College of Engineering, Informatics,
and Applied Sciences

SAE Aero Design West - Micro Class

Flap Jacks #329

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2018-2019

Project Sponsor: SAE, Northern Arizona University, Quality Vans and Specialty Vehicles, Coconino High School Engineering Group

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APPENDIX A

STATEMENT OF COMPLIANCE

Certification of Qualification

Team Name	**Flap Jacks**	Team Number	**329**
School	**Northern Arizona University**		
Faculty Advisor	**Dr. John ~~Terster~~** Tester		
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Statement of Compliance

As faculty Adviser:

JIT (Initial) I certify that the registered team members are enrolled in collegiate courses.

JIT (Initial) I certify that this team has designed and constructed the radio controlled aircraft in the past nine (9) months with the intention to use this radio controlled aircraft in the 2019 SAE Aero Design competition, without direct assistance from professional engineers, R/C model experts, and/or related professionals.

JIT (Initial) I certify that this year's Design Report has original content written by members of this year's team.

JIT (Initial) I certify that all reused content have been properly referenced and is in compliance with the University's plagiarism and reuse policies.

John I. Tester

Signature of Faculty Advisor

Signature of Team Captain

Note: A copy of this statement needs to be included in your Design Report as page 2 (Reference Section 4.3)

Contents

List of Figures and Tables

List of Symbols and Acronyms

δ_B	Maximum deflection at B
ρ_∞	Density upstream
μ	Dynamic viscosity
ABS	Acrylonitrile Butadiene Styrene
AR	Aspect ratio
b	Wing length
e	Wing Oswald efficiency factor
c	Wing chord length
$\bar{c}$	Wing mean aerodynamic chord
c.g.	Center of gravity
C_D	Coefficient of drag
$C_{D,i}$	Induced drag
$C_{D,o}$	Parasitic drag at zero lift
C_L	Coefficient of Lift
CAD	Computer aided design
D	Drag
E	Modulus of elasticity
I	Moment of inertia
L	Lift
L_{AB}	Length of beam from A to B
l_t	Distance from vehicle center of gravity to tail quarter chord
q	Declining distributed load
q_∞	Dynamic pressure upstream
Re	Reynolds Number
RC	Remote controlled
S	Wing planform area
S_t	Tail planform area
SAE	Society of automotive engineers
V_H	Horizontal tail volume ratio
V_∞	Velocity upstream

1.0 Executive Summary

The SAE Aero West design competition teaches students how to complete a year-long project and successfully design aspects of an aircraft. The micro class competition focuses on specific components of aircraft such as assembly and disassembly, weight minimization, and payload attachments. The micro aircraft that the team at Northern Arizona University designed was created to meet the competition requirements and uses a Clark Y 11.4% airfoil, an RC plane racing motor, a 7”x4” propeller, a unique bolt payload attachment system, and modular sub assembly attachment systems for the tail, wing, and fuselage. Based on initial calculations, the lift and drag generated for cruise by the wing at 30 mph is 1.4 lbs. and 0.12 lbs., respectively. The maximum dynamic thrust produced is 1.4 lbs. at 30 mph, which is much greater than the drag that is generated. The maximum weight of the aircraft is 0.9 lbs. and can carry approximately 0.3 - 0.5 lbs. of payload. The modular designs use brackets and pins to attach subassemblies and meets the competition requirement of fitting within a fixed volume box and the requirement of assembling the aircraft within a specific time frame. Based upon the competition requirements and the design of the aircraft, the aircraft should place within the top five of teams in the micro class competition.

1.1. System Overview

The selected aircraft design has a wing span of 30 inches, a wing chord length of 4 inches, an 850 mAh battery, a 7”x4” propeller, an 1850 kV electric motor, and has control surfaces that include ailerons, elevators, and a rudder. With these selected components, the aircraft has a weight of approximately 0.8 lbs. and can generate a thrust to weight ratio of 2.66:1 with a flight time of 5 minutes. The wing and tail sections are constructed using birch ribs and spars with Monokote stretched and applied over the length of the sections. The wing is split into two 11-inch sections with one 8- inch section. The tail has one elevator that will span the length of the 9-inch horizontal stabilizer. A rudder, 5” tall by 1” wide, will accompany the vertical stabilizer. The aileron dimensions are 10”x1” making the aircraft maneuverable, even with payload under the wings.

1.2. Competition Projections

The scope of the project is to design and build a micro aircraft. The Northern Arizona University micro team plans to compete a micro aircraft at the SAE Aero West competition in April 2019. The SAE Aero West competition is an international competition where universities compete to win monetary prizes and potential job offers. The micro class involves designing an all-electric, radio-controlled aircraft that focuses on minimizing weight while maximizing payload. A constraint is placed on the size of the aircraft where the entire aircraft and necessary parts must fit within a cardboard container with maximum outside dimensions of 12.125 inches x 3.625 inches x 13.875 inches. To prepare for competition, construction, testing, design iterations, and report generations that meet competition guidelines must be completed.

1.3. Discriminators

Discriminating design features are found throughout the design of the aircraft. The most notable discriminating factor of the design is the modularity of the subassemblies and the disassembly of each part. Specifically, the Lego-type fit of the fuselage components that are easily replaceable and are placed correctly due to the interlocking shape. The next discriminating factor is the plastic bracket that connects the three main beams within the fuselage to the tail and centers each piece within the design. Lastly, the wing connectors are designed with small turned aluminum clips that benefit assembly and are unlikely to be replicated by competitors.

2.0 Schedule Summary

The project was assigned the beginning of September of 2018. Preliminary research and models were completed by the start of November. Then, parts for an alpha prototype were ordered and subassemblies were built by January of 2019. The report was started in January and was due by late February 2019. The beta prototype was built in February and tested in March of 2019. The final competition plane was iterated and built based on the results of this initial flight to be prepared for the competition in April 5, 2019.

3.0 Design Layout & Trade Offs

3.1. Overall Design Layout and Size

The size of the aircraft is as follows: tip-to-tail length is 18 inches; wingspan is 30 inches; fuselage is 2.5 inches x 2.5 inches x 9 inches. More detailed dimensions including center of gravity location can be found in the 2D drawing shown in the Drawing 11x17 section.

3.2. Optimization

3.2.1. Competitive Scoring and Strategy Analysis

The team's strategy for a successful competition is to excel in the assembly demonstration, report, and presentation, as those points are critical to success. The strategy for trails is to use a predetermined load for the first run and then adjust payload as necessary. It is important to maintain reliability as a major requirement for competing is that every run is completed with payload. The team would like to carry the maximum payload possible but understands flight conditions on any given day can be poor which is why the focus is on various parts of the competition.

3.2.2. Optimization and Sensitivity Analysis

There are two major subsystems of the aircraft that have been carefully analyzed and optimized. These subsystems are the electronics subsystem and the wing subsystem. The propeller was designed based on aircrafts approximately the size of the one built for competition and a desired value was selected. Due to the plane carrying payload under the wing, there is ample room for a larger diameter propeller. This resulted in a 7-inch diameter propeller. From there, the motor was sized and an 1810 kV scorpion SII was chosen due to the thrust needed and recommendations based on propeller size. Using an Excel sheet with an equation derived for dynamic thrust, pitch was adjusted to maximize static thrust for takeoff and maximum thrust at a cruising speed of 30 mph. Figure 1 shows the thrust to speed plot [1].

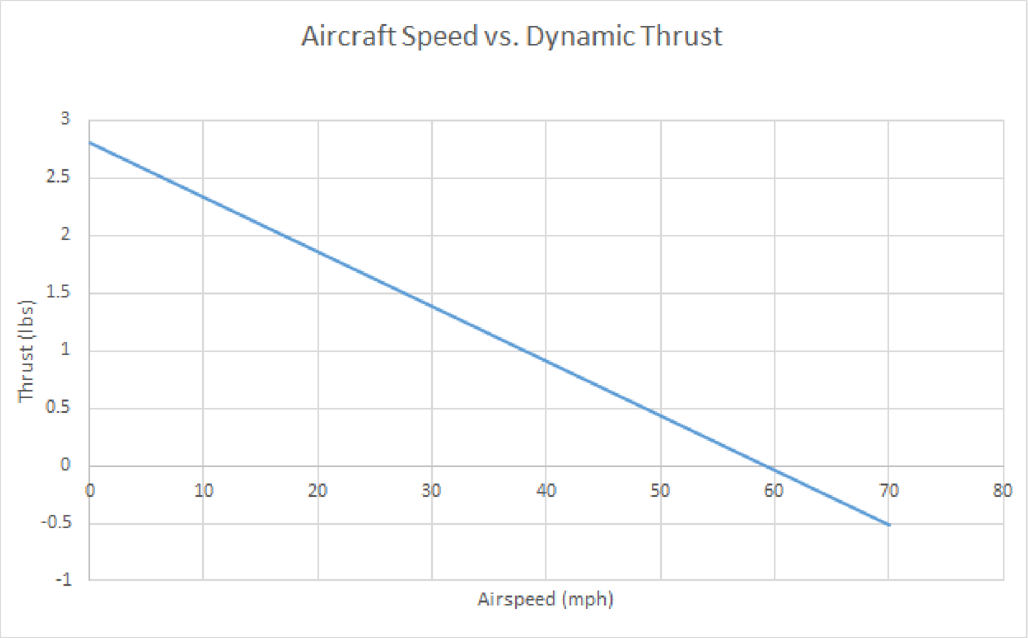

Figure 1: Thrust vs. Speed

The plot shows that the plane will be able to fly at the desired cruising speed of 30 mph. The dynamic thrust generated is 1.4 lbs., which is greater than the weight of the aircraft plus the drag forces. Based on the results of this mathematical simulation, a 7x4 APC E-prop was chosen. Finally, a battery was chosen using an online calculator that would give at least 4 minutes of flight time and minimized weight [2]. An 800 mAh battery was chosen that is a 3 cell LiPo and meets the rule requirements given.

The second subsystem that was optimized was the wing and control surfaces. Using the rule of thumbs for aircraft design found in Appendix A, a desired chord length and aspect ratio were selected. The wing was originally designed using a 3.5-inch chord to minimize space usage within the box requirements and had an aspect ratio of 7. A wing was designed that was 22.5 inches in length and the tail had a horizontal stabilizer that was 25% of the wing planform area and a vertical stabilizer that was 10%. Control surfaces were sized using the same rule of thumbs. The results were ailerons that were 7” x 1”, an elevator that was 9” x 1”, and a rudder that was 5” x ½”. Using the dimensions stated and a Clark Y-11 airfoil, the aircraft physics were modeled in RealFlight8 (a model aircraft simulation software). Using this method of analysis, the wing chord length was increased to 4 inches and the wing length was increased to 30 inches for a new aspect ratio of 7.5. The installation incidence angle on the wing was set to 1^o from 3^o and the control surfaces were re-sized and optimized. This resulted in ailerons that are 10” x 1”, an elevator size that is 9” x 1”, and a rudder that is 5” x 1”. These changes made the aircraft more controllable and capable of carrying more payload as a result of more lift.

3.3. Design Features and Details

The sub-assemblies in the aircraft were sized based on the optimization discussed in section 3.2.2. Notable design features are related to assembly and compact features but also to how the payload will be mounted to the plane. Most notably, is the interlocking nature of the pieces that comprise the fuselage and tail. The design of these pieces are instrumental in making assembly and repair of the fuselage quick and easy as it aligns the pieces and provides additional support. Another key feature related to assembly is how the wing sections slide and lock together. This is accomplished using a small amount of hardware and machined aluminum end pieces that centers dowels with drilled holes and provides consistent placement and a rigid fixture to the aircraft. Lastly, the payload attachment is creatively designed. The payload mounting system is a 3D printed spacer that is built into a wing rib. This piece has a small protrusion on the bottom that separates the payload from the bottom of the airfoil to minimize the effects of its shape on the aerodynamics of the wing. This makes attaching payload easy and does not require disassembly of any part of the aircraft to remove the payload for weighing. Table 1 shows the aircraft components and their size needed for the electronics sub assembly.

Table 1: Aircraft components

Component	Size	Number
Motor	1850 Kv	1
Battery	800 mAh	1
Servo	7.5 g	4
Electronic Speed Control	30 A	1
Receiver	N/a	1

3.4. Interfaces and Attachments

Due to the competition requirements of containing the aircraft within a box, aircraft attachment is an important consideration. The fuselage is the main structure that each subassembly attaches to. The center section of the wing is bolted to a 3D printed ABS plate with 2mm bolts that are not disconnected unless the entire wing need replaced. That plate, with the wing center section, then mounts to the fuselage with four posts and clips. The outer wing sections are inserted into the center section, locking their displacement and rotation in place. The tail section contains a one-piece tail shaft and vertical stabilizer that slides into a 3D printed bracket that has two bolts to secure them in place. Then, the horizontal stabilizer slides onto the end of the tail shaft and is bolted in place. A built in battery tray uses Velcro to wrap the battery, which keeps it secure and protected from puncture.

4.0 Loads and Environments, Assumptions

4.1. Design Loads Derivations

The design loads are the loads that each assembly experiences. All loads were assumed to be greater than what would be experienced to maintain a conservative estimate in constructing the aircraft. Assumed loads are shown in table 2.

Table 2: Load assumptions

Location	Amount (lbs.)
Wing	2.5
Tail shaft	3
Landing assembly	3

The first load is the load on the wing. A load of 2.5 lbs. is the maximum calculated load at the center of the planform area. The Reynolds number was assumed to be around 50,000 and the angle of attack before stall is 10.75^o, which is the location of maximum lift. The loads that the tail shaft and the landing assembly were assumed to be 2 times the weight of the plane with payload. This is a conservative estimate of loading as it is unlikely to occur due to the effects of the glide slope of the aircraft.

4.2. Environmental Considerations

The two main environmental considerations are wind and altitude. The wind affects the ability to fly due to the impacts on controllability during flight. The second consideration is altitude. Northern Arizona University sits at 7000 ft above sea level so the testing of the aircraft is not accurate to the altitude conditions at sea level in Van Nuys. As a result, less lift and thrust is created during testing which corresponds to relying on mathematical predictions of payload capacity during competition.

5.0 Analysis

5.1. Analysis Techniques

5.1.1. Analytical Tools

The primary tools used for analysis were SolidWorks and MATLAB. SolidWorks was used to design the plane and determine component placement and weight as well as evaluate the effect of components on the center of gravity of the plane. MATLAB was used to calculate lift, drag, stability, and wing deflection. Lastly, a simple flow analysis using Ansys and a Reynolds number of 50,000 was performed on the payload and concluded that very little drag would be induced by it.

5.1.2. Developed Models

To see effects of take-off, turning flight, and landing, the RealFlight 8 flight simulation software was used. The software allowed modeling of physics and environmental effects to visually see performance of the aircraft. Using this software, small changes were made to make flight adequate. These changes included increasing the chord length and wing length, adjusting control surface sizing, and correctly placing the wing over the c.g. This software was essential in modeling how hand launching would affect take-off, how ailerons and control surfaces would control banking, and how much landing distance would be needed to successfully land.

5.2. Performance Analysis

5.2.1. Runway/Launch/Landing Performance

Due to the aircraft being hand launched, the angle of attack of the aircraft will be greatly increased during launch. The aircraft will be thrown upwards at an angle of attack of about 30 degrees with thrust activating once the aircraft is separated from the hand. This is to ensure that the aircraft will not nose dive and a proper flight path can be generated. Per the SAE rules with a maximum of 200 ft landing distance, the aircraft will be tail controlled during landing. Once touch downed, the aircraft will yaw to decrease the distance needed to stop. The estimated landing distance is 100 ft, which is well under the 200 ft maximum requirement.

5.2.2. Flight and Maneuver Performance (Incl. Surface Sizing)

Using the flight simulation software and general rules of thumb for aircraft design, the control surfaces and aspect ratios were fine tuned. The aspect ratio of the aircraft is 7.5. A smaller aspect ratio correlates to more maneuverability due to smaller moments of inertia [3]. This is a good aspect ratio for this aircraft due to the need for gliding during landing and not needing to make tight banks in flight.

5.2.3. Shading and Downwash Analysis

A MATLAB script was generated to determine the effects of downwash on drag. Equation 1 was used to calculate the Reynolds number of the aircraft.

$$Re = \frac{\rho_\infty V_\infty c}{\mu} \tag{1}$$

A Reynolds number of 50,000 was calculated for the aircraft but could reach a maximum of 100,000. Using the Clark Y 11.4% airfoil, text files were inputted and coefficients of drag versus angle of attacks were plotted [4]. Figure 2 shows the plots generated at two different Reynolds number.

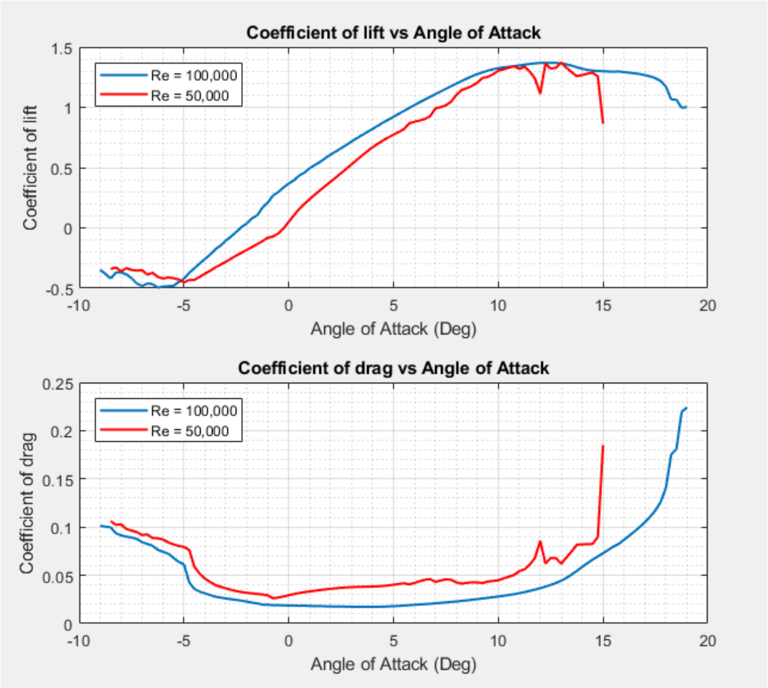

Figure 2: Lift vs. drag at varying angle of attacks

Using these text files and plots, the drag at various operating speeds were plotted. Equation 3 was used to calculate the drag [5].

$$D = C_D q_\infty S \tag{3}$$

Using this equation with the value of coefficient drag at 50,000 Reynolds number being 0.054, and at 100,000 Reynolds number being 0.04, a plot was generated. Figure 3 shows the maximum drag and the drag at cruise angle of attack.

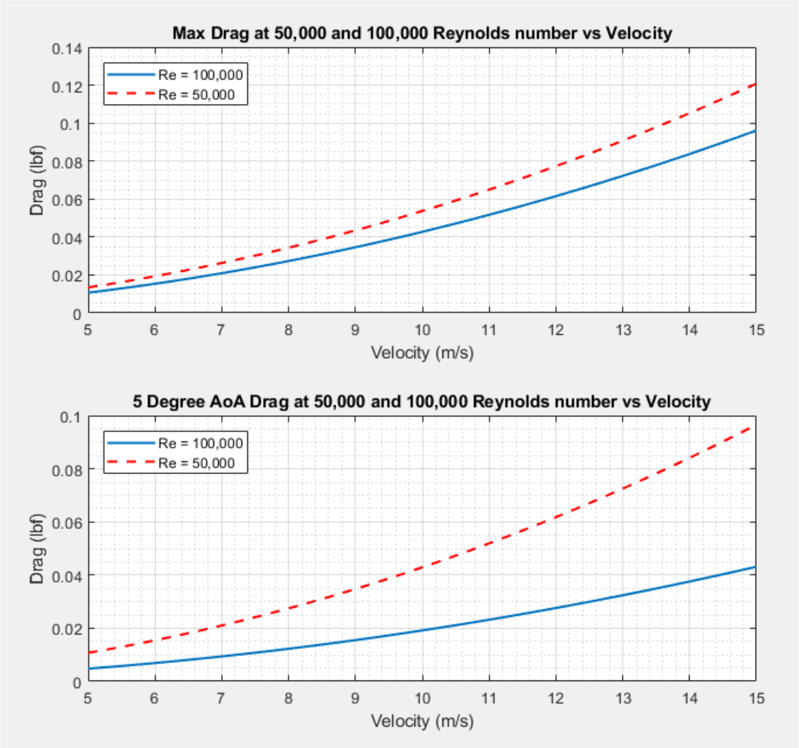

Figure 3: Drag vs. velocity at varying Reynolds numbers

As shown in Figure 3, the maximum drag is 0.09 lbs. assuming velocity is 13 m/s.

Equation 4 was used to calculate the induced drag effects [5].

$$C_{D,i} = \frac{{C_L}^2}{\pi e AR} \tag{4}$$

Equation 5 was used to calculate the total coefficient of drag [5].

$$C_D = C_{D,o} + C_{D,i} \tag{5}$$

Figure 4 shows the downwash effected drag at cruise angle of attack over varying velocities.

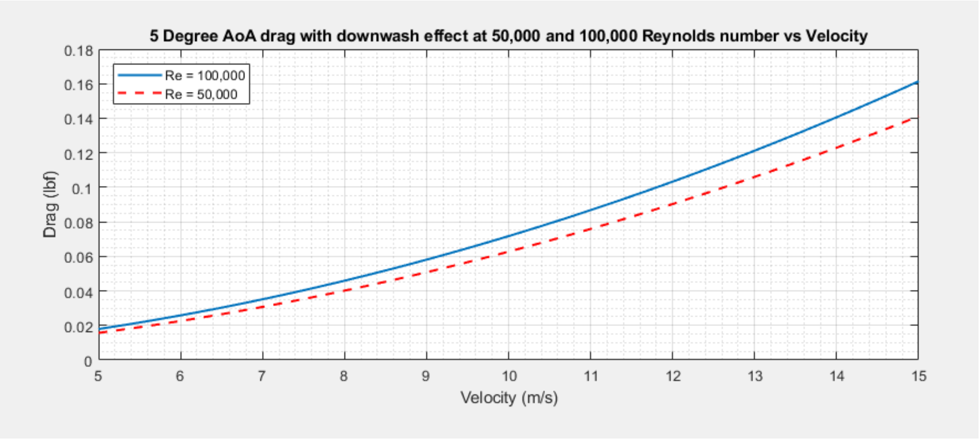

Figure 4: Cruise drag with downwash effects

If the flying speed of the aircraft is 13 m/s and the Reynolds number is 50,000, the maximum drag with downwash effects is about 0.12 lbs. over the wing. This effect is not extremely significant due to the thrust being much greater than this.

5.2.4. Dynamic & Static Stability

The pitch stiffness for static longitudinal stability is heavily influenced by center of gravity placement and the horizontal tail volume ratio [6]. Following typical placements of c.gs for aircraft being around 25% of the mean chord, the aircraft was designed to place the c.g. on the mean chord to achieve 25% ± 2%. This placement helps achieve stability by minimizing the amount of pitching that occurs in flight.

The pitching moment is also influenced by the horizontal tail volume ratio due to the effect that this ratio has on pitch sensitivity. Equation 6 was used to calculate the ratio.

$$V_H = \frac{l_t S_t}{\bar{c} S} \tag{8}$$

For an aircraft to perform reasonably, V_H falls between 0.3 and 0.6 [7]. The V_H for this aircraft was determined to be 0.619. This is slightly higher than the maximum range which will influence the aircraft’s pitch behavior to not be extremely sensitive to the placement of the c.g. and will be able to resist perturbations that occur in flight. Due to this higher horizontal tail volume ratio and the placement of the c.g., the pitch stiffness of the aircraft is high and can resist and recover from perturbations in flight.

The short period mode of the dynamic longitudinal stability is largely determined by the vehicle pitch stiffness. The vehicle pitch stiffness of the aircraft is high which correlates to a small period during the short period mode. The period of the short period mode determines how long the mode will last and a small period corresponds to the aircraft recovering quickly to any perturbation that is experienced during flight. This is excellent for the aircraft because any turbulence experienced will be damped out quickly and will not drastically affect the flight path.

5.2.5. Aeroelasticity

Due to the complexity of calculating aero elasticity, focus was turned to the most critical aspect being the deflection of the wing. To simplify the math, the wing could be modeled by a cantilever beam with a distributed load as shown in figure 5.

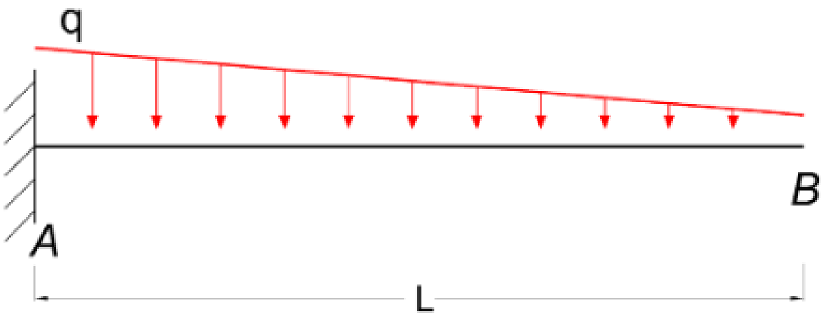

Figure 5: Cantilever beam with distributed loading [8]

Equation 9 was used to calculate the maximum deflection.

$$\delta_B = \frac{qL_{AB}{}^4}{30EI} \quad (9)$$

To approximate accurate deflections, the combined area of the spars was approximated as the area of a single circle and the moment of inertia was calculated for a solid cylinder. The modulus of elasticity of pine is 570 kPsi and was used for the calculations due to the spars of the wing being made of pine dowels [9]. The force of lift was 2.5 lbs. based on maximum lift calculations.

Once the parameters were defined and equations were selected, MATLAB was used to calculate the deflection at point B for the force of lift. This result is shown in table 3.

Table 3: Deflection results

Deflection Category	Results in inches
Deflection from Lift	0.6539

Based on this result, the performance characteristics are not likely to be significantly affected by the deflection of the wing due to lift. As a result, the team feels this design is a safe design for competition.

5.2.6. Lifting Performance, Payload Prediction, and Margin

The lift generated by the wing is determined by the coefficient of lift, the dynamic pressure upstream, and the planform area. Equation 10 was used to determine the lift of the wing [5].

$$L = C_L q_\infty S \tag{10}$$

As shown in figure 6, the lift generated by the wing at cruise is about 1.4 lbs. at 50,000 Reynolds number based on an aircraft speed of 13 m/s.

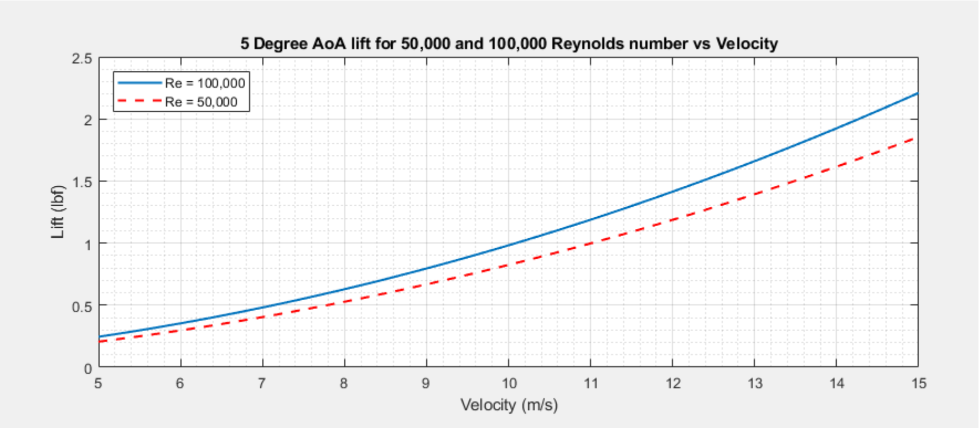

Figure 6: Lift generated at cruise

The maximum lift generated was about 2.5 lbs. based on the coefficient of lift just before stall. Assuming the aircraft weighs a maximum of 0.9 lbs., the minimum payload prediction is 0.3 - 0.5 lbs. Any weight that is eliminated from the overall weight of the aircraft can be converted into payload weight. With an optimal weight of the aircraft being 0.75 lbs., the payload prediction is 0.65 lbs. This would correlate to a payload fraction of 87% and a flight score of 1.67. This payload fraction would correspond to at least a top three finish based on past competition results.

5.3. Structural Analysis

The aircraft's structure can be affected by a couple key subassemblies. These subassemblies are the fuselage and the wing. The first iteration of the aircraft involved small, very weak, fuselage ribs. This contributed to the fuselage unable to support its own weight and resulted in fracturing and failure. A new design was developed where the ribs were much thicker to adequately support the aircraft during flight. The wing has several key parameters that contributes to the structure. These parameters are shown in table 4.

Table 4: Wing support components

Name	Critical Value
Main Wing Length	30 inches long
Chord Length	4 inches long
Wing ribs	16

The wing length combined with dowel rods are adequately supported for flight performance. If the wing length increase, the result would have an increase in deflection at the tip of the wing which could cause failure. A chord length increase would increase the amount of dowels needed for support. This increase would correspond to an increase in weight and could be inadequate for the necessary flight performance. The wing ribs are the main contribution to the structure of the wing. The wing ribs combined with the dowels create a stable platform for wing due to the interlocking of each component. An increase in wing ribs would also increase the weight of the wing which could collapse the fuselage and cause failure. Each parameter and subassembly that were chosen for the aircraft are properly equipped to handle the loads experience during flight based on simulation and hand calculations.

5.3.2. Mass Properties & Balance

The materials used for construction of the aircraft are shown in Table 5.

Table 5: Building materials

Materials	
Balsa/Birch/Pine	Wood Glue
ABS	Motor and other Electronics Devices
Monokote	

For the manufacturing of aircraft, main components of the aircraft were made using birch wood in place of balsa due to the significant strength increase and slight weight increase. The wood glue and Monokote had minimal weight impact on construction due to the density and amount used of both materials. The 3D printed ABS materials had significant impact on the mass of the aircraft because the density difference between the plastic and the wood used was much greater. Most of the weight of the aircraft comes from the electronics used but cannot be changed due to the optimization of each component for flight performance. The final weight of the aircraft will be approximately 0.85 lbs when fully assembled.

6.0 Assembly and Subassembly, Test and Integration

Preliminary testing of the aircraft was done by modeling the physics of the plane in RealFlight8 and flying the computerized model. From this testing phase, changes were made to the wing length, control surface dimensions, and c.g. location. Using the results from this testing, a SolidWorks model was adjusted to conform to the requirements of manufacturing. Once the aircraft was manufactured and constructed, final test flights and iterations were completed to modify small aspects of the aircraft.

7.0 Manufacturing

The manufacturing process for the aircraft included laser cutting, turning, 3D resin printing, Monokote covering, and the creation of wing jigs to pursue a dimensionally accurate and consistent final product. First, all wood products and assemblies were laid out and laser cut. Aluminum pieces that connect the wings were turned carefully on a lathe. Wing jigs were then designed and printed using a 3d resin printer and AB material. The wing ribs were laid out inside the jig, checked for tolerances, and glued into place. The leading and trailing edges then were glued into place and the wing was sanded to final dimension and surface finish. The machined wing clips were glued to the end of each spar rod on the left and right wing, respectively. Parallel to the construction of the wing, the fuselage was glued together and the tail section was covered in Monokote. Lastly, the fuselage and the wing were wrapped in Monokote after the electronics were placed and the subassemblies were assembled to complete the final assembly.

8.0 Conclusion

In conclusion, the aircraft is aerodynamically capable of carrying the predicted payload of 0.3-0.5 lbs.; is structurally strong enough to support the loads experienced during flight and landing; and meets all requirements as set out by SAE rules and guide lines. The lift generated during cruise flight is 1.4 lbs. with 0.12 lbs. of maximum drag. The modular components of the fuselage and wing create small deflections during take-off, flight, and landing. Based on the analysis done, the plane should be place in the top five of competition teams at the competition in April.

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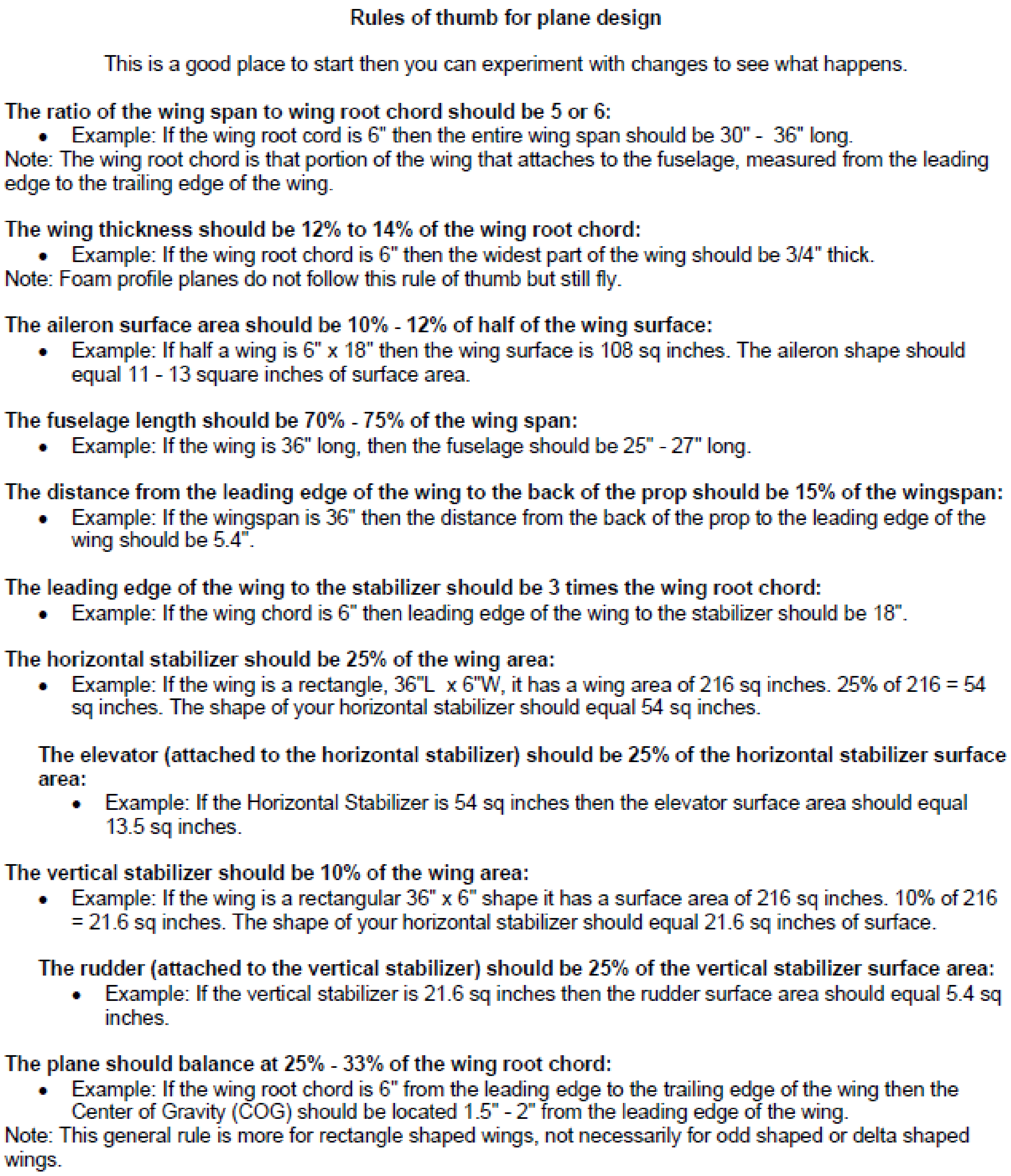
Appendix A – Supporting Documentation and Backup Calculations



Rules of thumb for plane design

This is a good place to start then you can experiment with changes to see what happens.

The ratio of the wing span to wing root chord should be 5 or 6:

- Example: If the wing root cord is 6" then the entire wing span should be 30" - 36" long.

Note: The wing root chord is that portion of the wing that attaches to the fuselage, measured from the leading edge to the trailing edge of the wing.

The wing thickness should be 12% to 14% of the wing root chord:

- Example: If the wing root chord is 6" then the widest part of the wing should be 3/4" thick.

Note: Foam profile planes do not follow this rule of thumb but still fly.

The aileron surface area should be 10% - 12% of half of the wing surface:

- Example: If half a wing is 6" x 18" then the wing surface is 108 sq inches. The aileron shape should equal 11 - 13 square inches of surface area.

The fuselage length should be 70% - 75% of the wing span:

- Example: If the wing is 36" long, then the fuselage should be 25" - 27" long.

The distance from the leading edge of the wing to the back of the prop should be 15% of the wingspan:

- Example: If the wingspan is 36" then the distance from the back of the prop to the leading edge of the wing should be 5.4".

The leading edge of the wing to the stabilizer should be 3 times the wing root chord:

- Example: If the wing chord is 6" then leading edge of the wing to the stabilizer should be 18".

The horizontal stabilizer should be 25% of the wing area:

- Example: If the wing is a rectangle, 36"L x 6"W, it has a wing area of 216 sq inches. 25% of 216 = 54 sq inches. The shape of your horizontal stabilizer should equal 54 sq inches.

The elevator (attached to the horizontal stabilizer) should be 25% of the horizontal stabilizer surface area:

- Example: If the Horizontal Stabilizer is 54 sq inches then the elevator surface area should equal 13.5 sq inches.

The vertical stabilizer should be 10% of the wing area:

- Example: If the wing is a rectangular 36" x 6" shape it has a surface area of 216 sq inches. 10% of 216 = 21.6 sq inches. The shape of your horizontal stabilizer should equal 21.6 sq inches of surface.

The rudder (attached to the vertical stabilizer) should be 25% of the vertical stabilizer surface area:

- Example: If the vertical stabilizer is 21.6 sq inches then the rudder surface area should equal 5.4 sq inches.

The plane should balance at 25% - 33% of the wing root chord:

- Example: If the wing root chord is 6" from the leading edge to the trailing edge of the wing then the Center of Gravity (COG) should be located 1.5" - 2" from the leading edge of the wing.

Note: This general rule is more for rectangle shaped wings, not necessarily for odd shaped or delta shaped wings.

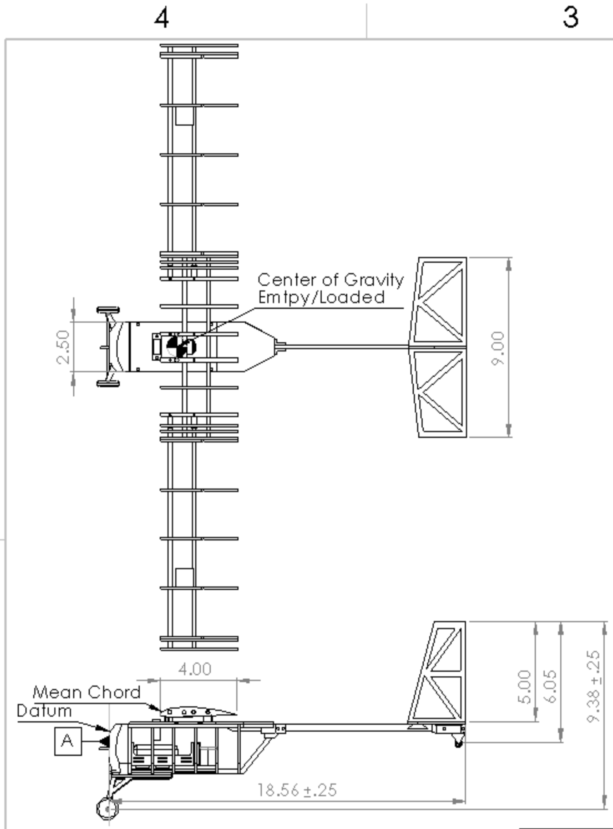
Figure 7: Rules of thumb for plane design [10]

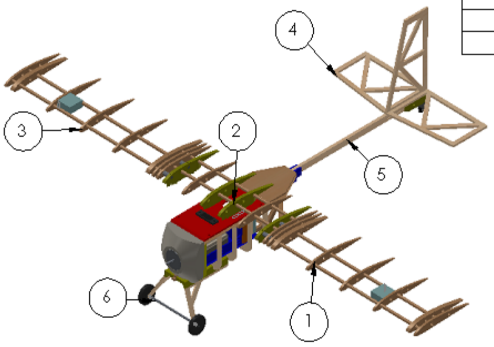
Appendix B – Technical Data Sheet

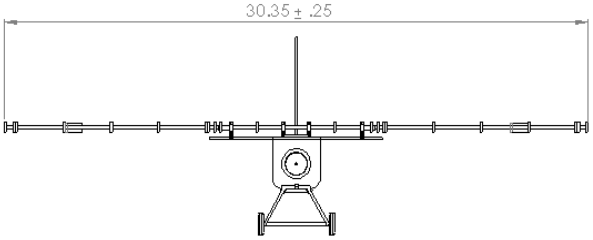
	Component	Weight (lb.)
1	Battery	0.15
2	Battery Tray	0.06
3	Motor	0.10
4	Motor Mounting Plate	0.03
5	Propeller	0.01
6	Side Wing	0.02*2=0.04
7	Center Section Wing	0.05
8	Tail	0.05
9	Micro Servos	0.01*2=0.02
10	ESC controller	0.09
11	Receiver	0.02
12	Red arming plug	0.05
13	Fuselage	0.08
14	Fuselage Cover Plate	0.04
15	Rear Cover Plate	0.01
16	Landing gear	0.02
17		
18		
Total		0.82

Drawing 11x17

Item Number	Description
1	Left Wing Assembly
2	Center wing Assembly
3	Right Wing Assembly
4	Horizntal Stabilizer Assembly
5	Tail And Vertical Stabilizer
6	Landing Gear Assembly







Equipment Data Summary	
Wingspan	30.6 inches
Empty weight	.80 lbs
Battery	850 mAh 3s Lipo
Motor	Scorpion SII-2212-1850
Propeller	7x4 APC E-prop
Servo All Posisitons (4)	HobbyKing BA-TS-25 Torque = 2.36 oz/in

Item	Distance from Datum In X inches	Component Weight Lbs	Resulting Moment (lbs)
Motor	.51	.125	.02
Battery	2.43	.150	.03
Wing Servos	3.9	.011	.005
Rudder and Elevator servos	4.75	.011	.007
Reciever	4.56	.018	.02
Assembled Tail Section	15.56	.05	.24
Center of Gravity	3.67	N/A	N/A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
TWO PLACE DECIMAL ± .0625
THREE PLACE DECIMAL ± .005

DO NOT SCALE DRAWING

TITLE: Assembly Drawing NAU FlapJacks Team 329

SIZE	DWG. NO.	REV
B	SAE 2D	

SCALE: 1:5 WEIGHT: SHEET 1 OF 1