SAE Micro Aero Plane

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Abstract

The SAE Aero Design Competition is an annual competition between colleges and universities. Sponsored by the Society of Automotive Engineers, teams from around the country come together to compete to see who can design and implement the best airplane based on rules made by SAE. This year, the NAU team has designed a brand-new airplane for the micro class competition. Although the team were not able to attend the competition this year due to a summer-fall schedule, these design requirements were followed strictly as if it were to be flown at competition. This year's plane differs from previous teams due to being a twin boom design. There is no use of a hollow fuselage, instead the plane is simplified into carbon fiber rods, aluminum bayonet mounts, wooden ribs and tail sections, and 3D printed trailing edges, landing gear and electronics tray. On December 6th, 2019 the plane underwent a flight test. Unfortunately, the results were not what was expected. Attempting a runway takeoff broke the landing gear, which led to a thrown takeoff, upon which the plane rolled and drove itself into the ground.

SAE Rules/Requirements

The main rules and restrictions for the Micro class SAE competition are listed below

- Must use electric motors
- Individual batteries must not exceed 2200mAH 3s capacity
- Plane and payload must fit into a medium shipping box with dimensions 11.875" x 13.625" x 3.375"
- The plane must be assembled in 180 seconds or less during competition, 60 seconds preferred
- Must be hand thrown or launched
- Must fly around a closed course both with and without payload

Scoring Equation:

$$Final\ Flight\ Score = FSS = 20 * \left[0.5 * \left(\frac{1}{N}\sum_{1}^{N} FS_n\right) + 0.5 * MAX(FS_n)\right] + AD$$

Where:

$$FS_n = Flight\ Score_n = \frac{W_{payload}}{\sqrt{W_{empty}}}$$

Assembly Demonstration

$$AD = Assembly\ Demonstration = 5 * \left(2 - \frac{t}{60}\right)^3$$

$MAX = Team's\ maximum\ single\ flight\ round\ score$

$t = time\ recorded\ in\ seconds$

$N = total\ number\ of\ flight\ rounds\ during\ the\ competition$

Figure 1: Scoring equations used for Micro class competition

Design Process

The design of this aircraft changed and evolved each time that the team found any issue to be solved. The original design proposed in the summer still featured a twin boom design with two motors and no fuselage, but each iteration changed different small aspects of the design. Beginning with the wings the team decided that it would be beneficial to have a dihedral (U-shaped) wing profile, using the S1223 airfoil, made from 1/8th inch utility plywood covered with Monokote. The dihedral removed the necessity of having ailerons on the wings for roll control.

Figure 2: Dihedral U-shape of wing profile

Figure 3: S1223 Airfoil shape, hole sections removed for spar location and weight reduction

Another important part of the design process was to ensure that we could fit the plane into the required box. This meant that we had limiting factors for every dimension of every part, particularly for the wings. As seen in figure 2 the wing has three different sections (two clear and one blue). These were connected by small elbows inserted into each wing section to give the dihedral profile. An additional issue stemming from the rule requirements were the time spent to build the plane during competition. Between the box size and time limit, we had to design a fast way to assemble the plane from completely packed into the shipping box. Thus we designed different snap fits and locking pins to accommodate for different sections of the aircraft. With the cross-member structure and upper wing connection, different snaps had to be created for each connection point to rotate accordingly to assemble the structure of the plane.

Figure 4,5: Bayonet mount snap fits male (left) and female (top)

Manufacturing

Mentioned in the design process, the structure comes from the carbon fiber booms that run the length of the aircraft. The wings and tail section are made of plywood that is covered with Monokote. To do this the team had to iron layers of the Monokote on and cover the correct profile of the plane, particularly the airfoil of the wings. The wing sections have laser cut airfoil ribs that are held together down the center by Pultruded spars. The connectors for each boom section are machined male/female ends with small locking pins to hold themselves together, all glued into the booms. The landing gear and electronics tray main structures are 3-D printed, and also contain wires, a battery, and off the shelf parts added to complete the designs, and power the motors and servos.

Figure 6: Wing sections under construction, prior to monokote

Testing and Results

The first test of the aircraft was a runway takeoff, for which we had removed the rear landing gear and repositioned weight of the aircraft. Uneven wheel rotation from the rough ground caused the plane to nose forward before takeoff and break the landing gear and propellers. For the next test we removed the rest of the landing gear for less weight, repositioned again and attempted a thrown takeoff. Upon throwing the aircraft there was a moment where the plane was able to fly flat, before beginning a barrel roll which it completed before landing flat on the Earth. This was likely caused by either the rotation of the propellers, an uneven weight, or the dihedral shape of the craft not controlling the roll.

Figure 7: Thrown launch of aircraft

Final Design

The final design of the aircraft is shown below and features the dihedral wing profile covered with Monokote, an electronics tray below the center wing section, twin booms for structure connected to the two motors, four landing gear, and all wiring connected to the servos for the rudder and elevator in the tail section. This picture does not include the payload for the competition. Possible improvements on this design would be to change the electronics tray to sit closed and further forward to compensate for weight around the center of gravity, lighten the weight of all landing gear and the tail section, and to extend the wing profile to have three flat center sections before beginning the U-shape of the dihedral.

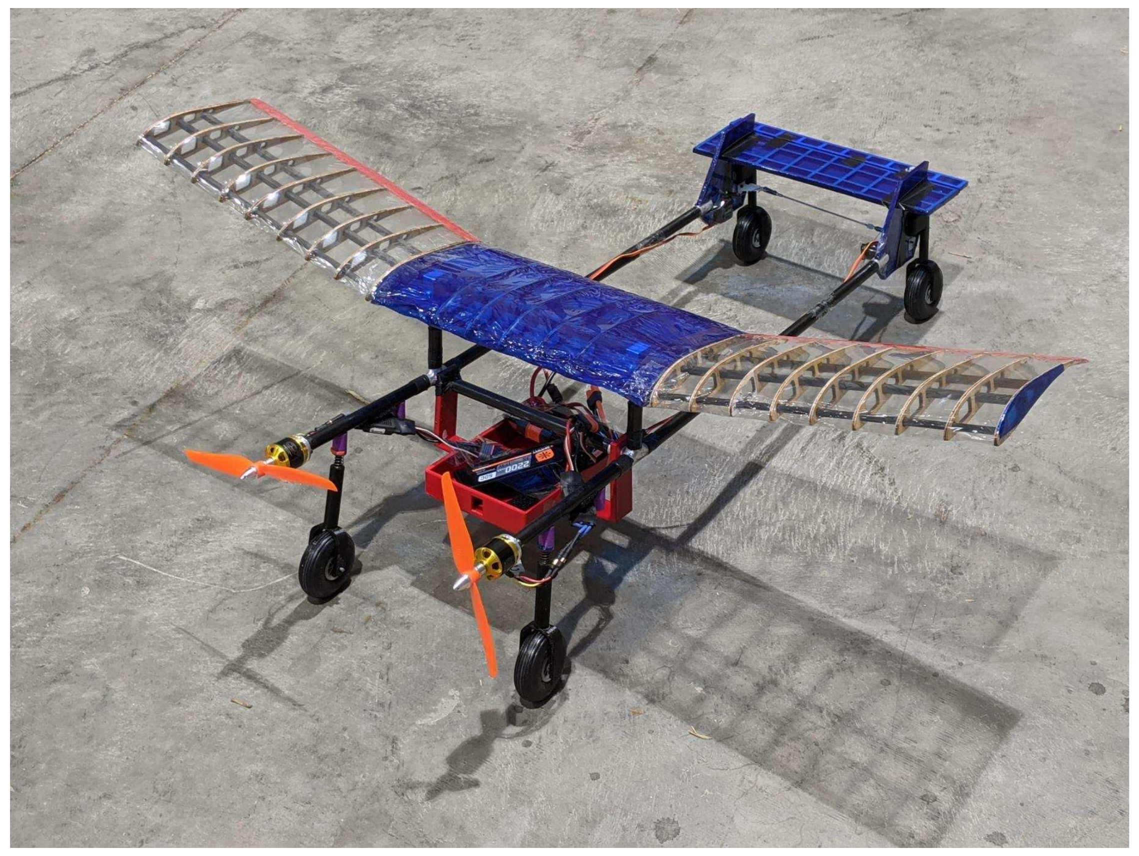

Figure 8: Final design of Aircraft

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