2025 SAE AERO DESIGN FINAL DESIGN REPORT
Tulane University Airtime Aviation Team #326

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Executive Summary: Problem Statement/Background:

The SAE aero competition annually gives students from across the world the chance to prove their engineering skills in an RC-plane competition. Students are given guidelines to build an RC plane meant to fit one of three possible categories: Micro, Regular, and Advanced class. During this academic year 2024-25, as part of the Tulane senior capstone, we represented Tulane as “Airtime Aviation”. We successfully learned the required aeronautical physics, research and development, along with baseline manufacturing skills required to compete in the SAE Aero Design Competition. This took place as part of the West Division Competition in Van Nuys, California on April 4th through 6th of 2025. Beginning with SAE regulation guidelines, mentor recommendations, and Leland Nicholai’s “White Paper”, we successfully designed an aircraft that drew design inspiration from existing full-scale planes, and adhered to the well-established RC flight principles. The year could be holistically broken into three parts: aerodynamic principles and design decision breakdowns, prototyping and manufacturing, and iteration and testing. Some of the more important literature we used to understand and perform calculations include: *General Aviation Aircraft Design* by Snorri Gudmundsson, and Airplane Design, Vol II, by Jan Roskam.

Success Criteria:

According to SAE regulations, a successful project must fulfill the following criteria: (1) development of a fully functional prototype; (2) strict adherence to all competition rules and SAE micro class build guidelines; (3) timely registration to the event; (4) demonstration of an original design manufactured in house; and (5) submission of comprehensive design deliverables, including a presentation, that verify compliance, delivered directly to SAE judges. [8] The additional margin of success is gauged based on flight points. These are derived from an equation provided by SAE. This allows teams who meet all the previous criteria to participate competitively to attempt scoring during flight runs. However, earning these points depends heavily on how well performance factors are integrated into the plane during the design and build phases, not just at the time of competition.

$$Flight\ Score = FS = 3 * W_{Payload} * M + Z$$

$$M = \frac{11}{(W_{Empty} - 1)^4 + 8.9}$$

$$Z = B_{Takeoff} - S^{1.5}$$

$W_{Payload} = Payload\ Weight\ (lbs)$

$W_{Empty} = Empty\ Weight\ (lbs)$

$S = Wingspan\ (ft)$

$$B_{Takeoff} = \begin{cases} 20 & 0 \leq x \leq 10\ ft \\ 15 & 10 < x \leq 25\ ft \\ 9 & 25 < x \leq 50\ ft \\ 0 & 50 < x \leq 100\ ft \end{cases}$$

Figure 1: *SAE Micro Class Flight Point Equation*

The variable values of empty weight, wingspan, and takeoff distance must be minimized while payload weight is maximized. Empty weight in particular would need to be as close to 2<x<4 lb after fabrication. However, two of these specifications actively work against each other. A small takeoff distance requires a larger lift force, which is most easily achieved with a larger wingspan. Generally, a smaller wingspan increases the distance required for the aircraft to take off. The plane is additionally constricted by the duration that the electric power train can run per flight attempt, the torque of the control surfaces, and the ultimate cost of the build.

Customer Need	Description	Metric	Target Value
Take-Off Distance	The plane must take off before a maximum distance of 20 feet.	Distance (ft)	<20 ft
Wingspan	A lower wingspan will increase our points for the competition	Length (ft)	<4.3 ft

Dead Weight Plane	The plane must not exceed 4 pounds empty to maximize flight points.	Mass (lbs)	2-4 lbs
Payload Capacity	Internal, ridgid payload container must hold the required amount of liquid water	Volume (oz)	67 oz
Servo Control	Crucial aspect for aircraft control	Torque (in-lbs)	0.133 in-lbs
Cost of 1st Prototype	Cost is constrained to the grant/sponsorship funds available.	Cost (USD)	<800 USD
Lift Force	Force pushing the plane up must overcome the aircraft's weight times the force of gravity	Force (lbs)	4-5 Ibs
Electric PowerTrain	Create and implement Power Train to last the duration of the SAE Flight Run	Time (min)	2-3 min

Table 1: *Aircraft Success Criteria Parameters Micro Class Design Requirements*

<u>Design Overview</u>:

Our design centers around building a lightweight, modular RC aircraft capable of carrying a 2-liter payload, conforming to the SAE Aero Design Micro Class constraints. The concept employs highly aerodynamic structures with practical, modular assembly. We aimed to minimize total mass without sacrificing structural integrity, allow rapid assembly, and provide sufficient thrust and control authority for stable flight. The aircraft's major components: fuselage, wing, empennage, and powertrain, were each optimized to balance manufacturability, weight, and performance. Figure 1 displays the drawing for our plane, and figure 2 displays the fully connected CAD of the exterior of our plane.

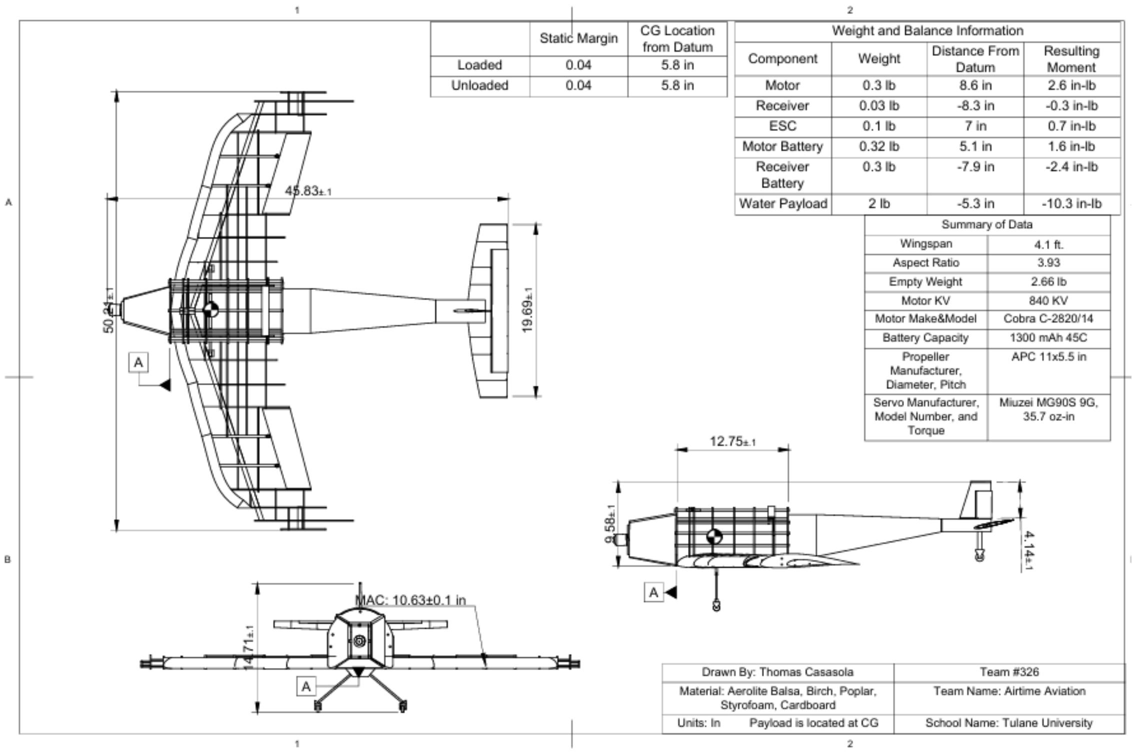

***Figure 2**: 2-D Drawing of Plane (Measurements and Specifications)*

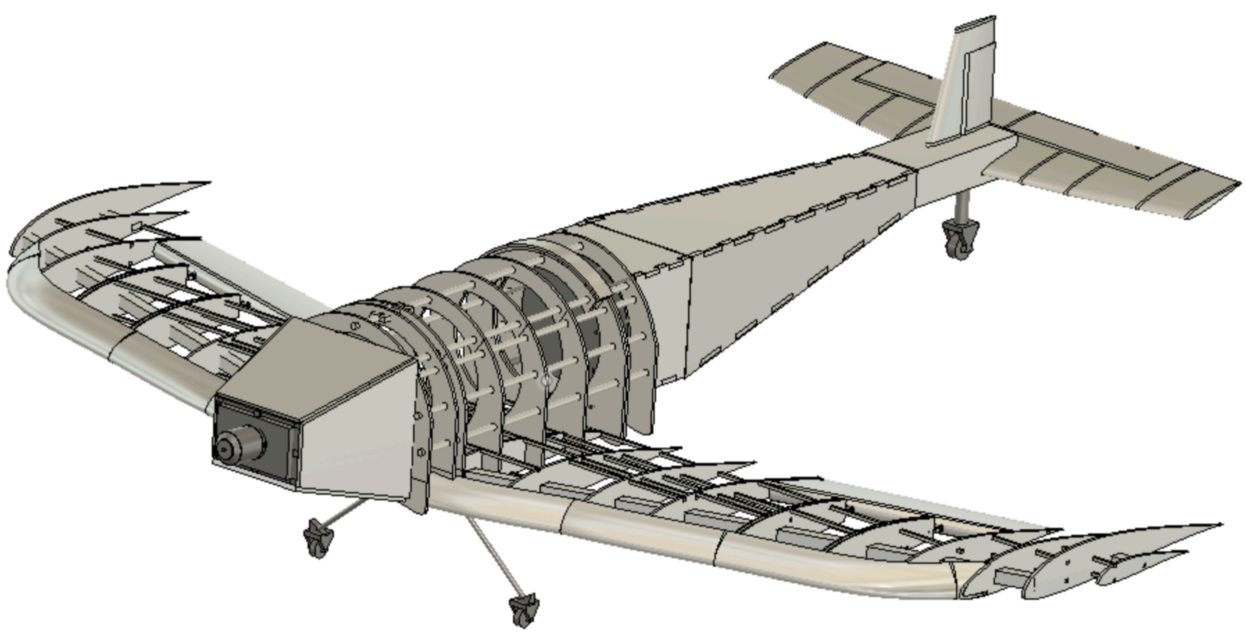

***Figure 3:** Comprehensive CAD Fully Built Plane*

The dimensions and aerodynamic data for our plane were compiled using XFLR5, a software tool for analyzing airfoils and planes. We decided on a swept-back wing configuration to push the aerodynamic center of the wing backward. This was important for ensuring the longitudinal stability of the plane. Placing the aerodynamic center behind the center of mass created positive static and dynamic margins, synonymous with stability. This resulted in various successful stability simulations in various motions including phugoid, oscillations, and dutch roll, displayed in figure 4. From these simulations, we compile the aerodynamic data displayed in figure 5.

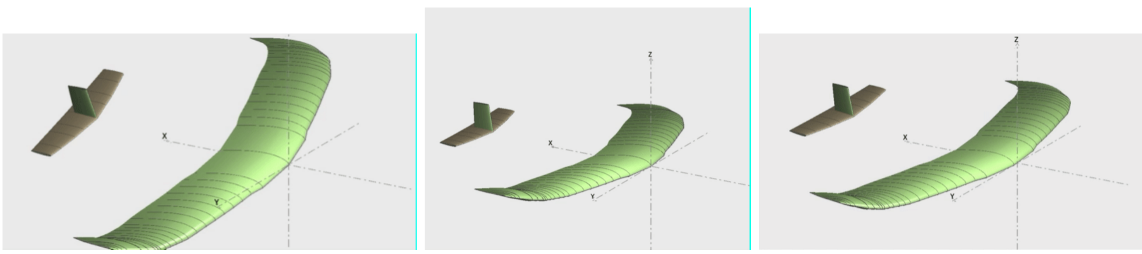

Figure 4: *XFLR5 Animation of Phugoid, Short Period Oscillation, and Dutch Roll*

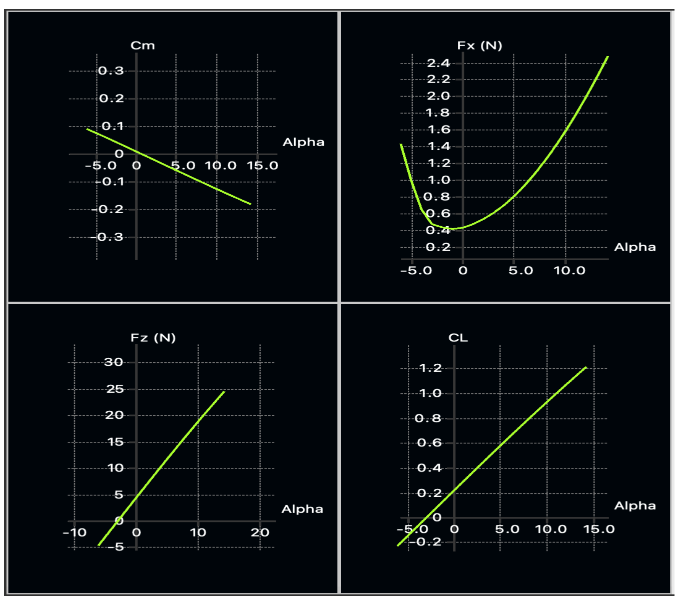

Figure 5: *Aerodynamic Data from XFLR5 [Top Left] Pitching Moment Coefficient vs Angle of Attack; [Top Right] Drag Force vs Angle of Attack; [Bottom Left] Lift Force vs Angle of Attack; [Bottom Right] Coefficient of Lift vs Angle of Attack*

The maximum lift for our aircraft at takeoff was simulated to be 5.5 lbs at the optimal angle of attack (AoA) of 12 degrees. The maximum drag of the aircraft is 0.53 lbs, produced at the stalling AoA of 18 degrees. This value accounts for the plane's overall structure. The total drag can be simulated using component weights, as outlined in Table 2.

Component	Weight (lbs)	Drag (lbs)
Wing Fuselage Body	2.15 lbs	0.259 lbs
Nose Cone	0.72 in	0.087 lbs
Back Fuselage and Empennage	1.12 in	0.135 lbs
Landing Gear	0.41 in	0.049 lbs

Table 2: *Component Wise Weight Distribution and Drag*

The aircraft is primarily constructed from aero balsa, poplar, and birch wood, each selected for their structural properties and weight efficiency. Aero balsa comprises most of the wing and fuselage due to its low density and high flexibility, making it ideal for components subjected to continuous aerodynamic loads. The wing experiences significant torsion during flight, with forces acting in multiple directions. Aero balsa's rupture resistance (2,940 lbf/in²) and high elastic modulus (537,000 lbf/in²)[10] allow the wing ribs to withstand these forces and flex without permanent deformation. In the fuselage, aero balsa's low weight helps maintain a balanced center of mass. To minimize weight, metal usage was restricted to bolts, electronics, and fasteners, concentrating mass at the front of the aircraft for stability.

Our fuselage, seen in figure 6, was made by creating a three-point spline shape in AutoCAD, and then using the laser-cutter to produce aero balsa semi-circles that assembled longitudinally, using birch dowels, to create a frame with a hollow payload bay. This structure reduces weight compared to solid-body alternatives and enables quick access to internal components such as the Electronic Speed Controller (ESC), receiver, and payload container. The payload bay itself was lined with polyurethane foam to snugly fit a custom-made 2-liter bottle.

This facilitated quick insertion and draining. This matched the regulation specification “*9.9 - Payload container is fully enclosed with a top fill port and bottom drain port. Static volume is 67 fl oz and no external force is required to drain.*”

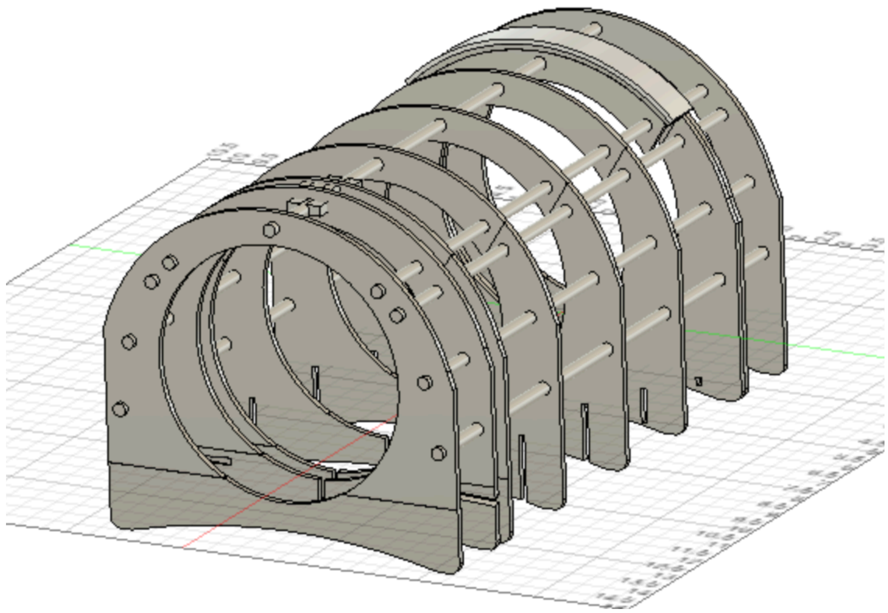

Figure 6: *Fuselage Member Section. Cut Out to Fit onto the Wing Ribs*.

The tail boom, displayed in figure 7, is constructed in the shape of a four-sided 3-dimensional trapezoid, extending from the main fuselage and anchoring the empennage at the other end, allowing a sufficient counter-moment for pitch control without compromising the plane’s aerodynamic capability.

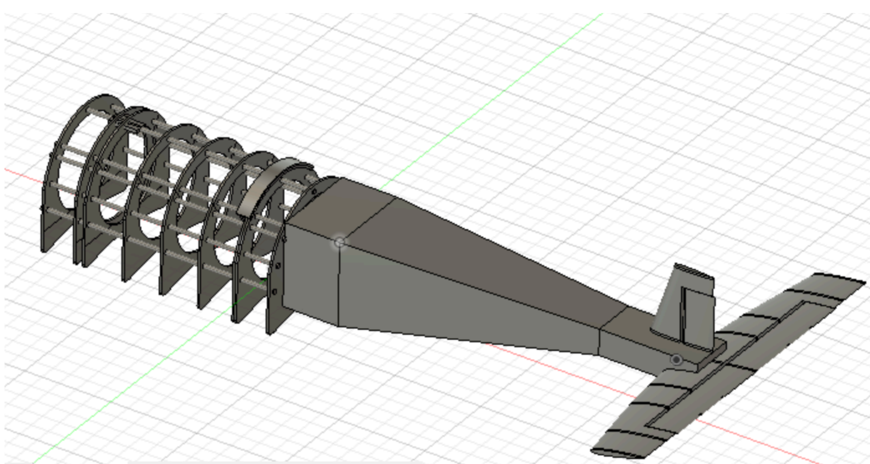

Figure 7: *Tail Boom Connecting Empennage with Fuselage Members*

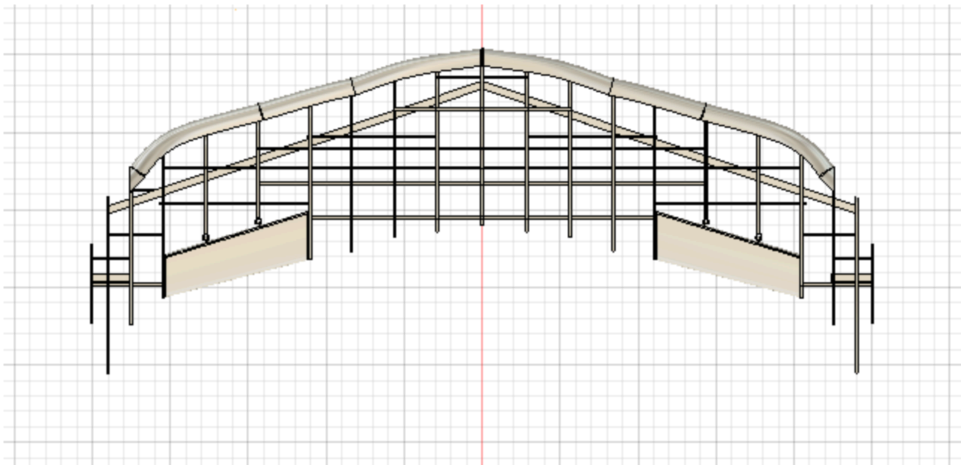

Figure 8: *Wing Structure with Selig S7062 Airfoils; Leading and Trailing Edge Moulded and Reinforced with Styrofoam*

The wing features a backward sweep, displayed in figure 8. The airfoil employs the Selig 7062 model, known for its high lift-to-drag ratio at low Reynolds numbers. This shape was transferred into Adobe Illustrator and then aligned on the laser cutter interface to produce individual wing ribs. Ribs were precision-cut from aero balsa and slotted onto dual main spars, enabling consistent airfoil geometry across the span. To reinforce high-stress areas, a balsa shear web was added at the wing root and servo mounts. While the current wing used minimal internal bracing to reduce weight, future iterations would greatly benefit from a shear web across the entire wing. This would require removing the sweep, which we highly recommend avoiding in the first place, to improve rigidity under basic loading. Ailerons were initially sized to the servos, but testing revealed their surface area and the installed servo torque were insufficient for reliable roll control. This highlights a tradeoff between aerodynamic efficiency of the overall wing and control authority.

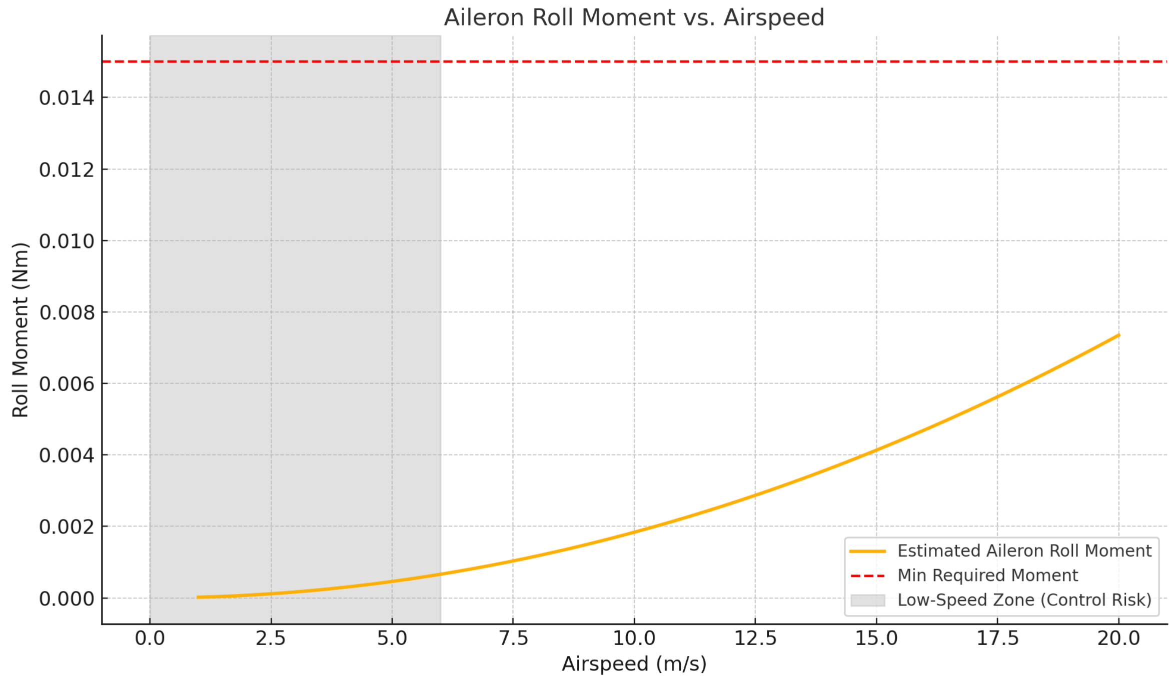

Figure 9: *Aileron Roll Moment vs Airspeed*

Our propulsion system was centered around a FlashHobby D3542 1000kV motor, paired with an 11-inch propeller and a 4S 1400mAh LiPo battery. This setup delivered high thrust at low RPM, supporting short takeoff performance. The motor was mounted forward of the fuselage nose on a reinforced balsa nose cone, with internal webbing to dampen vibrations and mitigate fatigue on the structure. Power distribution was handled through XT60 connectors and a 450W power limiter we were required to purchase and install, delivering stable voltage to the ESC and motor, separately from the receiver and servos. Those were powered by a separate 2000 mAh NiMH battery.

Throughout the design process, SAE Micro Class rules and fundamental aerospace codes shaped key decisions. For instance, the ban on composite fiber materials necessitated a creative use of birch and balsa for structural strength, as opposed to carbon fiber-reinforced rods or duct tape. Standards on safety and accessibility led us to avoid retractable landing gear and instead integrate fixed, modular gear directly into the fuselage rings and tail boom.

The landing gear was designed for structural simplicity and high-load endurance, using fixed gear in compliance with SAE Micro Class Rule 9.6 (Table 3). The front gear, as seen in figure 10, was mounted between the fuselage support rings using a birch reinforcement plate, while the rear gear was fixed to the tail boom with a shear-fitted notch reinforced inside and out with an extra layer of balsa. The struts used 3 mm diameter wooden dowels, connected to a trapezoidal main fitting. During ground testing, the landing gear supported over twice the aircraft's gross weight without deformation. While effective for taxi and static tests, future teams should explore shock-absorbing materials or a lightweight spring-loaded design to improve landing survivability without exceeding mass constraints.

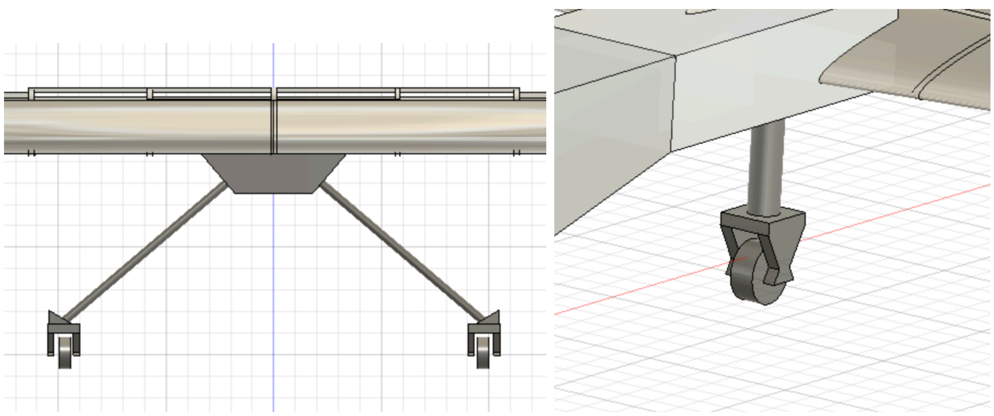

Figure 10*: Front [Left] and Rear Landing Gear [Right]*

After completing fabrication and component integration, our team assessed the prototype against the full set of SAE Aero Design Micro Class specifications. Each requirement, from payload container dimensions to structural material limitations, shaped both the design and the assembly approach. Table 4 summarizes the core specifications alongside how our final prototype satisfies each rule.

Ultimately, the aircraft was shaped by a deliberate focus on minimizing weight, enabling modularity, and optimizing flight dynamics. While our prototype encountered limitations in control authority and wing deflection that prevented successful flight, the underlying framework proved robust, adaptable, and competition-ready in nearly all other respects. These insights will serve as a springboard for future teams to refine and fly a fully capable aircraft.

Codes and Standards:

As our project's scope and creative boundaries were constrained by the SAE Aero Micro Class codes and standards for material selection, aircraft design choices, and building parameters, most of the project's sessions were conducted in tandem with consulting the provided SAE 2025 Codes and Rules. These rules informed our decision making to ensure we passed the technical inspection and met the safety requirements for competition.

Code	Policy
§1.6 Design and Fabrication	Entire design, fabrication, and testing processes - including laser-cutting and electronics integration - were performed by student team members only.
§9.2 Aircraft Systems Requirements	The aircraft uses electric motor propulsion only, with a 4-cell LiPo battery and a 2025 450W Neumotors power limiter as required.
§2.22 Red Arming Plug	A discrete red arming plug is installed on the positive lead, visible, and positioned away from the propeller per Micro Class safety guidelines.
§9.3 Payload Requirements	Payload container is fully enclosed with a top fill port and bottom drain port. Static volume is 67 fl oz, and no external force is required to drain.
§9.4 Micro Class Payload Unloading	Our system allows complete drainage of water within 60 seconds using gravity alone, with no squeezing or pressurization.
§9.1 Aircraft Dimension Requirements	The aircraft meets Micro Class constraints and was designed to balance a compact frame with maximum lift efficiency.
§4.4 2D Drawing Requirements	Drawing, including a neutral point plot, static margin curve (-10° to +15° AoA), and CG location (with the water container half-full),we submitted as per technical design sheet specifications.

***Table 3**: SAE Micro Class Codes and Standards*

Current State of Project:

Our team successfully turned our design into reality with an SAE Micro Class compliant aircraft. This process was iteratively refined through numerous CAD designs, XFLR5 simulations, component testing, and logistical adherence, culminating in a prototype worthy of passing inspection. In passing the technical inspection, we established proof of concept for our design, ensuring eligibility to compete at the SAE Aero West Design 2025.

Criteria	Target Value	Actual Value
Take-Off Distance	<20 ft	7.17 ft
Wingspan	<4.3 ft	4.1 ft
Dead Weight Plane	2-4 lbs	4.4 lbs
Payload Capacity	67 oz	67 oz
Servo Control	0.133 in-lbs	0.062 in-lbs
Cost of 1st Prototype	<800 USD	640 USD
Lift Force	4-5 Ibs	5.5 lbs
Electric PowerTrain	2-3 min	3-4 min

***Table 4**: Plane target parameters compared to actual values*

Flight attempts were not performed on site due to our SAE provisional pilot's concerns regarding the controllability of the aircraft's ailerons, their size and the torque generated by the servo actuation on the wing, some of the actual values for our performance criteria were derived using empirical simulations. Overall, the aircraft design exceeded target expectations in all but two areas: the dead weight of the plane and the servo control effectiveness. These shortcomings stemmed from a combination of limited aileron surface area and the torque generated during servo arm actuation. Our capstone was successfully completed on the timeline of the SAE Competition and requested deliverables all being received and processed.

Figure 11: *Final Aircraft Prototype Built*

<u>Future Actions:</u>

Prior to continuing with a new prototype, various design choices need to be analyzed. This includes but is not limited to designing the wing to be straight, as opposed to swept back, redesigning the landing gear from the ground up, and reconstructing our control surfaces.

Like the team before us, we were motivated to ensure that the next Tulane team performing at SAE Aero would not repeat our mistakes. One of our most notable setbacks was an overemphasis on rigidly following SAE rules. While rule compliance is important, our strict adherence caused production delays and unnecessary redesigns. Time spent reordering materials and replacing parts could have been better used on actual construction and testing. After visiting other teams at the competition, we observed that several high-performing aircraft did not fully conform to the rules, but succeeded by prioritizing the ability to fly and consequently scoring more points. Many teams lost inspection points but regained them with strong flight performance, and some even flew with open fuselages or materials previously thought to be banned (such as carbon fiber rods). In hindsight, a more balanced approach focused on build execution and testing would have better served our timeline.

The current prototype provides a strong structural and aerodynamic baseline from which future improvements can be developed. Moving forward, the primary focus should be on refining flight control and increasing structural rigidity. Key enhancements include enlarging the ailerons to improve roll authority, upgrading to high-torque digital servos for greater actuation precision, and reinforcing the wing with a continuous shear web to reduce in-flight flexing. Additional refinements such as trimming the control surfaces and verifying the center of gravity with a static balance rig will contribute to overall flight stability and controllability.

To implement these changes, a staged development and testing plan is recommended. This process begins with design modifications and progresses through rebuild, validation, and flight testing. In the first week, redesigns of the wing and control surfaces should be finalized. The second week should focus on sourcing necessary materials and fabricating the updated wing structure. Reassembly and subsystem validation, including servo and linkage testing, would be completed in the third week. The fourth week would be dedicated to center of gravity adjustments and static testing. The final two weeks would include a staged flight test campaign, beginning with ground-based actuation checks and taxi trials, followed by glide and powered flight evaluations.

A budget of approximately 200 USD is expected to cover the required upgrades. This includes the purchase of servos, adhesives, aerobalsa, and fasteners. With these improvements, the aircraft has the potential to become a reliable and reusable platform in the future. It may also serve as a valuable teaching tool in capstone courses or flight mechanics labs.

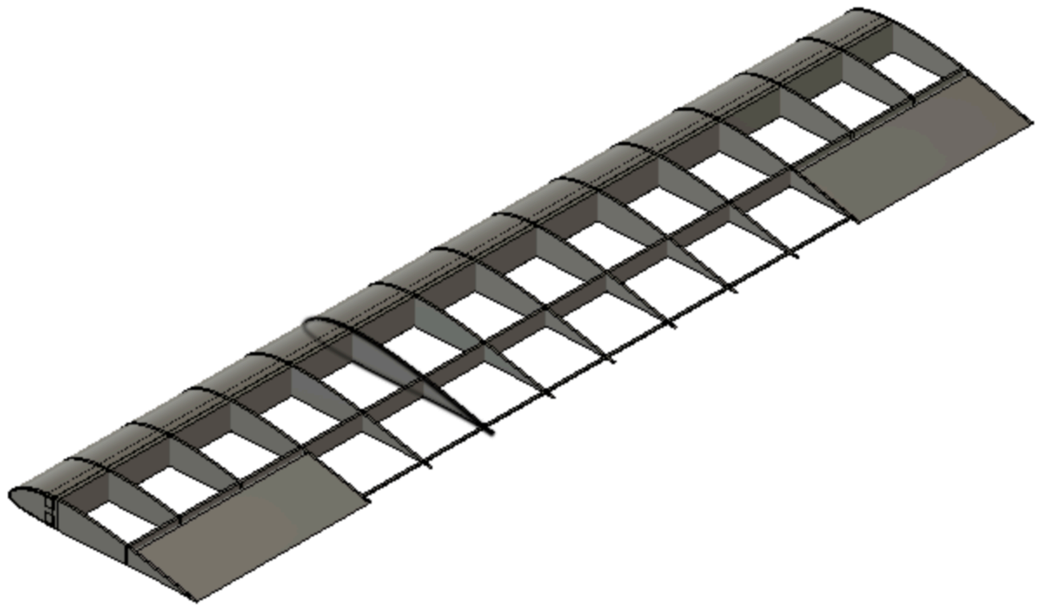

Figure 12: *CAD Straight Wing Configuration (Designed)*

Figure 13: *Reinforced Carbon Fiber Landing Gear (Purchasable)*

Sponsor Approval:

Both Jack Hawkins and Keelan Collins, SAE Airtime Aviation's capstone sponsors, were sent a copy of the updated Final Design Report for review on (5-3-2025 at 11:21 PM). Tentative approval and feedback are pending and will be incorporated in the document and re-disseminated via email once received.

Jack Hawkins

Keelan Collins

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