SAE Aero Oral Presentation

University of Tulsa Regular

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The “Hurricane Hunter”

Competition Requirements

Wattage	< 1000 Watts
Size	< 12ft wingspan (only requirement)
Battery	22.2V lithium polymer (LiPo), Min: 3000mah
Takeoff	< 200ft
Flight Circuit	1 Loop
Max Weight	55 pounds
Motor	Electric
Materials	No fiber reinforced plastics

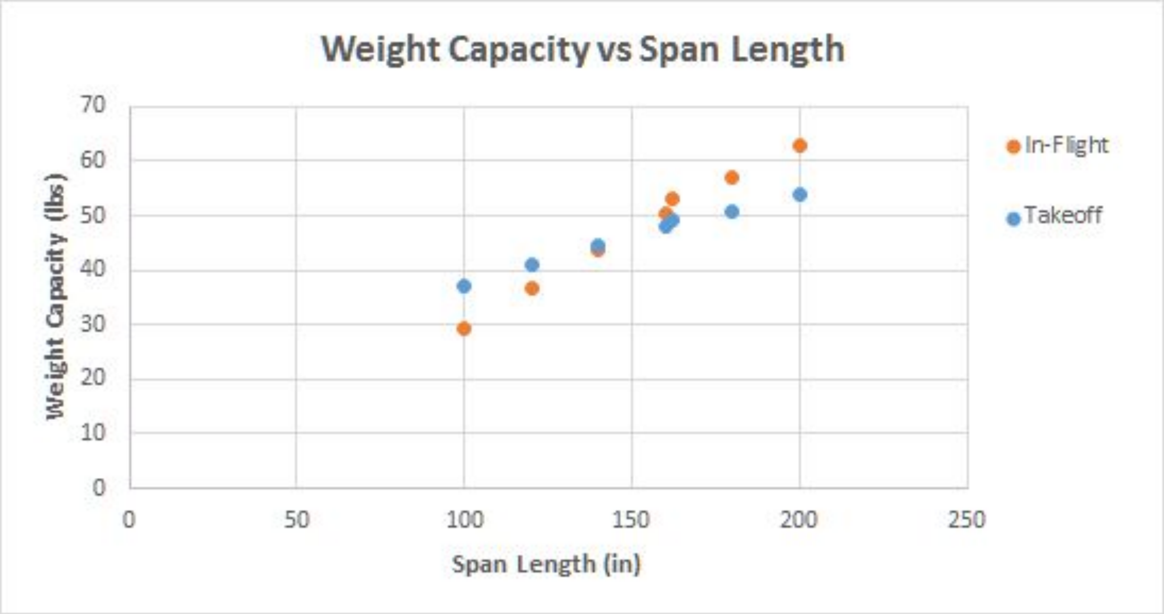
Airfoil Analysis

- We want
  - High lift
  - Low drag
- S1223 wing and S1210 wing to determine best

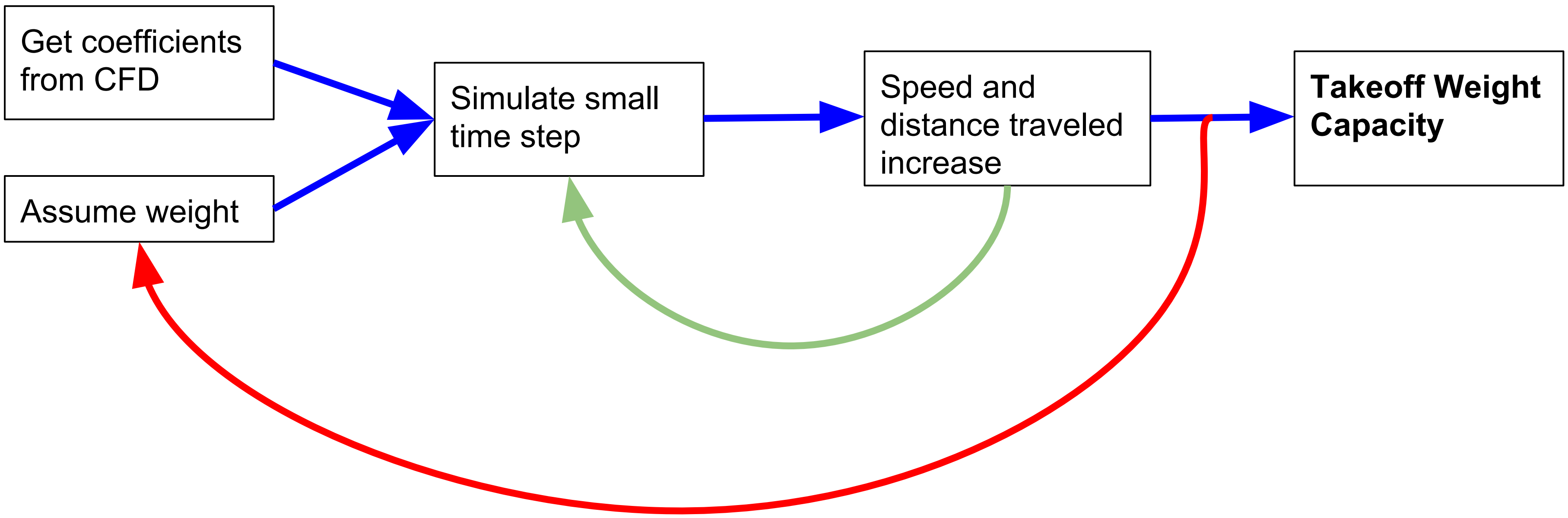
Rank	Airfoil	C_L at 0°	C_D at 0°	C_L/C_D at 0°	Max C_L
1	S1223	1.11	0.020	55.3	1.84
2	S1210	0.99	0.018	55.7	1.77
3	NACA 9312	0.844	0.019	44.6	1.50

Wing Analysis

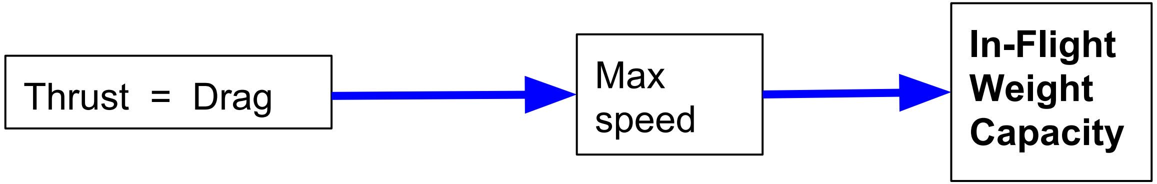
- Two weight capacities
  - Takeoff
  - In-flight
- Lower considered wing weight capacity



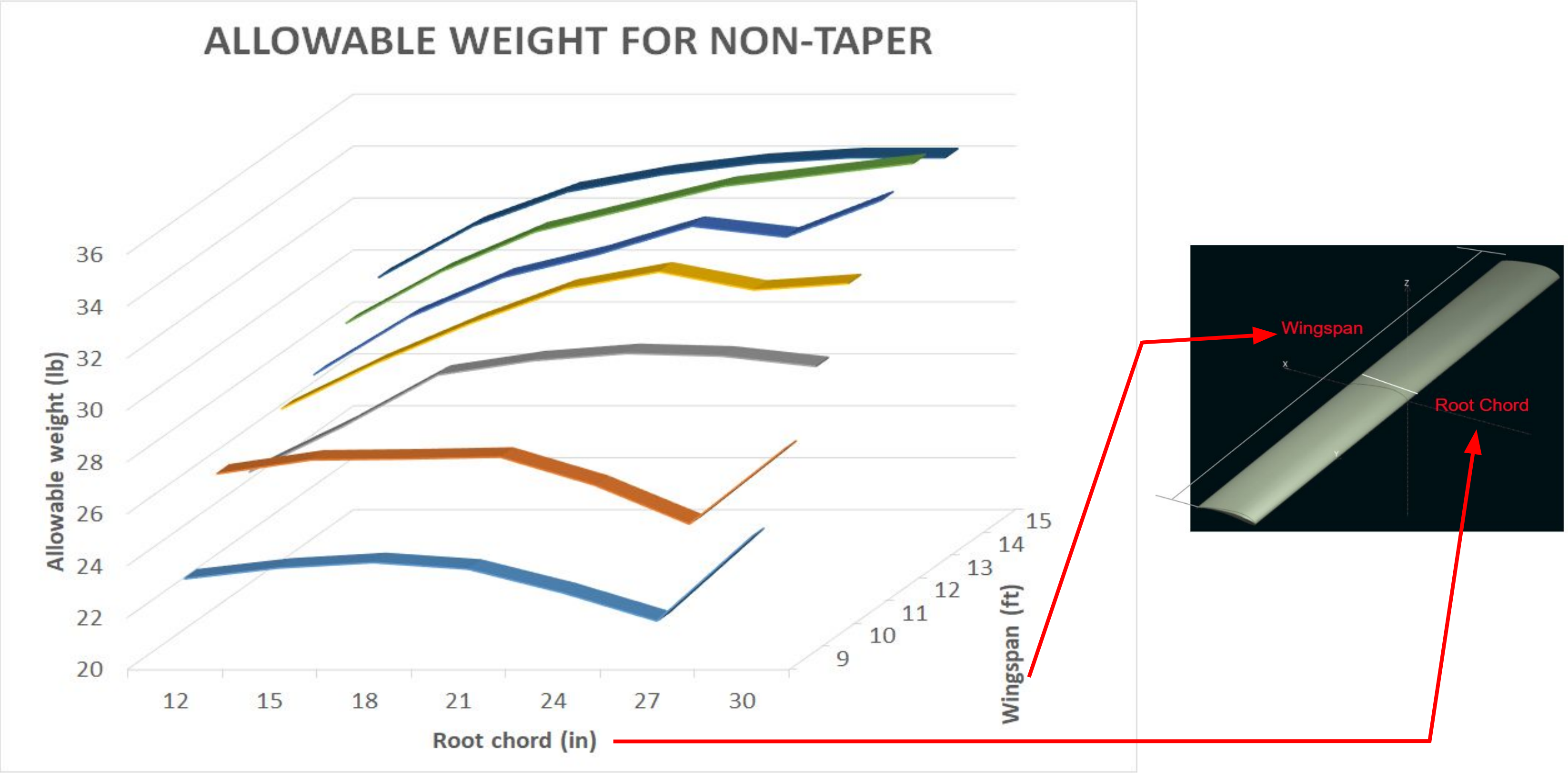
Takeoff Weight Capacity Analysis Method



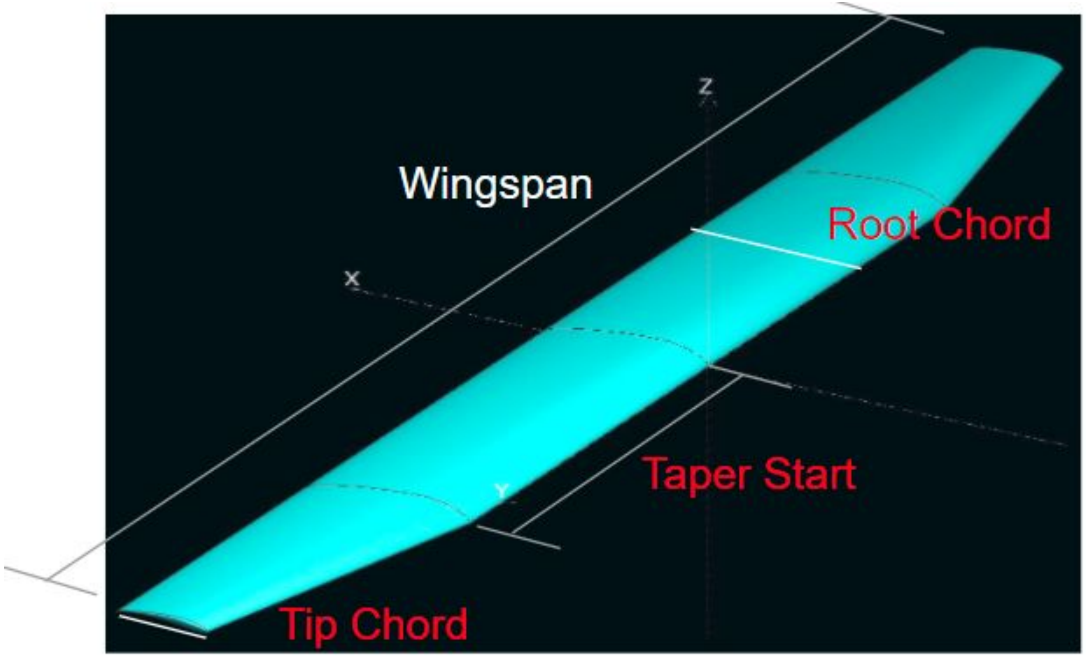
In-Flight Weight Capacity Analysis Method



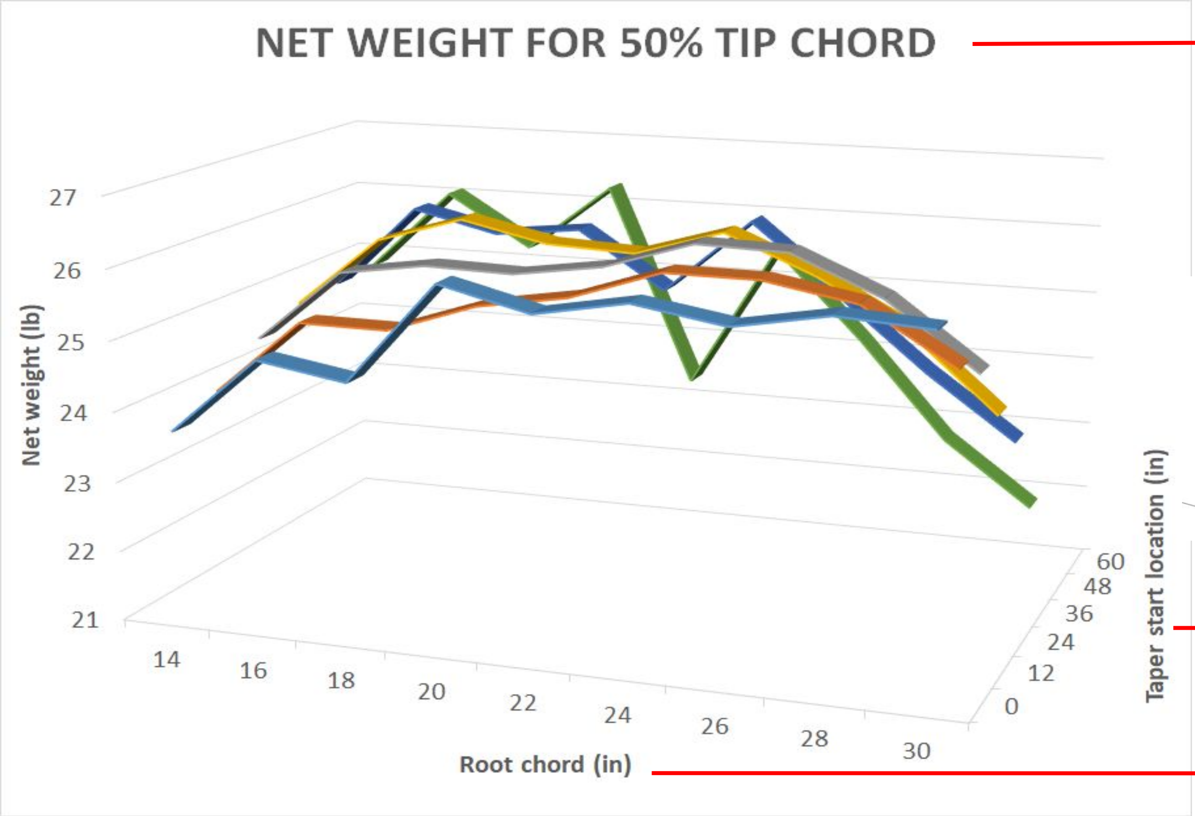
Performance Simulation and Analysis



Performance Simulation and Analysis

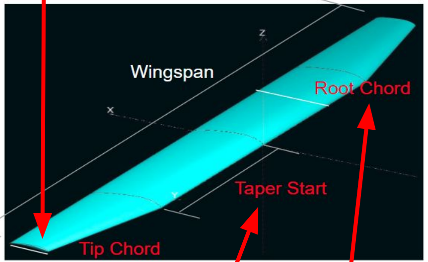


Performance Simulation and Analysis



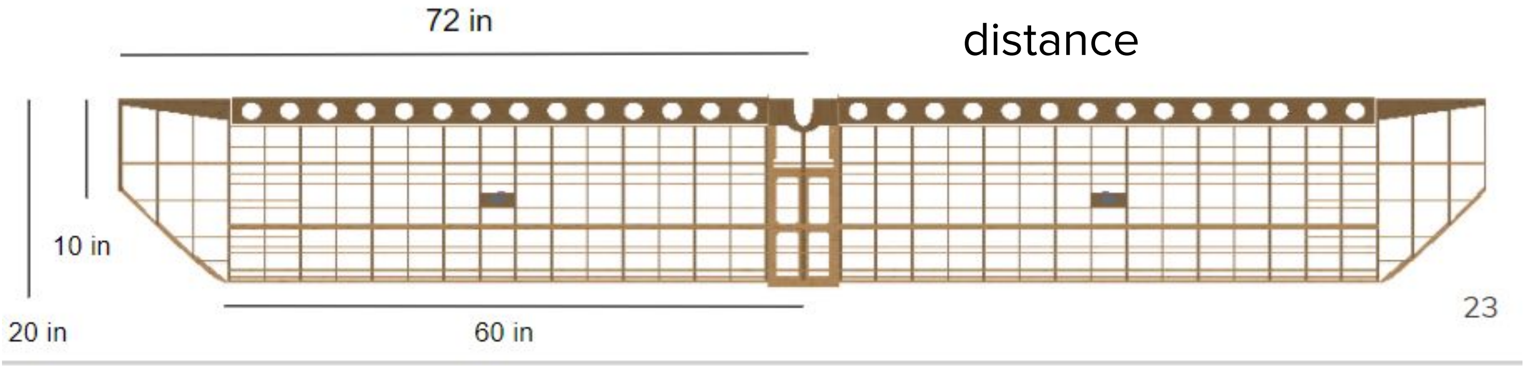
12 ft wingspan

Net weight =
allowable weight - wing weight



Final design selection

- Final wing dimensions after simulating over 500 wing shapes:
  - 12 ft wingspan
  - 60 inch taper start location from root
  - 20 inch root chord
  - 10 inch tip chord length



- This wing design had a projected weight capacity of 31.7 lbs

- Numerical simulation predicted 200 ft takeoff distance but test flight showed a 150 ft takeoff distance

Scoring

- 0.5lbs weight per 1 Tennis ball
- More balls + weight = more points
- Flight score = # tennis balls **(+)** weight carried **(-)** tennis balls not carried (from estimate)
- Final score = Average of flight score
- Not flying a round = 0 points -> counts towards average

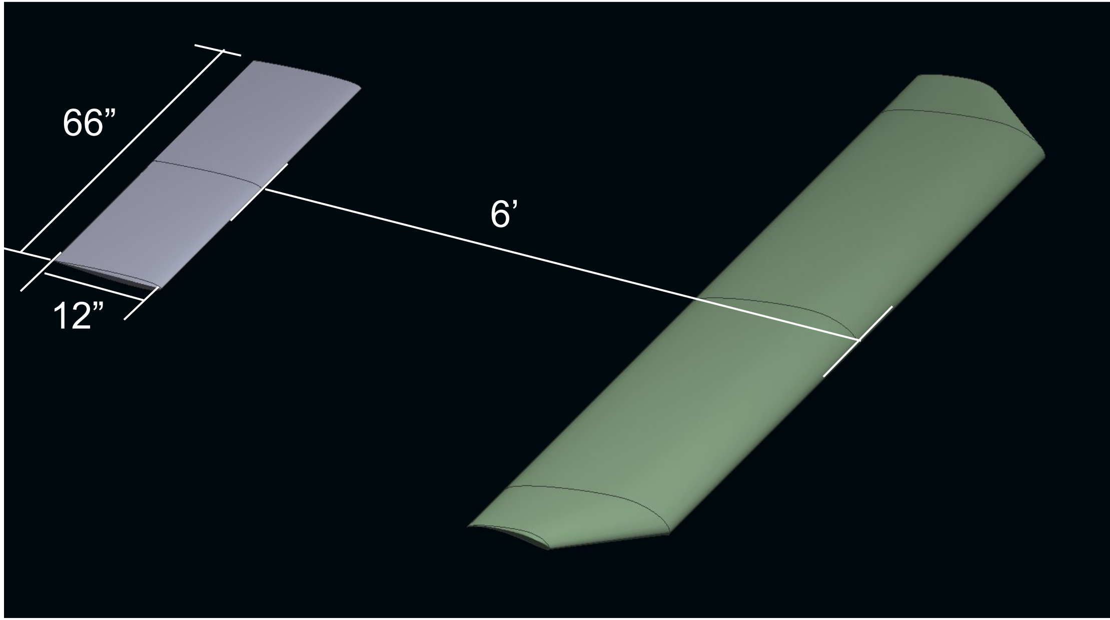
Plane Weight	17 lbs
Wing area	19.2 ft^2
Max weight	31.7 lbs
Carried weight	14.7 lbs
Score	68.7
Tennis balls carrying	22
Cargo carrying	11 lbs

$$FS = Flight\ Score = \$100P + \$50C - \$100E\ for\ each\ flight$$

$$FFS = Final\ Flight\ Score = \frac{1}{40\ N}\left[\sum_{1}^{N} FS\right]$$

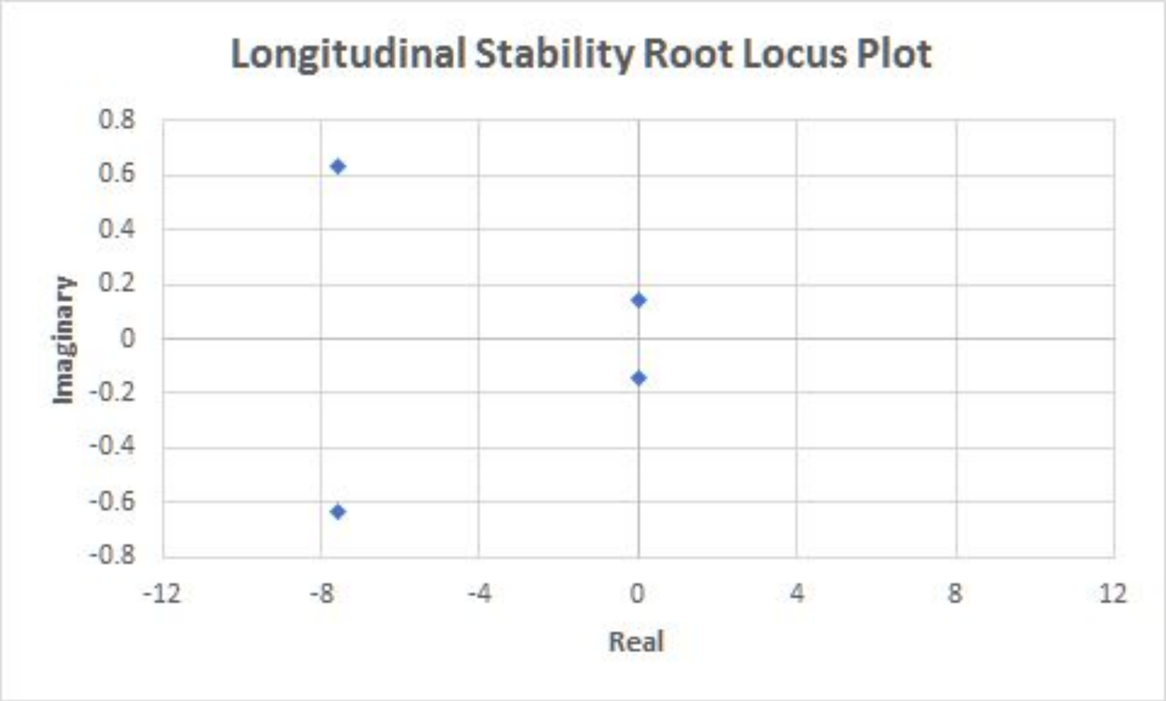
Horizontal Stabilizer

- 66” x 12”
- 6 feet from wing



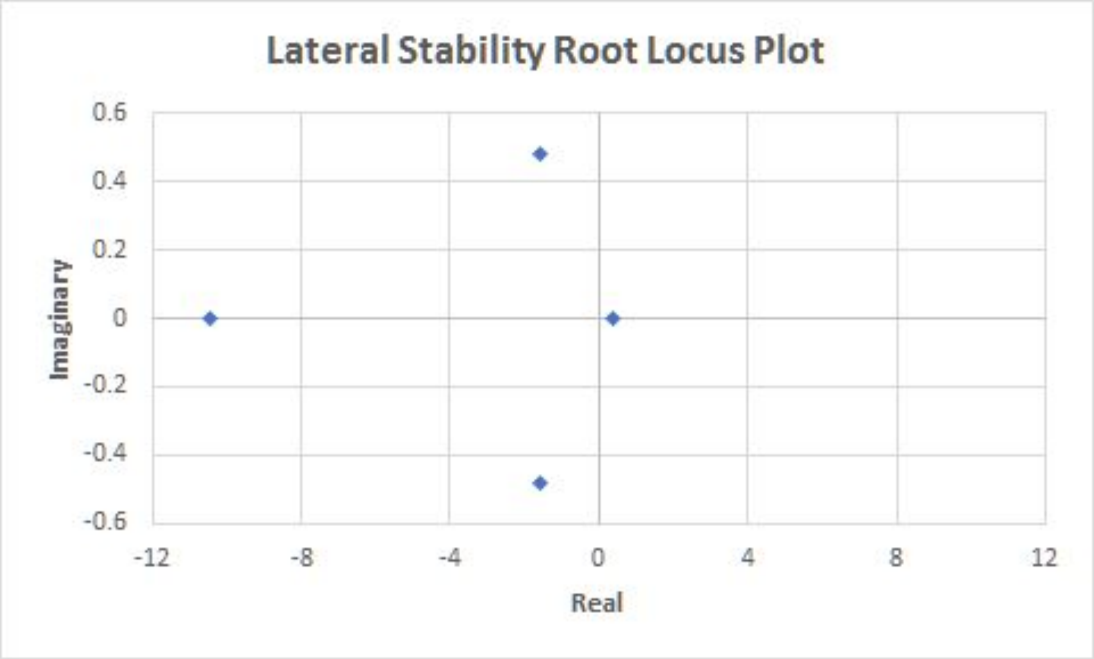
Longitudinal Stability

- All points to left of imaginary axis
- CFD analysis confirms self-stabilization at 0 degrees angle of attack



Lateral Stability

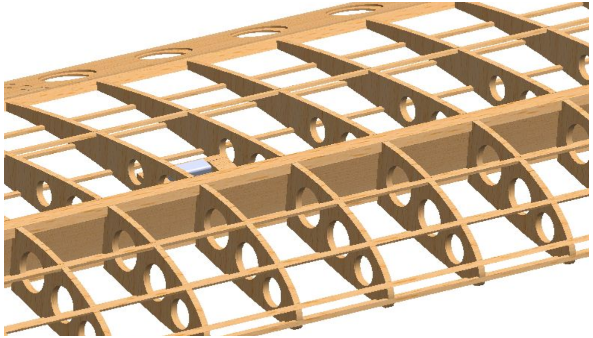
- Root locus predicts instability
  - Only remedied by dihedral
- High wing configuration
  - Inherent stability from CG below wing
- Piloting sufficient to maintain stability

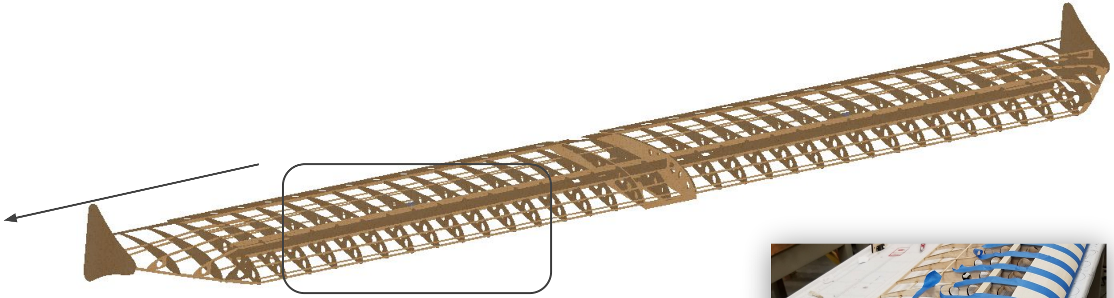


Detailed Design

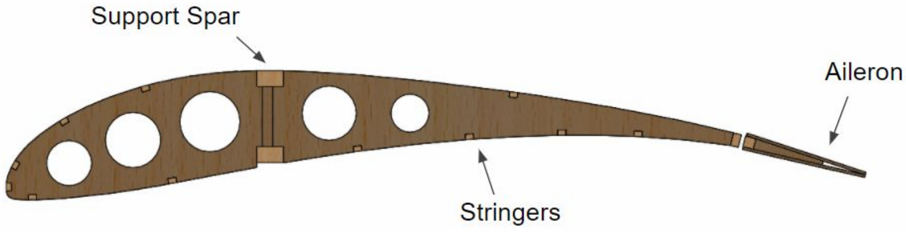
- Six major separable components
  - Vertical Stabilizer
  - Horizontal Stabilizer
  - Tube + tail wheel
  - Landing gear
  - Wing
  - Fuselage
- Held together with #6 -32 bolts

Detailed Design - Wing

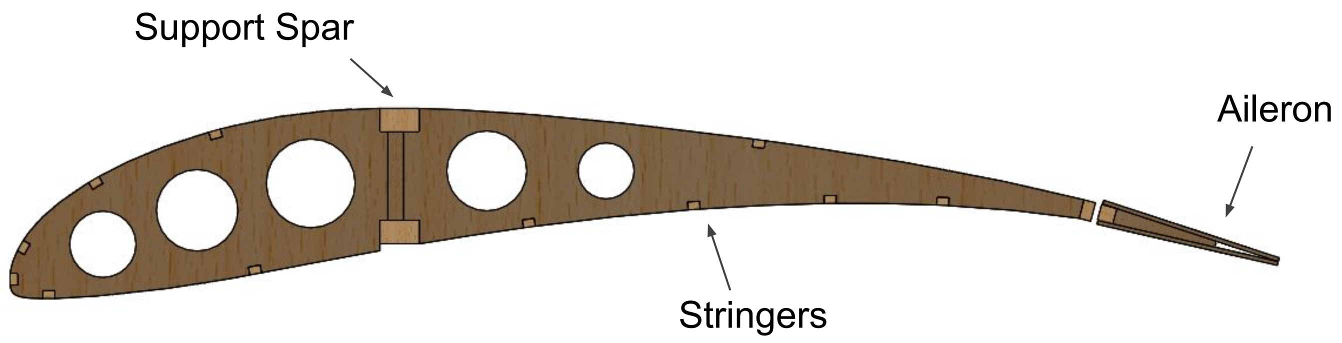




- Balsa Ribs
- Spruce Support Spars & Stringers
- Full length ailerons until taper
- Removable winglets
- 1/32” Balsa sheeting on leading edge
- Foam blocks in tapered edge



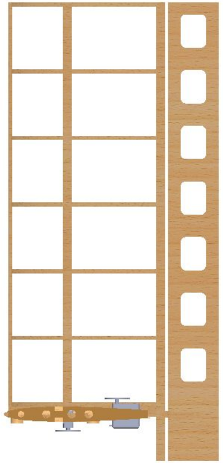
Detailed Design - wing cross section

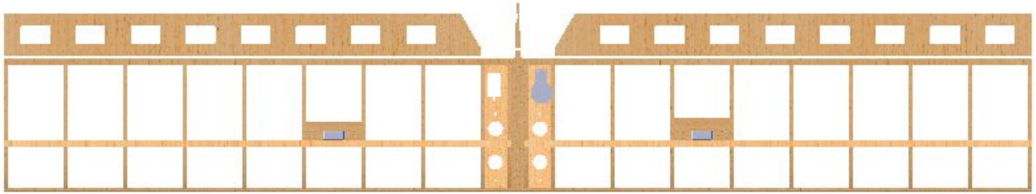


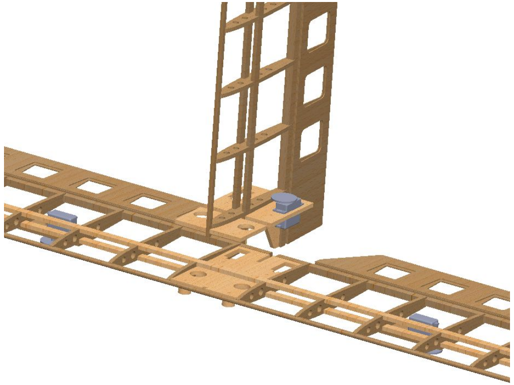
- S1223 Airfoil
- Two spruce main support spars to support weight
- Smaller stringers to support monokote and add torsional rigidity
- Holes to make it lighter + sized for a tube to keep wing straight while gluing

Detailed design - Tail

- NACA 0008 Airfoil
- Detachable for shipping
- Control Surfaces: 33% of stabilizer surface area - increased after test flight
- Split elevator with two servos







Structural Analysis - Wing and Tail

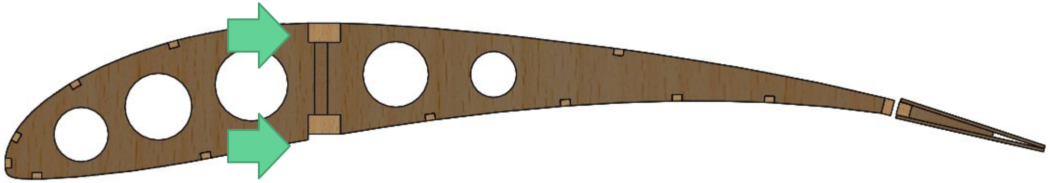
Spar Sizing

- Bending is considered most critical load
- Analysis performed to determine optimum shape assuming 1 in^2 area
  - Four shapes considered
  - Assume spars feel all load (conservative)
- Loading is found from distributed load from CFD
  - Modeled as point load at wing tip (conservative)

Rank	Shape	Inertia (in^4)	Maximum Bending Stress Experienced (psi)
4	Square cross Section	.083	6763
3	Circular Cross Section	.080	2995
2	Channel	1.036	1631
1	Parallel Spars	1.864	580

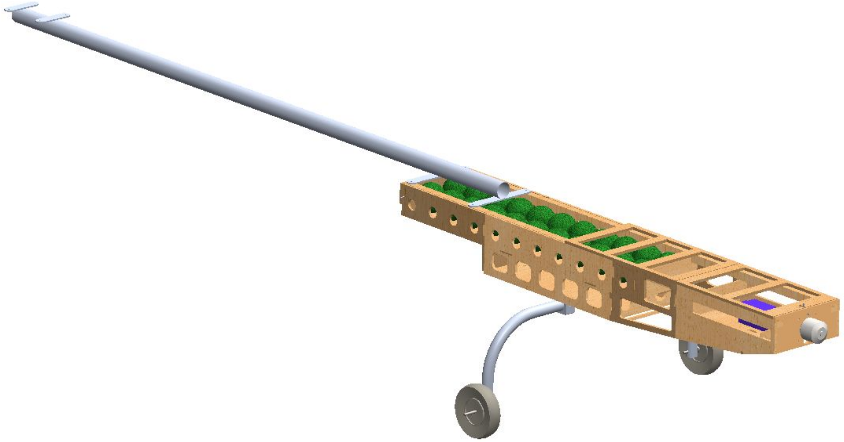
Structural Analysis - Wing and Tail

- Final Wing Spar Sizes: ⅜” by ⅝ ”
  - FS: 3.66
- Final Tail Spar Sizes: ½” in by ¼”
  - FS: 2.56
- Additional stringers are added for additional strength and to create a smooth wing profile
- Balsa Center Section Added for I-Beam configuration



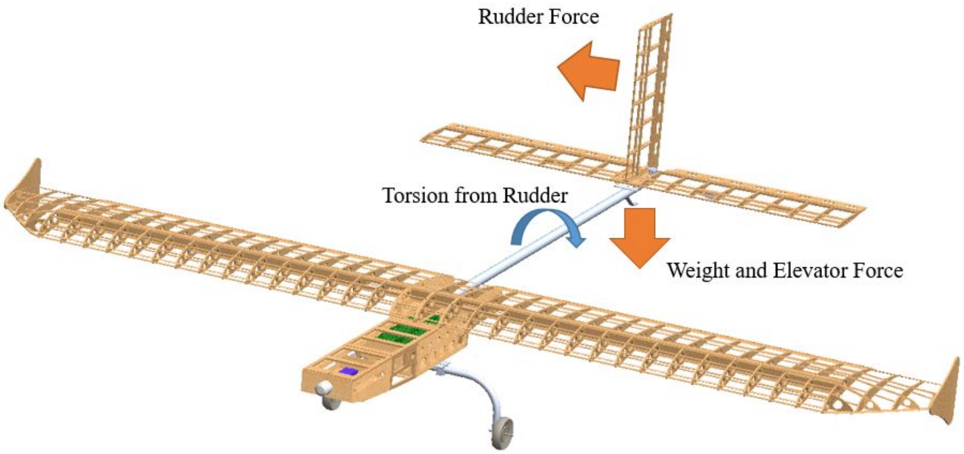
Detailed Design - Fuselage

- Balls and cargo loaded in from back towards front
- Cargo box holds weight on threaded rod for easy CG adjustment
- 1.5” OD x 0.032” Thick Tube from fuselage to tail



Structural Analysis - Tube

- Forces Considered:
  Bending from tail weight, elevator at 40, & rudder at 40°
- Torsion from rudder at 40°
- Tube Size: 1.375” OD, .049” thickness
  - -6061 Aluminum
- Size chosen to minimize deflection to 1.26°

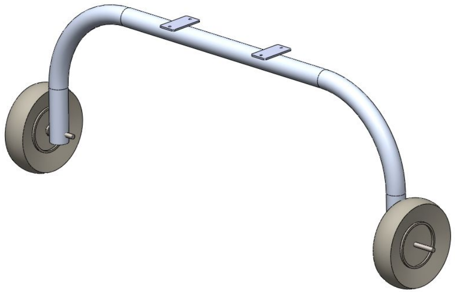


Type	Cause	Moment (lbin)	Stress Induced (psi)
Bending	elevator	215.59	3300.95
Bending	weight	108.00	1653.63
Bending	rudder	57.74	884.09
Torsion	rudder	12.30	331.59

Von Mesis Equivalent Stress	5848	psi
Yield Strength of 6061 Aluminum	40000	psi
Factor of Safety	6.84	

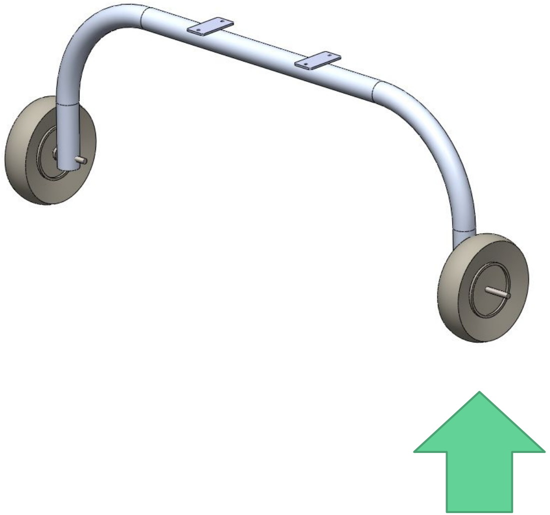
Detailed design - Landing Gear

- Tail dragger
- Landing gear - Bent 1” x .065” aluminum tube welded with brackets
- Steerable tail wheel controlled by rudder



Structural Analysis - Landing Gear

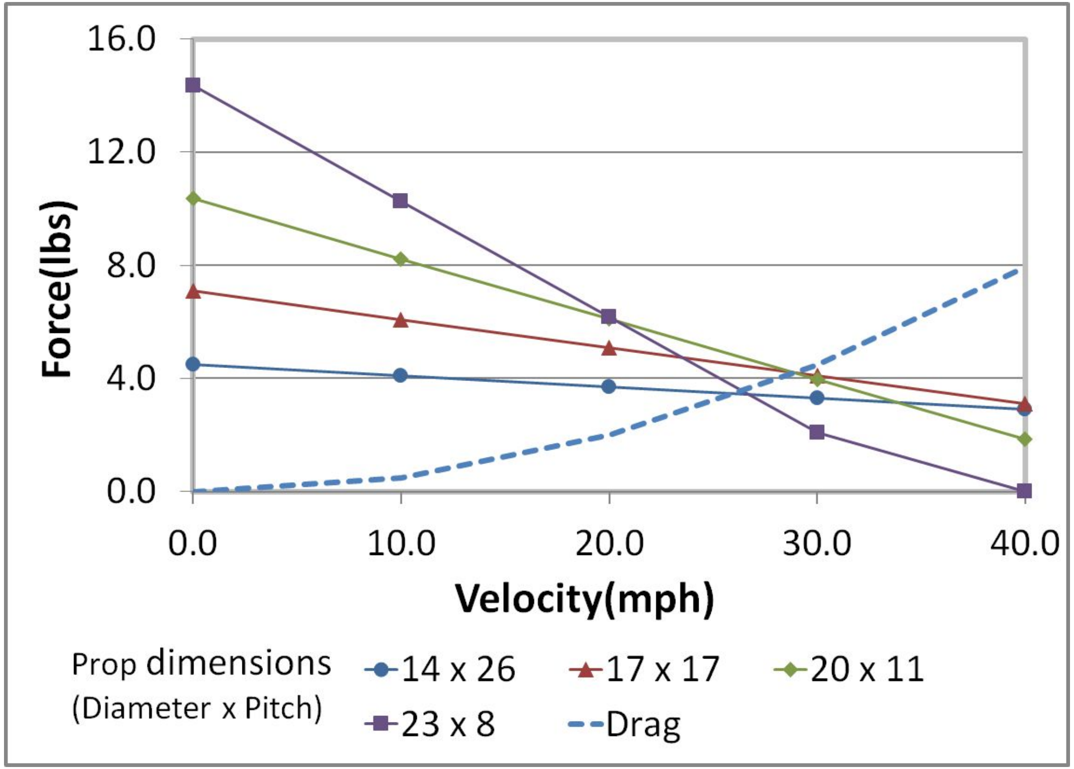
- Forces derived: Impact force from hard landing (100 lbs)
- Loads considered: bending and shear
- Conservative Assumption: load applied to one side to simulate rough landing



Shear Stress on Cross Section	185.2	psi
Bending Stress at Center	21473	psi
Von Mesis Equivalent	21473	psi
6061-T6 Aluminum Yield Strength	30000	psi
Factor of Safety	1.40	

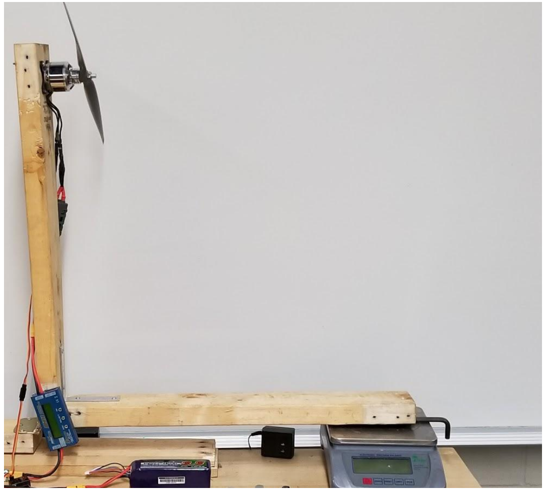
Propeller and Motor Simulations

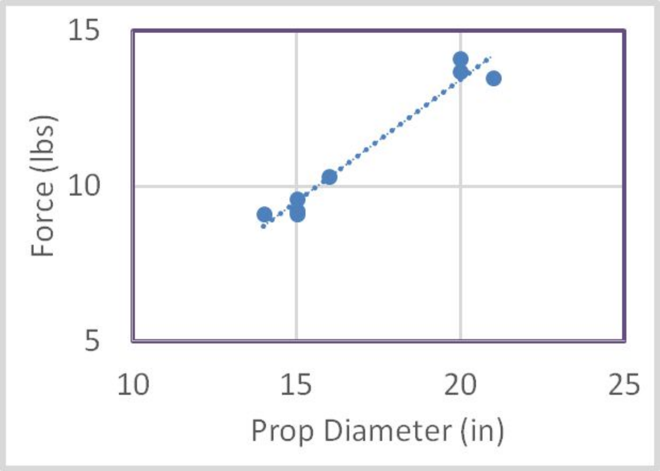
- 260KV Motor Analyzed
- Intersection of curve shows 20 x 11 and 17 x 17 props have highest max velocity
- 20 x 11 chosen to test around because it has highest force at static thrust



Propeller + Motor Testing

- Graph includes 500KV, 450KV motor and 260KV motor with 8 props tested
  - 500KV & 450KV from 2017
  - Limiter included in tests
- Tests show 260KV motor has higher static thrust using same analysis methods
- 20 x 10E Graupner prop chosen with highest static thrust and low vibrations





Test Flight

- First Test flight conducted at 50% loading capacity (5 lbs cargo + 17 lb plane). Plane took off in less than 50 ft

- For the second test flight, the plane was loaded up to 75% of it's max designed capacity (7.5 lbs cargo) and took off in about 100 ft - However the plane experienced receiver issues and crash landed

- 2nd iteration improved upon a wing warp that was present in the first plane and increased surface area for the control surfaces upon the pilots input

Schedule - Fall Semester

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
	September 25-October 1	October 2- 8	October 9-15	October 16-22	October 23-29	October 30-November 5	November 6 - 12	November 13-19	November 20-26	November 27-Dec 3
Air Frame Design (Fluid Analysis)										
Structural Design Brainstorming										
Inventory Closet										
Research Vendors										
Propeller and Motor Test										
Solidworks Modeling										

Schedule

Spring Semester														
	Week 1	Week 2		Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
									Report due to SAE				Ship the Plane	Competition
	January 8-14	January 15-21		January 22-28	January 29-February 4	February 5-11	February 12-18	February 19-25	February 26-March 4	March 5-March 11	March 12-March 18	March 19-March 25	March 26-April 1	April 2-April 8
Finish Structural Design														
Structural Analysis														
Order Parts														
Build Frame														
Cover Frame														
Install Electronics														
Test Flight														
Repairs, Improvements														
Write Report														
Create Presentation														
Practice Presentation														
REBUILD														
Build Spare Parts														

Budget

Electronics	
Motor	63.38
ESC	133.98
Battery & charger	257.5
Receiver	79.98
Servos	127.14
Other Electronic components	274.42
Total	936.4
Plane Components	
Balsa	778.72
Spruce	1050.56
Aluminum	353.31
Airplane related components	462.26
Total	2644.85

Covering, glues, tools ,etc.	
Monokote	793.7
Glues & Epoxy	135.81
Useful Building tools	482.52
Total	1412.03
Shipping and Rental	
Shipping crate	368
Insulations	64.06
Shipping cost	900
Vehicle Rental	408.00
Total	1740.06

Materials total cost	$ 6,733.34

Team Differentiation

- All Mechanical Engineering Majors
  - University of Tulsa does not have an aerospace engineering program
- Custom Fluid Analysis Method
  - Utilize 12 foot wingspan limitation
  - 500+ iterations

Questions?