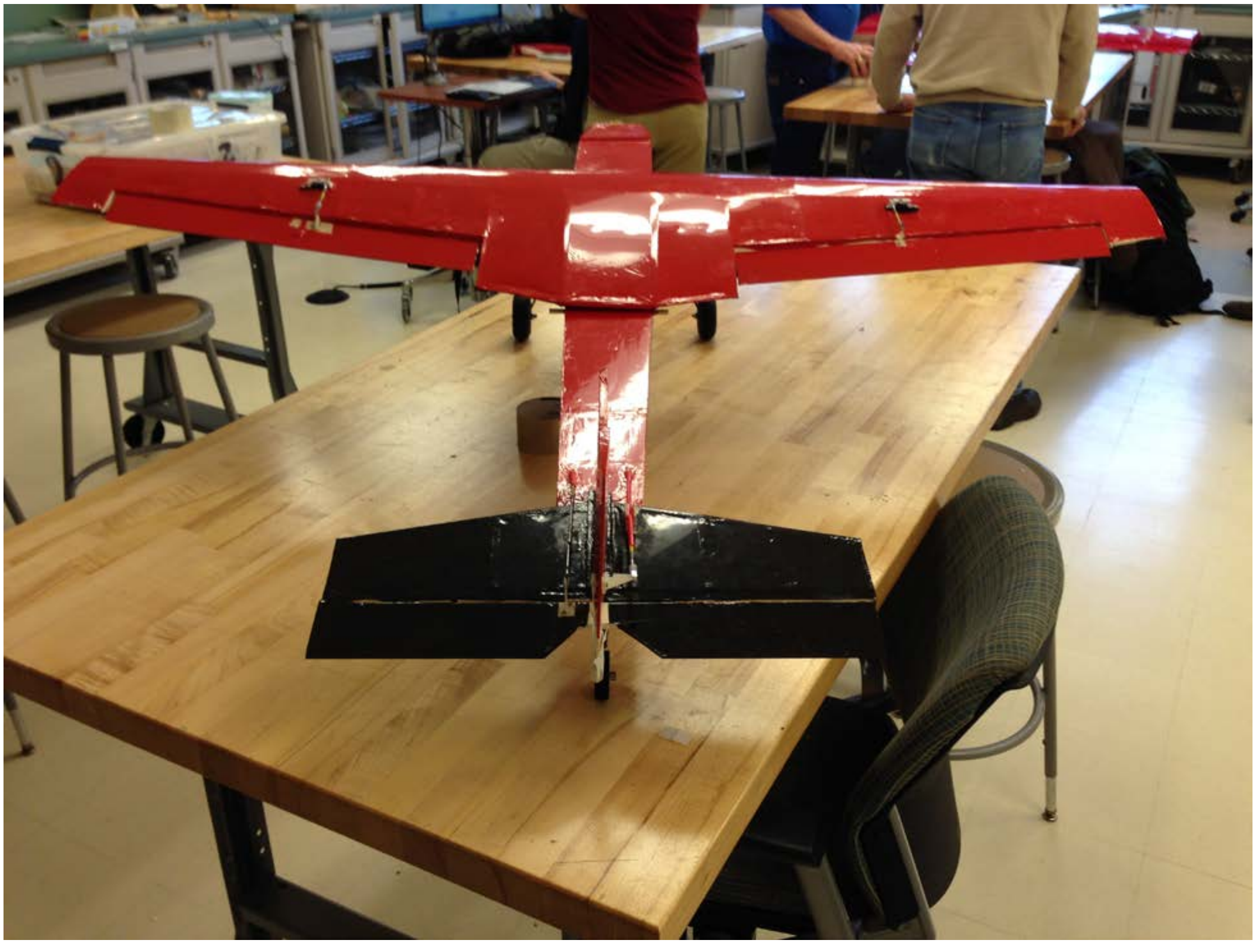
Senior Design Project

AME 40462 - Aerospace Design

Spring 2015



Group 2

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I. Conceptual Design

Design Proposal:

This design will compete for a contract with Crazy Air Taxi Planes, LLC (CATplanes). It will be required to carry at least 2 lb worth of passengers in an acceptable seating arrangement while flying 3 laps around the flying course with and without these passengers. These laps will also include a full 360 degree turn during each lap. The 3 laps without passengers, the loading of the passengers after landing, and the final 3 laps with the passengers will all separately be timed and added to attain the final success factor.

With these mission objectives, there are many different approaches one could take to optimize the success factor; our group has decided to focus on turn rate and speed with and without the passengers as our primary design drivers. To accomplish this, we have done a number of things; most notably, (1) minimizing our weight, (2) configuring our passengers in the most efficient way possible to make the plane stable with and without them, (3) minimizing our main wing aspect ratio, (4) over sizing control surfaces, and (5) making the fuselage as narrow (aerodynamic) as possible.

Although there are 3 aspects of the objective, we have decided to primarily focus on the 2 flying scenarios in comparison to the loading time. This decision was based on the fact that the 2 flying scenarios will most likely consist of most all of the success time/factor. Because of this decision, our group will not have any sliding compartments or other rigs for loading the passengers, but instead will just load them through a side hatch on fuselage. Although we don't have a complex loading plan, we are confident that our compact configuration will be sufficient and timely. Figure 1 below illustrates our passenger configuration.

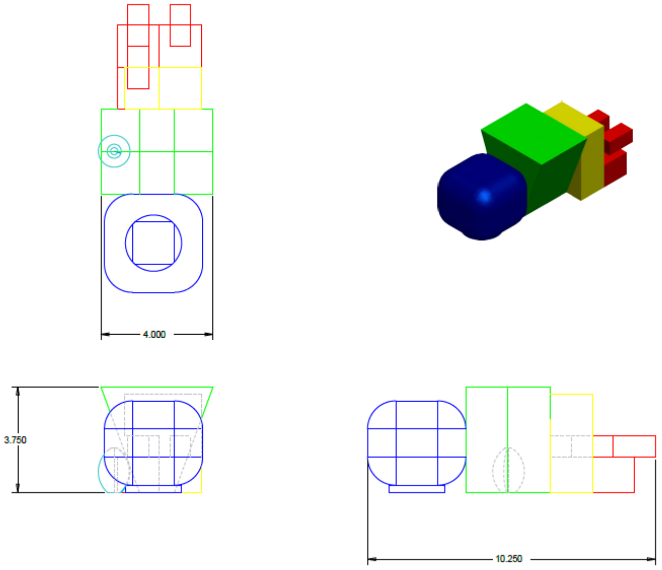


Figure 1. Passenger configuration

Estimated Weight:

The takeoff weight was estimated to be 7.2 pounds, including the weight of the passengers. The fuselage was estimated to weigh 1.5 pounds based on the material needed to make the fuselage and was compared to previously built airplanes of similar size. The components and electronics weigh 2.431 pounds. This weight includes the propeller, the engine and mount, the speed controller, flight battery, flight data recorder, GPS module, accelerometer, transmitter receiver, large and small servos, and the landing gear. The wing weight was estimated to be 1.1 pounds. The tail sections, vertical and horizontal, were estimated to be a combined 0.2 pounds. Finally, the passengers weigh 2 pounds.

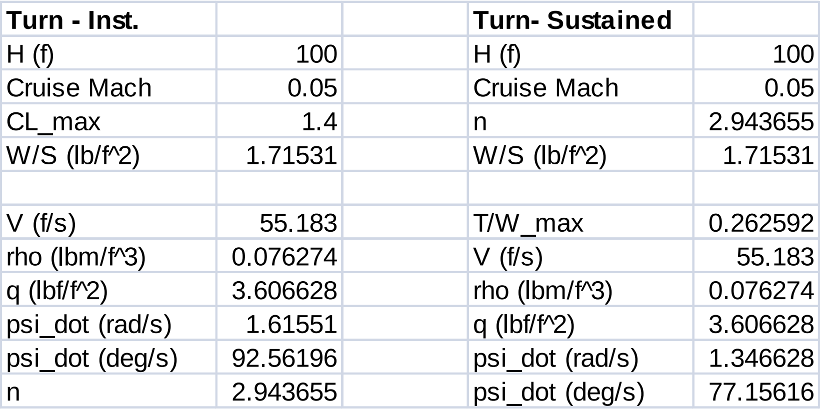
Table 1. Estimated weight

	Weight (lbs.)
Fuselage	1.5
Wing	1.1
Vertical Tail	0.1
Horizontal Tail	0.1
Components	2.431
Passengers	2
Total	7.231

Wing Loading:

For both stability and turn rate, the wing loading is a crucial design parameters. All of the calculations used were from the “wingload” spreadsheet from *Design of Aircraft*. Notably, we estimated our $C_{L\ max}$ to be 1.4 from our Clark-Y airfoil section, cruise Mach number to be 0.05, and altitude equal to 100 ft. Using these numbers and the "turn" section of the wing loading spreadsheet, we calculated a wing loading of ~ 1.72 lb/ft^2 and a load factor of ~ 2.9. These numbers seemed reasonable for the design drivers we have and in comparison to previous aircraft of similar size. We also had outputs of relatively high instantaneous and sustained turn rates of 92 and 77 deg/s respectively which is exactly what our design driver was. The spreadsheet calculations for the turn rate section of wing loading can be seen below in Table 2.

Table 2. Wing loading/turn rate calculations

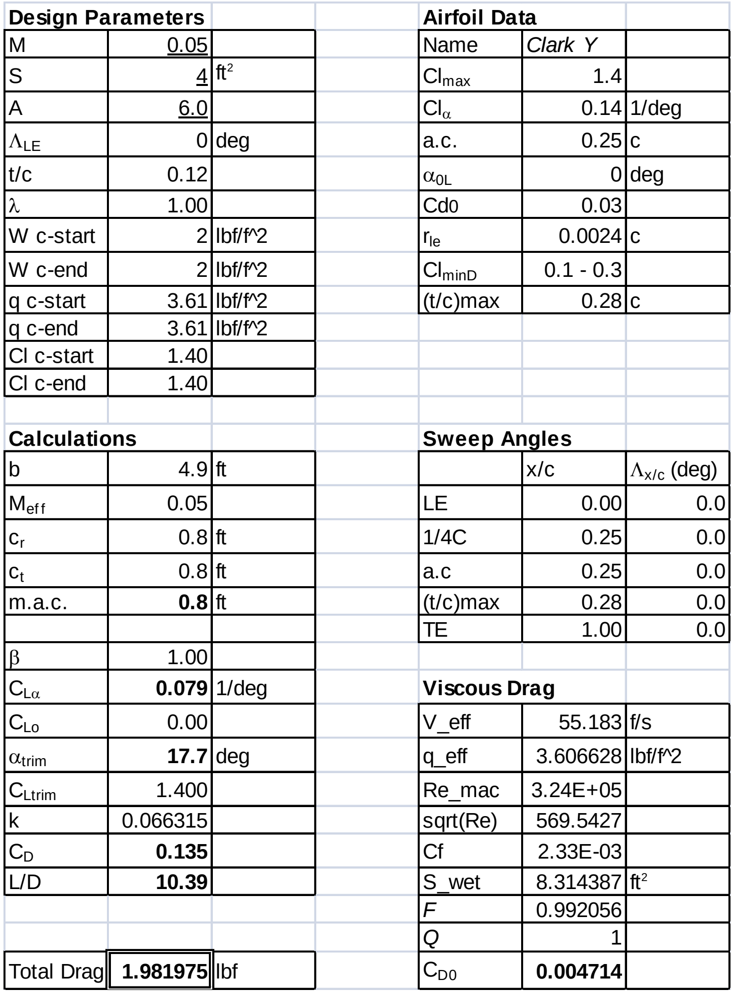


Turn - Inst.			**Turn- Sustained**	
H (f)	100		H (f)	100
Cruise Mach	0.05		Cruise Mach	0.05
CL_max	1.4		n	2.943655
W/S (lb/f^2)	1.71531		W/S (lb/f^2)	1.71531
V (f/s)	55.183		T/W_max	0.262592
rho (lbm/f^3)	0.076274		V (f/s)	55.183
q (lbf/f^2)	3.606628		rho (lbm/f^3)	0.076274
psi_dot (rad/s)	1.61551		q (lbf/f^2)	3.606628
psi_dot (deg/s)	92.56196		psi_dot (rad/s)	1.346628
n	2.943655		psi_dot (deg/s)	77.15616

Main Wing Design:

After some research, our group decided to implement the Clark Y airfoil for our main wing. We did this for a number of reasons including: the nearly flat bottom for ease of construction, high coefficient of lift, and noted success rate on many RC planes of similar size. Our wing area is 4 ft^2 while our aspect ratio is 6.0. This is a fairly small aspect ratio which will help maximize the turn rates. Nothing special was done with the taper or sweep due to the relatively low Mach and Reynolds numbers (i.e. no sweep and a taper ratio of 1.0). The Clark Y airfoil will be able to produce a maximum coefficient of lift ~ 1.4 with a t/c = 0.12 which is sufficient for this design. With an estimated aerodynamic center at the quarter chord, we got values of $C_D = 0.135$; L/D = 10.39; and total drag = 1.98 lbf. These values are all within reason for this size plane and we are confident that the overall wing design will work well to maximize our speed and turn rates. Figure 2 illustrates the main wing design along with the airfoil cross section and Table 3 demonstrates the calculations made regarding the main wing/airfoil characteristics.

Table 3. Main wing/airfoil calculations



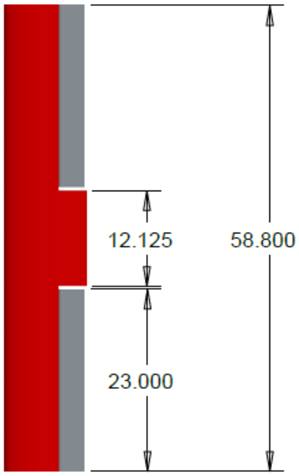
Design Parameters		
M	0.05	
S	4	ft^2
A	6.0	
Λ_{LE}	0	deg
t/c	0.12	
λ	1.00	
W c-start	2	lbf/f^2
W c-end	2	lbf/f^2
q c-start	3.61	lbf/f^2
q c-end	3.61	lbf/f^2
Cl c-start	1.40	
Cl c-end	1.40	

Airfoil Data		
Name	*Clark Y*	
Cl_{max}	1.4	
Cl_{α}	0.14	1/deg
a.c.	0.25	c
α_{0L}	0	deg
Cd0	0.03	
r_{le}	0.0024	c
Cl_{minD}	0.1 - 0.3	
(t/c)max	0.28	c

Calculations		
b	4.9	ft
M_{eff}	0.05	
c_r	0.8	ft
c_t	0.8	ft
m.a.c.	**0.8**	ft
β	1.00	
$C_{L\alpha}$	**0.079**	1/deg
C_{Lo}	0.00	
α_{trim}	**17.7**	deg
C_{Ltrim}	1.400	
k	0.066315	
C_D	**0.135**	
L/D	**10.39**	
Total Drag	**1.981975**	lbf

Sweep Angles		
	x/c	$\Lambda_{x/c}$ (deg)
LE	0.00	0.0
1/4C	0.25	0.0
a.c	0.25	0.0
(t/c)max	0.28	0.0
TE	1.00	0.0

Viscous Drag		
V_eff	55.183	f/s
q_eff	3.606628	lbf/f^2
Re_mac	3.24E+05	
sqrt(Re)	569.5427	
Cf	2.33E-03	
S_wet	8.314387	ft^2
F	0.992056	
Q	1	
C_{D0}	**0.004714**	



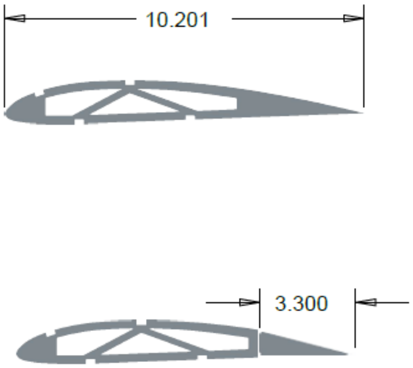


Figure 2. Main wing and airfoil design

Fuselage Design:

Our fuselage can be seen in Figure 3 where all dimensions are illustrated. The fuselage can be best explained in 3 separate sections: (1) the nose section which will taper back from the front to the back as demonstrated in Figure 3. This compartment will house the battery and the engine. (2) The second section will be a 4.5" X 4.5" rectangular box which will house all of the passengers. (3) Lastly, the rest of the fuselage will act as the tail's moment arm and will taper on all sides like the nose. Most all of the fuselage will be constructed out of ply wood in which we will cut out different sections to make the plane as light as possible while still being structurally sound. The drag from the fuselage was calculated as negligible using the "fuse" spreadsheet from *Design of Aircraft*.

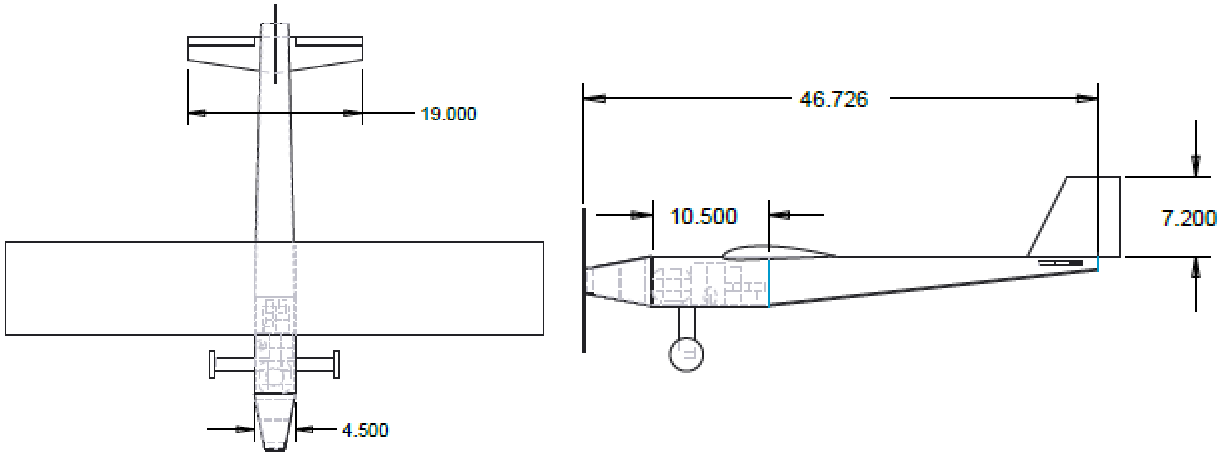


Figure 3. Fuselage

Vertical and Horizontal Tail Design:

The original vertical tail calculations required the surface area to be 0.2613 ft^2. However, in order for the vertical tail to be taller than the propeller wash, the height and therefore the area was increased. The current surface area is 0.33 ft^2, with a height of 7.2 inches. The root chord is 8.4 inches and the tip chord is 4.8 inches. Table 4 illustrates the calculations made for the minimum size of the vertical tail.

Table 4. Vertical tail calculations

Main Wing Reference				**Air Properties**	
b	4.9000	ft	Cruise Alt. (ft)	100.0000	ft
m.a.c.	0.8000	ft	V	55.1830	f/s
S	4.0000	ft^2	□	0.0763	lbm/f^3
M	0.0500		q	3.6066	lbf/f^2
□$_{LE}$	0.0000	deg	□	0.0000	lbm/(f-s)
t/c	0.1200		□ (cruise)	0.0001	f^2/s
□	1.0000				
Vertical Tail					
Design Parameters			**Airfoil Data**		
Cvt	*0.0400*		Name	*Flat Plate*	
Lvt	*2.2583*	ft	Cl_{max}	*0.7000*	
□$_{LE}$	*45.0000*	deg	Cl□	*0.1110*	1/deg
t/c	*0.0300*		a.c.	*0.5000*	c
□	*0.6000*		□$_{0L}$	*0.0000*	deg
Avt	*1.1000*		Cd	*0.0580*	
Calculations			**Sweep Angles**		
Svt	0.3472	ft^2		x/c	□$_{x/c}$ (deg)
b	0.6180	ft	LE	0.0000	45.0000
c_r	0.7022	ft	1/4 chord	0.2500	37.6942
c_t	0.4213	ft	(t/c)max	0.3500	34.2869
m.a.c.	0.5735	ft	TE	1.0000	5.1944
□	0.9987				
C_L□	**0.0274**	1/deg			
Total Drag	**0.0075**	lbf			

The horizontal tail is also larger than the original calculations in order to avoid the propeller wash. The span was increased to 19 inches. The original calculations required a surface area of 0.22 ft^2. After enlarging the horizontal tail, the current surface area is 0.433 ft^2. The root chord is

4 inches and the tip chord is 2.56 inches. Figure 3 above demonstrates our design for the vertical and horizontal tail surfaces. Table 5 shows the horizontal tail calculations. The vertical and horizontal tails are made of ¼ inch balsa wood.

Table 5. Horizontal tail calculations

Horizontal Tail					
Design Parameters			**Airfoil Data**		
Cht	0.5000		Name	*NACA 64-004*	
Lht	2.2580	ft	Cl_{max}	*0.7000*	
$\square_{LE}$	30.0000	deg	$Cl_{\square}$	*0.1110*	1/deg
t/c	0.0300		a.c.	*0.5000*	c
□	0.4000		$\square_{0L}$	*0.0000*	deg
Aht	3.0000		Cd	*0.0580*	
Calculations			**Sweep Angles**		
Sht	0.7086	ft^2		x/c	$\square_{x/c}$ (deg)
b	1.4580	ft	LE	0.0000	30.0000
c_r	0.6943	ft	1/4 chord	0.2500	23.4846
c_t	0.2777	ft	(t/c)max	0.3500	20.6740
m.a.c.	0.5158	ft	TE	1.0000	0.3393
□	0.9987				
$C_{L\square}$	**0.0570**	1/deg			
Total Drag	**0.0151**	lbf			

Stability Analysis:

The leading edge of the main wing was placed at 28% of the length of the fuselage, putting the center of lift at roughly 35% of that length. This puts the leading edge near the midpoint of the passenger compartment and the center of lift near the compartment's back. The landing gear was placed at 15% of the length of the fuselage, and the battery is placed in front of the passenger compartment. This puts most of the payload in front of the center of lift with a large portion of the fuselage behind it.

Without the passengers loaded, the static margin for longitudinal stability is 0.135, and the center of gravity is at 32% of the length of the fuselage (1.25 feet). With the passengers loaded, the static margin is 0.246, and the center of gravity is at 30% of the fuselage (1.17 feet). Both of these margins provide a comfortable degree of stability without creating too much of a nose-down moment.

The estimated longitudinal stability coefficient $C_{M\alpha}$ is -2.26 unloaded and -3.20 loaded, although admittedly this is a very rough estimate. While stable, the magnitude of this coefficient is rather large, which could lead to increased trim drag on the horizontal tail. However, this is a tradeoff made to maximize the size of the control surfaces on the horizontal tail, which will increase the maneuverability of the aircraft (the primary design driver). This number can be improved by moving the main wing forward. The directional stability coefficient $C_{n\beta}$ is roughly 0.22 loaded or unloaded, which is relatively high but still stable and acceptable. The rudder is being sized to 30% of the chord of the vertical tail, which is larger than it needs to be, but this will allow for a greater degree of maneuverability. Figures 4 and 5 below illustrate our final conceptual design and Tables 6-8 demonstrate the calculations made for the stability coefficients.

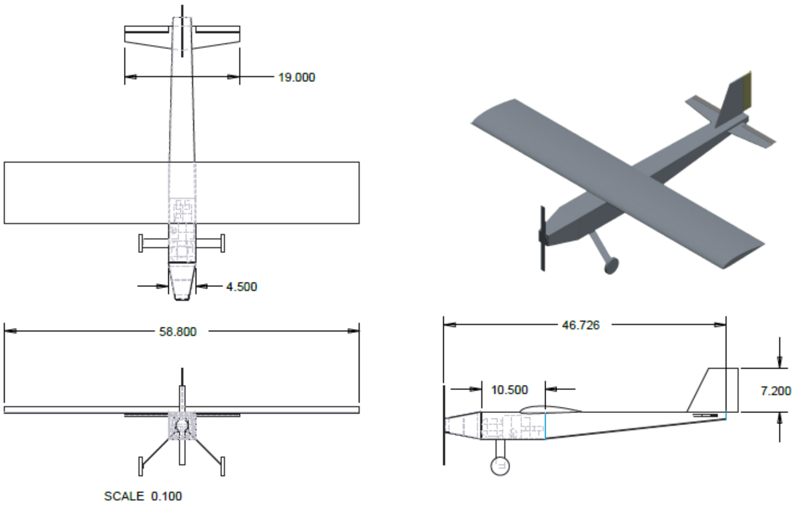


Figure 4. Conceptual design drawings

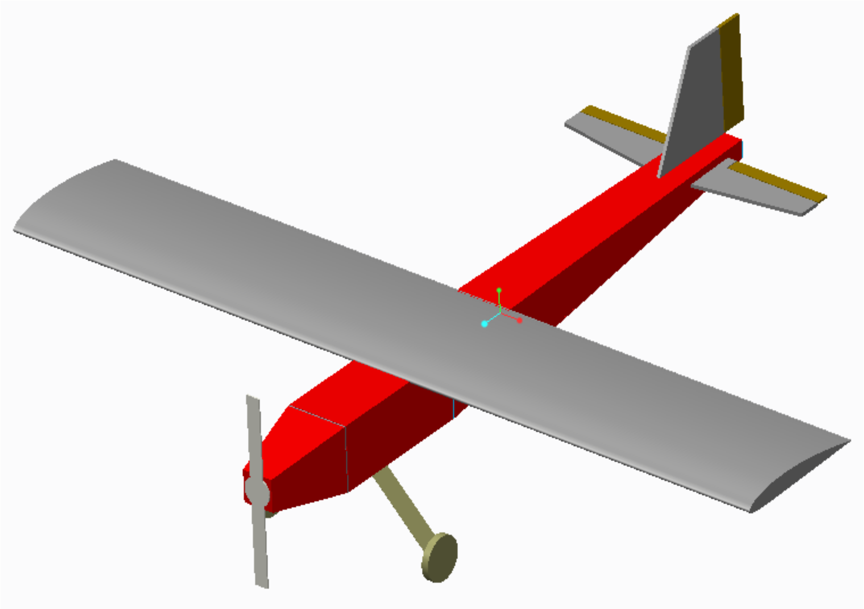
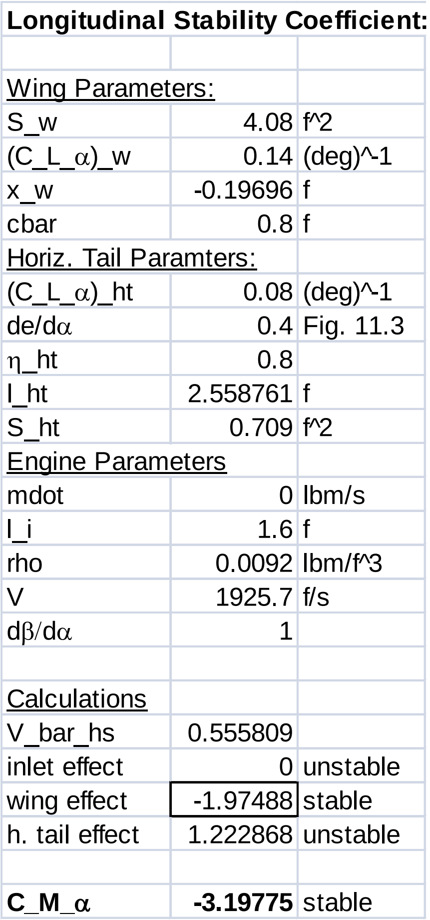


Figure 5. Isometric view of conceptual design

Table 6. Center of gravity and stability margin calculations with passengers

Load Summary (fuselage)						
Load Type	Magnitude (lbs)	x/L_start	x/L_end	resultant x/L	M @C_lift f-lb (+ cw)	dw
Fuel	0	0.4	0.6	0.5	0	0
Payload	2	0.13	0.36	0.244473	-0.80773	0.352307
Fus.Struct.	1.5	0	1	0.5	0.8967	0.071429
Battery	1.47	0.05	0.05	0.05	-1.71431	1.47
Wing Struct.	1.1	0.28	0.48	0.382041	0.14894	0.216466
Horiz. Tail	0.1	0.9	1	0.95	0.23618	0.033333
Vert. Tail	0.1	0.9	1	0.95	0.23618	0.033333
Landing Gear	0.4	0.15	0.15	0.15	-0.30968	0.4
Σ L	6.67			Σ M	-1.31373	
Tail Lift (req)	-0.55624	0.9	1	0.95	-1.31373	-0.18541
Center of Gravity						
X_cg / L	0.297255					
X_cg (ft)	1.165239	f				
Static Margin						
S.M.	0.246201	stable				

Table 7. Longitudinal stability calculations with passengers



Longitudinal Stability Coefficient:		
Wing Parameters:		
S_w	4.08	f^2
(C_L_α)_w	0.14	(deg)^-1
x_w	-0.19696	f
cbar	0.8	f
Horiz. Tail Paramters:		
(C_L_α)_ht	0.08	(deg)^-1
de/dα	0.4	Fig. 11.3
η_ht	0.8	
l_ht	2.558761	f
S_ht	0.709	f^2
Engine Parameters		
mdot	0	lbm/s
l_i	1.6	f
rho	0.0092	lbm/f^3
V	1925.7	f/s
dβ/dα	1	
Calculations		
V_bar_hs	0.555809	
inlet effect	0	unstable
wing effect	-1.97488	stable
h. tail effect	1.222868	unstable
C_M_α	**-3.19775**	stable

Table 8. Directional stability calculations with passengers

Directional Stability Coefficient:			
Wing Parameters:			
A_w	6		
Λ	0	deg	
λ	1		
S_w	4.08	f^2	
b	4.9	f	
z_w	0.166667	f	
C_L (cruise)	1.4		
Fuselage Parameters:			
h	0.333333	f	
w	0.333333	f	
Vol_f	0.2884	f^3	
Vertical Tail Parameters:			
(C_L_α)_vs	0.08	(deg)^-1	
l_vs	2.558761	f	
S_vs	0.33	f^2	
Λ_vs	45	deg	
Calculations			
V_bar_vs	0.042236		
(1+dσ/dβ)q/q	1.122982	Eq[11.42]	
v. tail effect	0.217407	Eq[11.40]	stable
fuse. effect	-0.01875	Eq[11.44]	unstable
wing effect	0.025995	Eq[11.43]	stable
C_n_β	**0.224648**	stable	
C_*L*_β	**-0.22465**	stable	

II. Detailed Design

CAD Design:

The next step in the design process was to complete a detailed design of the aircraft. This was done using the CAD software *Creo 2.0*. Using the information gained through the preliminary conceptual design phase, we started to tweak the plane in CAD until it was detailed enough to be built using only the CAD drawings found in Appendix A of this report. These drawings illustrate the exact design used in the building phase of this project.

The main wing design was fairly standard: a top-mounted wing with no dihedral and a taper ratio of 0.4 to mimic an elliptic wing. This design choice was made to maximize strength and ease of construction without making large sacrifices in terms of flight performance. The construction followed a conventional rib and spar design, with plywood ribs spaced every four inches along the length of the wing. The root chord length was 14.4 inches, so to achieve the desired taper ratio, the tip chord was 5.76 inches. The ribs were connected by six balsa spars; the leading edge spar was straight in order to allow for accurate placement of the ribs, and the other spars were angled, as they corresponded to positions on the ribs in terms of percentage of chord length. To reduce weight, the larger ribs had material cut out of the centers. The ailerons were located in the middle sections of the wings, with a span of 20 inches and a thickness of 30% of the chord. In the CAD design, the ailerons had variable thickness to match the change in thickness along the span due to taper: this could not be achieved in the physical build as the aileron stock was pre-built and had constant thickness.

The fuselage design consisted of three main sections: the nose, the cabin, and the tail moment arm. All three sections of the fuselage were built out of 1/8" thick ply with cut-outs in areas where structure was not needed in order to cut-down on weight. Also, double-thick ply was used in areas that needed additional structural support such as the bottom section of the cabin where the passengers sit and landing gear was attached. Bulkheads made out of the same ply-wood were used at the meeting of each of the three sections of the fuselage. These bulkheads were supported on both sides by triangle balsawood sticks. An additional bulkhead was added to the nose and tail section of the fuselage for additional support.

Finally, the horizontal and vertical tail were built out of balsa sticks. We decided on a stick build because that would give us sufficient structural support (due to the grains of balsa facing different directions) in addition to being very light in comparison to balsa or ply sheeting. The rudder and elevator were made out of balsa aileron stock and connected to the tail surfaces using hinge tabs.

Physical Build:

Once the entire aircraft was designed on the software with respected densities, we used the *Creo 2.0* center of gravity function to check our stability analysis performed in the conceptual design section. Our goal was to have the CG in the same location for the loaded and unloaded cases in-order to have a fixed wing location for both. There is a figure illustrating the CG for both cases in Appendix A.

The following discussion will describe how the aircraft was actually built using the CAD model described above. The first step in the physical build was to convert the CAD drawings into component-separated drawings that were compatible with the laser cutter. Using these drawings, we were able to cut all of our pieces in the laser cutter. In addition to these main pieces, we took advantage of the balsawood sheeting, sticks, and triangle sticks to provide extra support where it was needed. We implemented a combination of thick and thin wood glue as-well-as epoxy to connect all of our pieces. The main landing gear was drilled into a double thick ply area. The main wing was connected to the fuselage with rubber bands that were connected to 2 wood dowels placed ahead and behind the wing.

III. Flight Tests

Predicted vs. Measured Performance Specifications:

It is interesting to look at the performance specifications of the plane during its flight versus those that we predicted from theory. Table 9 below illustrates these results and findings.

Table 9. Predicted and measured performance specifications

Team Number:	2	Team Name:		The Dawghouse	
Metric	Units	Empty		Loaded	
		Predicted	Measured	Predicted	Measured
Fuselage weight	lb	3.9	4		
Wing weight	lb	1.1	0.8		
Empty weight	lb	5.2	4.8		
Payload weight	lb			2	
Loaded weight	lb			7.2	6.8
CG location	x/L	0.32	0.3	0.32	0.3
CL location	x/L	0.34	0.33	0.34	0.33
Static margin		0.06	0.03	0.06	0.03
Wing area	ft^2	4			
Wingspan	ft	4.9			
Aspect ratio		6			
Wing loading	lb/ft^2	1.3	1.2	1.8	1.7
Min. level speed	ft/s	45	44	40	42
Max. level speed	ft/s	60	64	55	55
Max. climb rate	ft/min	700	888	500	642.6
Best gliding descent rate	ft/min	242	732	287	663
Best glide speed	ft/s	50	44	50	49
Maximum L/D		10.4	13.7	10.4	11.5
Load factor		4.12	2.38	2.94	2.16
Max. inst. turn rate	deg/s	134	72	92	64.3
Max. sust. turn rate	deg/s	113	43.9	77	25
Takeoff distance	ft	105	259.8	142	278.3
Landing Distance	ft	504	503.6	545	530.9
Lap Time	s	24.6	27.6	27.5	30.8

The weights of the various aspects of the plane ended up being about what was predicted. The actual loaded and unloaded weights ended up being less than was anticipated, which was a pleasant surprise. This had a lot to do with the handful of minor design changes that were made during construction. The removal of material from the bulkheads and nose section, in addition to various others areas, shaved off about 0.4 pounds from both the loaded and unloaded weights. Both the centers of gravity and lift were located as expected.

There were a handful of differences between predicted and measured values. Both the maximum climb rate and the best gliding descent rate were noticeably higher than expected. This can be accounted for in a number of different ways. Since this was not a primary design driver, the pilots understandably never pushed the plane to its limits. Thus, it is difficult to determine what the actual maximum climb rates and best gliding descent rates are.

In addition to those errors, both the instantaneous and sustained turned rates were noticeably smaller than was predicted. Part of the reason for this was that the plane was not pushed to its maximum capabilities. There was also error built into the estimations, leading to different numbers.

While the landing distances were just as predicted, there were errors in the takeoff distances for both the loaded and unloaded scenarios. Part of the reason for this was because the plane was a bit uneven during takeoff. This was partially because of landing gear complications. It also seemed like it took some time for the pilot to gain stability before going into climb, which also added distance during takeoff.

Despite the differences in the aforementioned metrics, most of the measured numbers lined up with their predicted values. Both the minimum and maximum level speeds were as predicted. Also the glide speed, maximum L/D, and load factors were similar to what was predicted. With only a couple of exceptions, most of the measured metrics were similar, if not the same, as their predicted values.

Mission Results:

The following will be a brief discussion of the mission results. The figures in Appendix B illustrate the flight tests for both the loaded and unloaded cases. The official time for the ground mission (i.e. loading the passengers) was 2:43.7, the time for the empty payload mission was 1:22.9, and the time for the loaded payload mission was 1:32.3. We were very satisfied with the results of the flight missions. They were slightly slower than our predicted times, but still were fast relative to other groups, and the slower times could be the result of less-than-ideal weather conditions or pilot error. Our ground mission time, however, was disappointing. We did not have a means to quantitatively estimate the ground loading time, but we erroneously assumed that it would be much smaller than the flight lap times. Therefore, we decided to make turn rate, maneuverability, and speed the design drivers of our aircraft, as we thought this would allow us to reduce our times in the lengthier missions. However, in doing so, we settled on a design with minimal space in the fuselage and only a small hole under the wing in which to load passengers and connect electronics. The battery was particularly difficult to reach due to its placement near the front of the aircraft far away from the access hole. In retrospect, we perhaps should have made the fuselage larger to allow easier access to electronics and an easier placement of passengers. We also should have thought more carefully about how to access the battery between flights, perhaps placing it farther back in the aircraft and/or creating a larger hole or hatch on top of the fuselage.

IV. Summary and Improvements

Summary:

In conclusion, our group was very pleased with the performance of our aircraft. Each phase of the design was challenging and brought forth changes and improvements to our overall design. We were successful with our mission and were especially happy with our lap times and maneuverability of the plane. Although our plane flew well, it was not perfect; therefore, we will talk briefly about improvements we did implement and also some that we would suggest below.

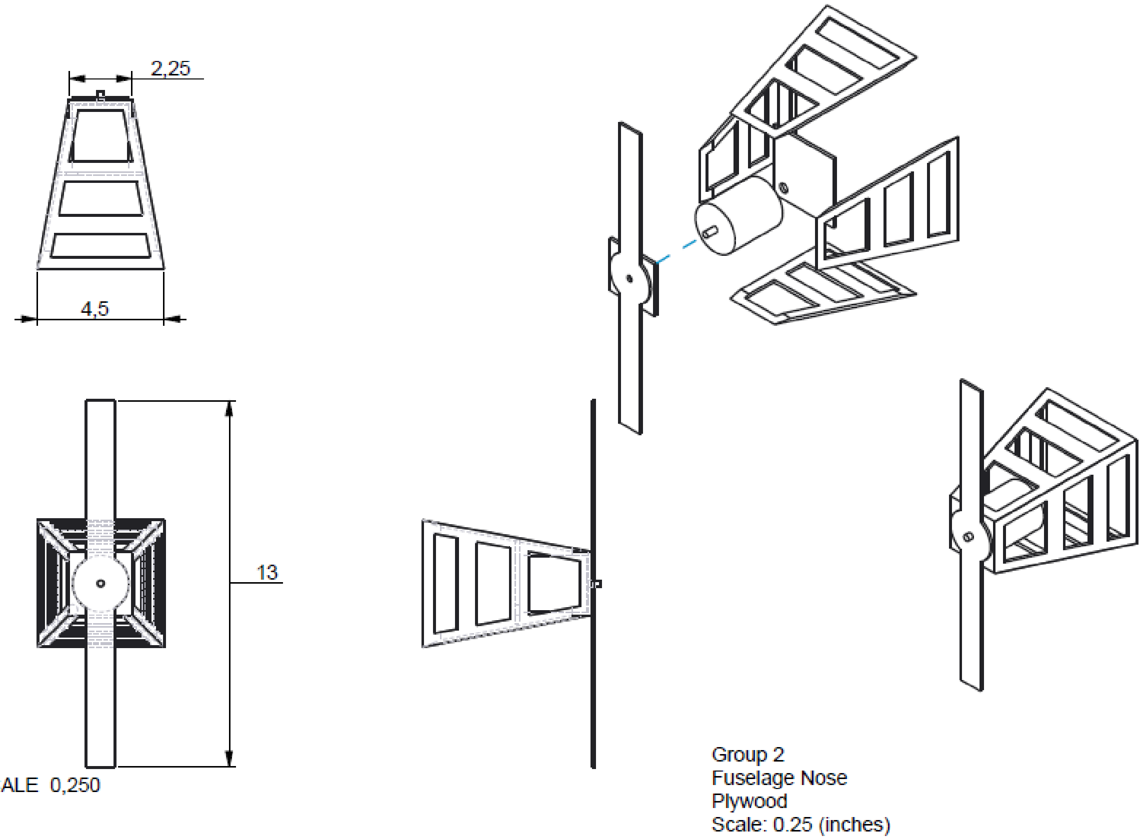
Recommendations and Improvements:

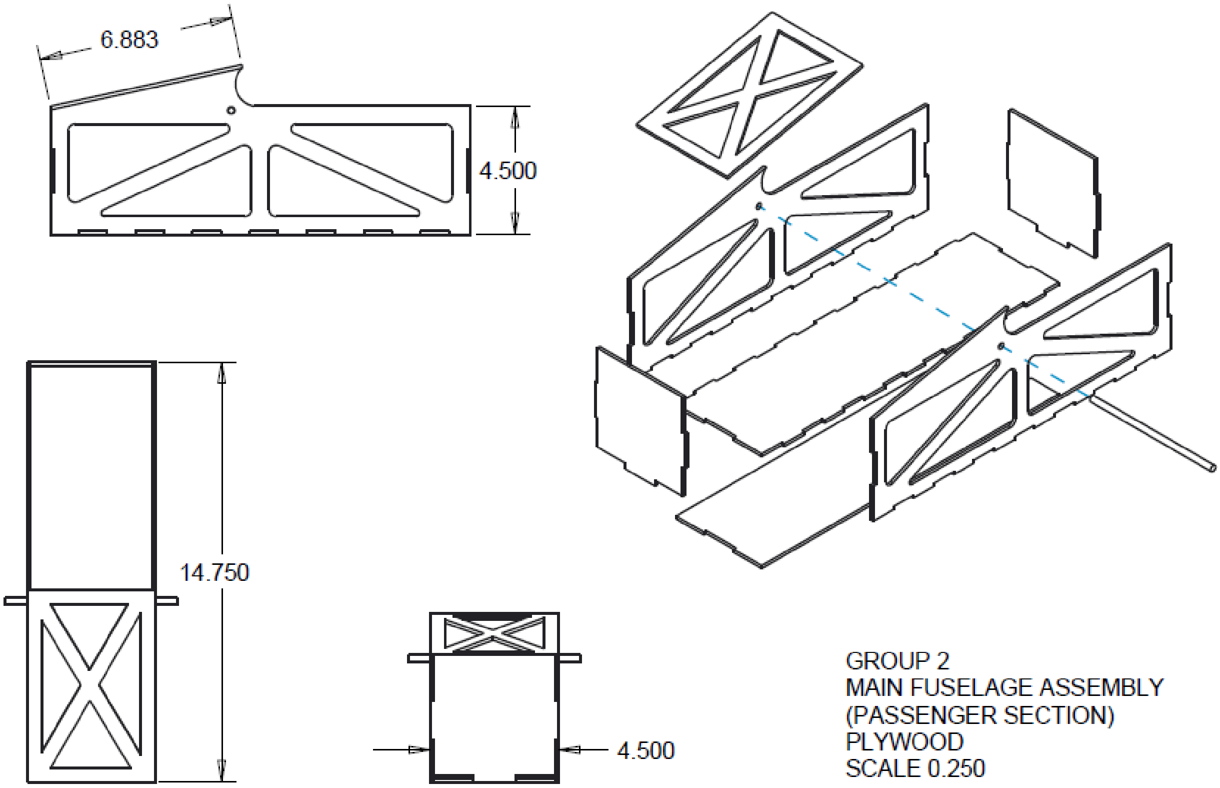
There were some design changes made after building began. The front fuselage was shortened in order to expose the engine. This allowed for more airflow over the engine and for easier installation of the engine to the bulkhead. After the build was complete, it was found that the rubber bands were not sufficient to secure the fuselage to the wing under the weight of the loaded plane. Duct tape was used to secure the wing to the fuselage.

Some recommendations can be made to future designers. An emphasis on a fast load time should have been made. We chose to focus on lap time rather than load time, which severely hindered out performance. Using a hatch instead of a removable wing would have decreased the load time significantly. A shorter fuselage with larger tail surfaces would have increased control and strength and made the build easier. A more accessible electronics section would have allowed for easier flight data collection. The use of balsa wood as the bottom of the back fuselage section made attaching the electronics difficult because the Velcro did not stick to the balsa. Finally, ensuring that the landing gear and tail gear were aligned perpendicular to the fuselage would have ensured straight takeoffs and landings.

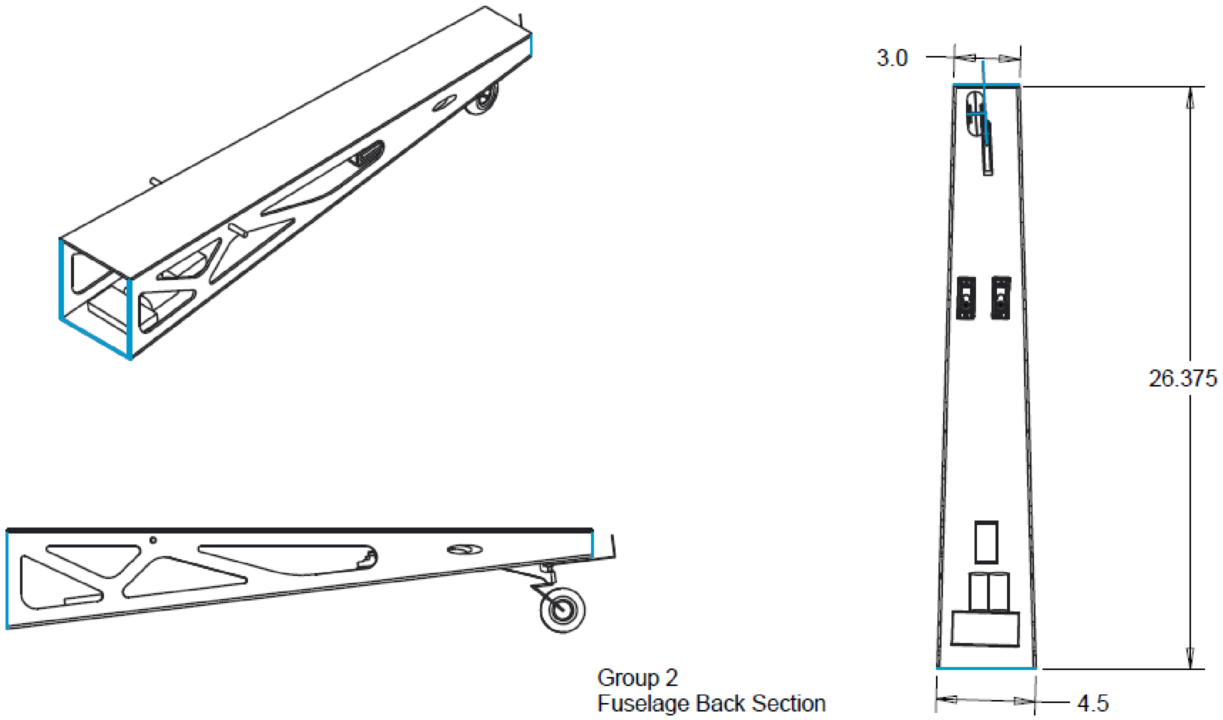
V. Appendices

Appendix A (Detailed Design):

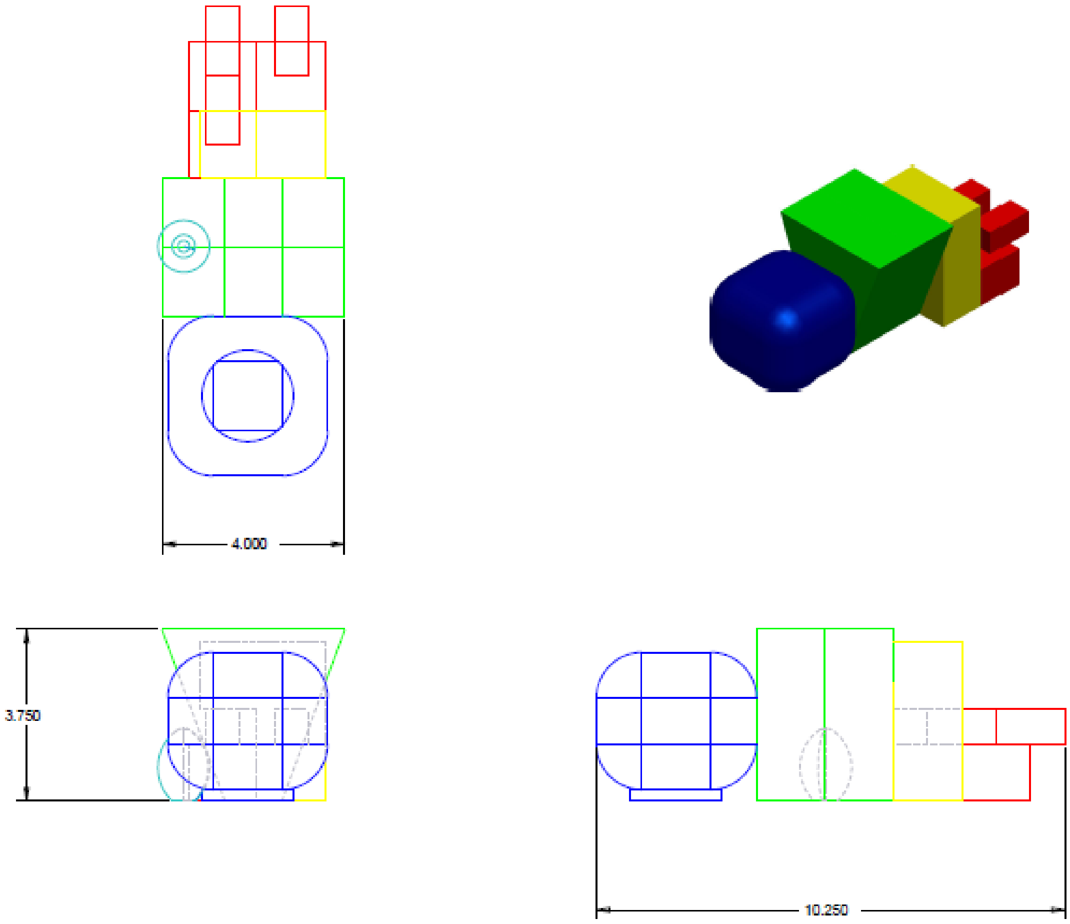




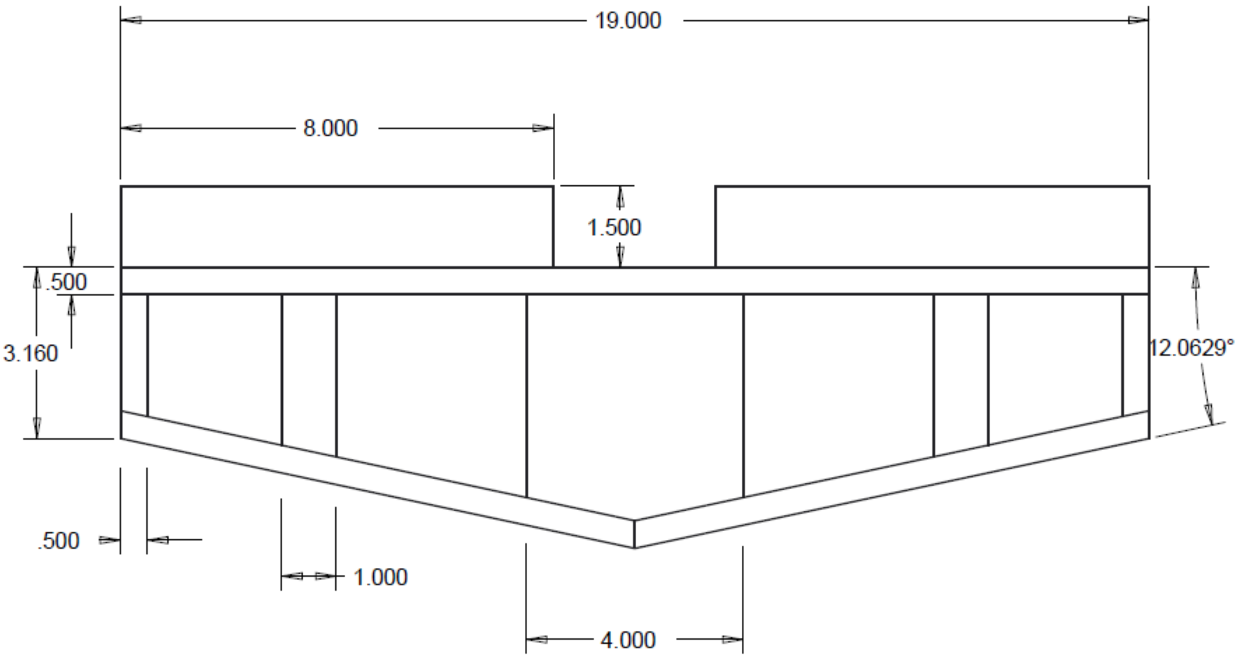
GROUP 2
MAIN FUSELAGE ASSEMBLY
(PASSENGER SECTION)
PLYWOOD
SCALE 0.250



Group 2
Fuselage Back Section
Scale .2

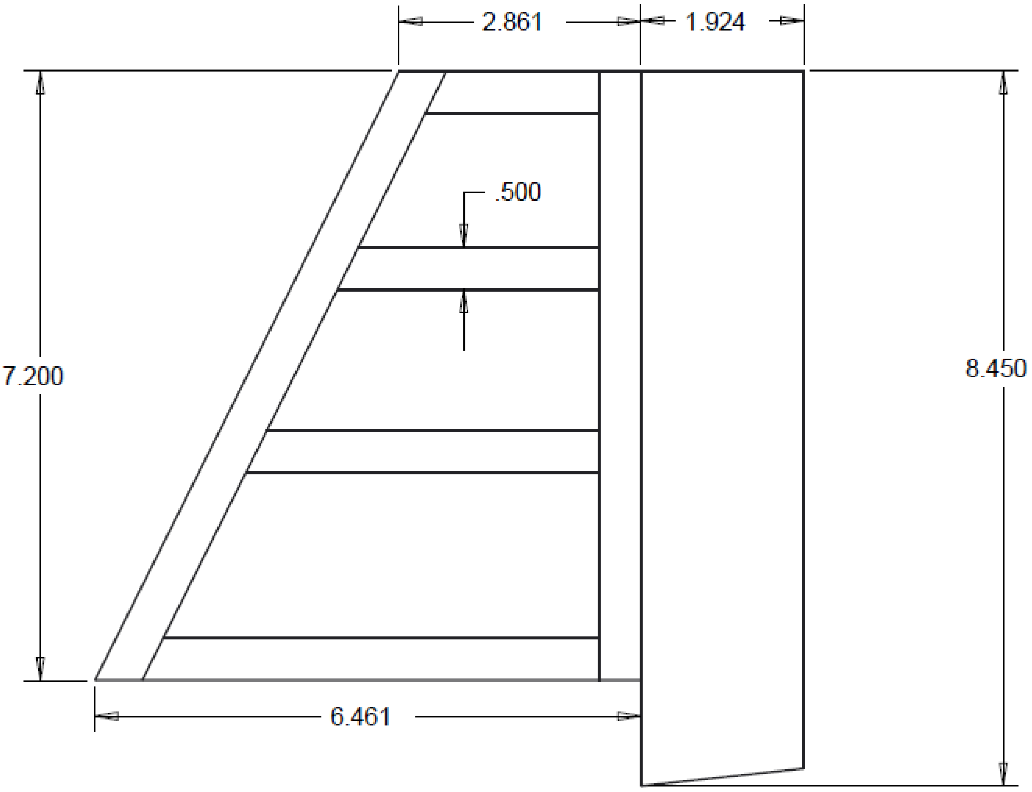


Group 2
Passenger Configuration



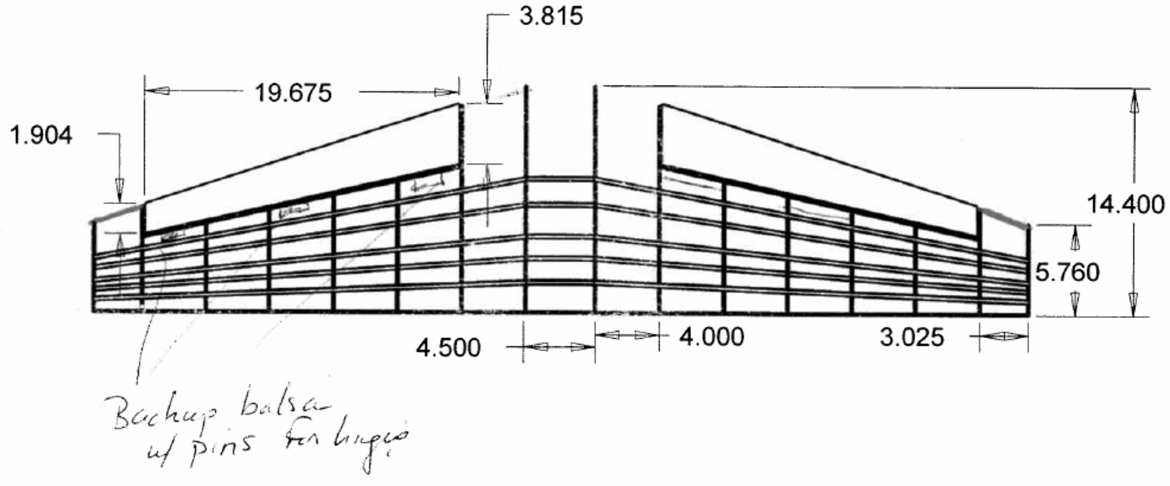
Group 2 - Horizontal Tail - Stick Build
1/4 - Inch Balsa

SCALE 0.500



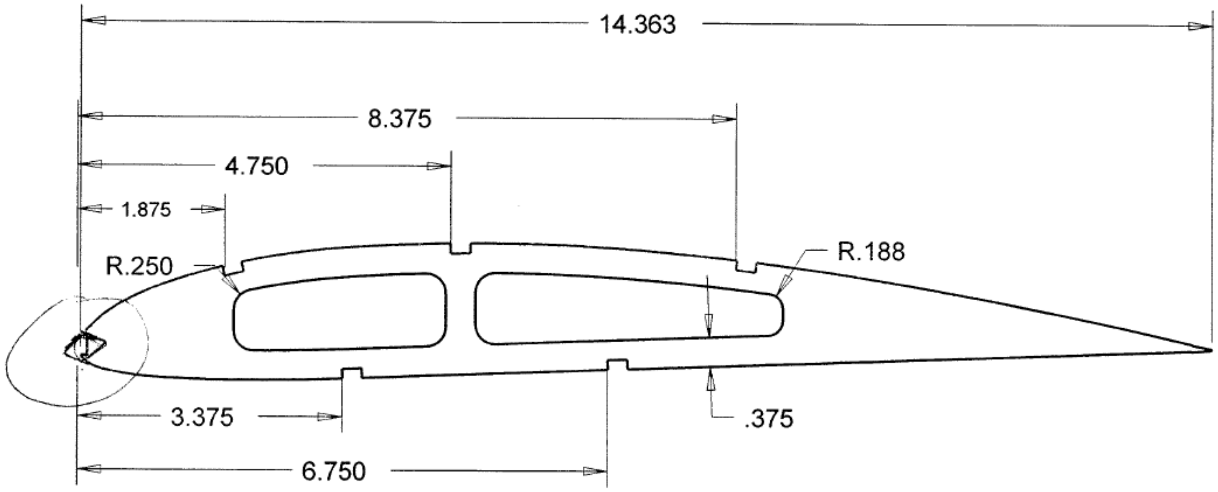
GROUP 2 - VERTICAL TAIL - STICK BUILD SCALE 0.700

3/8-INCH BALSA



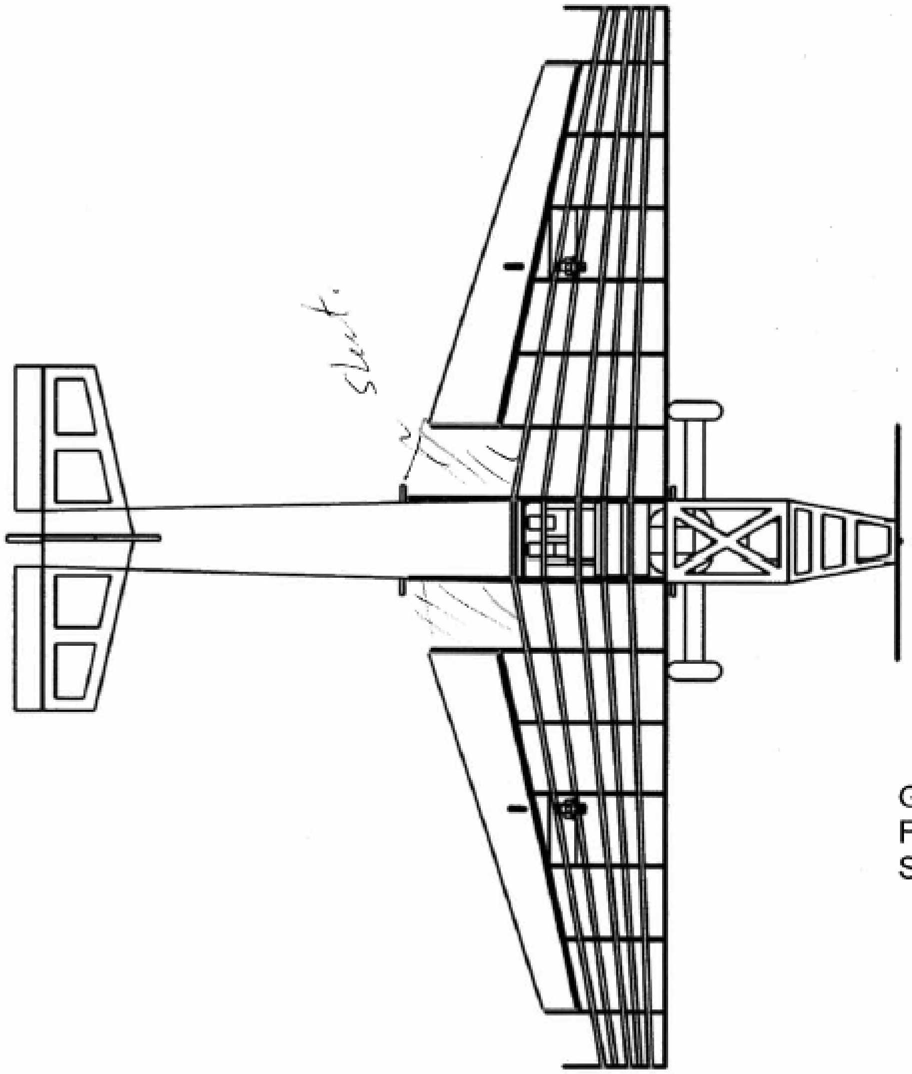
Backup balsa
w/ pins for hinges

Group 2
Wing

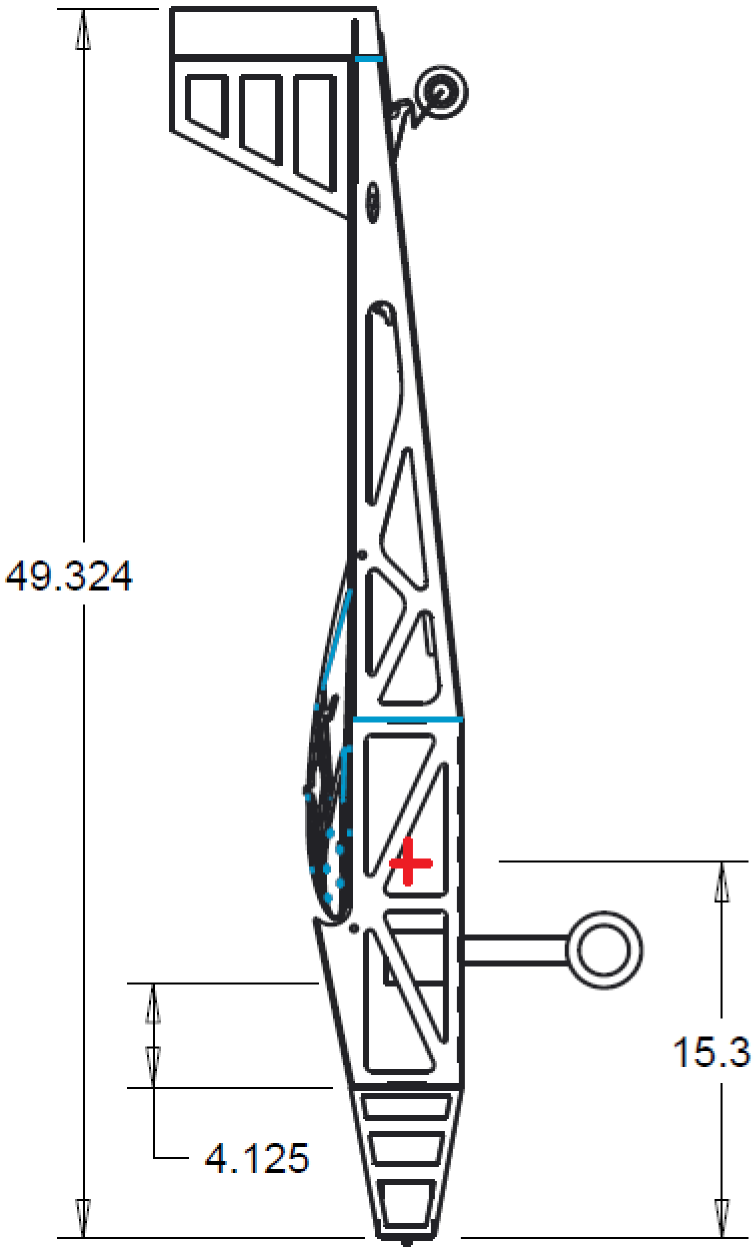


All features scaled down in other sections
except outer slots

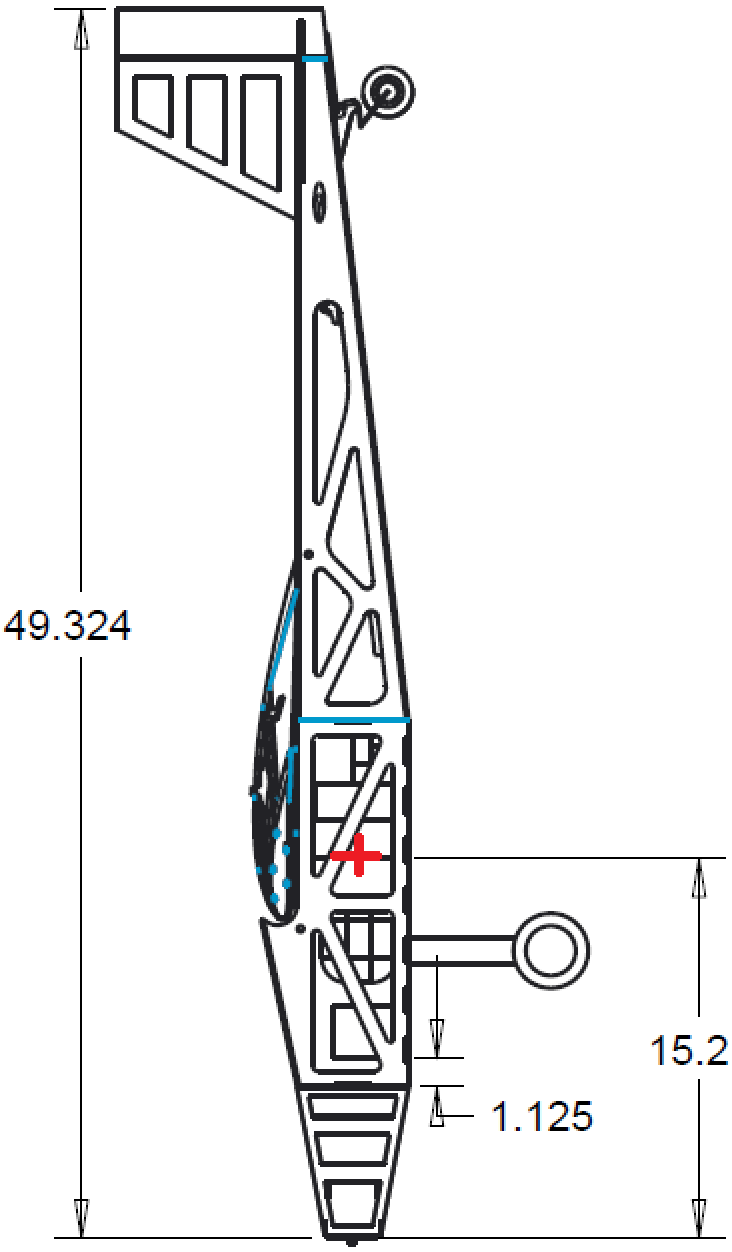
Group 2
Airfoil Section



Group 2
Full Assembly
Scale 1.2

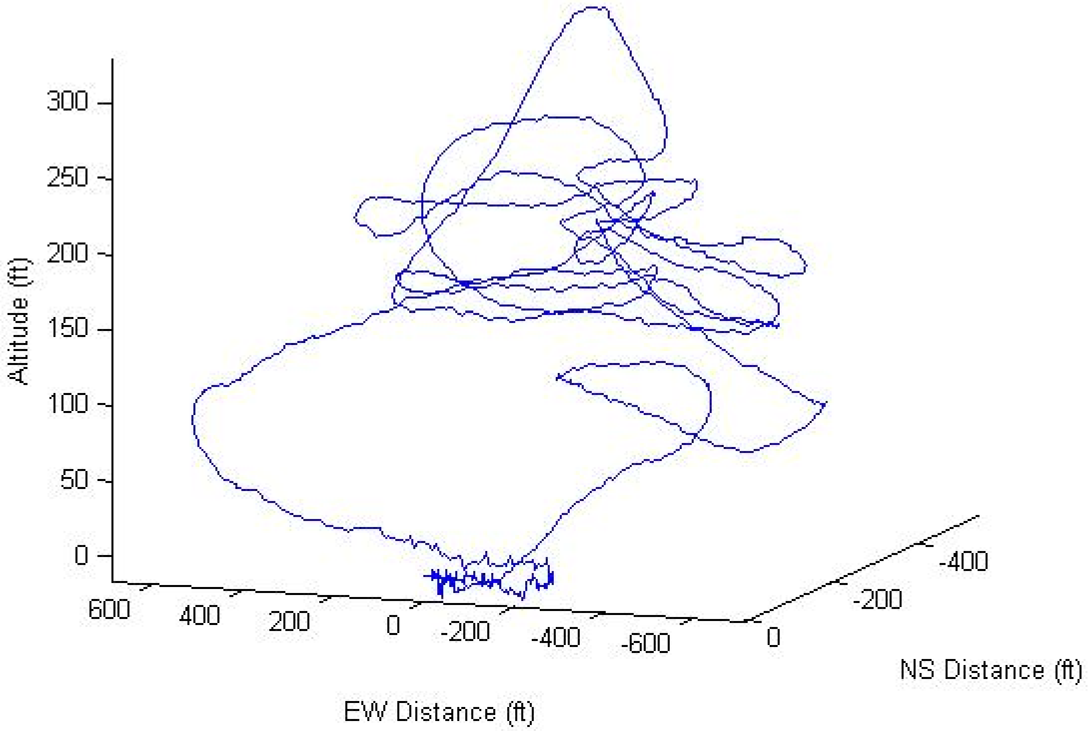


Unloaded Center of Gravity

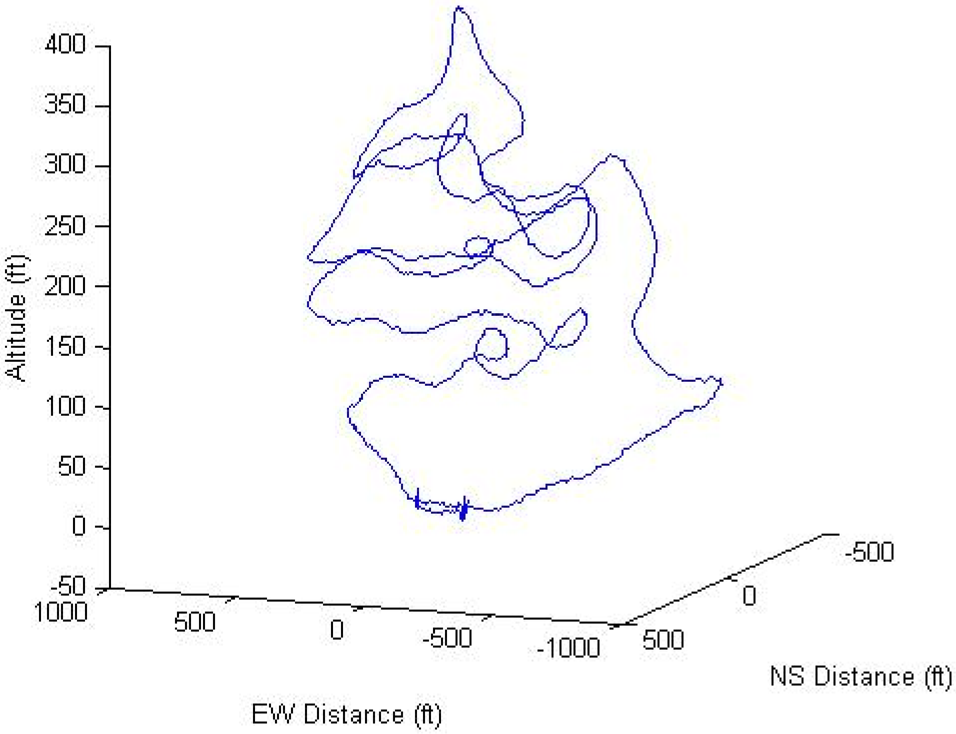


Loaded Center of Gravity

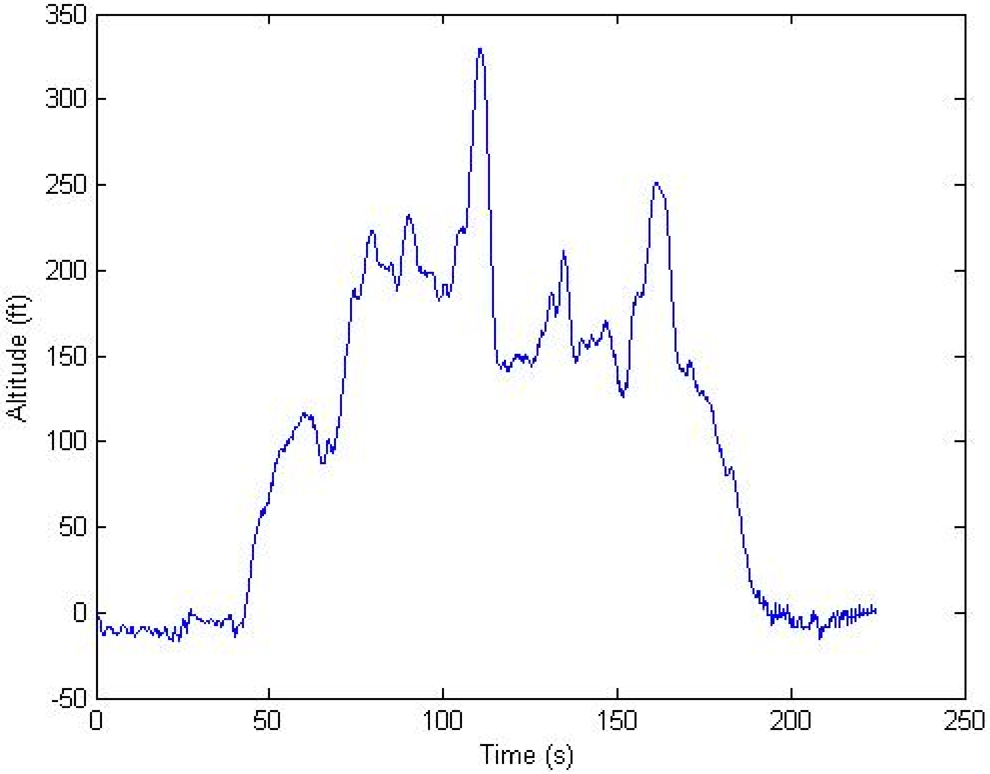
Appendix B (Flight Test Data):



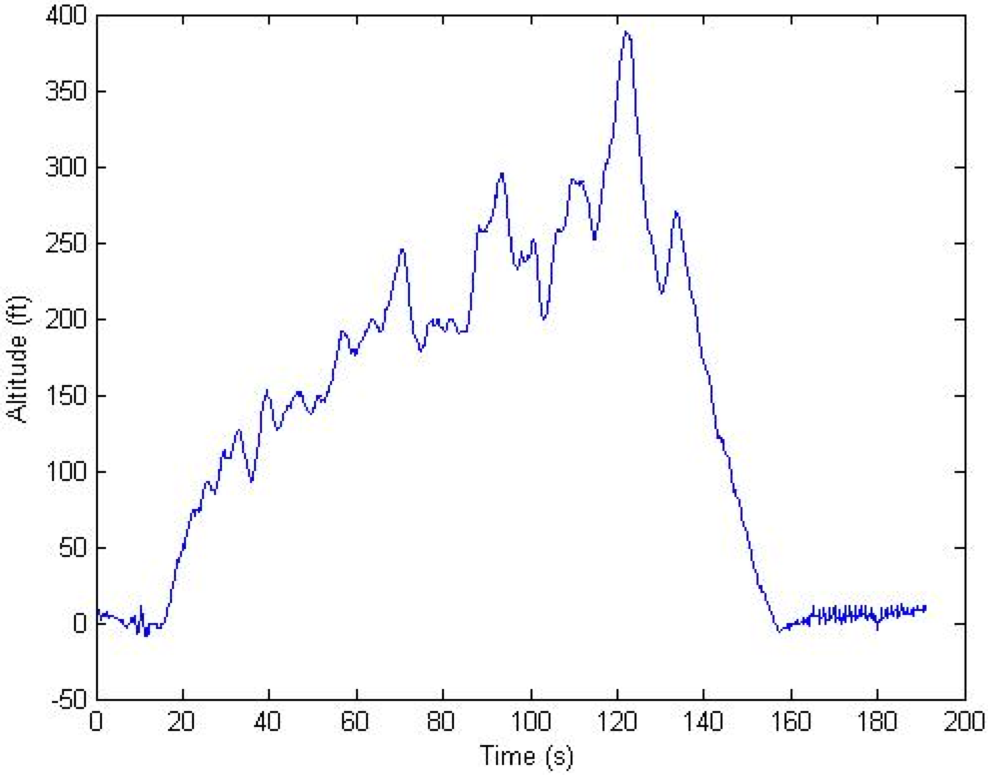
Unloaded Flight GPS



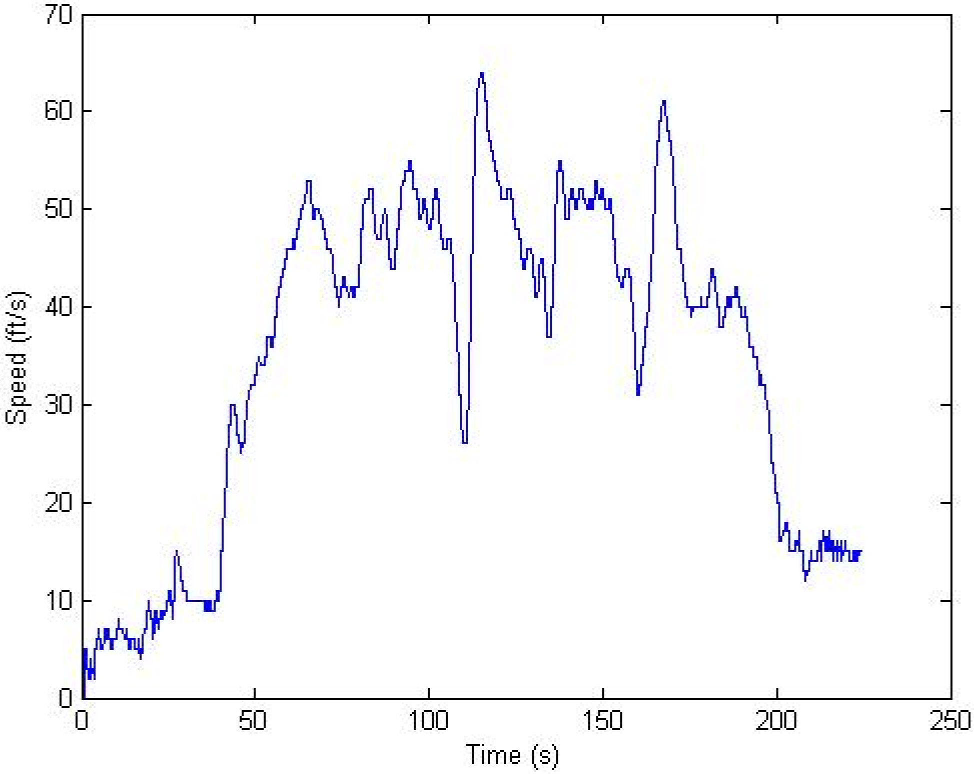
Loaded Flight GPS



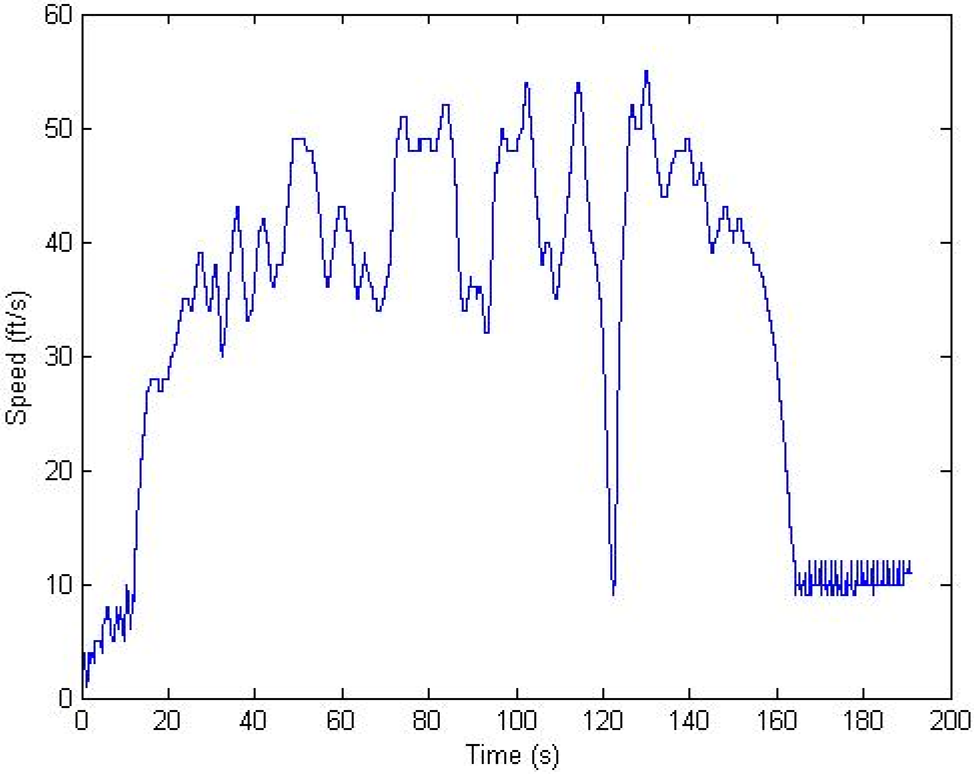
Unloaded Altitude



Loaded Altitude



Unloaded Speed



Loaded Speed