EML4551-2

Team 507: SAE Aero Competition (Fuselage)

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Abstract

Two senior design teams' shared objective is to design and build a 3D printed, radio-controlled airplane to compete in the Society of Automotive Engineers (SAE) Aero Design competition. The plane must take-off within 100 feet, and land within 400 feet while carrying a payload, this being a 9in diameter soccer ball, and a 1lb weight. Team 507 focuses on the fuselage of the plane, the fuselage being the section where the electronics and payload are housed, as well as the landing gear. This year's fuselage features a streamlined design that appears whale-like to reduce drag on the plane as much as possible. A hatch on top of the plane opens to load and unload the soccer ball payload. The landing gear of the plane is arranged as a tail-dragger configuration meaning, two wheels are placed close to the front of the plane and one wheel toward the rear section of the plane. The front two wheels are resting under the wings to increase stability on land and decrease landing impact, and the back wheel is placed close to the tail. The partnering team, Team 508, is responsible for the wings, tail, and electronics of the plane. The fuselage accommodates the design decisions of the partnering team, Team 508. Those design decisions being a low-wing with dihedral configuration meaning, that the tips of the wings are higher than where the wings connect to the plane. The team decided to select a standard tail. The entire plane aside from the landing gear and electronics is 3D printed using light-weight PLA, a filament made of plastic and foam. The main challenges the team overcomes in this project include designing the fuselage for printability and structural integrity.

Acknowledgement

Thank you to the Florida Space Grant Consortium for providing us the funds needed to finish our project. Your contribution relieved us of excessive financial stress.

Thank you Dr. McConomy for sponsoring our project. Your advice and guidance have been invaluable. Thank you for your willingness to discuss ideas and encourage our team in times we needed it the most.

Thankyou Dr. Hruda for advising our project. We have appreciated your insight into the 3D print aspect of our design. Your encouragement and light-hearted humor has lifted our spirits when it seemed like the project was hopeless.

Thankyou also to Jacob Pifer and Sasindu Pinto for your guidance in the design aspect of our plane. Your insight from previous experience in this project greatly affected the direction we went with our design.

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Notation

SAE	Society of Automotive Engineers
RC	Remote Controlled
LW-PLA	Light Weight Thermoplastic

Chapter One: EML 4551C

1.1 Project Scope

For this project the team will be composed of two separate groups, group 507 will be working on the fuselage, and geometry of the plane and group 508 will be working on propulsion systems and controls. The following sections will cover the scope of group 507's portion of constructing the airplane following competition guidelines.

1.1.1 Project Description

The objective of this project is to design and manufacture a radio-controlled aircraft for the 2022 SAE Aero Design Competition. The aircraft will operate from short runways and complete the necessary flight path while carrying outsized spherical cargo. The plane will be constructed primarily out of 3D-printed materials.

1.1.2 Key Goals

The goals of this project define the plane's route and operation so that the team's objective may be achieved and the requirements for the 2022 SAE Aero Design Competition may be met. The team's project goals include but are not limited to the following.

- The plane is controllable via remote control which is operated by a single person
- The airplane's landing gear system is capable of controlling the steering of the airplane while on land the plane's propulsion system will be powered by 1 electric motor
- The team will stay within budget while building and purchasing components
- The cargo bay will secure two payloads that aren't subject to airstream

- The plane is constructed within the SAE competition guidelines
- The plane is primarily constructed of 3D-printed parts
- The plane can operate with and without payloads
- The payloads must load/unload in 1 minute
- The plane can takeoff within 100 feet in 120 seconds
- The plane can securely land within 400 feet
- The plane can be disassembled and reassembled

1.1.3 Markets

One of the team's primary markets is the judges of the 2022 SAE Design Competition. The team will design the plane to the competition's standards to gain approval by the judges. The team believes that the plane's unconventional, 3D-printed makeup will excite the judges so long as the design successfully completes the flight path of the competition. The RC plane community and 3D printing community are also included in the team's primary markets. If the team produces a successful design, members of the RC plane community may replicate the design so long as the members have access to a 3D printer. Likewise, the 3D printing community may also take an interest in building their own 3D printed planes. The team's manufacturing choice could potentially encourage the sharing of knowledge between the RC plane and 3D printing communities. The innovation and potential success of the team's plane could bring entertainment and advancement to the 2022 SAE Design Competition, RC plane community, and 3D printing community.

When considering how the plane may be used outside of the competition, the team determined its secondary markets as agriculture, conservation, and the U.S. military and its allies. The team's consideration of two payloads could be potentially useful for these fields. For instance, a farmer could fly the team's RC plane over his crops to record atmospheric data or other data related to his crops. A conservationist may fly the team's design over land to conduct vegetation mapping or to assess the damage caused by a wildfire. The military may find the team's design useful as a vehicle for aerodynamic modeling or delivering a special payload. The team's design introduces agriculture, conservation, and the military to one potential uses of additive manufacturing, a medium which may become more commercial in decades to come.

1.1.4 Stakeholders

The stakeholders in this project include the FAMU-FSU College of Engineering, the Florida Space Grant Consortium, the SAE Aero Competition judges, and the team's sponsor Dr, McConomy. The stakeholder specific to the fuselage group is their advisor Dr. Simone Hruda.

The team will be attending a competition representing the FAMU-FSU College of Engineering, making it a stakeholder in the project. The plane's performance will reflect not only on the sponsor and advisor but the college as a whole. The competition judges are stakeholders because they are putting in their time as well as providing their input on the design of the plane. Project advisors, Dr. Hruda, stakeholder in the project as they are providing oversight and counsel to make sure the team is successful. Our project sponsors, the Florida Space Grant Consortium as well as Dr. McConomy are stakeholders because they provide us with the necessary funding for the manufacturing stage of our plane's production.

1.1.5 Assumptions

The assumptions made by the team define the conditions the plane is expected to withstand as well as conditions the airplane is expected to perform through.

1. The plane will be operated within normal atmospheric weather conditions for Fort Worth, Texas in May
2. The plane will only be used for the competition
3. The plane will not operate in rain
4. The plane can operate from a flat runway.
5. The plane operator is acquainted with the controls
6. The plane operator has sufficient vision
7. The payloads will be purchased off shelves

1.2 Customer Needs

This project, being part of a competition, means that there are needs specified by the competition and regulations that the team must follow. Besides the competition rules, the team's sponsor has specified other needs that involve what the team must accomplish and manufacturing methods. The table below, Table 9, describes the customer needs that were gathered from the SAE competition rulebook, as well as the engineering interpretation from said need statement.

Some of the general requirements include the necessity to have a properly identified aircraft including school's name, mailing address, and other specifications mentioned in Table 9 found in Appendix C: Figures and Tables. The students must design and manufacture an airplane that can be controlled wirelessly in air and on ground. The plane must also weigh less than 55 pounds and place a sticker where the empty center of gravity would be located. The aircraft's electrical components must be secured in a way that there are no protrusions that may puncture said components, as well as design the aircraft to have a fail-safe mechanism in case signal between the controller and the airplane is lost. The students must also include a power limiter to limit the power output from the battery and motor. The propeller used must be made of a non-metal material, and no lead can be included in any part of the airplane. Regarding the design of the aircraft, the plane must have a wingspan that is less than 120 inches, and the payload inside must not help with the aircraft's structural integrity.

As a part of the mission requirements, the airplane needs to complete a flight pattern specified by the competition guidelines after ascending to a specified altitude. The aircraft must takeoff within 100 feet in 120 seconds and must land within 400 feet.

Besides customer needs, the sponsor for the project has asked the team to make the airplane out of as much 3D printed material as possible, and to be able to justify why a component is used that is not 3D printed. There is no minimum amount to be 3D printed but every part must have a reason for it to be chosen. The connection between the wings and the fuselage must be secure and must limit the amount of wiring to reduce excessive weight.

These customer needs and sponsor needs will help the students properly build the airplane and meet all specifications from the SAE rulebook as well as the sponsor specifications. Having said information, the students will be able to start researching and looking into a variety of concepts to move forward with. The team will be working on producing a design that uses innovative manufacturing methods that will not only catch the judges' attention, but also fly and complete the flight pattern specified by the SAE guidelines.

1.3 Functional Decomposition

Once the customer needs were received and analyzed, the students were able to create the functional decomposition for the project. As part of the process of analyzing the functional decomposition, the students created individual hierarchy charts where the customer's needs were taken into consideration and the systems that make up the airplane were broken down into smaller functions. The team came up with the following hierarchy chart shown below, where the components are broken down into a function they must complete.

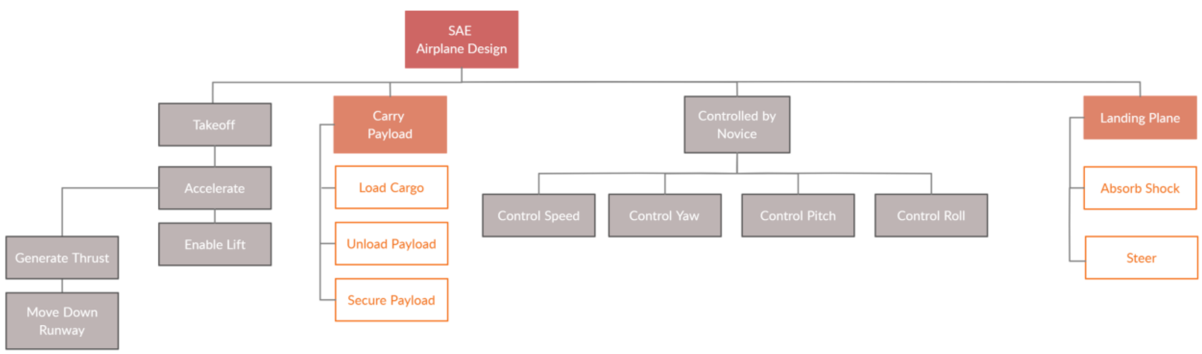


Figure 1: Functional Decomposition Hierarchy Chart.

Figure 1 shows the first tier of boxes as the major functions of the airplane including takeoff, transportation of payload, controllability during flight, and landing the plane. Each of these were then broken down into further functions and the last tier is composed of minor functions.

The minor functions are important toward successful completion of the function their corresponding major functions.

While the airplane is still on ground, one of the requirements made by the competition is that the payload has the capability to be removed and replaced by two members of the team in under 1 minute. Synthesized as a function, the students must be able to load, unload, and secure the cargo so that it does not move inside the airplane. A secure payload will allow the controls of the aircraft to not work as hard to steady the plane and thus improve the performance of the plane. Once the cargo is secured, the students will be able to proceed into takeoff sequences.

During takeoff the students must take into consideration how the airplane will accelerate down the runway and how the airplane will overcome drag and produce lift to fly. Viewing these needs as functions the airplane must complete; the plane must accelerate down the runway and generate lift by generating circulation under the wings which then produces a pressure difference between the surfaces of the wing. Once the airplane takes off, the pilot must be able to control the aircraft.

The pilot of the aircraft is assigned by the competition, this person is acquainted with the controls of an RC airplane, and so the students the controls of the plane should resemble the controls of most remote-controlled planes. As a part of the controls, the students will need to control the motor, rudder, elevator, and ailerons. The students will be controlling the speed of the motor to produce acceleration and thrust, rudder to control the yaw, elevator to control pitch and ailerons to control the roll. Each of these are very important to complete the flight pattern required by the competition guidelines. After completion of the flight pattern, the plane must land safely back on the runway.

The final step toward flight completion would be landing. The landing gear must complete further functions such as absorb shock from landing impact as well as steer the aircraft while the plane is on land.

Figure 1 highlights in color the functions pertaining to the Fuselage team while graying out the functions pertaining to the Aero-Propulsion team. Because the fuselage will hold the payload, the fuselage team must ensure that the payload is loaded, unloaded, and secured. Both teams agreed that the Fuselage team would be in charge of the design of the landing gear. Therefore, it is the Fuselage team's responsibility to ensure the plane can move down the runway, steer on land, and absorb the shock upon impact. While the Fuselage team is not necessarily responsible for ensuring lift or control of the plane, the fuselage must minimize its drag as much as possible to ensure the fuselage does not work against the plane's goal to generate lift. The fuselage will also hold or connect to the material that will allow the plane to be controlled in the air. Thus, it will be important for the Fuselage team to communicate about how parts like wings or tail will be connected as well as ensuring the fuselage has enough space to hold wires and electronic parts such as the motor.

All of these major and minor functions are crucial toward the success of the project. After all of these functions were defined the students proceeded to set up a cross reference matrix in Table 1: Table 1 shown below.

Table 1: *Functional Decomposition Table*

	Major Functions:				
Minor Functions:	Carry Payload	Takeoff	Controlled by Novice	Land Plane	**Minor Function Ranking:**
Accelerate		X	X		2

Generate Thrust		X	X		2
Move Down Runway		X	X	X	1
Enable Lift		X	X		2
Load Cargo	X				3
Unload Cargo	X				3
Secure Payload	X				3
Control Yaw		X	X	X	1
Control Pitch		X	X	X	1
Control Roll		X	X	X	1
Absorbs Shock			X	X	2
Steer on land		X	X	X	1
Balances plane on land		X		X	2
Major Function Ranking:	4	2	1	3	

Table 1 above is used as our group's functional decomposition table. It lists our major functions as well as any minor functions that can help us reach the goals set in customer needs. The goal of this table is to attain a ranking of each of our major functions in order of importance. The matrix is used to compare the major and minor functions so that an X can be placed, representing that they are related. For example, the steering of the plane while on the ground is related to the control systems, so we place an X at that intersection. This is used to determine the ranking order of the major functions. Whichever column has the most X's tells us the most important major functions. The controllability of the plane by a novice has the most X's, so it is ranked as the major function of the highest importance. The ability of the plane to carry the payload has the least number of X's, so it is ranked as the major function of the least importance. The minor functions are also ranked by order of importance. The rankings are found by totaling the score from the major functions, as well as the customer needs.

When analyzing the order of important of the minor functions in Table 1, the students found that the controllability of the plane was most important to design for. Surprisingly, the plane's ability to lift in the air and its ability to withstand impact came in second. Finally, all functions pertaining to the payload were determined as the least important. The plane may be designed as aerodynamically sound, but if the plane is unable to be controlled it will be unable to compensate for the fluctuations in the air. For this reason, the controllability of the plane takes precedence over its ability to lift off.

In Table 1, the function "Carry Payload" and its corresponding minor functions do not relate to any of the other functions in the table. If the payload were not a part of this project, our plane could still fly, land, and takeoff. However, the plane's ability to carry the payload is crucial to plane's ability to compete in the 2022 SAE Aero Design Competition. Thus, the plane's ability to carry the cargo must be included in the functional decomposition of the plane.

We feel that the rankings properly reflect the competition guidelines and help us in looking toward out targets. The table shows us how the systems rank in order of importance, but also that they have many overlapping minor functions that relate to separate major functions. It is crucial that all the major functions are achieved, because failing in only one would mean we don't reach our goal of creating a plane that meets all the requirements set by the competition guidelines. If we create a plane with aerodynamic surfaces that can be controlled by a novice, but the plane can't take off, then the control systems while in flight become irrelevant. Also, if the plane can't be controlled while in flight, then it will crash and the landing system will be irrelevant. For the plane to work as we design it, all of the functions will need to be successful. To create a plane for the competition, all of the functions must be met, regardless of rank or order of importance.

1.4 Target Summary

The targets and metrics for this project were adapted toward the functions that were decided upon the functional decomposition by using the SAE Aero Design Competition rulebook. Each function is assigned a metric, target, and validation tools and methods. Metrics are the information that is being tested from the function, the target is a specific value that is being set as the maximum or minimum for a condition. Validation method, and tools are the method that is being used to test the metric and the tools that are going to be used for the validation method.

Besides the SAE Aero Design Competition rulebook, the students came up with important functions that need to be tested for the success of the overall team. Both teams conducted research on traditional RC planes, cargo planes as well as calculations regarding the total weight of the airplane, as well as important physical restrictions toward the airplane. In Table 2 the most critical targets and metrics toward the fuselage team are disclosed.

Table 2: *Critical Targets and Metrics*

Functions	Metrics	Targets	Validation Method	Validation Tools
Plane Weight	Maximum weight	15 lbs	Previous testing	Theoretical Calculations
Load Payload	Time	Less than 1 minute	Time Trial Test	Prototype
Secure Payload	Movement	Payload does not move	Prototype movement and tilting	Prototype
Unload Payload	Time	Less than 1 minute	Time Trial Test	Prototype

Absorb landing impact	Ability of landing gear to withstand force of impact	45 lbF	Physical Drop Test	Prototype

As a part of the fuselage team, the students felt that some of the most important functions directed toward the team include the overall plane weight meaning what will be the maximum weight of the airplane. According to the SAE competition rulebook, the airplane must not exceed 50 lbs but according to calculations made by the students, the maximum weight to achieve flight would be of 15 lbs. Previous years projects have had an average close to 15 lbs of total weight of would be of 15 lbs. Previous years projects have had a total weight of around 15 lbs, none of their airplanes have flown which also show that we should attempt to stay under 15 lbs.

Another major function of the airplane is to carry an outsized spherical cargo as well as a rectangular block of cargo. The first step to this function would include the loading of the payload into the aircraft for which the metric would be time. The target set by the competition rulebook is to load the payload within 1 minute with the assistance of two team members. The method that the students will be using to test this metric would be to print practice components and run time trials to better understand how the locking mechanisms perform, and if any changes need to be made. A very similar process would apply to the process of unloading the payload from the airplane where time trials would be performed on prototypes made. While the payload is in the aircraft, it is important for the payload to remain secure so that the center of gravity of the plane does not change while in flight. The students will be testing the amount of movement of the payload within the plane by creating prototypes and shaking and tilting the prototype while holding the payload. The students will take a video while the testing is taking place to analyze how the payload reacts to movement and determine if the mechanism would work toward the plane or if any changes should be made.

Once the airplane completes the flight pattern required by the competition rulebook, the students must land back on ground safely. During the process of landing, the plane must absorb impact from the ground, considering this as a function the students will be generating calculations so that the airplane during the process of landing may withstand roughly 3Gs of force or three times the total weight of the plane. This target will be validated by constructing physical prototypes of the landing gear that will be dropped and assessed for damage.

To meet the objective for this project, the team must satisfy more than just the critical targets outlined in Table 2. Table 11 of Appendix C: Figures and Tables lists the rest of the targets that must be met as well as the validation methods and tools we need. The team arrived at these targets and metrics through research and calculations. Although the critical functions are the most important because they are necessary for us to meet the competition requirements, the rest of the functions are also important for us to achieve our goal. The plane will not always be in the air, it must be able to move down the runway, to take off, and have the stability to properly land. Having a steering angle that provides us with a 150-degree range of motion, as well as a 24-inch wheel track, will provide the plane with the stability and maneuverability on land that it needs. The team found that these are the metrics the plane needs through research and stability calculations. For the plane to be able to move at all, we need to generate thrust with our motor and propeller. With the plane accelerating down the runway, our wings begin to produce lift so the plane can take off and begin its flight path. By looking at the weight of the fuselage from past years combined with the components that we will be using, we found the metrics for thrust and lift to be at least 15-lbF. The team decided it necessary to include the aerodynamic surfaces that will control the plane while in flight. The rudder controls the yaw, the elevator controls the pitch, and the ailerons control the roll. All of these functions must be included if we are to have a plane that is controllable in flight. The metrics that we are targeting for the control surface angles were found through research on remote control planes. Our plane is to be mostly 3D-printed so it is important that our printed parts function as we design them to. The team must produce quality parts by learning the tolerancing of the printers so the parts connect properly. We found through testing our printed parts that aiming for a tolerance of 0.05-inches provided us with the precision required for quality parts and connections. For the plane to operate safely, the propeller must have full range of motion without risk of touching the ground. This function allows the plane to generate thrust and move down the runway for takeoff. We want the propeller to have a clearance of 3-inches, because it is what the RC-club recommends.

The methods used to validate the plane design consist of CAD simulations, prototyping, and some theoretical calculations augmented by MATLAB. To validate the payload targets, one prototype will be constructed to simulate the payload securing, unloading, and loading method. The prototype may consist of a container such as a cardboard box with metal spares protruding into and through the box. The container will simulate the fuselage and the wing spares will simulate the wing placement. The team will simulate different openings and securing methods for the payload using this prototype to fulfill these targets.

Simulations of the plane assembly in CAD will be used to ensure the plane is balanced, the wheel has clearance to steer on land, and the landing gear is appropriately arranged underneath the plane's center of gravity. CAD has the ability detect collisions between objects and efficiently calculate the center of gravity of an assembly. Once the team is confident in the design of a landing gear, the team will construct a prototype of the landing gear, then drop the prototype to assess its durability. This prototype will consist of attaching the landing gear to pieces of metal or wood representing the length of the wingspan and fuselage.

The plane's ability to accelerate will be validated by mainly theoretical calculations and testing of the propulsion systems. The thrust produced by different propellers will be tested by attaching the motor and propeller to an L-shaped prototype with the other end resting on a weight scale. When the motor is turned on and the propeller begins to spin, the prototype will bear down on the scale and the team will be able to record the force produced.

The motion of the controls of the plane will be tested through prototyping the movement of the elevator, flaps, ailerons. CAD simulations will ensure that no interference of the movement of the controls occurs. The 3D-printing aspects of the manufacturing of the plane will be validated through simulating different 3D-printing settings, printing test parts, and printing different connection methods of parts. CAD simulations will ensure that the propeller has an appropriate clearance to the ground and does not exceed the maximum planned weight.

1.5 Concept Generation

The Fuselage team partnered with the Aero team to generate concepts for the basic design of the plane. One hundred design concepts developed by the Fuselage team are listed in Appendix E: Concept Generation. After initial ideation was conducted, the Fuselage and Aero teams agreed on three high fidelity and five medium fidelity concepts.

The concepts were generated using a morphological chart, biomimicry, competitive benchmarking, and anti-problem concept generation tools. The majority of the concepts were developed using the morphological chart. The morphological chart allowed the team to determine all the possible combinations of the presumed, most feasible designs of the key parts of the plane. The team also assessed possible animals to mimic key parts of the plane from. This technique known as biomimicry allowed the team to look outside of conventional aircraft and toward designs that may be feasible if 3D printed. However, conventional aircraft has been improved upon for decades now. It would be foolish not to consider mimicking decades worth of designs. Therefore, the team researched different planes that may be useful to mimic or benchmark our designs on. Finally, the team decided it may be useful to come up with terrible ideas. By determining what it would take for the design to fail, the team was more able to assess what designs would help the team succeed.

After generating 100 concepts, three high fidelity concepts and five medium fidelity concepts were determined. The high-fidelity concepts represent designs that are optimized to the functions the team believes are most important. The medium fidelity concepts represent designs that are optimized to functions that the team is willing to compromise on.

1.5.1 High Fidelity Concept 1

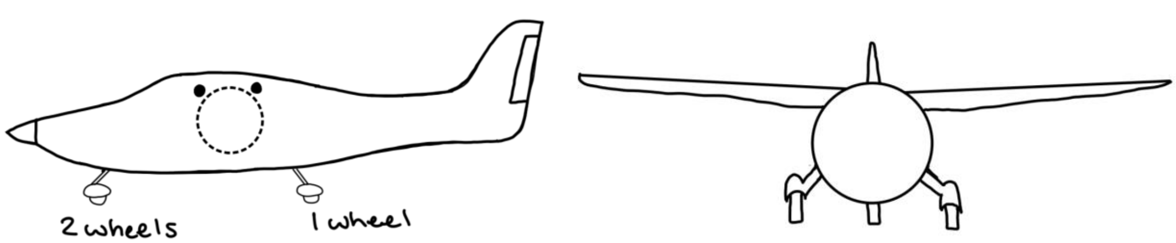


Figure 2: High Fidelity Concept 1

The 1st high-fidelity concept features the wings higher on the fuselage. The advantage of this wing placement would be the in-flight stability because the center of gravity would be below the center of lift. This concept also features a taildragger landing gear because it has more stability while on the ground due to the wheelbase being longer. The widest point on this fuselage design is between the spars so that is where we will place the soccer ball. A conventional tail means that the horizontal stabilizer is at the bottom of the vertical stabilizer, attached to the fuselage. An advantage of the dolphin-shaped fuselage, based on the cirrus sr22, is that there isn't a negative lift force that counters the wings. The propulsion system will be placed in front of the fuselage. This concept features a rectangular wing with no winglets because this makes for a shorter wing and therefore the center of lift is closer to the fuselage.

1.5.2 High Fidelity Concept 2

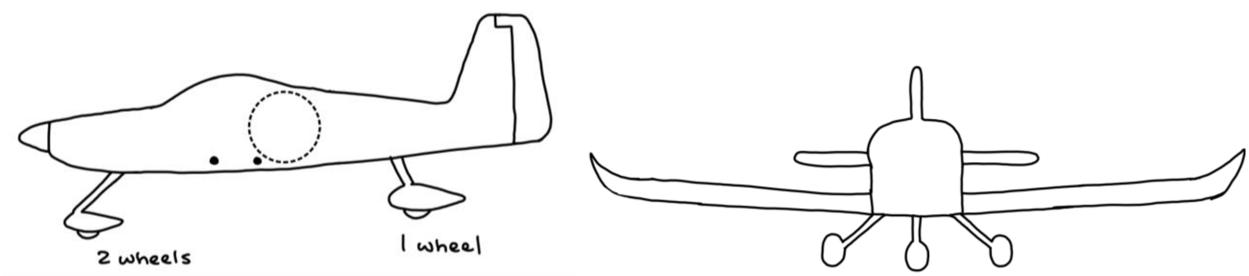


Figure 3: High Fidelity Concept 2

The 2nd high fidelity concept is modelled after the RV-14 plane. The RV-14 was chosen to model after because it features a taildragger landing gear, a conventional tail, and a bulbous section in the fuselage near the wing of the plane. To decrease the diameter of the plane, the soccer ball is placed behind the spars running through the wing and fuselage. The wings are in a low wing configuration with a taper and winglets. While the wings have increased complexity compared to rectangular wings, the team believes the complexity could increase the stability of the plane and decrease the mass and drag of the plane. The Fusealge team is interested in how the soccer ball placement affects the CG, overall mass, largest fuselage diameter, and payload insertion. Whether or not a fuselage must require a change in shape depending on the landing gear configuration is considered important to the fuselage team.

1.5.3 High Fidelity Concept 3

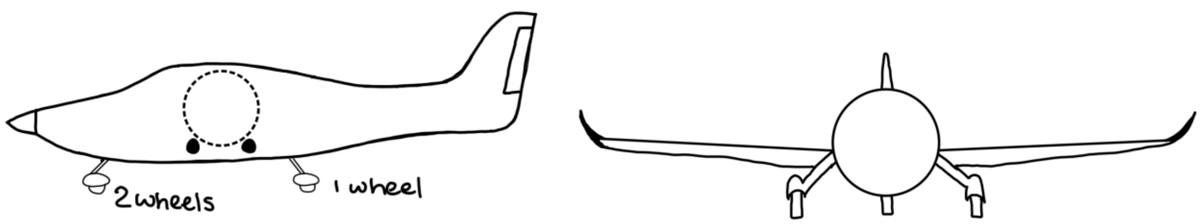


Figure 4: High Fidelity Concept 3

The 3rd high fidelity concept consists of a plane modeled from the SR-22 which would have 1 propulsion system placed at the tip of the aircraft. This airplane would have a taildragger landing gear setup which should help the aircraft resist the landing forces as well as would make it easier to steer while on ground. The wings would be placed in a low wing configuration with two metal spars running through the wings to improve the integrity of the wings. The payload would be placed in between the spars to use the spars as two points of contact to maintain the payload secure as well as two points of contact from above the payload to completely secure the payload while in flight. The wings would be tapered and have winglets similar to the ones on the drawing above.

The SR-22 is a very common cargo plane which can takeoff on short runways and the combination of having tapered wings and winglets would benefit the team in achieving lift and stability. The wings could be complicated to print due to the wings being tapered but it could improve the performance of the airplane. The wings would include ailerons to control the roll of the aircraft while the conventional tail would include elevator and rudder. The manufacturing process for this aircraft would be 3D printing with LW-PLA which while being more fragile than regular PLA, it would reduce the total weight of the plane reducing the amount of lift necessary to get the plane to fulfill it's overall purpose.

1.5.4 Medium Fidelity Concept 1

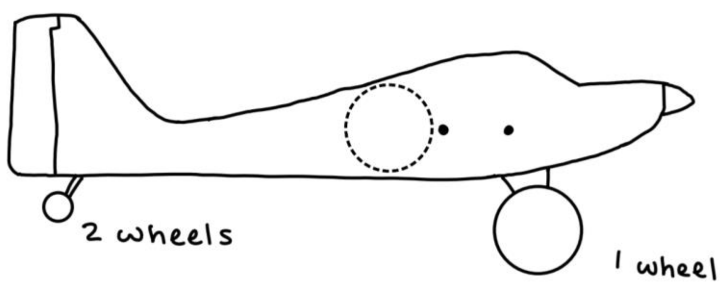


Figure 5: Medium Fidelity Concept 1

The team's 1st medium fidelity concept consists of using the side profile of a regular RC plane as well as a similar cross section which encloses the payload securely. This concept would use one propulsion system. The concept would use a mid-wing setup with tapered wings and no winglets. The tail used for the plane would be conventional and the landing gear would follow the tricycle setup. The payload for this concept would be placed behind the spars of the airplane in comparison to the other examples which would have the payload placed in between the spars.

1.5.5 Medium Fidelity Concept 2

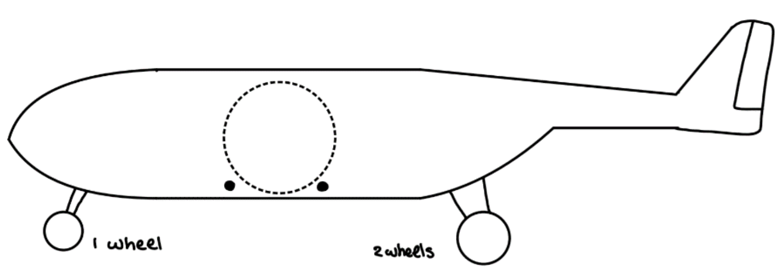


Figure 6: Medium Fidelity Concept 2

The second medium-fidelity concept features the propulsion system in front of the fuselage. The symmetrical whale fuselage makes it easier to calculate and design the most effective layout of the inner structure relative to the center of gravity. The widest portion of the fuselage is where the wings are placed, so this is where our large cargo will be placed. This concept is unique in that it features a delta-wing with winglets. This will allow for the landing gear to be attached to the wing, so this concept will have a tricycle landing gear.

1.5.6 Medium Fidelity Concept 3

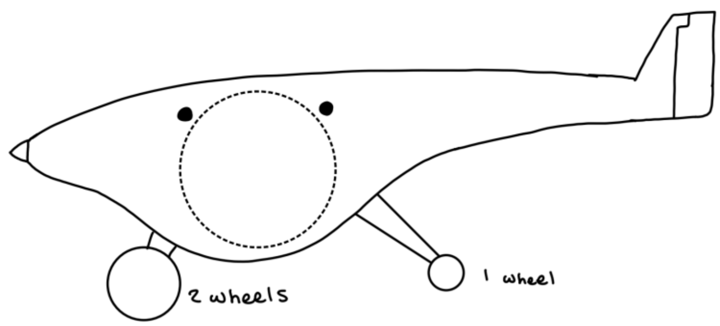


Figure 7: Medium Fidelity Concept 3

The 3rd medium fidelity concept features a guppy fuselage, with taildragger landing gear, and a high wing. The guppy fuselage shape is bulbous underneath the wing of the plane. This bulbous area is where the soccer ball would be placed. The wing spars and fuselage shape could effectively stabilize the payload. However, inserting the payload may prove tricky. The payload would have to avoid colliding with the landing gear and wing when inserted. The high wing and conventional tail would help increase lift and stability. The rectangular wing shape would reduce complexity of the plane. Landing gear placement may prove tricky from the fuselage shape design. The landing gear may have to increase in length or could rest close together.

1.5.7 Medium Fidelity Concept 4

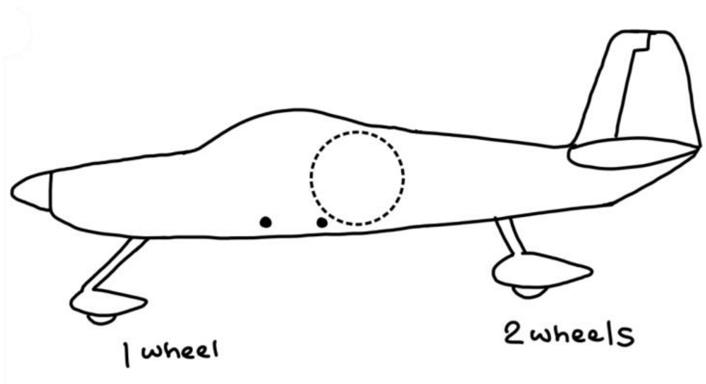


Figure 8: Medium Fidelity Concept 4

The 4th medium fidelity concept consists of a body similar to the RV-14 with a tricycle landing gear orientation. A "T" tail would be implemented for this design which includes elevator and rudder controls. The RV-14 body could provide with the aerodynamics necessary for successful flight with collaboration from the wings from group 508. The wings would be supported by two metal spars to provide structure and rigidity. The payload would be placed behind the spars. The wings would be elliptical and would not have winglets. The image shown above is an example drawing of what the airplane would look like.

1.5.8 Medium Fidelity Concept 5

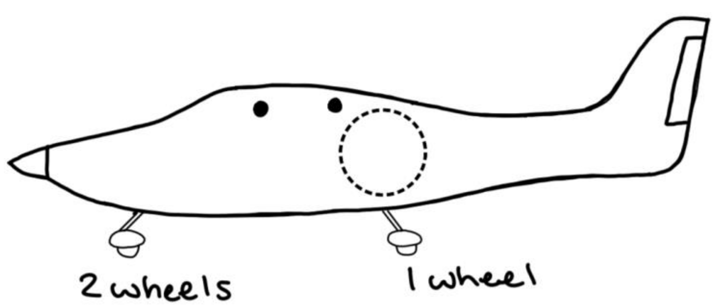


Figure 9: Medium Fidelity Concept 5

This concept is the 5th medium fidelity concept which would use a body similar to the SR22 using a tail dragger wheel orientation. This model would have a single front propeller, and wings that include flaps and a tail that includes elevator and rudder. This concept would use rectangular wings without winglets in a high wing setup. The payload would be placed behind the spars that support the wings. A conventional tail would be used for this concept.

For the manufacturing portion of this airplane, it would be 3D printed with LW-PLA which should reduce the total weight of the airplane while still having the structural integrity that the design of the SR-22 provides.

1.6 Concept Selection

Once the students have generated a sufficient number of concepts, they started to analyze the concepts by first setting up a binary pairwise comparison chart (BPC). The purpose of this chart, referenced in Table 12 in Appendix C: Figures and Tables, is to compare features specified by the sponsor directly with each other. The feature on the left side column is the same as the features on the top row, each feature is then compared to the other by giving a 1 to the feature that is most important, and a zero to the feature that is less important. Then we add the values up in a vertical manner and the features with the highest values, have the most importance toward the project. From the students graph's they analyzed that the most important features were controls, loading the payload, and plane maneuverability. The students arrived to this conclusion by adding the values on each column and the greater the value results in the feature being the muost important.

After completing the BPC chart, the next step was to do the house of quality chart (HoQ) featured in Table 3. This chart is a matrix that shows the customer requirements from the BPC and relates them to the engineering characteristics of the plane that a manufacturer may use to fulfill these requirements. This chart is commonly used in the process of selecting the most important functions. The students used sponsor specified targets as well as mission requirements to be able to compare the customer requirement to the critical targets. Table 3 shown below describes the customer requirements and the importance weight factor determined from the BPC.

Table 3: *House of Quality*

		Engineering Characterisitics										
Improvement Direction			–		–	–	–	–	–		–	–
Units		ft, sec	ft.	ft, lbs	Non-Dim	Min.	Deg.	Deg.	Deg.	%	ft/s	lbs.
Customer Requirements	**Importance Weight**	Thrust Generation	Moving Down	Ability to Provide Lift	Overcoming Drag	Load/Unload Cargo	Rudder	Elevator	Aileron	Static Margin	Resist Effects of Stress	Weight
Material	5		1	3	1		9	9	9	3	9	9
Stability	5	3	1		1	3	9	9	9	9		
Takeoff/Landing Requirements	6	9	9	9	3		3	3	3	9		3
Wingspan Restrictions	4			9	9	3		3	9	3	3	
Power	5	9	3	3			1	1	1			9
Manueverability	7	1	9	3	9	9	9	9	9	3		9
Lightweight	5		3	9						3	3	9
Landing Shocking	2		1			1					9	3

Controls	11	9	9	9		3	9	9	9			
Minimum Cargo Load Required	3	1	1	1		3				3		9
Loading/Unloading Payload	9					9				9		3
Innovation	4					3				3		
Raw Score (2629)		223	261	288	127	227	275	287	311	264	90	276
Relative Weight %		8.48	9.93	10.95	4.83	8.63	10.46	10.92	11.83	10.04	3.42	10.50
Rank Order		9	7	2	7	6	4	2	1	2	2	1

For the HoQ any cell that is left empty has a 0, each value represents how closely the customer needs relate to the engineering characteristics where a 1means that both relate slightly, 3 means that they relate moderately, and 9 that both relate strongly. The improvement direction row at the top of the chart indicates which features exceed expectations, meet requirements or which can be improved. By using the weight factors found in BPC, each cell is multiplied by the weight factor corresponding to the row and each column is then added up. These totals are then divided by the sum of all the totals to determine the relative weight. From this the students determined that the most important engineering characteristics included the ability to produce lift and limit the weight of the design while some of the least important were overcoming drag and resisting stress forces according to the relative weight percentages.

Having the most important engineering characteristics the students set up a Pugh chart which presented the engineering characteristics with the higher relative weights. Included in the Pugh chart shown below are some of the high fidelity and medium fidelity concepts generated by the team, and each of these concepts is compared to the "industry standard", for which the students decided to use the 2019 SAE Aero competition airplane, regarding engineering characteristics.

The datum selected was the 2019 FAMU-FSU College of Engineering SAE Aero Competition airplane, the 5 concepts selected include the SR-22 modeled airplane with a high wing setup and a middle payload placement as well as another concept where the payload is placed behind the wings, RV-14 modeled airplane with a low wing setup, SR-22 modeled plane with a low wing setup, and a plane modeled around a conventional RC airplane.

As each of these concepts are compared to the datum regarding a specific engineering characteristic, the concept will receive a plus, minus or "S" depending on if the concept would overperform, underperform or is up to par with the datum. Each of these classifications is the added up per column and a new datum is selected. The datum must be a concept that stands in the middle of the field. As shown in the Pugh chart below, the concept that satisfies this requirement is the SR-22 with high wing placement and behind the wing payload placement.

Table 4: *PUGH Chart (First Iteration)*

PUGH Chart: First Iteration		Concepts				
Selection Criteria	Datum	SR-22 H	RV-14 L	SR-22 L	RC-V1	SR-22 HB
Thrust Generation	2019 SAE Aero Comp	S	S	S	S	S
Moving Down Runway		+	+	+	S	+
Ability to Provide Lift		+	+	+	+	+
Overcome Drag		-	+	+	S	-
Load/Unload Cargo		S	+	+	-	-
Rudder		S	S	S	S	S
Static Margin		+	+	+	+	+
Resist Effects of Stress		+	+	+	+	+
Weight		S	+	-	-	+

# of pluses		4	7	6	3	5
# of Minuses		1	0	1	2	2
# of S		4	2	2	4	2

The reason for the results for the first Pugh chart are as follows. Regarding thrust generation all of the concepts would use a very similar propeller and motor, the largest limiting factor to this is the power limiter implemented in the design. For the airplanes ability to move down the runway, the worst performing concept is the RC-V1 due to the landing gear type which is a tricycle setup which makes it harder to move at high speeds in comparison to tail dragger landing gears which is the same as the datum. Each of these concepts theoretically would provide better lift properties since we would be implementing proper placement of the center of gravity in comparison to the datum.

The concept that would underperform the datum as far as drag is considered would be the SR-22 with a high wing setup. The best performance for loading and unloading procedures is provided by the SR-22L and RV-1L while planes for which the payload is placed behind the wings would tend to underperform since is would be more difficult to move electrical components so close to the tail of the plane. It would be expected for the rudder of all of our concepts to perform just as well as the datum as there are no drastic changes made in the controls for the tail.

One of the largest complications for the 2019 team was the static margin and center of gravity, all of the concepts this team provided would overperform against the datum as well as would be able to resist effects of stress during landing and takeoff.

Weight being one of the most important engineering characteristics it is very important for the concepts to perform better than the datum, the concepts that did so were the RV-14L and SR-22 HB.

Having selected the SR-22 HB as the new datum, the worst performing concept from the first Pugh chart is removed from the next iteration of the Pugh chart in this case the RC-V1 was removed. The same process is done using the same criteria.

Table 5: PUGH Chart (Second Iteration)

PUGH Chart: Second Iteration		Concepts		
Selection Criteria	Datum	SR-22 H	RV-14 L	SR-22 L
Thrust Generation	SR-22 HB	S	S	S
Moving Down Runway		S	+	+
Ability to Provide Lift		S	-	-
Overcome Drag		S	+	+
Load/Unload Cargo		S	S	+
Rudder		S	+	+
Static Margin		S	S	+
Resist Effects of Stress		-	+	-
Weight		S	+	+
# of pluses		0	5	6
# of Minuses		1	1	2
# of S		8	3	1

Regarding thrust generation all of these concepts would be satisfactory but the RV-14 L and the SR-22 L would perform better while moving down the runway due to difference in landing gear. The RV-14 L and SR-22 L would provide less lift due to the nature of high wing setups producing more lift. In comparison both of the low wing airplanes presented a better performance when overcoming drag.

The SR-22 L would result to be better when loading and unloading the payload into the fuselage due to the shape and placement of the payload within the payload. The rudder for the SR-22 L and RV-14 L would perform better than the datum due to slight changes in the tail. The SR-22 L and RV-14 L would both provide weight reduction in comparison to the datum, while only the SR-22 L provides a better static margin, and the RV-14 L would resist stress effects better than all other concepts.

According to the Pugh chart the best 2 performing concepts were the RV-14L and the SR-22L each having a similar number of plusses while the SR-22L had one more minus than the RV-14L.

With this information the students then performed analytical hierarchy process charts.

Table 6: *Normalize Comparison Matrix*

NORMALIZE COMPARISON MATRIX					
Engineering Charactertistics	Rudder	Stability	Resist Stress	Weight	**AVERAGE:**
Rudder	0.0833	0.25	0.0625	0.0625	0.1146
Static Margin	0.0833	0.25	0.3125	0.3125	0.2396
Resist Stress	0.4167	0.25	0.3125	0.3125	0.3229
Weight	0.4167	0.25	0.3125	0.3125	0.3229
SUM:	1	1	1	1	1

The purpose of the criteria comparison matrix is to determine the importance weight factors of each engineering characteristic. These engineering characteristics were chosen because the house of quality chart shows us that these have the biggest impact on our design. Now that we have our four most important engineering characteristics, we complete a pairwise comparison matrix and normalize it by dividing each column by the sums. Now that each column is normalized, we add up the rows to determine the relative weight of each characteristic as shown above in Table 6. The reason we obtain these values is to multiply them by the values in the final rating matrix so that we can have an alternative value chart which selects our concept. Before we accept the values in Table 6, we must conduct a consistency check to make sure we don't have any contradictions in our logic. The goal of a consistency check is to obtain a consistency ratio as close to or below 0.1. Our value is just a little above which indicates small contradictions in our logic but we deemed in close enough to suffice and we can call the table consistent.

Table 7: *Final Rating Matrix*

Final Rating Matrix		
Selection Criteria	SR22L	RV-14L
Rudder	0.5	0.5
Static Margin	0.75	0.25
Resist Stress	0.25	0.75
Weight	0.75	0.25

From Table 5, the team determined that the SR22L and RV-14L were the most promising configurations and thus decided to further analyze the two concepts. Many calculations and tables later, the best design for the project was determined as the SR22L which is composed of the Cirrus

SR22 fuselage, a taildragger landing gear configuration, the soccerball placement as between the spars, a conventional tail, a low wing, tapered, and winglet configuration.

The final rating matrix in Table 7: *Final Rating Matrix*Table 7 demonstrates that the SR22L will be lighter in weight and more stable than the RV-14L. The Ciruss-SR22 fuselage is slightly leaner in the rear fuselage than the RV-14L. The slenderness of the fuselage will decrease the weight of the plane, but is more likely to fail due to stress. The team believes the rear of the fuselage can be reinforced with additional means and therefore this is an acceptable risk. The SR22L has the soccerball between the spars while the RV-14L will have the ball behind the spars. The ball would be better placed on top of the wing so that the ball does not disturb the center of gravity and consequently the static margin too much. The same tail configuration is offered in both concepts and thus the SR22L and RV-14L should perform the same. The individual comparison matrixes for rudder, static margin, stress, and weight of the plane are given in Table 15, Table 16, Table 17, and Table 18.

Table 8: *Alternative Values*

Concept	**Alternative Value**
SR22L	0.560
RV-14L	0.440

The alternative values were determined for the SR22L and RV-14L in Table 8. The SR22L wins by a small margin. This reflects the team's belief that either of these designs would be acceptable to produce. With the information available to the team at the present, the SR22L is the best option to proceed with.

1.6 Spring Project Plan

18	9/29/2021		1/21/2022	CAD Generation	50%	Incomplete	1/21/2022
19	1/21/2022	21	2/11/2022	Fuselage Printing	0%	Incomplete	2/11/2022
20	1/21/2022	21	2/11/2021	Wing Printing	0%	Incomplete	2/11/2021
21	1/28/2021	14	2/12/2021	Fuselage Assembly	0%	Incomplete	2/12/2021
22	1/28/2021	14	2/12/2021	Motor and Electronics Installation	0%	Incomplete	2/12/2021
23	2/13/2021		4/1/2021	Testing Validation	0%	Incomplete	4/1/2021
24			TBA	VDR 4-7	0%	Incomplete	TBA
25			4/1/2021	Engineering Design Day	0%	Incomplete	4/1/2021
26			TBA	Finals	0%	Incomplete	TBA
27			TBA	Graduation	95%	Incomplete	TBA

Chapter Two: EML 4552C

2.1 Project Scope

For this project the team will be composed of two separate groups, group 507 will be working on the fuselage, and geometry of the plane and group 508 will be working on propulsion systems and controls. The following sections will cover the scope of group 507's portion of constructing the airplane following competition guidelines.

2.1.1 Project Description

The objective of this project is to design and manufacture a radio-controlled aircraft capable of flying in the 2022 SAE Aero Design Competition. The aircraft will operate from short runways and complete the necessary flight path while carrying outsized spherical cargo. The plane will be constructed primarily out of 3D-printed materials.

2.1.2 Key Goals

The goals of this project define the plane's route and operation so that the team's objective may be achieved and the requirements for the 2022 SAE Aero Design Competition may be met. The team's project goals include but are not limited to the following.

- The plane is controllable via remote control which is operated by a single person
- The airplane's landing gear system is capable of controlling the steering of the airplane while on land the plane's propulsion system will be powered by 1 electric motor
- The team will stay within budget while building and purchasing components
- The cargo bay will secure two payloads that aren't subject to airstream
- The plane is constructed within the SAE competition guidelines

- The plane is primarily constructed of 3D-printed parts
- The plane can operate with and without payloads
- The payloads must load/unload in 1 minute
- The plane can takeoff within 100 feet in 120 seconds
- The plane can securely land within 400 feet
- The plane can be disassembled and reassembled

2.1.3 Stakeholders

The stakeholders in this project include the FAMU-FSU College of Engineering, the Florida Space Grant Consortium, the SAE Aero Competition judges, and the team's sponsor Dr, McConomy. The stakeholder specific to the fuselage group is their advisor Dr. Simone Hruda.

The team will be attending a competition representing the FAMU-FSU College of Engineering, making it a stakeholder in the project. The plane's performance will reflect not only on the sponsor and advisor but the college as a whole. The competition judges are stakeholders because they are putting in their time as well as providing their input on the design of the plane. Project advisors, Dr. Hruda, stakeholder in the project as they are providing oversight and counsel to make sure the team is successful. Our project sponsors, the Florida Space Grant Consortium as well as Dr. McConomy are stakeholders because they provide us with the necessary funding for the manufacturing stage of our plane's production.

2.1.4 Assumptions

The assumptions made by the team define the conditions the plane is expected to withstand as well as conditions the airplane is expected to perform through.

1. The plane will be operated within normal atmospheric weather conditions for Tallahassee, Florida
2. The plane will only be used for the competition
3. The plane will not operate in rain
4. The plane can operate from a flat runway.
5. The plane operator is acquainted with the controls
6. The plane operator has sufficient vision
7. The payloads will be purchased off shelves

Appendices

Appendix A: Code of Conduct

Mission Statement

Working in a professional manner alongside with team 508, team 507 will be committed to meet all of the requirements set for our Senior Design project as the fuselage team. The team will represent the FAMU – FSU College of Engineering values and standards expected of its students. The students will maintain a professional attitude throughout the entirety of the project. The team expects to have a finished project that represents the knowledge gained throughout the completion of the degree as well as the class. The team hopes to leave the university proud of the work accomplished and setting the bar higher for next years to come.

Team Roles

As a team we understand that some members have outside obligations, below is a list of obligations each of the team members has presented to the team. If there is an absence from a team meeting due to one of these reasons, they will be excused if they have declared they will be taking the time off at least 12 hours before the meeting time.

The team divided the project roles according to the specialties and interests of each team member in the project. However, a team member's role does not excuse team members from the responsibility of calculations and CAD work outside of the scope of their specific role.

- Alejandro Toro: *Loading Engineer, Connections Engineer, Meeting Coordinator*

- Member of the men's FAMU golf team, may be traveling multiple times a month with the golf team resulting in class days missed. Any days missed will be disclosed before any meetings are scheduled or at least 24 hours before the meeting
  - As the loading engineer, he will assume responsibility over the design of the loading mechanism and locking mechanism for said design.
  - As the connections engineer, he will focus on how the parts of the plane will fit with each other and how to divide the plane into sections to print it modularly.
- Bridget Andrews: *Aerodynamics Engineer, Fuselage Engineer*
  - Weekends may have personal compromises; these details will be disclosed before any meetings are scheduled.
  - As the aerodynamics engineer, she is responsible for calculations including but not limited to the drag force, weight distribution, and aerodynamic stability of the plane.
  - As fuselage engineer, Ms. Andrews designs the overall shape of the fuselage as well as the general layout for the components inside the fuselage.
- John Healy: Systems Engineer, Landing Gear Engineer
  - Available when in Tallahassee
  - As the systems engineer, he is responsible for the placement and securing of any electronics and wiring inside the fuselage.
  - As Landing Gear Engineer, he will design and manufacture the main and steerable landing gear for the plane.

** These “roles” may change through the semester and does not mean that a specific person will be the only member working on that area of the project, each member is expected to help in any way that will benefit the project and team**

Communication

As a preferred method of communication the team has agreed upon using iMessage for daily communication, Microsoft Office products for formal communication and sharing group documents, and Zoom for remote team meetings.

The “Team 507” group chat in iMessage will be used as communication between the team members alone. The communication in the group chat is limited to progress updates regarding everyone’s own work related to the project as well as any communication relevant to scheduled meetings. The “SAE Aero” group chat in iMessage is between all members of Team 507 and Team 508. The communication in this group chat is limited to information related to scheduled meetings as well as any brief update or question regarding the project.

Team 507 and Team 508 have agreed to use Microsoft Teams as their main platform for sharing files and assigning tasks related to the project. When a recent file has been shared, the individual is expected to notify group members who would find the information relevant to their specific tasks. Project deliverables and presentations which are team specific will be shared via Microsoft One Drive. Mr. Toro is primarily responsible for sharing these documents with Team 507 members and submitting the documents at the appropriate time. However, there will be times when other group members must share and submit project deliverables.

Meetings between Team 507 and Team 508 occur after Senior Design dismissal every Tuesday and Thursday unless previously rescheduled or cancelled. All group members are expected to come prepared to take notes and have topics ready to regarding their current and future work. If a team member does not have anything to contribute at a particular meeting, he or she is still expected to engage in the conversation with attention or input. Meetings between members of Team 507 occur as needed on Fridays at 11am. The group will decide at least one day prior if a meeting on Friday is needed. If a meeting on Zoom or Facetime is necessary, all group members tuning in virtually are expected to give their full attention to the conversation, take notes, and comment as needed. Tardiness or absence to a meeting should be given at least 12 hours in advance or as soon as realized.

Dress Code

For presentations the team will wear matching colors which will be decided upon, and will be wearing business attire. For class meetings the team will be expected to dress business casual.

Attendance Policy

Each meeting must have at least 2 attendees, meetings where both teams will be meeting should have at least 2 attendees from each team to properly communicate what each team is working on and discuss what the next steps are including dates for completion. Both teams will communicate to establish times to meet individually with their respective team, as well as joint group meetings. The team will be meeting every Friday with the adviser, Dr. Hruda, from 11:30-12 pm.

If a team member was to miss a meeting, they should notify the group through iMessage at least 12 hours before the meeting is to take place, if this is not met, they should make the effort to log into a zoom call, if this is not possible, said team member must get up to speed afterwards.

If the team is in a professional meeting, the team is prepared and expected to speak professionally while being aware of the targeted audience. In case a question may not be answered at the moment, the students will thank the participant for the question, apologize for not having the data to answer said question, and will make sure to provide a concrete answer as soon as possible.

In case there are recurring team issues, before contacting Dr. McConomy and the TA's the team members will attempt to communicate with the team member which is not complying with this document and attempt to reach an agreement. For example if there is a member that is unable to work on an assignment for some reason, that member is expected to complete a majority of the next assignment, if this is not met the other members will be forced to contact Dr. McConomy or the TA's.

When we contact Dr. McConomy the team would like for him to provide as much information regarding the question as possible, if the reason for contacting Dr. McConomy is regarding issues with the team, we would like for him to attempt to contact the person that is causing disruptions and hopefully help solve the issue at hand.

Changes to the Code of Conduct

Any time this document is updated each team member will be required to resign and date the document approving of the changes made. If the changes affect team 508, team 507 will make sure to contact each of the other team members and get to an agreement that benefits both parties.

Appendix B: Work Breakdown Structure

Item No.	Date Entered	Duration	Expected End Date	Information	Decision	Action	Progress	Result	Status	Date Compl	Date due
1	**9/9/2021**	**7**	**9/16/2021**	**Project Scope**			**100%**		**Complete**	**9/16/2021**	**9/17/2021**
1.1	9/9/2021	3	9/12/2021	Project Description	Alejandro				Complete	9/14/2021	
1.2	9/9/2021	3	9/12/2021	Key Goals	John				Complete	9/14/2021	
1.3	9/9/2021	3	9/12/2021	Market	John				Complete	9/14/2021	
1.4	9/9/2021	3	9/12/2021	Assumptions	Bridget				Complete	9/14/2021	
1.5	9/9/2021	3	9/12/2021	Stakeholders	John				Complete	9/14/2021	
1.6	9/13/2021	1	9/14/2021	Review Grammar / Format	Alejandro				Complete	9/15/2021	
1.7	9/14/2021	1	9/15/2021	Review Rubric	Alejandro				Complete	9/16/2021	
1.8	16/9/2021	0	9/16/2021	Submit Project Scope	Alejandro				Complete	9/16/2021	
1.9				Revision after Grading	Alejandro				Incomplete		
2	**9/16/2021**	**7**	**9/23/2021**	**Work Breakdown**			**80%**		**Incomplete**		**9/24/2021**
2.1	9/16/2021	0	9/16/2021	Share Schedule with Team	Alejandro				Complete	9/	
2.2	9/16/2021	2	9/18/2021	Enter Tasks	John				Complete	11/9/2021	
2.3	9/16/2021	2	9/18/2021	Assign Tasks	Alejandro				Complete	11/9/2021	
2.4	9/17/2021	1	9/18/2021	Assign Dates and durations	John				Complete	11/9/2021	
2.5	9/23/2021	0	9/23/2021	Submit W.B.	Bridget				Incomplete		
				Revision after Grading	Bridget				Incomplete		
3	**9/20/2021**	**2**	**9/22/2021**	**Advisor Meeting 1**			**100%**		**Incomplete**		**9/24/2021**
3.1	9/20/2021	1	9/21/2021	Create Meeting Agenda	Alejandro				Complete		
3.2	9/21/2021	0	9/21/2021	Send Advisor Meeting Agenda	Alejandro				Complete		
3.3	9/21/2021	0	9/21/2021	Meet with Advisor	Bridget				Complete		
3.4	9/21/2021	1	9/22/2021	Take Down Meeting Minutes	John				Complete		
3.5	9/22/2021	0	9/22/2021	Submit Meeting Minutes	Alejandro				Complete		
3.6	9/22/2021	0	9/22/2021	Submit Advisor Form	Alejandro				Complete		
4	**9/24/2021**	**7**	**10/1/2021**	**Customer Needs**			**0%**		**Incomplete**		**10/1/2021**
4.1	9/25/2021	1	9/26/2021	Meet with Sponsor	John				Incomplete		
4.2	9/27/2021	3	9/30/2021	Competition Regulations	John				Incomplete		
4.3	9/27/2021	3	9/30/2021	Sponsor Regulations	Alejandro				Incomplete		
4.4	9/28/2021	2	9/30/2021	Discussion of Regulations	Bridget				Incomplete		
4.5	9/30/2021	1	10/1/2021	Review Grammar / Format	Alejandro				Incomplete		
4.6	9/30/2021	1	10/1/2021	Review Rubric	Bridget				Incomplete		
4.7	10/1/2021	0	10/1/2021	Submit Needs	Bridget				Incomplete		
				Revision after Grading	Alejandro				Incomplete		
5	**9/26/2021**	**7**	**10/3/2021**	**Webmaster**			**0%**		**Incomplete**		**10/1/2021**
5.1	9/26/2021	0	9/26/2021	Create/Publish the website	John				Incomplete		
5.2	9/26/2021	2	9/28/2021	Website Homepage	Alejandro				Incomplete		
5.3	9/26/2021	2	9/28/2021	Team member page	Bridget				Incomplete		
5.4	9/26/2021	2	9/28/2021	Project Deliverables page	John				Incomplete		
5.5	9/29/2021	1	9/30/2021	Review Grammar / Format	Bridget				Incomplete		
5.6	9/29/2021	1	9/30/2021	Review Rubric	Alejandro				Incomplete		
5.7	9/29/2021	1	9/30/2021	Submit Webpage	Alejandro				Incomplete		
				Revision after Grading	John				Incomplete		
6	**10/1/2021**	**7**	**10/8/2021**	**Functional Decomposition**			**0%**		**Incomplete**		**10/8/2021**
6.1	10/1/2021	1	10/2/2021	Split up airplane 507 / 508	TEAM				Incomplete		
6.2	10/2/2021	3	10/5/2021	Start with a Verb	Alejandro				Incomplete		
6.3	10/2/2021	3	10/5/2021	Cross-reference table	John				Incomplete		
6.4	10/2/2021	3	10/5/2021	Creation of heirarchy chart	Bridget				Incomplete		
6.5	10/2/2021	3	10/5/2021	Explanation of results	John				Incomplete		
6.6	10/2/2021	3	10/5/2021	Connection to Systems	John				Incomplete		
6.7	10/2/2021	3	10/5/2021	Smart integration	Bridget				Incomplete		
6.8	10/3/2021	2	10/5/2021	Ensure action and outcome	Alejandro				Incomplete		
6.9	10/3/2021	2	10/5/2021	Review the function resolution	Alejandro				Incomplete		
6.10	10/3/2021	2	10/5/2021	Check Grammar	Bridget				Incomplete		
6.11	10/6/2021	1	10/7/2021	Submit FD	Bridget				Incomplete		
				Revision after Grading	Alejandro				Incomplete		
7	**10/8/2021**	**7**	**10/15/2021**	**VDR 1**			**0%**		**Incomplete**		**10/15/2021**
7.1	10/8/2021	0	10/8/2021	Create PPT	Alejandro				Incomplete		
7.2	10/8/2021	2	10/10/2021	Introduction	Alejandro				Incomplete		
7.3	10/8/2021	2	10/10/2021	Project brief	Alejandro				Incomplete		
7.4	10/8/2021	2	10/10/2021	Background	Bridget				Incomplete		
7.5	10/8/2021	2	10/10/2021	Project scope	John				Incomplete		
7.6	10/8/2021	2	10/10/2021	Customer needs	John				Incomplete		
7.7	10/8/2021	2	10/10/2021	Functional Decomposition	John				Incomplete		
7.8	10/8/2021	2	10/10/2021	References	John				Incomplete		
7.9	10/11/2021	2	10/13/2021	Transitions	Bridget				Incomplete		
7.10	10/11/2021	2	10/13/2021	Animations	Bridget				Incomplete		
7.11	10/11/2021	4	10/15/2021	Presentation Testing	Bridget				Incomplete		
7.12	10/15/2021	0	10/15/2021	Submit assignment	Bridget				Incomplete		

Continuation of work breakdown in next page

8	10/15/2021	7	10/22/2021	Targets		0%	Incomplete	10/22/2021
8.1	10/15/2021	3	10/18/2021	Create document	Alejandro		Incomplete	
8.2	10/15/2021	3	10/18/2021	Targets/Metrics match functions	Alejandro		Incomplete	
8.3	10/15/2021	3	10/18/2021	Targets/Metrics go beyond	Alejandro		Incomplete	
8.4	10/15/2021	3	10/18/2021	Method of Validation	Bridget		Incomplete	
8.5	10/15/2021	3	10/18/2021	Derivation of Targets/Metrics	Bridget		Incomplete	
8.6	10/15/2021	3	10/18/2021	Discussion of measurement	John		Incomplete	
8.7	10/15/2021	3	10/18/2021	Critical Targets/Metrics	John		Incomplete	
8.8	10/15/2021	3	10/18/2021	Summary and Catalog	Alejandro		Incomplete	
8.9	10/19/2021	2	10/21/2021	Review communication/grammar	Bridget		Incomplete	
8.10	10/22/2021	0	10/22/2021	Submit Assignment	John		Incomplete	
				Revision after grading	Bridget		Incomplete	
9	10/22/2021	7	10/29/2021	Concept Generation		0%	Incomplete	10/29/2021
9.1	10/22/2021	3	10/25/2021	"100" concepts	John		Incomplete	
9.2	10/22/2021	2	10/24/2021	Medium Fidelity Concepts	Alejandro		Incomplete	
9.3	10/22/2021	2	10/24/2021	High Fidelity Concepts	Bridget		Incomplete	
9.4	10/22/2021	2	10/24/2021	Concept Generation Tools	Alejandro		Incomplete	
9.5	10/25/2021	2	10/27/2021	Review Communication/Grammar	Alejandro		Incomplete	
9.6	10/28/2021	1	10/29/2021	Submit Assignment	Alejandro		Incomplete	
				Revision after grading	John		Incomplete	
10	10/29/2021	7	11/5/2021	Concept Selection		0%	Incomplete	11/5/2021
10.1	10/29/2021	4	11/2/2021	House of Quality	Alejandro		Incomplete	
10.2	10/29/2021	4	11/2/2021	Pugh Charts	John		Incomplete	
10.3	10/29/2021	4	11/2/2021	AHP	John		Incomplete	
10.4	10/29/2021	4	11/2/2021	Final Selection	Bridget		Incomplete	
10.5	10/31/2021	2	11/2/2021	Review Communication/Grammar	Alejandro		Incomplete	
10.6	11/5/2021	0	11/5/2021	Submit Assignment	Alejandro		Incomplete	
				Revision after grading	Bridget		Incomplete	

11	10/26/2021	2	10/28/2021	Advisor Meeting 2		0%	Incomplete	10/29/2021
11.1	10/26/2021	1	10/27/2021	Create Meeting Agenda	Alejandro		Complete	
11.2	10/27/2021	0	10/27/2021	Send Advisor Meeting Agenda	Alejandro		Complete	
11.3	10/27/2021	0	10/27/2021	Meet with Advisor	Bridget		Incomplete	
11.4	10/27/2021	1	10/28/2021	Take Down Meeting Minutes	John		Incomplete	
11.5	10/28/2021	0	10/28/2021	Submit Meeting Minutes	Alejandro		Incomplete	
11.6	10/28/2021	0	10/28/2021	Submit Advisor Form	Alejandro		Incomplete	
12	11/5/2021	7	11/12/2021	VDR 2		0%	Incomplete	11/12/2021
12.1	11/5/2021	3	11/8/2021	Create PPT	Alejandro		Incomplete	
12.2	11/5/2021	3	11/8/2021	Title/Introduction	Alejandro		Incomplete	
12.3	11/5/2021	3	11/8/2021	Accomplishments since VDR1	Alejandro		Incomplete	
12.4	11/5/2021	3	11/8/2021	Concept Generation	John		Incomplete	
12.5	11/5/2021	3	11/8/2021	Concept Selection	John		Incomplete	
12.6	11/5/2021	3	11/8/2021	Summary/Takeaways	Bridget		Incomplete	
12.7	11/9/2021	2	11/11/2021	Review Communication/Grammar	Bridget		Incomplete	
12.8	11/12/2021	0	11/12/2021	Submit Assignment	Bridget		Incomplete	
13	11/12/2021	7	11/19/2021	Risk Assessment		0%	Incomplete	11/19/2021
13.1	11/12/2021	3	11/15/2021	What can go wrong?	Alejandro		Incomplete	
13.2	11/12/2021	3	11/15/2021	Accidents Identified	Alejandro		Incomplete	
13.3	11/12/2021	3	11/15/2021	Steps to avoid hazards	John		Incomplete	
13.4	11/12/2021	3	11/15/2021	Safety Measures	Bridget		Incomplete	
13.5	11/12/2021	3	11/15/2021	Emergency Response	Bridget		Incomplete	
13.6	11/12/2021	3	11/15/2021	Emergency Contacts	John		Incomplete	
13.7	11/15/2021	3	11/18/2021	Review Communication/Grammar	John		Incomplete	
13.8	11/18/2021	0	11/18/2021	Submit Assignment	Alejandro		Incomplete	
				Revision after grading	Bridget		Incomplete	
14	11/23/2021	2	11/25/2021	Advisor Meeting 3		0%	Incomplete	11/26/2021
14.1	10/23/2021	1	10/24/2021	Create Meeting Agenda	Alejandro		Complete	
14.2	10/24/2021	0	10/24/2021	Send Advisor Meeting Agenda	Alejandro		Complete	
14.3	10/24/2021	0	10/24/2021	Meet with Advisor	Bridget		Incomplete	
14.4	10/24/2021	1	10/25/2021	Take Down Meeting Minutes	John		Incomplete	
14.5	10/25/2021	0	10/25/2021	Submit Meeting Minutes	Alejandro		Incomplete	
14.6	10/25/2021	0	10/25/2021	Submit Advisor Form	Alejandro		Incomplete	

Continuation of work breakdown in next page

14	**11/23/2021**	**2**	**11/25/2021**	**Advisor Meeting 3**		**0%**	**Incomplete**	**11/26/2021**
14.1	10/23/2021	1	10/24/2021	Create Meeting Agenda	Alejandro		Complete	
14.2	10/24/2021	0	10/24/2021	Send Advisor Meeting Agenda	Alejandro		Complete	
14.3	10/24/2021	0	10/24/2021	Meet with Advisor	Bridget		Incomplete	
14.4	10/24/2021	1	10/25/2021	Take Down Meeting Minutes	John		Incomplete	
14.5	10/25/2021	0	10/25/2021	Submit Meeting Minutes	Alejandro		Incomplete	
14.6	10/25/2021	0	10/25/2021	Submit Advisor Form	Alejandro		Incomplete	
15	**11/19/2021**	**7**	**11/26/2021**	**Bill of Materials**		**0%**	**Incomplete**	**11/29/2021**
15.1	11/19/2021	1	11/20/2021	Line Items	Bridget		Incomplete	
15.2	11/19/2021	2	11/21/2021	Order Needs	Alejandro		Incomplete	
15.3	11/20/2021	1	11/21/2021	Check for thoroughness	John		Incomplete	
15.4	11/20/2021	3	11/23/2021	Identify Vendors	Alejandro		Incomplete	
15.5	11/20/2021	3	11/23/2021	Identify Part Details	John		Incomplete	
15.6	11/20/2021	3	11/23/2021	Line Item Maturity	Bridget		Incomplete	
15.7	11/20/2021	3	11/23/2021	Project Maturity	Bridget		Incomplete	
15.8	11/20/2021	3	11/23/2021	Project Cost	John		Incomplete	
15.9	11/20/2021	3	11/23/2021	Unit Cost	John		Incomplete	
15.10	11/20/2021	3	11/23/2021	Labor Cost	John		Incomplete	
15.11	11/24/2021	1	11/25/2021	Review Communication/Grammar	Alejandro		Incomplete	
15.12	11/24/2021	1	11/25/2021	Submit Assignment	Alejandro		Incomplete	
15.13				Revision after grading	John		Incomplete	
16	**11/26/2021**	**7**	**12/3/2021**	**VDR 3**		**0%**	**Incomplete**	**12/2/2021**
16.1	11/26/2021	1	11/27/2021	Aquiring Poster Materials	Alejandro		Incomplete	
16.2	11/27/2021	3	11/30/2021	Future Work	Bridget		Incomplete	
16.3	11/30/2021	2	12/2/2021	Verify Correct Specifications	John		Incomplete	
16.4	12/2/2021	1	12/3/2021	Submit Assignment			Incomplete	

Appendix C: Figures and Tables

Table 9: *Customer Needs*

Question	Need Statement	Need Interpretation
General Aircraft Requirements	Identified with the school's name, mailing address, and email address, 3 inches in height	Identify the airplane properly with university name and information
	Must have the fuselage clearly marked on both sides with a classic CG symbol (Figure 2.1) that is a minimum of 0.5 inches in diameter centered at the Empty CG position	Identify the center of gravity with a 0.5" sticker at the empty center of gravity
	Gross take-off weight may not exceed fifty-five (55) pounds	Limit the weight of the aircraft to less than 55 pounds
	All aircraft must be controllable in flight	Control the airplane while in flight to complete the specified flight pattern
	The aircraft must have some form of ground steering mechanism for positive directional control during takeoffs and landings	Steer the airplane while on the ground
	Must have a functional fail-safe system that will reduce the throttle to zero immediately if the radio signal is lost	Shut down the throttle automatically in case radio connection is lost
	Must utilize either a spinner or a rounded model aircraft type safety nut	The propeller will have a spinner or rounded safety nut
	Metal propellers are not allowed	Use propellers made from non-metal materials
	The use of lead in any portion of aircraft (payload included) is strictly prohibited	Will not use lead on any part of the aircraft

	The payload cannot contribute to the structural integrity of the airframe, meaning, the airframe must be able to fly without the payload installed	Design the aircraft so that the payload does not contribute to the structure of the airplane
	All static payload plates must be secured with metal hardware that penetrates all payload plates. Payload plates must also be secured to the aircraft structure with metal hardware as a single mass	Use metal hardware to secure static payload plates
	Control surfaces and linkages must not feature excessive slop	The control linkage dead zone will be minimized
	Demonstrate that the servos are adequately sized to handle the expected aerodynamic loads during flight	Calculate performance of the servos under flight conditions to show performance
	All control clevises must have additional mechanical keepers to prevent accidental opening of the control clevis in flight	Secure control clevises during flight
	All batteries must be commercially available. All batteries in the aircraft must be positively secured so that they cannot move under normal flight loads. The battery bay or location in the aircraft must be free of any hardware or other protrusions that could penetrate the battery in the event of a crash	Secure the commercially available battery in the airplane so that it does not move during flight and is away from any protrusions that may damage the battery.
	A third-party electronic device to limit the amount of power the propulsion system can use is required	Include a power limiter in the system to limit the power output from the battery
Mission Requirements and Scoring	The aircraft must takeoff in 100 ft within 120 seconds	Takeoff must occur within 100 feet or 120 seconds.
	The landing distance limit is 400 ft	Land the aircraft within 400 feet.

Regular Class Design Requirements	The aircraft is limited to a maximum wingspan of 120 inches	Airplane must have a wingspan less than 120 inches
	The use of Fiber-Reinforced Plastic (FRP) is prohibited on all parts of the aircraft	Fiber-reinforced plastic is prohibited for aircraft construction
	Elastic material such as rubber bands shall not be used to retain the wing or payloads to the fuselage	Secure the payload and wings by using methods other than rubber bands
	All types of gyroscopic or other stability assistance are prohibited	Stability assistance is prohibited
	The aircraft shall be propelled by a single electric motor	Propel the aircraft by use of only one propeller

Table 9 of customer needs is mainly a list of constraints that will limit and specify how the team will design some components of the aircraft. These needs must be considered carefully since to be able to qualify for flight, the airplane must pass the judges analysis, as well as follow all specified guidelines

Table 10: *Sponsor Needs*

Question	**Need Statement**	**Need Interpretation**
Are the students interpreting the SAE guidelines as the only customer needs?	The rules are the bare minimum that the students should follow. Not only are you trying to make it fly but you must also impress the judges.	Find innovative designs that will stand out in the competition.
Are outside sponsors allowed for project funding as well as travel funding?	Outside sponsorships are allowed.	Reach out to possible outside sponsors to help fund the team further.
Are there any recommendations regarding electrical components?	Reduce the wiring and make sure to account for connections and how they	Limit the number of wires wherever possible.

	will join. Wires are dead weight.	
What percentage of the aircraft must be 3D printed?	There are no weight specifications as to how much, but you will try to 3D print as much as you can within reason.	Print as much of the plane as possible.

***These include specifications made by the project sponsor/ professor**

Table 11: *Catalog of Targets and Metrics*

Functions	Metrics	Targets	Validation Method	Validation Tools
Load and Unload Payload				
Load Payload	Time to Load Payload	Less than 1 minute	Time Trial Test	Prototype
Secure Payload	Movement of the Payload	Payload does not move	Prototype movement and tilting	Prototype
Unload Payload	Time to Unload Payload	Less than 1 minute	Time Trial Test	Prototype
Landing				
Absorb landing impact	Ability of landing gear to withstand force of impact	45 lbF	Physical Drop Test	Prototype
Steer on Land	Steering Angle	-75 to +75 degrees	Servo testing, fourbar simulations	Prototype / CAD simulations
Balance Plane on Land	Wheel Track Distance	24 inches	Theoretical calculations	CAD simulations
	Center of Gravity	1/4-1/3 of Airfoil Cord Length	Theoretical calculations	Measurements and calculations, CAD simulation
Accelerate				
Generate Thrust	Thrust produced from propeller	>15lbf	Measurement	Physical Tests
Move Down Runway	Wheels Turn	360 degrees	Servo testing, four bar simulations	Roll Wheels / CAD simulations / prototypes
Enable Lift	Lift Force	>15 lbf	Theoretical Calculations	MATLAB
Controls				
Control Yaw	Rudder angle	20 degrees	Servo testing, four bar simulations	CAD simulation

Control Pitch	Elevator angle	15 degrees	Servo testing, four bar simulations	CAD simulation
Control Roll	Aileron angle	15 degrees	Servo testing, four bar simulations	CAD simulation
Manufacturing				
Produce quality plane parts	3D Printing Error Tolerancing	+/- 0.05in.	Print testing	Prototype
Plane Parts connect properly	Tolerancing of part connections	+/- 0.05in.	Print testing	Prototype
Propeller receives full range of motion	Propeller clearance from ground	3 inches	Measurement	CAD simulation
Plane Weight	Maximum weight	15 lbF	Previous testing	Theoretical Calculations

Table 12: *Binary Pairwise Comparison*

Binary Pairwise Comparison:		1	2	3	4	5	6	7	8	9	10	11	12	**Total**
Material	1	-	1	0	1	1	0	0	1	0	1	0	0	5
Stability	2	**0**	-	0	1	**1**	1	0	1	0	1	0	0	5
Takeoff/Landing Requirements	3	**1**	**1**	-	0	0	0	1	1	0	1	0	1	6
Wingspan Restrictions	4	**0**	**0**	1	-	0	1	0	1	0	0	1	0	4
Power	5	**0**	**0**	**1**	**1**	-	0	1	1	0	1	0	0	5
Manueverability	6	**1**	**0**	**1**	**0**	**1**	-	1	1	0	1	0	1	7
Lightweight	7	**1**	**1**	**0**	**1**	**0**	**0**	-	1	0	0	0	1	5
Landing Shock	8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	-	0	1	0	1	2
Controls	9	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	-	1	1	1	11
Minimum Cargo Load Required	10	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	-	0	1	3
Loading Payload	11	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	-	1	9
Innovation	12	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	-	4
	Total:	6	6	5	7	6	4	6	9	0	8	2	7	

Table 13: *Critical Comparison Matrix*

CRITERIA COMPARISON MATRIX

Engineering Characteristics	Rudder	Stability	Resist Stress	Weight
Rudder	1	1	0.2	0.2
Stability	1	1	1	1
Resist Stress	5	1	1	1
Weight	5	1	1	1
SUM:	12	4	3.2	3.2

Table 14: *Consistency Check Criteria*

Consistency Check Criteria					
Weight Sum Vector	Criteria Weights	Consistency Vector	λ (Average Consistency)	Consistency Index	Consistency Ratio
0.483333333	0.115	4.218181818	4.356088232	0.118696077	0.133366379
1	0.240	4.173913043			
1.458333333	0.323	4.516129032			
1.458333333	0.323	4.516129032			

Table 15: *Rudder Comparison*

Rudder			
	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	1	1	1
RV-14L	1	1	1

SUM:	2	2	2

Normalized: Rudder

	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	0.5	0.5	0.5
RV-14L	0.5	0.5	0.5
SUM:	1	1	1

Consistency Check

Weight Sum Vector	Criteria Weights	Consistency Vector
1	0.5	2
1	0.5	2
Average Consistency	Consistency Index	Consistency Ratio
2	0	0

Table 16: *Static Margin Comparison*

Static Margin

	SR22L	RV-14L	Design Alternative Priorities {P}

SR22L	1	3	2
RV-14L	0.333333333	1	0.666666667
SUM:	1.333333333	4	2.666666667

Normalized: Stability

	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	0.75	0.75	0.75
RV-14L	0.25	0.25	0.25
SUM:	1	1	1

Consistency Check

Weight Sum Vector	Criteria Weights	Consistency Vector
1.5	0.75	2
0.5	0.25	2
Average Consistency	Consistency Index	Consistency Ratio
2	0	0

Table 17: *Resist Stress Comparison*

Resist Stress

	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	1	0.333333333	0.666666667
RV-14L	3	1	2
SUM:	4	1.333333333	2.666666667

Normalized: Resist Stress

	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	0.25	0.25	0.25
RV-14L	0.75	0.75	0.75
SUM:	1	1	1

Consistency Check

Weight Sum Vector	Criteria Weights	Consistency Vector
0.5	0.25	2
1.5	0.75	2
Average Consistency	Consistency Index	Consistency Ratio
2	0	0

Table 18: *Weight Comparison*

Weight

	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	1	3	2
RV-14L	0.333333333	1	0.666666667
SUM:	1.333333333	4	2.666666667

Normalized: Weight

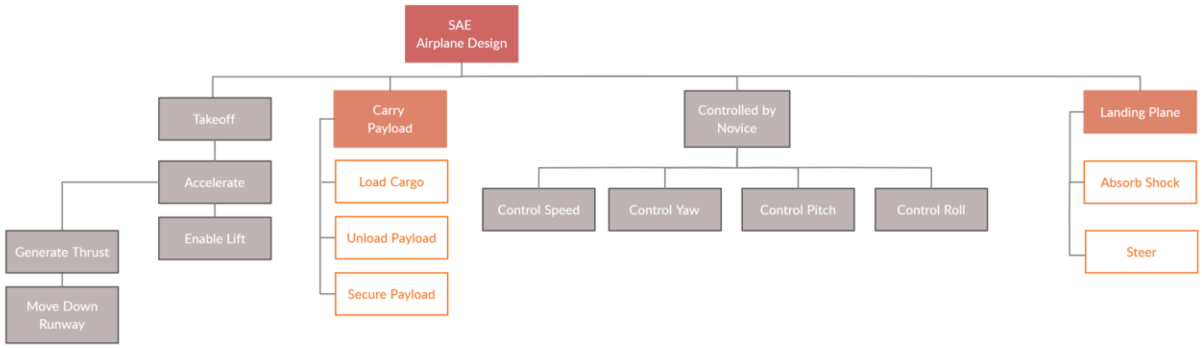
	SR22L	RV-14L	Design Alternative Priorities {P}
SR22L	0.75	0.75	0.75
RV-14L	0.25	0.25	0.25
SUM:	1	1	1

Consistency Check

Weight Sum Vector	Criteria Weights	Consistency Vector
1.5	0.75	2
0.5	0.25	2
Average Consistency	Consistency Index	Consistency Ratio

	2	0	0

Appendix D: Functional Decomposition



Appendix E: Concept Generation

**High Fidelity

*Medium Fidelity

Morphological Chart							
Concept	**Fuselage**	**Landing Gear**	**Payload Location**	**Tail**	**Wing Location**	**Wing Shape**	**Winglets**
1**	Cirrus sr22	Taildragger	Between spars	Conventional	Low	Tapered	Yes
2**	RV-14	Taildragger	Behind spars	Conventional	Low	Tapered	Yes
3	Guppy	Taildragger	Between spars	T-Tail	High	Tapered	Yes
4	Whale	Taildragger	Behind spars	T-Tail	Mid	Tapered	No
5	Square	Taildragger	Between spars	Conventional	Low	Tapered	No
6	Cirrus sr22	Taildragger	Behind spars	Conventional	High	Tapered	No
7	RV-14	Taildragger	Between spars	Conventional	High	Tapered	Yes
8	Guppy	Taildragger	Behind spars	T-Tail	Low	Tapered	Yes
9	Whale	Taildragger	Between spars	T-Tail	Mid	Tapered	Yes
10	Square	Taildragger	Between spars	T-Tail	High	Tapered	No
11*	Cirrus sr22	Taildragger	Behind spars	Conventional	High	Rectangular	No
12	RV-14	Taildragger	Behind spars	Conventional	Low	Rectangular	No

13*	Guppy	Taildragger	Between spars	Conventional	High	Rectangular	No
14	Whale	Taildragger	Behind spars	T-Tail	High	Rectangular	Yes
15	Square	Taildragger	Between spars	T-Tail	Mid	Rectangular	Yes
16	Cirrus sr22	Taildragger	Behind spars	T-Tail	Low	Elliptical	Yes
17	RV-14	Taildragger	Between spars	Conventional	High	Elliptical	Yes
18	Guppy	Taildragger	Behind spars	Conventional	Mid	Elliptical	No
19	Whale	Taildragger	Between spars	Conventional	Low	Elliptical	No
20	Square	Taildragger	Behind spars	T-Tail	Low	Elliptical	No
21	Cirrus sr22	Taildragger	Between spars	T-Tail	High	Delta	No
22	RV-14	Taildragger	Behind spars	T-Tail	Mid	Delta	Yes
23	Guppy	Taildragger	Between spars	Conventional	High	Delta	Yes
24	Whale	Taildragger	Behind spars	Conventional	Mid	Delta	Yes
25	Square	Taildragger	Between spars	Conventional	Low	Delta	Yes
26	Cirrus sr22	Tricycle	Between spars	T-Tail	High	Tapered	No
27	RV-14	Tricycle	Behind spars	T-Tail	Low	Tapered	No
28	Guppy	Tricycle	Between spars	T-Tail	High	Tapered	No
29	Whale	Tricycle	Behind spars	Conventional	High	Tapered	No
30	Square	Tricycle	Between spars	Conventional	Low	Tapered	Yes
31	Cirrus sr22	Tricycle	Behind spars	Conventional	High	Tapered	Yes
32	RV-14	Tricycle	Between spars	T-Tail	Low	Tapered	Yes
33	Guppy	Tricycle	Behind spars	T-Tail	High	Tapered	Yes
34	Whale	Tricycle	Between spars	T-Tail	Low	Tapered	No
35*	Square	Tricycle	Behind spars	Conventional	Mid	Tapered	No
36**	Cirrus sr22	Tricycle	Between spars	T-tail	High	Rectangular	No
37	RV-14	Tricycle	Behind spars	Conventional	Mid	Rectangular	No

38	Guppy	Tricycle	Between spars	Conventional	Low	Rectangular	Yes
39	Whale	Tricycle	Behind spars	Conventional	Low	Rectangular	Yes
40	Square	Tricycle	Between spars	T-Tail	High	Rectangular	Yes
41	Cirrus sr22	Tricycle	Between spars	T-Tail	High	Elliptical	Yes
42*	RV-14	Tricycle	Behind spars	T-tail	Low	Elliptical	No
43	Guppy	Tricycle	Behind spars	Conventional	High	Elliptical	No
44	Whale	Tricycle	Between spars	Conventional	Mid	Elliptical	No
45	Square	Tricycle	Behind spars	T-Tail	Low	Elliptical	No
46	Cirrus sr22	Tricycle	Between spars	T-Tail	Low	Delta	Yes
47	RV-14	Tricycle	Behind spars	Conventional	High	Delta	Yes
48	Guppy	Tricycle	Between spars	Conventional	High	Delta	Yes
49*	Whale	Tricycle	Between spars	T-tail	Low	Delta	Yes
50	Square	Tricycle	Behind spars	T-Tail	Mid	Delta	No
Biomimicry							
51	Condor (large wingspan)						
52	Pelican (cargo)						
53	Eagle (cargo)						
54	Penguin (surface friction)						
55	Vulture (altitude)						
56	Common Swift (flight time)						
57	Falcon (speed)						
58	Albatross (large size)						
59	Hummingbird (small size)						
60	Woodpecker (shock absorber)						
61	Owl (fuselage shape)						

62	Andean Condor (fuselage shape)
63	Penguin (fuselage shape)
64	Eagle (fuselage cross section)
65	Hawk (fuselage shape)
66	Hummingbird (tail shape)
67	Blue Jay (fuselage shape)
68	Seagull (fuselage cross section)
69	“Flying Fish” (fuselage shape)
70	Salmon (fuselage shape)
71	Swordfish (fuselage side profile)
72	Goldfish (fuselage side profile)
73	Shark (fuselage shape)
74	Killer Whale (fuselage shape)
75	Puffer Fish (fuselage side profile)
Competitive Benchmarking	
76	Boeing 757-200F
77	Aero Spacelines Super Guppy
78	Antonov An-124 Condor
79	Lockheed C-5 Galaxy
80	Airbus A300-600ST Beluga
81	Antonov An-22 Antei
82	Kawasaki C-2
83	Convair XFY-1 Pogo
84	AD-1 Oblique Wing
85	P-47 Thunderbolt

86	Mitsubishi A5M
87	Starr Bumble Bee II
88	Antonov An-225
89	Lockheed SR-71 Blackbird
90	Lockheed Martin F-22 Raptor
91	MacCready Gossamer Albatross
Anti-Problem	
92	Printed with standard PLA
93	Ignore sponsor requirements and use balsa wood
94	Use skis for landing gear
95	Fuselage manufactured entirely with aluminum
96	No tail with canards in front
97	Short wings with long chord length
98	No wings with air foil shape fuselage
99	Airplane uses retractable landing gear
100	No propulsion system and rely on wind for flight

Appendix F: Operation Manual

2.1 Project Overview

The team's project scope is to design a 3D printed remote controlled airplane for the SAE Aero-Design Competition in 2022 flying under regular class category. This is a competition with guidelines that each team must abide by as well as a set of specifications set by your project sponsor. The plane must take off within 100 feet while carrying a 9 inch diameter soccer ball which must be secured withing the aircraft and not be able to move. As a part of this project there will be 2 teams working in collaboration to generate a successful design. Team 507 will work on the design of the fuselage including the electronics placement and the payload integration to the airplane.

2.2 Disclaimer

Due to COVID-19 the team struggled to obtain some components and materials they wanted to purchase in a timely manner, this set the team back sometimes and made it more difficult to advance in the project. The team will also not be attending to the competition but the team was designed and manufactured to satisfy the guidelines set by the competition. A test flight will be conducted with help of the Seminole RC Club in Tallahassee Florida.

2.3 Additive Manufacturing

Section 2 describes the process of designing a part through CAD, all the way through prnting a part. The material that is being used is LW-PLA by ColorFabb. This filament foams out of the nozzle to decrease the density and weight of the component being printed.

2.4 CADing Parts

In the process of designing plane components, the printability of the parts must always be kept in mind. CAD is always producing the most perfect scenario which is very unlikely to occur when printing parts. Some of the most important things to keep in mind when designing and CADing a part is that the part must fit on the printing surface, if a part needs extra support, the slicing software may be used to add the necessary supports. When designing a part it must be designed in a way that printing failure is least possible. While it is tempting to print a part horizontally, it will usually be easier to print in the vertical axis and it is important to look into the printing pattern that requires the least amount of added supports and that would cause the least amount of stringing.

2.5 Printing a Part

After the gcode for a part is generated and uploaded to the SD card, the SD card can be inserted into the printer. Before the file is set to print, the user must verify that the filament is in the printer and that there is enough material to be able to finish printing the component. To do this take out the material from the spool and weigh it, this way you can determine if there is enough material to complete the component.

Once the material is inserted, the preheating process may be started. Once the printer is ready to print, the user may press the button and scroll down to "print from SD". While the printer is doing the auto leveling process make sure to pay attention that the nozzle is not pressing the printer bed too much which will produce failure in the printing process.

3.1 Component Description

Section 3 is about the modules of the fuselage such as the landing gear and the main fuselage.

3.2 Fuselage

The fuselage of the plane consists of a total of 10 sections, each one of those being 8 inches long and 2 of the sections being the hatch. Each one of these sections is attached by using bowties that measure 1 inch by 2 inches set at 120 degrees apart from each other. The last two sections of the fuselage are attached together.

3.3 Landing Gear

The landing gear used for our design is a tail dragger which is composed of two wheels in the front and one wheel toward the rear end of the airplane. The two front wheels are attached to the spars on the wings while the rear wheel is controlled by the remote using a servo motor which makes the airplane steerable.

4.1 Integration

Section 4 explains the process of integrating the work between team 507 and 508.

4.2 Fuselage

The first step is to place the nosecone in a flat surface and place all the bowties labeled A1, B1, and C1. These bowties will attach to section 2. The motor mount is placed on the nosecone and the motor is screwed onto the motor mount. To be able to put the screws in place, the user must place brass inserts into the sections by heating up the insert with a soldering iron.

After the motor mount is set in place and section 1 and 2 are set together, the rest of the sections can be put together by putting all of the bowties in the correct sections. The hatch is attached to the fuselage using the bowtie-hinge and the latch holds the hatch section closed. Once all of this is assembled, the team may collaborate with team 508 to be able to integrate the wings and tail to the plane.

5.1 Troubleshooting

The team has been using LulzBot 3D printers with ColorFabb LWPLA. The most common problem that occurs with the printers is the Z axis not being calibrated. This means that the printer things the print bed is lower than it really is, pushing the nozzle into the bed, bend it down. To avoid this, use felt to lightly brush the nozzle and probe point at each location. If the probing process completes successfully, the nozzle will return to the front left of the print bed and begin heating to the desired print temperature.

5.2 Printing Issues

The nozzle being dirty causes printing issues. The LulzBot printers have a wiping procedure to clean the nozzle however the wipe pads can often get clogged with filament so it's best to not completely rely on this procedure.

5.2.1 Plate Adhesion

Once the probing process for the print has been completed and the bed reaches the appropriate temperature, the print will begin. Most print failures can be attributed to failed plate adhesion. It is important to watch the first layer to make sure it sticks to the bed well.

5.2.2 Warping

The PLA material is melted by the nozzle to print and then solidifies again, however the cooling process can cause warping. This occurs when the PLA contracts, causing parts to curl or corners to contract. The team uses a heated print plate which combats warping of the prints, so it is important to ensure the plate is functional before printing.

5.2.3 Stringing

When undesired strings of PLA are left behind on a print, this is known as stringing. The most common causes of stringing are the retraction distance speed. The distance determines the amount of filament that gets pulled out of the nozzle. The more filament that's retracted from the nozzle, the less likely it is to string. The speed determines how fast the filament is retracted from the nozzle. It is important to ensure this setting is fast enough so that any oozing from the nozzle is avoided.

6.1 Collaboration

This project is split into two separate groups, the fuselage team and the aero-propulsion team. The bulk of the collaboration comes from the interfaces between our designs. This includes connections such as the landing gear to wing, wing to fuselage, tail to fuselage, propulsion system to fuselage, and electronic components.

6.2 College Resources

Many resources are made available to us outside of the senior design class. We are connected to a faculty advisor who in our case is Dr. Simone Hruda. Once our project passes the design phase and we are ready to start the manufacturing process, we can reach out to the machine shop to have parts made. The printers in the senior design lab may not be sufficient for the number of prints that are needed, so the innovation hub is a useful resource for printing smaller parts of PLA. Eric at the innovation hub is also a good resource for his knowledge of additive manufacturing.

Appendix G: Risk Assessment

FAMU-FSU College of Engineering
Project Hazard Assessment Policy and Procedures

INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

PROJECT HAZARD ASSESSMENT POLICY

Principal investigator (PI)/instructor are responsible and accountable for safety in the research and teaching laboratory. Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures. PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.
3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.

6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :
    a. Performing periodic laboratory visits to prevent the development of unsafe practice.
    b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
    c. Assigning a safety representative to assist in implementing the expectations.
    d. Etc.
8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor's office (if experiment steps are confidential).

Project Hazard Assessment Worksheet				
PI/instructor: Dr. McConomy	Phone #: 850-410-6624	Dept.: ME	Start Date: 11/17/2021 End Date: 03/09/2022	Revision number: 1
Project: SAE Aero Design			Location(s): Senior Design / Airfield / FAMU-FSU COE	
Team member(s): Bridget Andrews, John Healy, Alejandro Toro			Phone #: 904-616-2833 516-320-4690 787-504-3850	Email: ba18@my.fsu.edu jkh17c@my.fsu.edu alejandro1.toro@famu.edu

Experiment Steps	**Location**	**Person assigned**	**Identify hazards or potential failure points**	**Control method**	**PE**	**List proper method of hazardous waste disposal, if any.**	**Residual Risk**	**Specific rules based on the residual risk**

3D Printing	Senior Design Lab – FAMU-FSU College of Engineering /Innovation Hub	All Team Members: Bridget Andrews, John Healy, Alejandro Toro	Physical, Ergonomic Hazard, Psychological Hazard, Temperature, Being Struck By, Loose Electrical Cables, Poor Desk Seating, Bright Lights, Hot Temperature from Nozzle, Moving Object. Chemical Hazard	Engineering Control: Close the door to the 3D printer to eliminate any risk from material projecting out. Avoid touching the nozzle and the bed while printing. Don't use material that could present harm to anyone. Administrative Control: Speak with Eric from	Gloves, Safety Glasses, Respirators	/A	HAZARD: 3 CONSEQ: Residual: Low	proceed	Safety controls are planned by both the worker and supervisor. A second worker must be in place before (buddy system). Proceed with supervisor authorization.

				Innovation Hub on all safety hazards and learn how to mitigate risk from 3D printing				
Flight Test-Prototypes and Full Scale Model (After 3D printing and assembling both the porotype and the final product they will be tested)	Outside/Air Field/ FAMU-FSU College of Engineering /Pending Location	All Team Members: Bridget Andrews John Healy Alejandro Toro	Physical, Ergonomic, Noise, Being Struck By, Entangled By, Slips, Trips and Falls Examples: Broken part from prototype can hit/strike someone, Lifting Heavy	Engineering Control: Utilize an aircraft type safety nut. Verify all sections, propeller, and tail are all secured prior to flight While still on ground verify that all controls are functioni	Safety Glasses, Close Toed Shoes, Earplugs, and Hard Hat	/A	HAZARD: 4 CONSEQ:	After approval by the PI, a copy must be to the Safety Commit A written Project Hazard Control is requ must be approved by before proceeding. must be sent to the Saf Committee. A second work must be in pla before work proceed (buddy system Limit the numb authorized wo the hazard area. (Society of Aut Engineers, 2018)

			Object, Loud Noise from E-Flight 90, Crushing/Bruising from Loose Parts on Plane/Prototype, Tripping Outside (Environmental Hazard)	ng properly Administrative Control: Have a certified RC pilot to test final product to prevent any risk				
Flight Test-Prototypes and Full Scale Model (After 3D printing and assembling both the	Outside/Air Field/ FAMU-FSU College of Engineering /Pending Location Outside of FAMU-FSU College of	All Team Members: Bridget Andrews John Healy Alejandro Toro	Physical, Ergonomic, Noise, Being Struck By, Entangled By, Slips, Trips and Falls Examples: Broken	Engineering Control: Utilize an aircraft type safety nut. Verify all sections, propeller, and tail are all secured prior to flight	Safety Glasses, Close Toed Shoes, Earplugs, and Hard Hat, Red Arming plug	/A	Residual: Med High HAZARD: 4 CONSEQ:	After approval by the PI, a copy must be to the Safety Commit A written Project Hazard Control is requ must be approved by before proceeding. must be sent to the Saf Committee. A second work must be in pla before work proceed (buddy system

porotype and the final product they will be tested)	Engineering		part from prototype can hit/strike someone, Lifting Heavy Object, Loud Noise from E-Flight 90, Crushing/Bruising from Loose Parts on Plane/Prototype, Tripping Outside (Environmental Hazard)	While still on ground verify that all controls are functioning properly Administrative Control: Have a certified RC pilot to test final product to prevent any risk				Limit the numb authorized wo the hazard area.
Thrust Test	Outside of FAMU-FSU College	All Team Members:	Physical, Ergonomic, Environmental,	Engineering Control:	Safety Glasses, Toe Shoes, Earplu	/A	HAZARD: 3 CONSEQ:	After approval PI, the Safety Co and/or EHS must rev approve the completed

	of Engineering	Bridget Andrews John Healy Alejandro Toro	Noise, Being Struck by, Entangled By, Vibration, Slips, Trips, and Falls Examples: Propeller can fly off thrust test and can strike someone, loud noise from battery, lifting heavy object	Use barriers in case of propeller flying off the thrust test Administrative Control: Having a professional verify our set-up and all linkages are secured. Utilize an aircraft type safety nut.	gs, and Hard Hat, Close Toed Shoes		Residual: Med High	A written Hazard Control is requ must be approved by th the Safety Committee proceeding. Two qualified must be in place befo can proceed. Limit the nu authorized workers hazard area. (Society of Automotive Engineers, 2018) References Society of Automotive Engineers. (2018). *2018 Collegiate Design Series* . Retrieved from SAE Organization Website: https://www.saeaerodesign.com/content/AE-2018.pdf

Principal investigator(s)/ instructor PHA: I have reviewed and approved the PHA worksheet.

Name	Signature	Date	Name
______________________	_______________	_________	_______________________

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date
Bridget Andrews	_______________	11/19/2021
John Healy	_______________	11/19/2021
Alejandro Toro	_______________	11/19/2021

DEFINITIONS:

Hazard: Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as "*any source of potential damage, harm or adverse health effects on something or someone"*. A list of hazard types and examples are provided in appendix A.

Hazard control: Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into following three groups (priority as listed):

1. **Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.

2. **Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.
3. **Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

Team member(s): Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

Safety representative: Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

Residual risk: Residual Risk Assessment Matrix are used to determine project's risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table2) are used to identify the residual risk category.

The instructions to use hazard assessment matrix (table 1) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.
2. Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

Table 1. Hazard assessment matrix.

		Complexity		
		Simple	Moderate	Difficult
Familiarity Level	Very Familiar	1	2	3
	Somewhat Familiar	2	3	4
	Unfamiliar	3	4	5

The instructions to use residual risk assessment matrix (table 2) are listed below:

1. Identify the row associated with the familiarity/complexity value (1 – 5).

2. Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
    a. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
    b. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
    c. Moderate: injuries that require treatment above first aid but do not require hospitalization.
    d. Significant: severe injuries requiring hospitalization.
    e. Severe: death or permanent disability.
3. Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.
4. Enter value next to: RESIDUAL on the PHA worksheet.

Table 2. Residual risk assessment matrix.

Assesse Level	**Consequences**				
	Negligible	Minor	Moderate	Significant	Severe
5	Low Med	Medium	Med High	High	High
4	Low	Low Med	Medium	Med High	High
3	Low	Low Med	Medium	Med High	Med High
2	Low	Low Med	Low Med	Medium	Medium
1	Low	Low	Low Med	Low Med	Medium

Specific rules for each category of the residual risk:

Low:

- Safety controls are planned by both the worker and supervisor.
- Proceed with supervisor authorization.

Low Med:

- Safety controls are planned by both the worker and supervisor.
- A second worker must be in place before work can proceed (buddy system).
- Proceed with supervisor authorization.

Med:

- After approval by the PI, a copy must be sent to the Safety Committee.
- A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee.
- A second worker must be in place before work can proceed (buddy system).
- Limit the number of authorized workers in the hazard area.

Med High:

- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written Project Hazard Control is required and must be approved by the PI and the Safety Committee before proceeding.
- Two qualified workers must be in place before work can proceed.
- Limit the number of authorized workers in the hazard area.
  High:
- The activity will not be performed. The activity must be redesigned to fall in a lower hazard category.

Appendix A: Hazard types and examples

Types of Hazard	Example
Physical hazards	Wet floors, loose electrical cables objects protruding in walkways or doorways
Ergonomic hazards	Lifting heavy objects Stretching the body Twisting the body Poor desk seating
Psychological hazards	Heights, loud sounds, tunnels, bright lights
Environmental hazards	Room temperature, ventilation contaminated air, photocopiers, some office plants acids
Hazardous substances	Alkalis solvents
Biological hazards	Hepatitis B, new strain influenza
Radiation hazards	Electric welding flashes Sunburn
Chemical hazards	Effects on central nervous system, lungs, digestive system, circulatory system, skin, reproductive system. Short term (acute) effects such as burns, rashes, irritation, feeling unwell, coma and death. Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage.
Noise	High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term.
Temperature	Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C. Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures.

Being struck by	This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death.
Crushed by	A typical example of this hazard is tractor rollover. Death is usually the result
Entangled by	Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death.
High energy sources	Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death.
Vibration	Vibration can affect the human body in the hand arm with `white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems.
Slips, trips and falls	A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills.
Radiation	Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples.
Physical	Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures
Psychological	Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects
Biological	More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response.

Project Hazard Control- For Projects with Medium and Higher Risks

Name of Project:		**Date of submission:**
Team member	**Phone number**	**e-mail**
Bridget Andrews	904-616-2833	Ba18@my.fsu.edu
John Healy	516-320-4690	Jkh17c@my.fsu.edu
Alejandro Toro	787-504-3850	Alejandro1.toro@famu.edu

Faculty mentor	**Phone number**	**e-mail**
Dr. Simone Hruda	(850) 410-6372	
Teaching Assistant		
Joseph Thyer		Jmn17@my.fsu.edu

Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

1. 3D Printing: Receive extra training to be aware of all hazard/potential risks that could occur
2. Thrust Test: Have a COE faculty member verify the thrust setup is properly done and that could potentially present a hazard to students
3. Flight Test: Have a COE faculty member verify all sections/propeller/tail/etc. (anything on the outside of the plane that could fly off) are securely fastended.
   - When flying, slowly reach the desired altitude
   - Verify the plane has a red arming plug, a means to disable the motor from outside the aircraft incase of a potential crash

4. When using a soldering iron, verify the person using it is instructed on how to safely use it. Unplug it after use and never leave the iron unattended.

According to SAE:

5. In accordance with the SAE guidelines, our plane will have a red arming plug incase of emergency

6. In accordance with SAE guidelines, our plane will not fly above people in case of crash landing

7. In accordance with SAE guidelines, our plane will have a a power limiter, to restrict the power level

8. In accordance with SAE guidelines,

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.
1. 3D Printing: - Incase of Burn: Thoroughly wash affected area, incase of increase severity of burn call 9-11 - Incase Exposure to additives or chemicals: depending on chemical call poison control or 9-1` 2. Flight Test - Incase of hit/strike: Depending on severity, either call 9-11 or ice the area, if laceration bandage the wounded area 3. Thrust Test - In case of propeller hiting someone call 9-11.
List emergency response contact information:
• Call 911 for injuries, fires or other emergency situations • Call your department representative to report a facility concern

Name	Phone number	Faculty or other COE emergency contact	Phone number
Shayne McConomy	850-410-6624	Faculty	
Dr. Simone Hruda	(850) 410-6372	Faculty	
FSU Emergency	850-644-9111	FSU Emergency Management	

Safety review signatures

Team member	Date	Faculty mentor	Date
Bridget Andrews	03/09/22	Dr. Simone Hruda	03/09/22
John Healy	03/09/22	Dr. Simone Hruda	03/09/22
Alejandro Toro	03/09/22	Dr. Simone Hruda	03/09/22

Report all accidents and near misses to the faculty mentor.

Appendix H: Static Margin Calculations

Ideal Center of Gravity

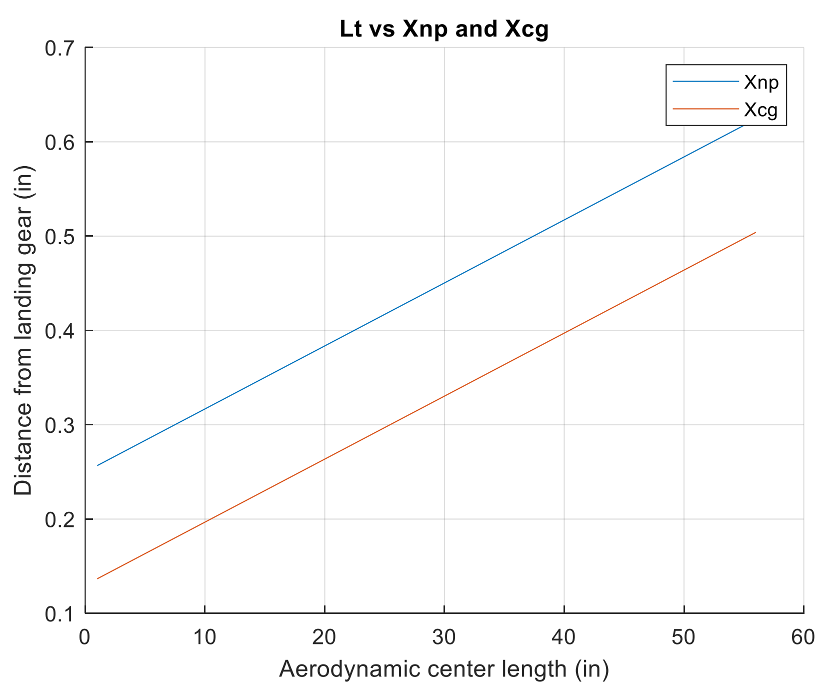
```
%% BRIDGET ANDREWS  Center of Mass 9/14/2021
%
clc
clear all
close all
format compact
disp('BRIDGET ANDREWS  Center of Mass 9/14/2021')
%% Where should the Wing be placed??
%in
lt = 1:0.5:56;              %distance between aerodynamic
centers
c = 14;                     %chord of wing
c_mean = 12.1;              %12.1 based on Tristan updated
code

%in^2
ct = 10;                        %tail chord length
St = 200;                       %horizontal tail area   based
on tristan's code
Sw = 6.4*144;                   %wing area    converted 6ft^2
to in^2
b = 85;                      %wing span
d = St/ct;                     %tail span
```

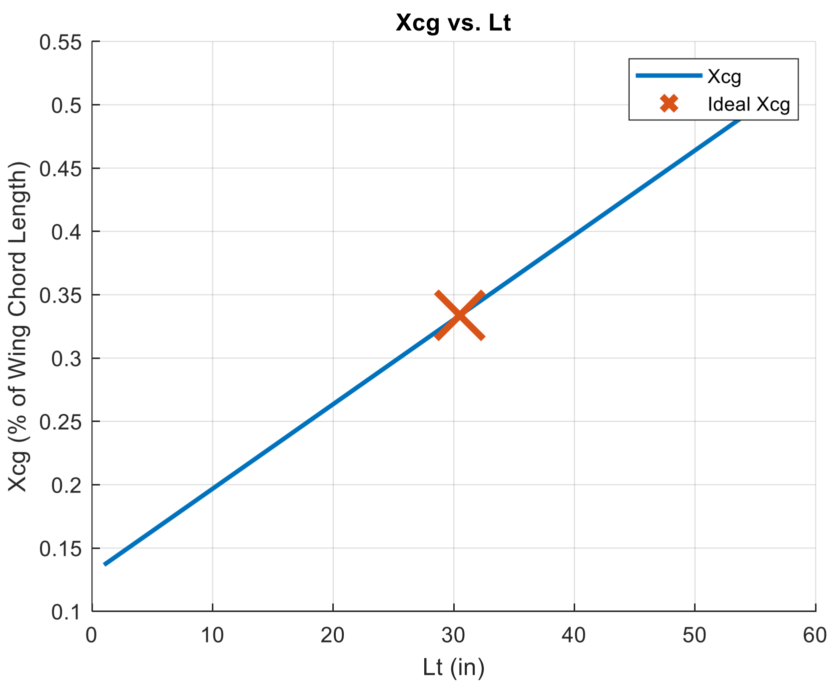
```
Vh = lt.*St./(c_mean*Sw);          %Volumetric Horizontal
Tail Coefficient
AR =  (b^2)/Sw;               %Aspect Ratio of Wing
ARh = (d^2)/St;               %Horizontal Tail aspect ratio

%Determine
Xnp = 0.25+ ((1+2/AR)/(1+2/ARh)).*(1-(4/(2+AR))).*Vh;
%distance of neutral point from beginnning of wing to the
actual chord length
Xcg = Xnp - 0.12;
%Ideal Static Margin is 0.12

figure (1)
hold on
plot(lt,Xnp, '-');
plot(lt,Xcg);
hold off
grid on
legend ('Xnp','Xcg');
title('Lt vs Xnp and Xcg')
xlabel('Aerodynamic center length (in)')
ylabel('Distance from landing gear (in)')
```



```
figure (4)
hold on
plot(lt,Xcg,'LineWidth',2);
plot(lt(60),Xcg(60), 'x', 'MarkerSize',30, 'LineWidth',3)
hold off
grid on
legend ('Xcg','Ideal Xcg');
title('Xcg vs. Lt')
xlabel('Lt (in)')
ylabel('Xcg (% of Wing Chord Length)')
```



Final Center of Gravity

```
%% BRIDGET ANDREWS  Center of Gravity 3/31/2022
%
clc
clear all
close all
format compact
disp('BRIDGET ANDREWS  Center of Gravity 3/31/2022')
```

```
%experimentally found weights
F_m1 = 6.550;
F_m2 = 6.595;
F_r = 2.145;

L_m = 16.0144;
L_r = 49;

F = [F_m1 F_m2 F_r];
L = [L_m L_m L_r];
M = F.*L;
M_sum = sum(M);
F_sum = sum(F);
CG = M_sum/F_sum;
fprintf('The current CG is %.2f \n', CG);

%% Static Margin
%in
lt = 30.5;              %distance between aerodynamic centers
c = 14;                     %chord of wing
c_mean = 12.1;              %12.1 based on Tristan updated
code

%in^2
ct = 10;                        %tail chord length
St = 200;                       %horizontal tail area   based
on tristan's code
Sw = 6.4*144;                    %wing area    converted
6ft^2 to in^2
b = 85;                       %wing span
d = St/ct;                      %tail span

Vh = lt.*St./(c_mean*Sw);         %Volumetric Horizontal
Tail Coefficient
AR =  (b^2)/Sw;                %Aspect Ratio of Wing
ARh = (d^2)/St;                %Horizontal Tail aspect ratio

%Determine
L_wing = 19.43;
```

```
Xnp = 0.25+ ((1+2/AR)/(1+2/ARh)).*(1-(4/(2+AR))).*Vh;
%distance of neutral point from beginnning of wing to the
actual chord length
Xcg = (CG - L_wing +c*0.25)/c;
SM = Xnp - Xcg;
fprintf('The current static margin of our plane is %.2f
\n', SM);

%%

L_plus = 2.27;
IdealCG = 20.6;
F_plus = (M_sum - IdealCG*F_sum)/(IdealCG - L_plus);
fprintf('The weight needed to attach to attach to the motor
mount is %.2f \n', F_plus);

%%

L_plus = 56;
IdealCG = 20.6;
F_plus = (M_sum - IdealCG*F_sum)/(IdealCG - L_plus);
fprintf('The weight needed to attach to attach to the end
of the fuselage is is %.2f \n', F_plus);

%Results
The current CG is 20.64
The current static margin of our plane is 0.12
The weight needed to attach to attach to the motor mount is 0.03
The weight needed to attach to attach to the end of the fuselage
is is -0.02
>>
```

References

There are no sources in the current document.