
Fast Aircraft		A	C	C		A	A												
Aircraft Range		A																	
Short Take-Off Distance	A	B		A															
Quick Payload Removal				C															
Cargo Bay Volume			C																
Power Limiter		A																	
Battery																			
Wingspan Length																			

*QFD and HoQ excel document available upon request

7.3 Drive System Performance

Model Weight: 1361 g incl. Drive 48 oz	# of Motors: 1 (on same Battery)	Wing Area: 16.77 dm² 259.9 in²	Drag: simplified 0.05 Cd	Cross Section: 0 dm² 0 in²	Field Elevation: 2134 m.ASL 7001 ft.ASL	Air Temperature: 18 °C 64 °F
Type (Cont. / max. C) - charge state: LiPo 2200mAh - 30/45C - normal	Configuration: 3 S 1 P	Cell Capacity: 2200 mAh 2200 mAh total	max. discharge: 85%	Resistance: 0.0077 Ohm	Voltage: 3.7 V	C-Rate: 30 C cont. 45 C max
Type: max 50A	Current: 50 A cont. 50 A max	Resistance: 0.005 Ohm	Weight: 65 g 2.3 oz	Battery extension Wire: AWG10=5.27mm²	Length: 0 mm 0 inch	Motor extension Wire: AWG10=5.27mm²
Manufacturer - Type (Kv) - Cooling: Scorpion - HK-2520-1880 (1880) good search...	KV (w/o torque): 1880 rpm/V Prop-Kv-Wizard	no-load Current: 2.25 A @ 10 V	Limit (up to 15s): 1050 W	Resistance: 0.026 Ohm	Case Length: 40 mm 1.57 inch	# mag. Poles: 10
Type - yoke twist: APC Electric E - 0°	Diameter: 9 inch 228.6 mm	Pitch: 4.7 inch 119.4 mm	# Blades: 2	PConst / TConst: 1.08 / 1.0	Gear Ratio: 1 : 1	Flight Speed: 72.5 km/h 45 mph



Remarks:

Battery	
Load:	22.24 C
Voltage:	9.97 V
Rated Voltage:	11.10 V
Energy:	24.42 Wh
Total Capacity:	2200 mAh
Used Capacity:	1870 mAh
min. Flight Time:	2.3 min
Mixed Flight Time:	4.4 min
Weight:	168 g
	5.9 oz

Motor @ Optimum Efficiency	
Current:	27.53 A
Voltage:	10.33 V
Revolutions*:	17369 rpm
electric Power:	284.3 W
mech. Power:	241.6 W
Efficiency:	85.0 %

Motor @ Maximum	
Current:	48.94 A
Voltage:	9.72 V
Revolutions*:	15135 rpm
electric Power:	475.9 W
mech. Power:	390.0 W
Efficiency:	81.9 %
est. Temperature:	46 °C
	115 °F
Wattmeter readings	
Current:	48.94 A
Voltage:	9.97 V
Power:	487.9 W

Propeller	
Static Thrust:	1771 g
	62.5 oz
Revolutions*:	15135 rpm
Stall Thrust:	- g
	- oz
avail.Thrust @ 72.5 km/h:	1092 g
avail.Thrust @ 45 mph:	38.5 oz
Pitch Speed:	108 km/h
	67 mph
Tip Speed:	652 km/h
	405 mph
specific Thrust:	3.72 g/W
	0.13 oz/W

Total Drive	
Drive Weight:	371 g
	13.1 oz
Power-Weight:	399 W/kg
	181 W/lb
Thrust-Weight:	1.30 : 1
Current @ max:	48.94 A
P(in) @ max:	543.2 W
P(out) @ max:	390.0 W
Efficiency @ max:	71.8 %
Torque:	0.25 Nm
	0.18 lbf.ft

7.3 Appendix C: Bill of Materials

Bill of Materials				
Part/Material	Cost Per Unit	Units Required	Total Cost	Supplier
Balsa wood sheets (1/8"x3"x24")	$ 2.00	8	$ 16.00	National Balsa [12]
Balsa Wood Spur (Square)	$ 2.99	3	$ 8.97	National Balsa [12]
Balsa Wood Spur (Circular)	$ 0.69	6	$ 4.14	National Balsa [12]
Foamboard(20"x30")	$ 1.00	25	$ 25.00	Dollar Tree [13]
Scropion HK (2320-1880KV)	$ 80.00	1	$ 80.00	Scorpion Performance [7]
Spektrum(30 Amp)	$ 40.00	1	$ 40.00	Flite Test [14]
Spektrum(14.8V/2200mAh)	$ 80.00	1	$ 80.00	Flite Test [15]
Servo(9g)	$ 42.00	1	$ 42.00	Flite Test [16]
Hot glue sticks (1 pack)	$ 12.00	1	$ 12.00	Amazon [17]
E-Flite UMX A-10	$ 16.00	1	$ 16.00	Flite Test [18]
Servo Rods	$ 8.00	1	$ 8.00	Amazon [19]
Propellors	$ 3.00	4	$ 12.00	RC Planet [8]
Overall Cost:			$ 344.11	