Team Final Approach

20F12: A2 Aero Micro

Final Presentation

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Project Introduction

- The Aero Micro capstone is based upon the SAE Aero Micro competition.
- The goal of the competition is to design a micro airplane that flies an air circuit while carrying maximum payloads, taking off from a small platform, and completing a portion of the circuit as fast as possible [1].
- The team recently dropped out of competition due to changes in the competition timeline.
- With the drop from competition, the team has been working to design and construct thrust and lift/drag test stands, along with testing procedures and methods, in order to aid future NAU SAE Aero Micro teams.

Figure 1: SAE Aero Design Logo (note that the date has not been updated by SAE to the actual competition date)

Project Requirements: CRs

Table 1: 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

- Wingspan is limited to 48”, designed to be 47” +/- 1”.
- Figure 2 shows the integrated Red Arming Plug that is compliant with the SAE regulations.
- Figure 3 shows the circuit diagram that was used, it adheres to the SAE CRs.

Figure 2: Red Arming Plug

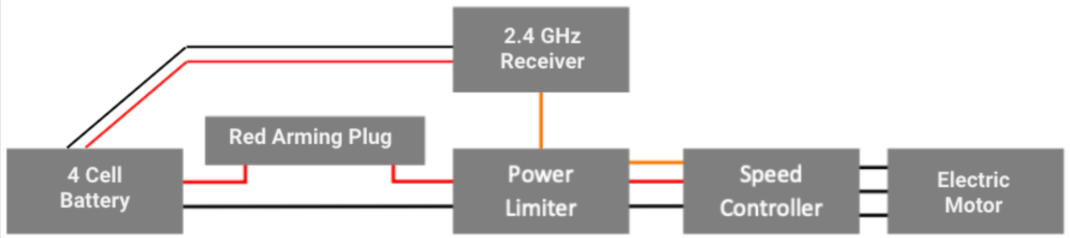

Figure 3: Aircraft Circuit Diagram [modified from 1]

Project Requirements: ERs

Table 2: Engineering Requirements

Ers	Wingspan Length	Battery	Power Limiter	Cargo Bay Volume	Quick Payload Removal	Short Take-Off Distance	Aircraftf Range	Can Carry A Lot of Weight	Short Landing Distance	Groos Weigth Limit	Radio Control System	Cost	Lift (60 MPH)	Thrust	Airfoil Drag	Ground Control Turn Radius	Reliability	Crashes Before Major Repair
Target Value	47	4	450	185	60	7	500	3000	150	1360	2.4	300	4000	2000	50	15	95	1.5
Units	Inches	Cells	Watts	Cubic Inches	Seconds	Feet	Feet	Grams	Feet	Grams	GHz	US Dollars	Grams	Grams	Grams	Feet	Perecent	Crashes
Tolerance	+/- 1	-1	-	+/- 10	-30	+/- 1	+/- 50	+/- 500	+/- 50	+/- 600	-	+/- 150	+/- 500	+/- 250	+/- 15	+/- 5	+/- 5	+/- 0.5
Actual	46.5	4	530.6	195.4	42	8	500+	2500	< 30	1129	2.4	148.85	4078	2061	40	6.5	100	2+

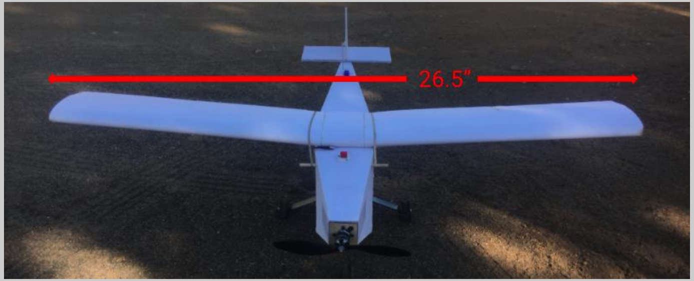

Figure 4: Airfoil Design Length

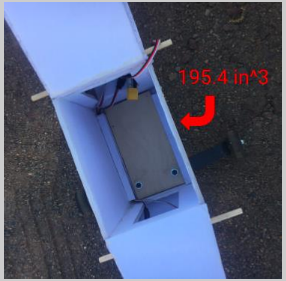

Figure 5: Cargo Bay Volume

Design Decision – Plane

- Team Based Design decision around maximizing scores during flights
- Potential design considerations
    - Extra batteries vs Single
    - Adding dihedral vs Not adding
    - Reinforcing bulkheads vs Not reinforcing
    - Flat bottomed airfoil vs undercambered
    - T-tail design vs Conventional design
- Based off of the budget, scoring equation, and decision matrices the team made various selections in order to maximize performance of the plane

Scoring Equation:

$$Final\ Flight\ Score = FSS = FS_1 + FS_2 + FS_3$$

Where:

$$Flight\ Score = FS = 80 * \frac{\sqrt{W_{Payload} * Bonus}}{T_{Flight}}$$

$$Bonus = 0.5 + (1.0 * N_{Large}) + (0.4 * N_{Small})$$

$N_{Large} = Number\ of\ Large\ Boxes\ Flown$

$N_{Small} = Number\ of\ Small\ Boxes\ Flown$

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

$T_{Flight} = Flight\ Time\ from\ Take - off\ to\ First\ Turn\ (s)$

Figure 7: Breakdown of Scoring for Flights

Table 3: Decision Matrix Used to Evaluate Airfoils

Airfoil Decision Matrix					
Criteria	Weight	Symmetrical	Semi-Symmetrical	Flat Bottomed	Under Cambered
Maximum Lift	0.4	1	2	4	5
Minimal Drag	0.2	4	4	2	1
Maneuverability	0.2	4	4	3	1
Ease of Creation	0.2	3	2	5	1
Total:	1	12	12	14	8
Weighted Total		2.6	2.8	3.6	2.6

Design Description - Plane

- Main design of the craft incorporates a standard, single-motor monoplane design for the performance aspects and ease of manufacturing.
- Wings are a Clark-Y design with a 47.5” wingspan and constructed out of balsa wood and foam board with a 5° dihedral.
- Fuselage constructed out of foam board with dimensions of 6”x6”x4.5” to securely hold cargo.
- Drive system comprised of a 400-Watt (max) motor, 10”x4.7” propeller, and 4-cell 2300mah 14.8-Volt battery.
- Landing gear is a tricycle design to maximize stability and minimize rollovers during landing.
    - Constructed out of aluminum to reduce overall weight and maintain structural integrity.

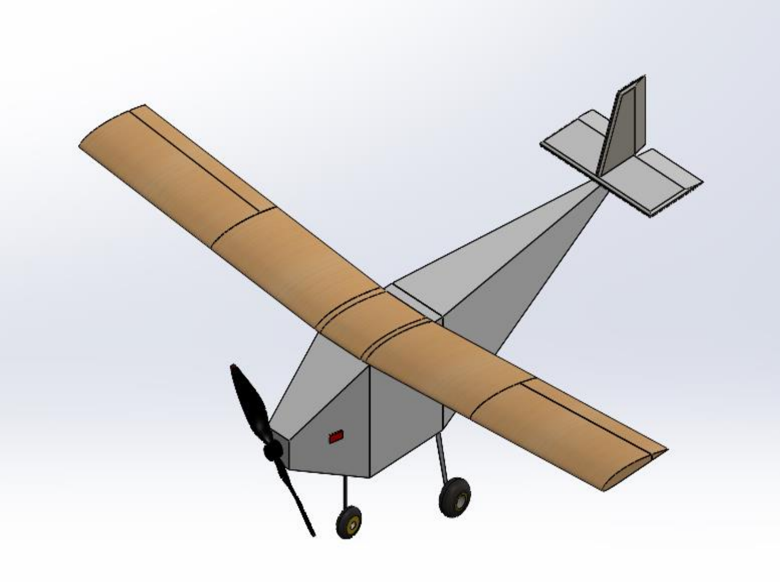

Figure 2: CAD Model of Completed Prototype

Manufacturing of Plane

- Manufacturing took place at Tim Kelly's residence.
- Designed plane within SolidWorks and used LightBurn to configure pieces that needed to be laser cut.
- Most pieces were made of foam board or balsa wood because of their lightweight and relatively strong characteristics.
- Used hot glue to secure all pieces together and construct the plane.

Table 4: Manufacturing Plan Team Followed

Step #	Item
1	Design in SolidWorks
2	Send files to LightBurn
3	Laser cut foamboard
4	Glue ribs & spars for wings
5	Fold and glue pieces
6	Wire and glue all servos & connecting rods
7	Bind avionics
8	Secure motor/propellor
9	Attach landing gear to fuselage
10	Insert battery, ESC, etc.
11	Secure wings on top of fuselage

Current State of Plane

- Plane is mainly made of foam board and balsa wood.
- Utilizes a Clark Y airfoil with a dihedral for added stability and control.
- Uses a 2300 mAh battery and an 1180KV motor to provide the necessary thrust.
- Weighs 2.7 lbs. without any payload plates in the cargo bay.
- Completed first test flight on 2/21/2021 with an empty cargo bay and all customer requirements met.
- After wings have been analyzed using test stands, team plans on completing additional test flights with weighted payload.

Figure 8: Current State of Plane

Test Stand CRs & ERs

- Design and construct thrust, drag, and lift tests stands that will aid in the success of future NAU AERO Micro teams.
- No additional budget provided.

Table 5: Test Stand Engineering Requirements

Ers	Measure Lift	Measure Drag	Measure Thrust	Propeller Size	Max Wattage
Target Range	0 - 5	0 - 3	0 - 4	0 - 12	0 - 450
Units	Kg	Kg	Kg	Inches	Watts
Actual Range	0.6 - 5.6	-	0 - 5	-	0 - 6500

Figure 9: NAU Wind Tunnel

Design Decision –Test Stands

- The team found a thrust test stand to purchase, but had to build a lift and drag stand.
- The main design decision the team had to make was to decide whether to use the wind tunnel, a car stand, or some sort of fan setup.
- The team used the decision matrix to decide on the car mount for several of the high scores shown.
- Another important design decision made was the use of spring scales instead of load cells.
- These designs were implemented into the design description on the following slide, and more decisions were made as the team began the build.

Table 6: Test Stand Decision Matrix

Test Stand Decision Matrix				
Criteria	Weight	Wind Tunnel	Car Mount	Fan Design
Easy to build	0.3	1	5	4
Easy to test	0.1	1	4	5
Inexpensive	0.1	1	4	4
Accurate	0.3	5	3	2
Reproducible	0.2	5	2	2
Total:	1	13	18	17
Weighted Total		3	3.6	3.1

Design Description – Test Stand

- Goal: Measure lift and drag on the airplane wing.
- To achieve this, the team isolated the drag and lift measurements into one degree of freedom using the lift stand section and frictionless roller.
- The test stand uses spring scales to measure the forces exerted on the wing.
- The test stand requires a lot of calibration to remove issues surrounding drag due to the base, the weight of the test stand and wing, and more.

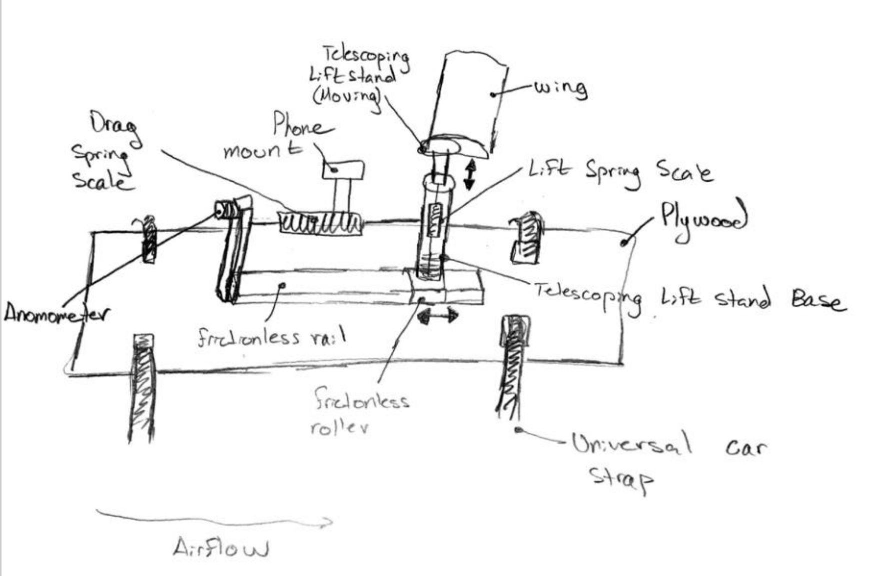

Figure 10: Test Stand Design

Manufacturing and Current State –Test Stand

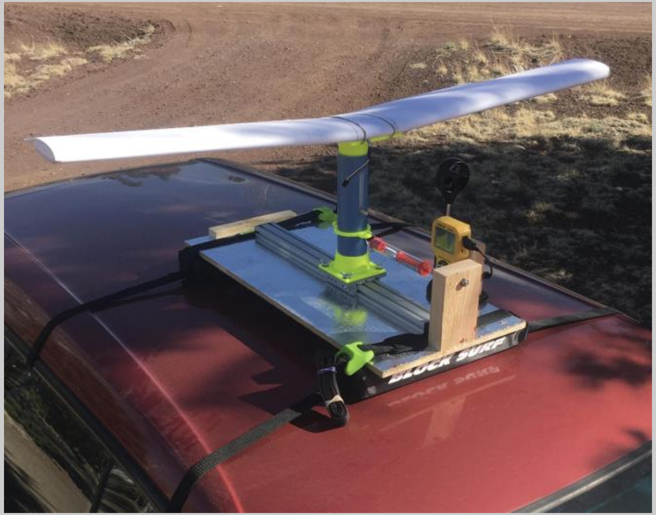

Figure 11: Drag and Lift Test Stand

Figure 12: Camera 1 Perspective

Figure 13: Camera 2 Perspective

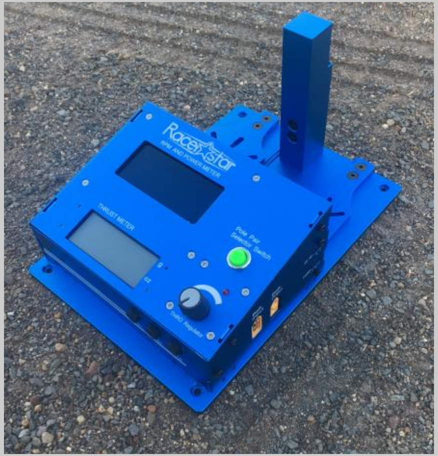

Figure 14: Thrust Test Stand [2]

Budget – BOM: Test Stand

Table 7: Test Stand Bill of Materials Purchased Items

Item Description	Quantity	Cost Per Unit
Set of 6 Spring Scales	1	$21.71
HVAC Anemometer	1	$65.15
Surfboard Car Rack	1	$55.98
Double Rail Carriage	1	$82.57
Double Rail (2ft)	1	$11.77
Rail End Caps (4)	1	$6.00
Rail T-slot Fasteners (2)	1	$3.70
PVC Pipe (1-1/2"x10')	1	$7.96
PVC Pipe (2"x10')	1	$10.74
Washers (1/4")	4	$1.18
Wing Nut (1/4")	4	$1.18
Flat Washers (1/4")	4	$1.18
Hexbolt	4	$0.60
Thrust Test Stand	1	$104.08
	Total:	$373.80

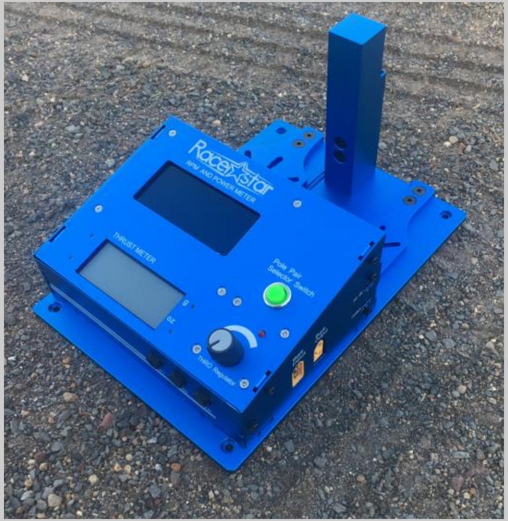

Figure 15: Thrust Test Stand [2]

Budget – BOM: Plane

- Teams Initial Budget $1,500
  - Spent approximately $1222.65
- The team spent 10% on the plane, 25% on test stands, 46.7% on competition fees.
  - Despite withdrawing from competition the team was unable to get a complete refund.
- After Completion of the project the team has $277.35 or 18.5% of the budget left to use on future work.

Table 8: Aircraft Bill of Materials Purchased Items

Item Description	Quantity	Cost Per Unit
ArmSafe Kit w/ 12AWG Wire (Max 80 Amps)	1	$14.50
Balsa Wood (Rectangular Profile)	2	$2.99
Balsa Wood (Circular Profile)	5	$0.69
Dollar General Foam Board	16	$1.00
Dubro Shock absorbing Steerable Nose Gear	1	$6.99
E-Flight T-28 Nose Landing Gear Set	1	$3.99
Flite Test FT 35A ESC w/XT60 Connector	1	$25.99
Flite Test 2.75" Airplane Wheels (2)	1	$6.99
Flite Test 16.5" Pushrods (8)	1	$6.00
Flite Test "Radial 2218B 1180 Kv Brushless Motor	1	$29.99
HD Prop 1-x4.7 Slow Flyer Propeller	3	$4.99
Tattu 4s LiPo Battery 45C (14.8V/2300mAH) x/ XT-60	1	$39.99
	Total:	$148.85

Future Work

- Design mounts to secure GoPro/phone to record the lift and drag force through the spring scales.
- Once test stand is complete, begin data acquisition of the forces the wings experience at various velocities.
- Inventory SAE Aero Micro cabinets in machine shop to ensure future capstone teams have easy access to all parts and do not buy components they already have access.
- Implement load cells into test stand so no GoPro/phone mount is necessary and all data can be more accurately obtained with an Arduino.

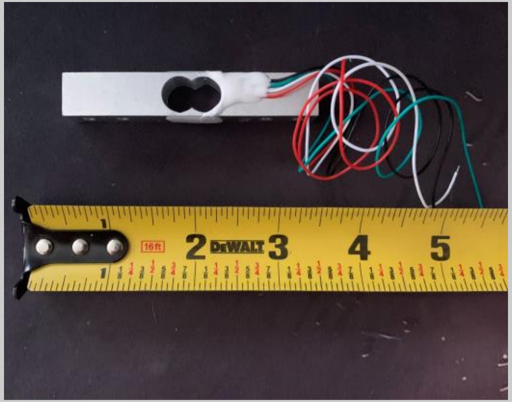

Figure 16: Load Cell Being Implemented into Design

Conclusion

- While the team is disappointed that we were not able to attend competition, the work we have done on test stands has been a suitable replacement.
- The team hopes to finish the project by testing the lift and drag stand, and creating documentation for the following team to use.
- Finally, the team will compile everything purchased, constructed, and written and leave it in a suitable place for the following teams.
- In conclusion, while the the project has taken many turns throughout, the overall results have been satisfactory and should leave a great foundation for those to come after us.

Figure 17: Current Prototype Before Test Flights on 2/21/2021

Thank you!

- The team will now take questions as the powerpoint cycles through the references and appendices.

References

[1] “2021 - SAE Aero Design - Rules,” SAE International, 21 Sept. 2020. [Online]. Available: https://www.saeaerodesign.com/cdsweb/gen/DocumentResources.aspx (Accessed: April 9th, 2021)

[2] Banggood.com, “Racerstar Brushless Motor Thrust Stand V3 For 11mm-59mm Outrunner Motor,” ***www.banggood.com.*** [Online]. Available: https://usa.banggood.com/Racerstar-Brushless-Motor-Thrust-Stand-V3-For-11mm-59mm-Outrunner-Motor-p-1168758.html?cur_warehouse=CN (Accessed: Feb, 28th, 2021).

Appendix A –Bill of Materials (purchased)

Item Description	Quantity	Cost Per Unit
ArmSafe Kit w/ 12AWG Wire (Max 80 Amps)	1	$14.50
Balsa wood (rectangular profile)	2	$2.99
Balsa wood (circular profile)	5	$0.69
Dollar General Foam Board	16	$1.00
Dubro Shock Absorbing Steerable Nose Gear	1	$6.99
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HD Prop 10x4.7 Slow Flyer Propeller	3	$4.99
Tattu 4s LiPo Battery 45C (14.8V/2300mAh) w/ XT-60	1	$39.99
	Total:	$148.85

Appendix B – Bill of Materials (free of charge)

Item Description	Quantity	Cost Per Unit
Apex RC Products #1030 "Y" Harness (3)	1	$0.00
Control Surface Control Horn	4	$0.00
Plywood (1/8" Thick)	1	$0.00
Plywood (1/4" Thick)	1	$0.00
Rear Landing Gear	2	$0.00
Spectrum DX 8e Transmitter	1	$0.00
Spektrum Receiver	1	$0.00
XT-60 (Female) Connector	1	$0.00
9g Servo	5	$0.00
	Total:	$0.00