Team Final Approach

20F12: A2 Aero Micro

Final Presentation

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Cad Model

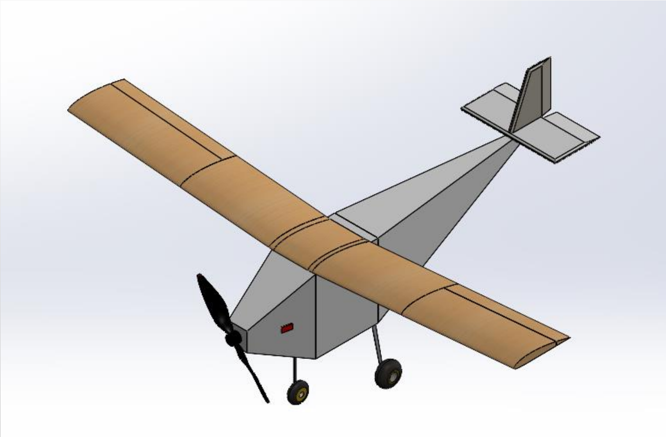


Figure 1: Tentative Final Design

Figure 2: C-212 Aviocar [1]

- Foamboard fuselage that can hold cargo and avionics
- Balsa wood wings with dihedral
- Foamboard tail
- Tricycle landing gear configuration

Cad Model – Continued

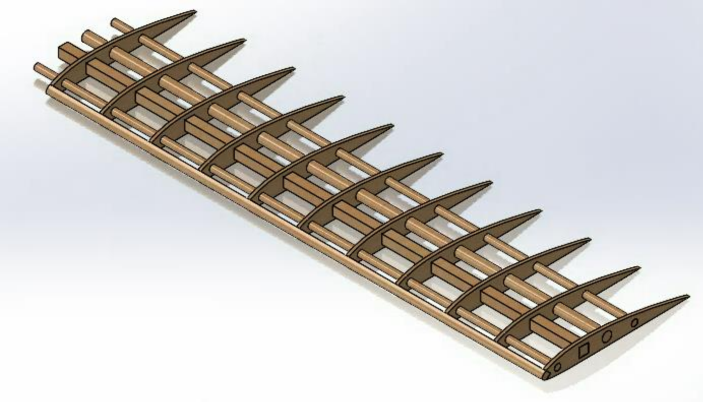


Figure 3: Interior Construction of Wing

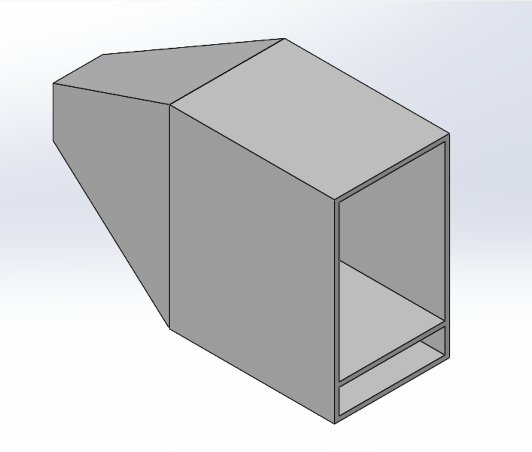


Figure 4: Fuselage without Tail Section

- Utilizes rib and spar design
- ⅛” balsa wood ribs 2” apart from one another

- Airfoil shape where it’s connected to wings
- Compartment for storing cargo boxes

SolidWorks Simulation – Pictures

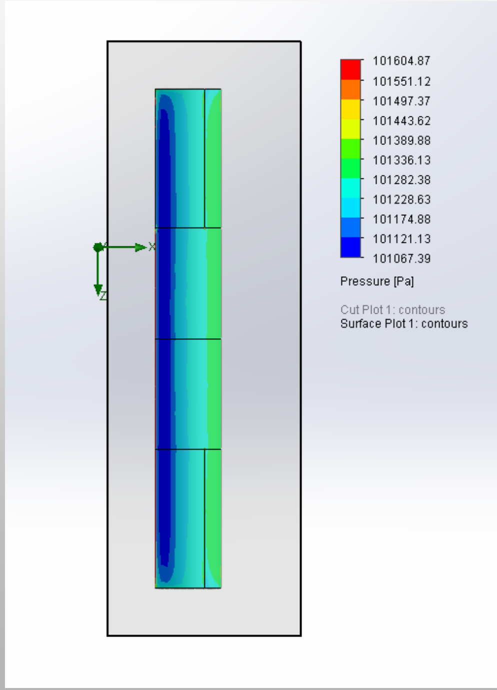


Figure 5: Airfoil Pressure Surface Plot

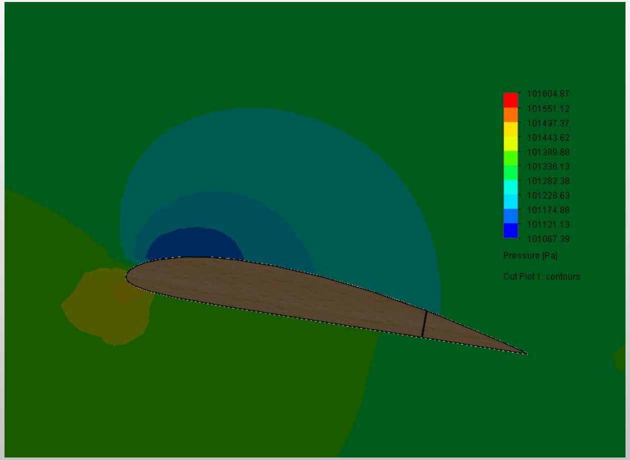


Figure 6: Airfoil Pressure Cut Plot

- Ran SolidWorks simulation at 20 m/s (44.7 mph)
- Simulated 3 different angles of attack (0, 5, and 10 degrees).
- Standard Temperature and Pressure in Flagstaff Arizona (101,325 pascals and 293.2 K [2])
- Plots show pressure changes at top and bottom of wing that generate lift.

SolidWorks Simulation – Data

Table 1: Simulation and Empirical Results for 20 m/s Flight

Angle of Attack	Lift from SolidWorks	Lift from Empirical Data
0 Degrees	3.5 N (0.787 lbf)	11.64 N (2.617 lbf)
5 Degrees	11.5 N (2.585 lbf)	30.32 N (6.816 lbf)
10 Degrees	20 N (4.496 lbf)	43.35 (9.745 lbf)

- SolidWorks simulation loses accuracy at low Reynolds number [3]
- Plane is expected to weigh in between 4 and 7 lbs
- Using the average of the SolidWorks and Empirical data, it can be reasonably expected that at with an angle of attack of 5 degrees, an airplane of 5 lbs will successfully fly

Design Description

- Main design utilizes a standard single-motor monoplane.
- Materials carefully selected in order to achieve lowest dry weight while maintaining strength.
- Redesigns of some of the components of the craft had to be made to comply with the new 2021 SAE Aero Micro rules set.
- Preliminary design was based off 2020 SAE Aero Micro rules.
- Basis of the scoring system was also changed in these new set of rules [4].
  - Timed assembly of craft no longer a scoring factor nor does the craft need to fit in a pre-dimensioned container.
  - Weight of payload plates carried and number of large or small delivery boxes is a factor in scoring.
  - Time of flight to complete first 180 degree turn in the course now a factor in scoring.
  - Damaged payload will result in deduction of points.
  - Must takeoff from 4’x8’ platform elevated at 24” from the ground.
  - Must be fitted with a 450-Watt power limiter.

Design Description–Wings

- Wings are constructed out of lightweight balsa wood.
- Traditional rectangular shape chosen for optimal lift and strength benefits.
- Fitted with ribs and spars that give it increased strength, rigidity, and resilience.
- Wingspan of 48” -1/16” and a wing area of 258 in^2.
- A brand new laser cutter here at NAU has been already been used to create the ribs of the wings.
- Simulated to generate between 3.5-20 N of lift, depending on angle of attack.

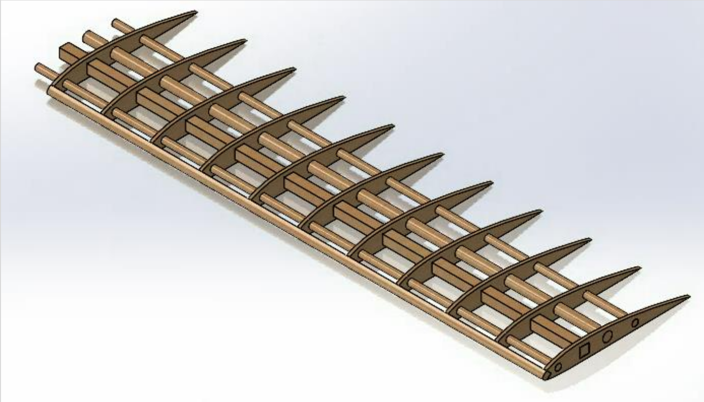


Figure 3: Interior Construction of Wing

Design Description–Fuselage

- Fuselage is composed of the nose, cargo bay, and tail.
- Entire fuselage is constructed out of lightweight foam board material.
- Nose will hold the components of drive system including the motor, battery, electric speed control, and other avionic components.
- Cargo bay will hold both payload types.
- Secured payload is a must, as damaged payload will result in points subtracted from overall score.
- Sleek geometric design for increased aerodynamic efficiency.

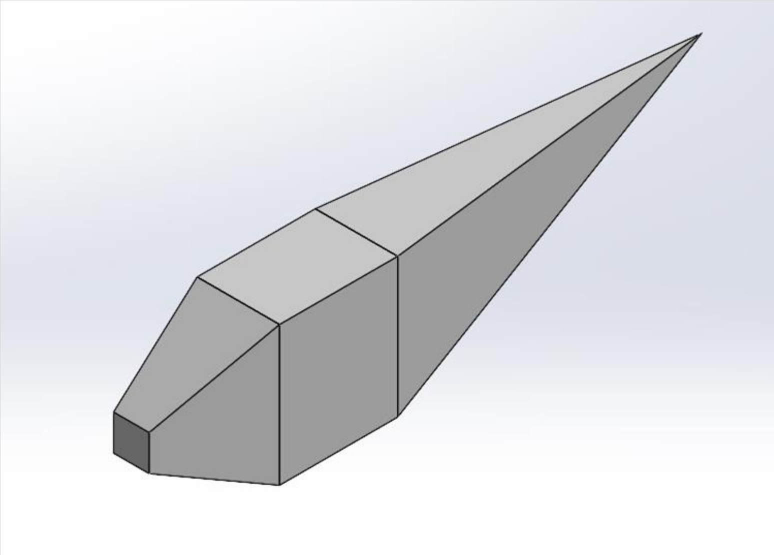


Figure 7: CAD Rendering of Fuselage Design

Design Description–Drive System

- Drive system consists of a motor, propeller, battery, electric speed controller, and more.
- To comply with new rules, must be fitted with a 450-Watt power limiter.
- The motor is capable of producing 800-Watt continuous maximum power.
- The APC 9” diameter with 4.7” pitch propeller allows for excellent balance of thrust and aircraft velocity.
- Current design calculations call for thrust-weight ratio of 1.30 at 7,000 ft elevation.
- Thrust-weight ratio can be improved by increasing diameter of propeller, decreasing dry weight of the craft, and flying at a lower elevation.

Figure 8: Scorpion Hk 2520-1880 Motor [5]

Figure 9: APC 9” dia. 4.7” Pitch Propeller [6]

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

Figure 10: Calculated Thrust of Drive System [7]

Design Description-Landing Gear

- Landing Gear will be composed of a tricycle design.
- Joint landing gear will rest under cargo bay behind where the center of gravity is designed to be located.
- Tricycle design will provide maximum stability and ease of landing.
- Manufactured out of aluminum for minimal weight added to the craft while also strong enough to withstand landing with a weighted payload.
- Will utilize DC servo motors to control the wheels of the landing gear to prevent the craft from steering off of the runway and losing points.

Figure 11: Rear Joint Landing Gear [8]

Design Description–Wing Prototype

- Skeleton balsa wood prototype of the wings.
- Constructed with ribs and spars to provide the wings with additional strength and rigidity, while using minimal material to preserve weight.
- Not yet wrapped in monokote, a lightweight material that will reduce drag
- Will have leading edge to hold together the spars.
- Requires Aileron spaces

Figure 12: Wing Prototype

Design Description– Fuselage Prototype

- Constructed with foam board and small amounts of hot glue.
- Matches the design of our CAD model
- Took less than an hour to manufacture, so it is easily reproducible and editable
- Should meet the requirements of our fuselage design.

Figure 13: Fuselage Prototype

Project Requirements: CRs

Table 2: Customer Requirements

Wingspan Dimension
Electric Motor
Battery Limited to 4 Cell
Power Limiter
Carries Metal Payload Plates
Carries Payload Boxes
Carries Payload Plates In Cargo Bay
One Fully Enclosed Cargo Bay
Securable Payload Plates
Quick Payload Removal
Short Take-Off Distance
Aircraft Range
Controllable in Flight
Fast Aircraft
Can Carry A Lot of Weight
Short Landing Distance
Red Arming Plug
Empty CG Markings
Gross Weight Limit
2.4 GHz Radio Control System
Spinners Or Safety Nuts
No Metal Propellor
No Lead
No Structural Support From Payload
Metal Payload Plate securing Hardware
Low Cost Build
Durable Design

- The wingspan is designed to be 48” -1/16”.
- Figure 14 shows the circuit that will be used which adheres to the CRs.
- Figure 15 shows the 2.4 GHz Transmitter that the team is using to control the aircraft.

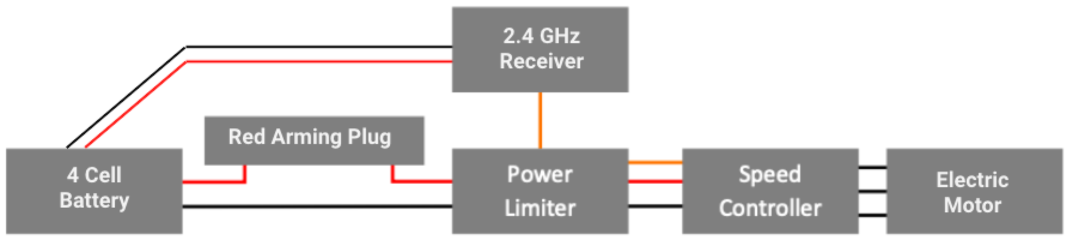


Figure 14: Aircraft Circuit Diagram [modified from 4]

Figure 15: Spektrum DX 8e 2.4 GHz Transmitter [9]

Project Requirements: ERs

Table 3: Engineering Requirements

ERs	Wingspan Length	Battery	Power Limiter	Cargo Bay Volume	Quick Payload Removal	Short Take-Off Distance	Aircraft Range	Fast Aircraft	Can Carry A Lot of Weight	Short Landing Distance	Gross Weight Limit	Radio Control System	Cost	Lift	Thrust	Drag	Ground Control Turn Radius	Reliability	Crashes Before Major Repair
Target Value	48	4	450	180	1	8	350	40	2	200	5	2.4	300	7.5	5	0.25	2	95	1.5
Units	Inches	Cells	Watts	Inches Cubed	Minute	Feet	Feet	Miles Per Hour	Pounds	Feet	Pounds	GHz	US Dollars	Pounds	Pounds	Pounds	Feet	Percent	Crashes
Tolerance	- 1/16	-3	+/- 0	+/- 25	-0.5	-2	+/- 25	+/- 15	+/- 1	-100	+/- 2	+/- 0	+/- 200	+/- 5	+/- 2.5	+/- 0.1	+/- 1	+/- 5	+/- 0.5

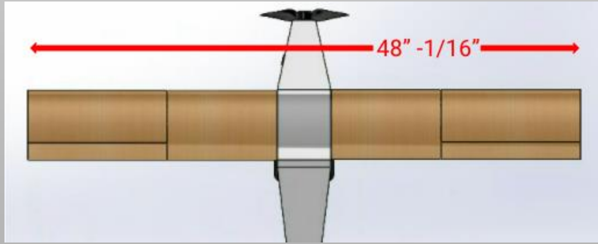


Figure 16: Airfoil Design Length

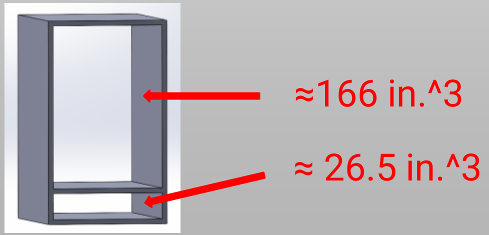


Figure 17: Cargo Bay Volume

Testing & Validation

- The Team will conduct three types of test
  - The first landing and taking off
  - The second durability and quality test
  - The third simulated competition runs
- These test cover the requirements set forth by the competition.
- The team will begin testing in January
  - This allows time for adjustments to be made to the aircraft

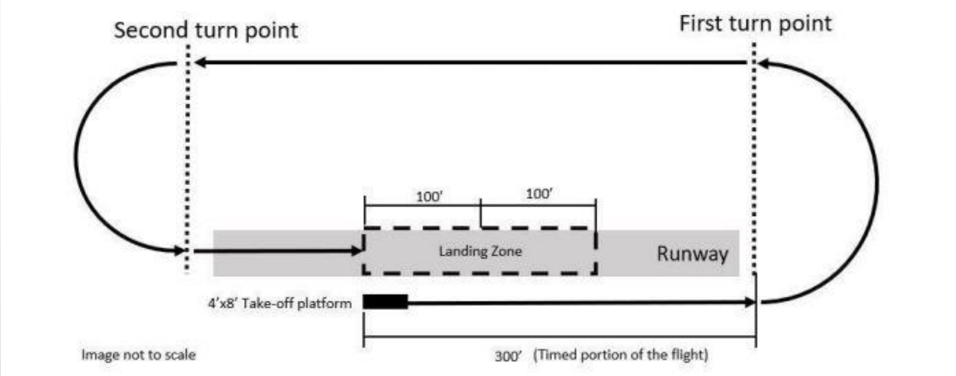


Figure 18: Flight Plan for the Competition [4]

Risk Analysis

- Critical Failure Points
  - Center of Gravity
  - Landing Gear
  - Take Off
- Mitigation Evaluations
  - Airfoil Simulations
  - Center of gravity simulations
- Design Mitigations
  - Tricycle landing gear
  - Multiple batteries

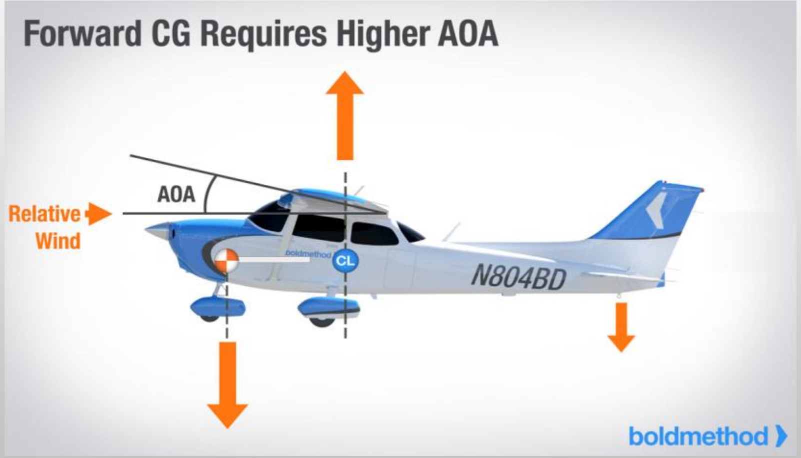


Figure 19: Center of Gravity/Lift Diagram [10]

Final Budget

Team Budget: $1500

Fees

- Competition Fees: $1,100
- Administration Fees: $250

Construction Costs

- Overall Costs (budgeted for multiple builds): $302.11
- Overall Cost of an Aircraft Skeleton: $15
- Cost of Avionics (motor, servos, etc.): $218
- Remainder of costs are for miscellaneous items.

Final Cost of Project: $1,652.11 - The team will look to secure a larger budget.

Table 4: Bill of Materials

Bill of Materials				
Part/Material	Cost Per Unit	Units Required	Total Cost	Supplier
Balsa wood sheets (1/8"x3"x24")	$ 2.00	8	$ 16.00	National Balsa [tko1]
Balsa Wood Spur (Square)	$ 2.99	3	$ 8.97	Hobby Lobby
Balsa Wood Spur (Circular)	$ 0.69	6	$ 4.14	Hobby Lobby
Foamboard(20"x30")	$ 1.00	25	$ 25.00	Dollar Tree [tko2]
Spektrum 2847 motor(3200kV)	$ 40.00	1	$ 40.00	Flite Test [tko3]
Spektrum(30 Amp)	$ 40.00	1	$ 40.00	Flite Test [tko3]
Spektrum(14.8V/2200mAh)	$ 80.00	1	$ 80.00	Flite Test [tko3]
Servo(9g)	$ 42.00	1	$ 42.00	Flite Test [tko4]
Hot glue sticks (1 pack)	$ 12.00	1	$ 12.00	Amazon [tko5]
E-Flite UMX A-10	$ 16.00	1	$ 16.00	Flite Test [tko3]
Servo Rods	$ 8.00	1	$ 8.00	Amazon [tko5]
Propellors	$ 10.00	1	$ 10.00	Flite Test [tko3]
Overall Cost:			$ 302.11	

Future Work - Winter Break and Testing

- Winter Break Plans
  - Construct Fuselage and Wings
  - Purchase Avionics
  - Finish Building Plane before new semester starts

- Testing Plans
  - Week 1 of Spring 2021: Begin Basic Flight Testing
  - Week 3 of Spring 2021: Begin Takeoff and Landing Tests
  - Week 4 of Spring 2021: Perform durability tests to ensure airplane can handle competition requirements

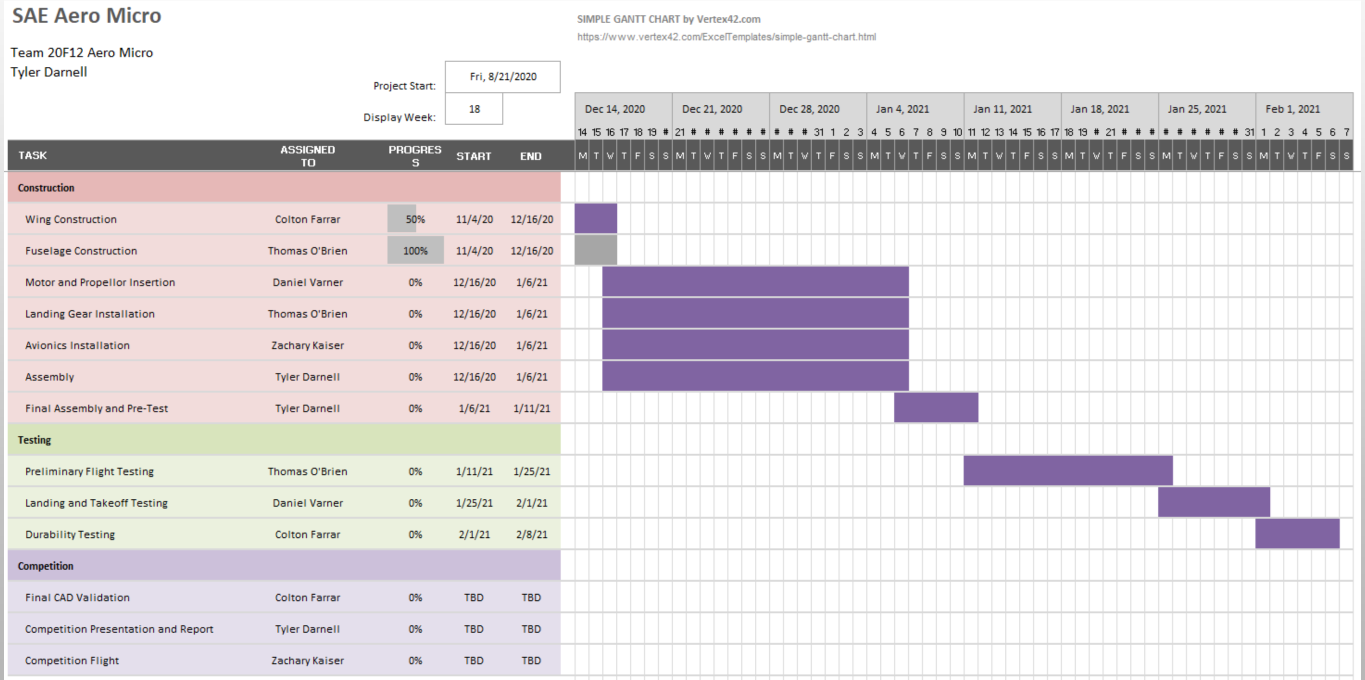
Figure 20: Balsa Wood Ribs Cut with a Laser Cutter

Future Work - Competition

- Complete Final CAD design and Finish Validation
- Prepare Report for Competition (date TBD)
- Prepare Presentation for Competition (date TBD)
- Compete at competition (possibly requires travel) by performing three flights of the required circuit

Figure 21: Flagstaff Flyer's Airstrip Where Testing Will be Performed before Competition

Future Work – Gantt Chart



SAE Aero Micro

Team 20F12 Aero Micro
Tyler Darnell

Project Start: Fri, 8/21/2020
Display Week: 18

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END
Construction				
Wing Construction	Colton Farrar	50%	11/4/20	12/16/20
Fuselage Construction	Thomas O'Brien	100%	11/4/20	12/16/20
Motor and Propellor Insertion	Daniel Varner	0%	12/16/20	1/6/21
Landing Gear Installation	Thomas O'Brien	0%	12/16/20	1/6/21
Avionics Installation	Zachary Kaiser	0%	12/16/20	1/6/21
Assembly	Tyler Darnell	0%	12/16/20	1/6/21
Final Assembly and Pre-Test	Tyler Darnell	0%	1/6/21	1/11/21
Testing				
Preliminary Flight Testing	Thomas O'Brien	0%	1/11/21	1/25/21
Landing and Takeoff Testing	Daniel Varner	0%	1/25/21	2/1/21
Durability Testing	Colton Farrar	0%	2/1/21	2/8/21
Competition				
Final CAD Validation	Colton Farrar	0%	TBD	TBD
Competition Presentation and Report	Tyler Darnell	0%	TBD	TBD
Competition Flight	Zachary Kaiser	0%	TBD	TBD

Figure 22: Gantt Chart of Construction and Testing Timeline

Works Cited

[1] "CASA C-212 Aviocar," *Wikipedia*, 22-Oct-2020. [Online]. Available: https://en.wikipedia.org/wiki/CASA_C-212_Aviocar. [Accessed: 13-Nov-2020].

[2] L. Minton, "Flagstaff Pulliam Airport," *National Weather Service: Observed Weather for past 3 Days: Flagstaff Pulliam Airport*. [Online]. Available: https://w1.weather.gov/data/obhistory/KFLG.html. (accessed: Oct. 25th, 2020).

[3] J. S. Wallace, "INVESTIGATION OF SOLIDWORKS FLOW SIMULATION AS A VALID TOOL FOR ANALYZING AIRFOIL PERFORMANCE CHARACTERISTICS IN LOW REYNOLDS NUMBER FLOWS," O.S.U., Stillwater OK, U.S.A., 2017. Date Accessed: November 11th, 2020. [Online]. Available: https://shareok.org/bitstream/handle/11244/321619/Wallace_okstate_0664M_16133.pdf?sequence=1

[4] "2021 - SAE Aero Design - Rules," SAE International, 21 Sept. 2020. [Online]. Available: https://www.saeaerodesign.com/cdsweb/gen/DocumentResources.aspx

[5] *Scorpionsystem. Scorpion HK-2520-1880KV motor (3.5mm shaft) - Scorpion Power System*, 2019. [Accessed: 11-Nov-2020]. [Online]. Available: https://www.scorpionsystem.com/catalog/helicopter/motors_4/hk-25/HK_2520_1880/.

[6] RC PLANET. 2020. *APC Propellers Slow Flyer Propeller 9 X 4.7 SF APC09047SF*. [online] Available at: https://www.rcplanet.com/apc-propellers-slow-flyer-propeller-9-x-4-7-sf-apc09047sf/. [Accessed 11 November 2020].

Works Cited

[7] Motor and Propeller Thrust Values (eCalc.com). [Online]. Available: https://www.ecalc.ch/motorcalc.php?ecalc&lang=en&weight=1361&calc=auw&motornumber=1&warea=16.77&elevation=2134&airtemp=21&motor=scorpion&type=8|hk-2520-1360&gear=1&propeller=apc_electric&diameter=11&pitch=4.5&blades=2&batteries=lipo_2200mah_-_30/45c&s=3&esc=max_50a&cooling=good (Accessed September 27, 2020)

[8] M. Kharudin. “Main Landing Gear” GrabCad, 12 Oct. 2020. [Online]. Available: https://grabcad.com/library/main-landing-gear-7

[9] “DX8e,” *Spektrum*. [Accessed: 10-Nov-2020]. [Online]. Available: https://www.spektrumrc.com/Products/Default.aspx?ProdId=SPMR8100.

[10] C. Cutler, “How Does CG Affect Aircraft Performance?,” *Online Flight Training Courses and CFI Tools*. [Online]. Available: https://www.boldmethod.com/learn-to-fly/performance/how-does-cg-affect-aircraft-performance/. [Accessed: 14-Nov-2020].