EML4552-2

TEAM 513: SAE AERO DESIGN COMPETITION

06-Feb-20

Team Introductions

Nestor Aguirre
Aeronautics/ 3D Printing Engineer

Zachary Silver
CAD Engineer

Martina Kvitkovicova
Electronics Test Engineer

David Litter
3D Printing Engineer

Hebert Lopez
Electrical Design Engineer

Leah Evans
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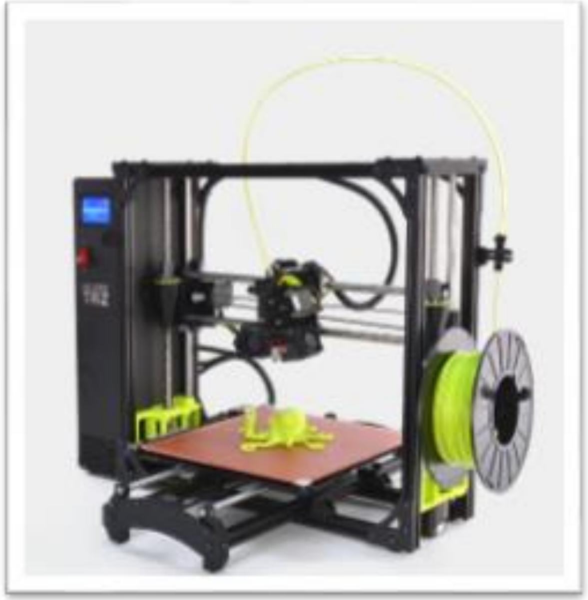
Sponsor and Advisor

Florida Space Grant Consortium	Seminole RC Club	3D Solutech	Dr. Shih
Providing Funding	Providing Equipment	Providing Various Filaments	Providing Technical Knowledge

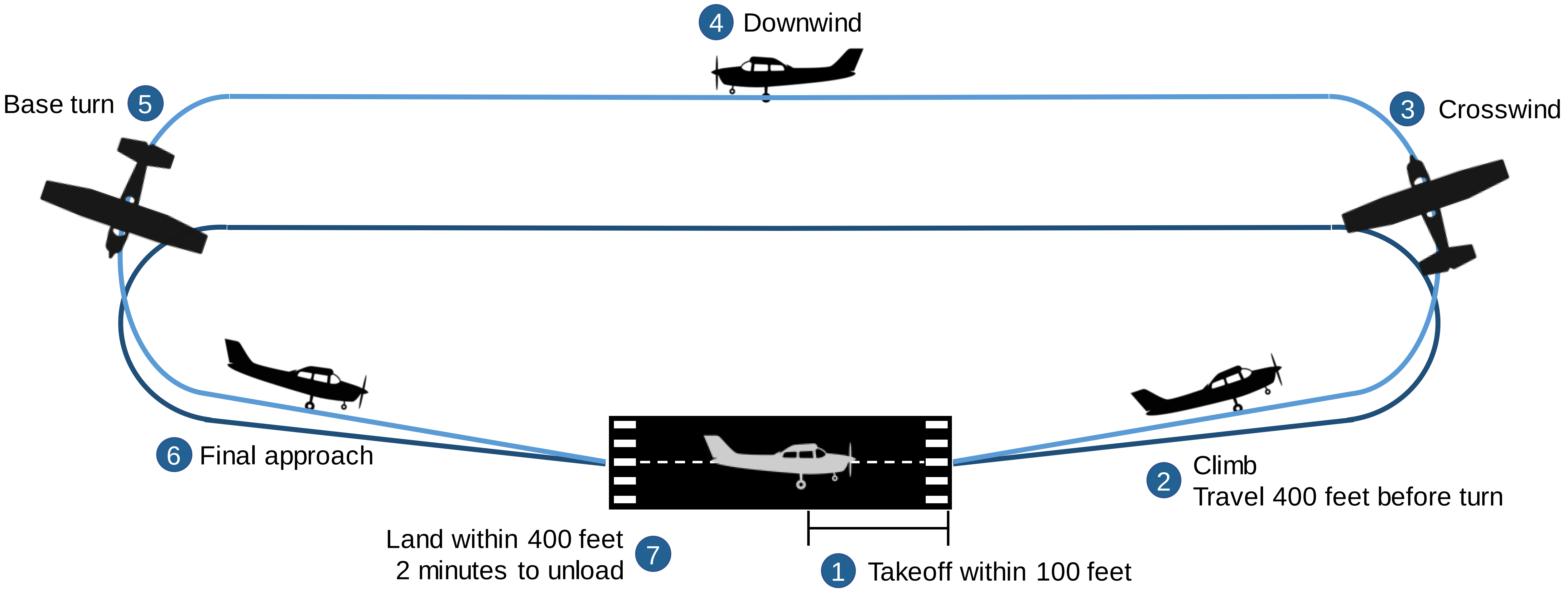
Objective

- The objective of this project is to design and manufacture a 3D printed remote controlled (RC) airplane that complies with all rules and regulations for competing in the regular class of the SAE Aero Design East competition.



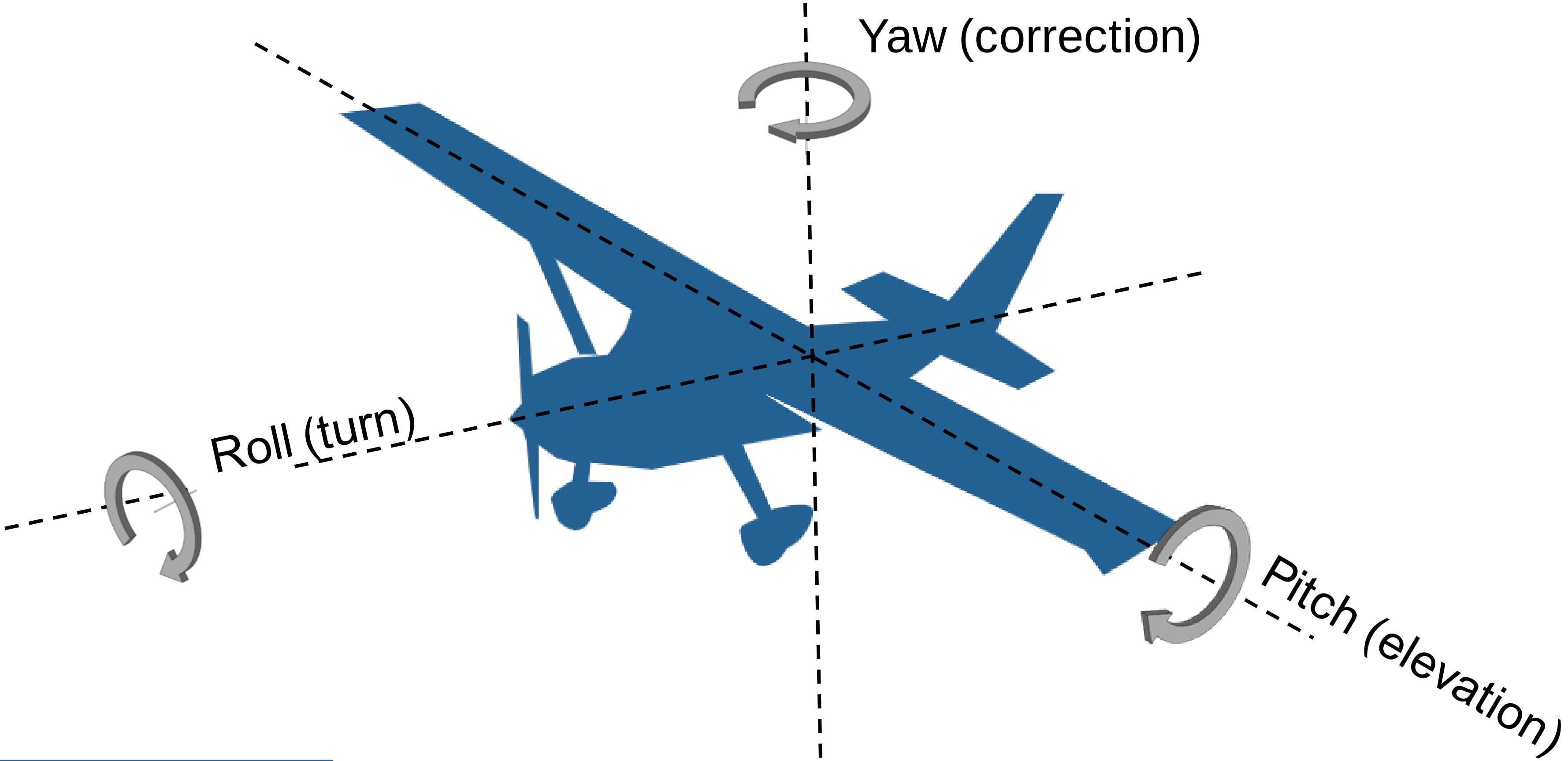
Project Summary

- Compete in the SAE Aero Design East Competition in March 2020
- Use additive manufacturing
- Improve upon prior teams' designs
- Innovate novel solutions



Competition Mission Requirements

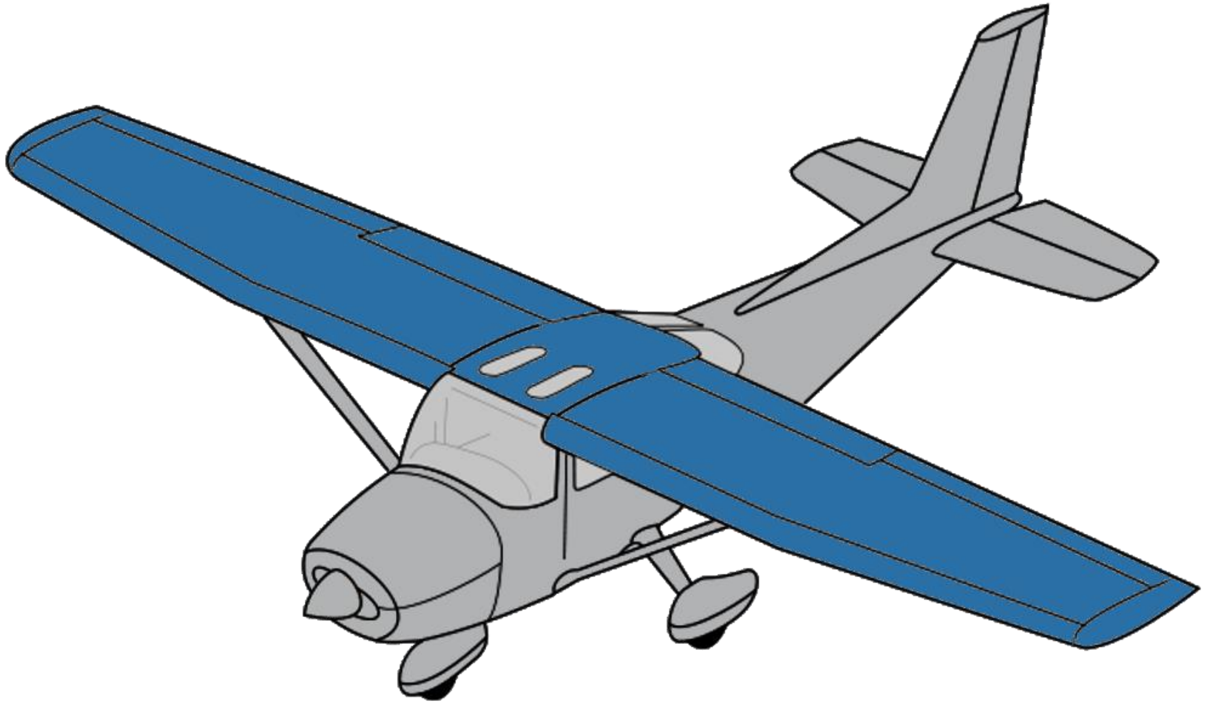
Functional Decomposition: Maneuver in Flight



Mission Requirements

Generate Lift:

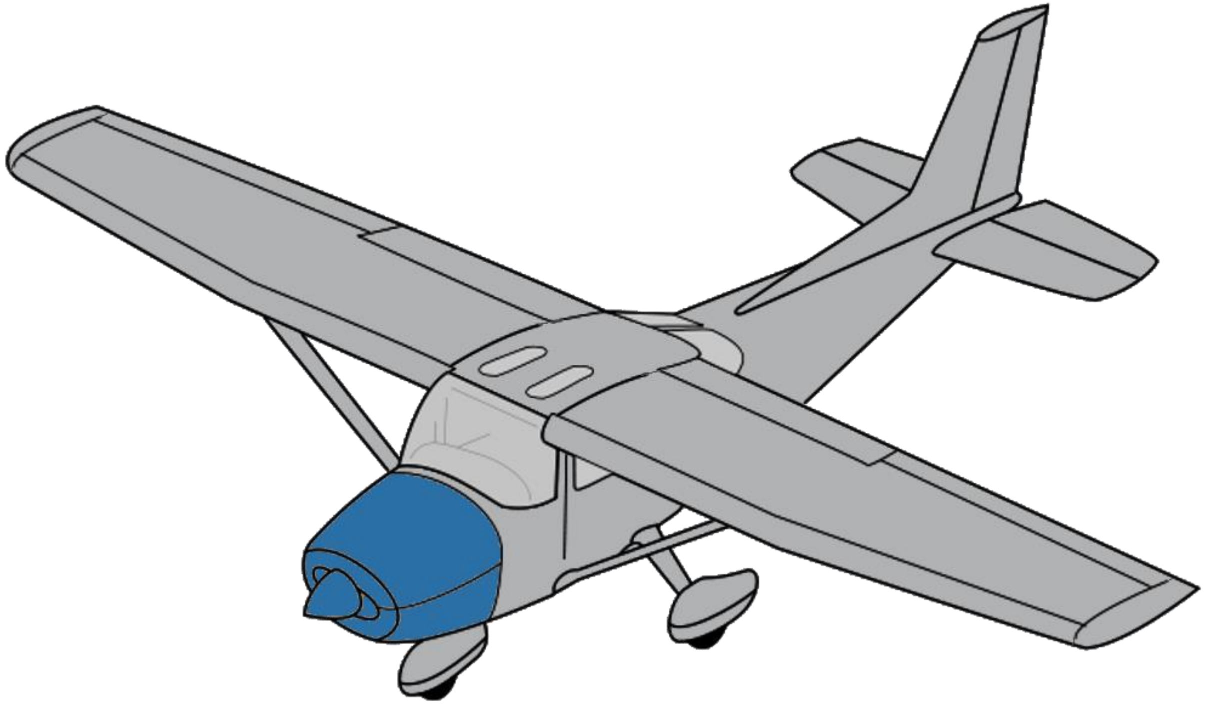
- Wingspan: 60 – 120 inches
- Wing loading: 10 – 20 oz/in^2
- Lift coefficient: 1.4 – 2.5



Mission Requirements

Accelerate/Decelerate:

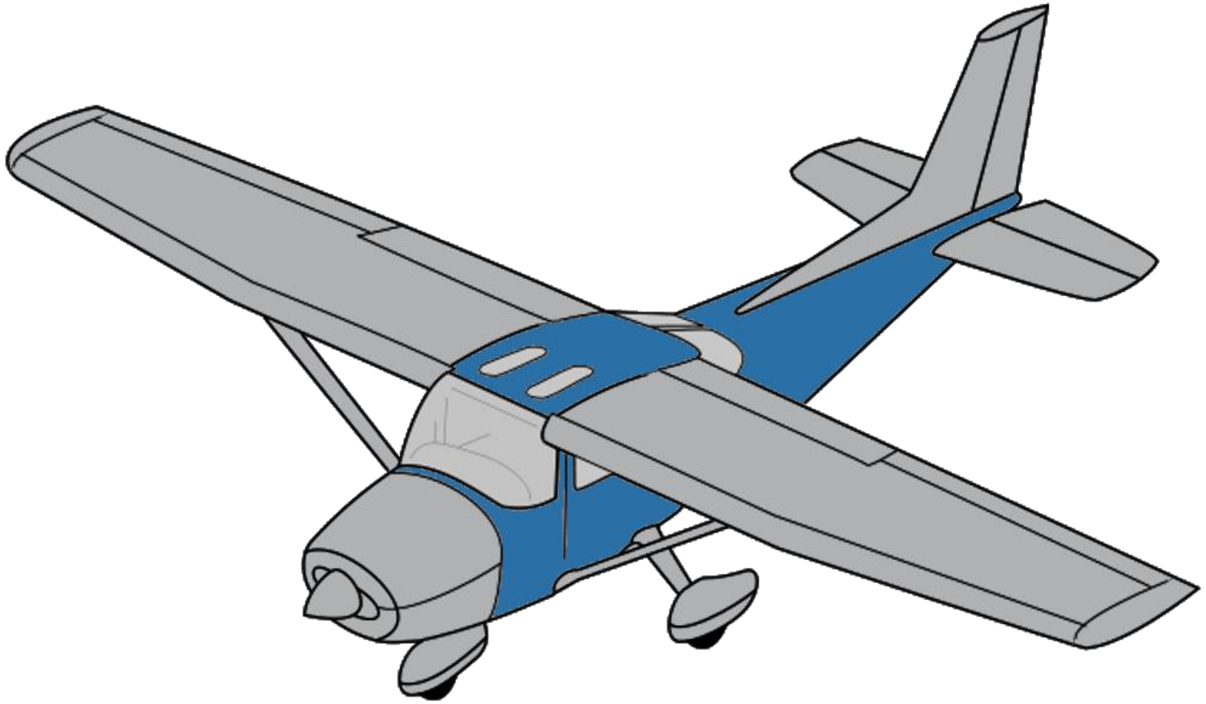
- Static Thrust: 8 – 12 lbs
- Takeoff Speed: 20 – 30 mph
- Takeoff Distance: < 100 ft

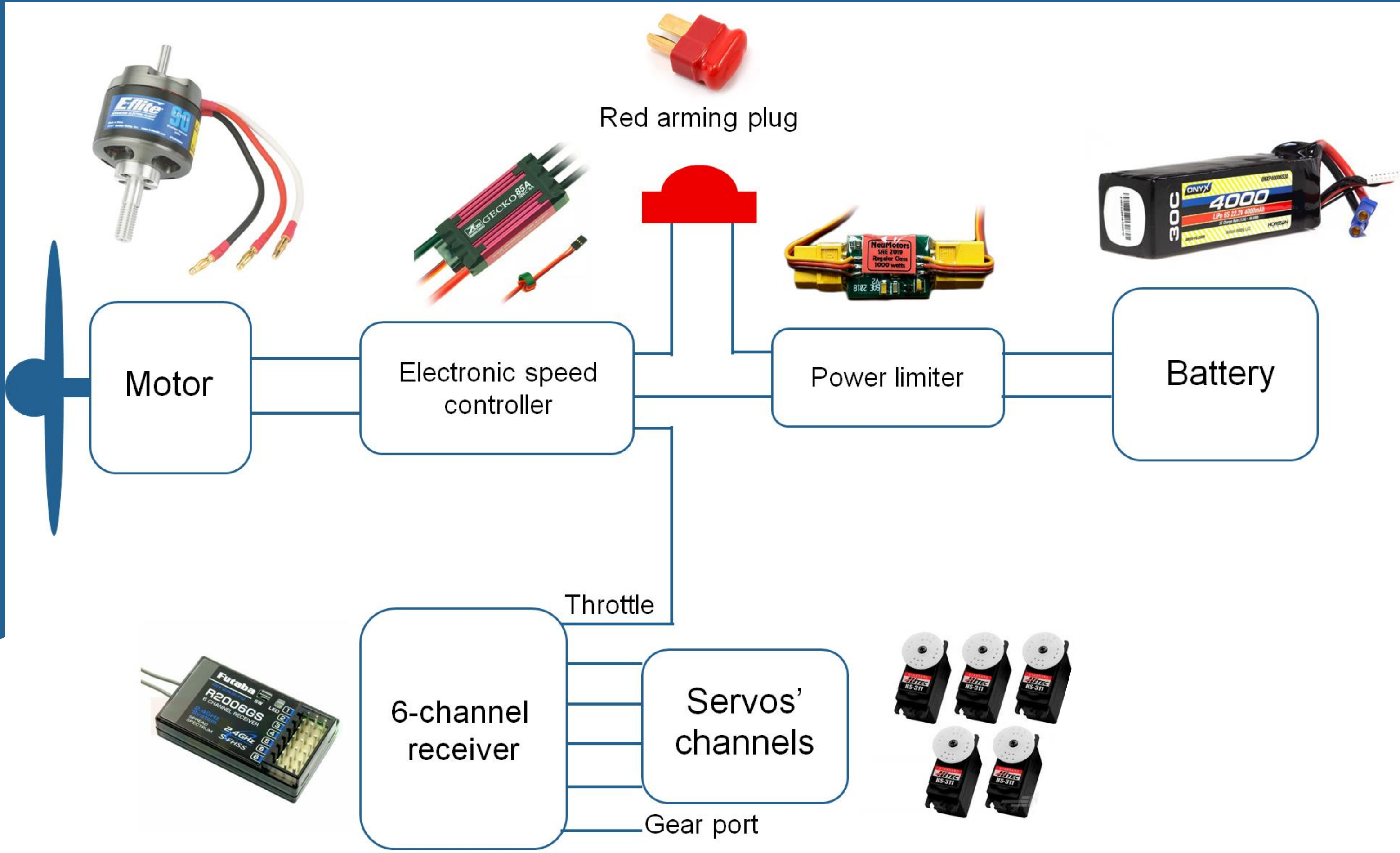


Mission Requirements

Transport Payload:

- Unload time: < 2 minutes
- Payload capacity: < 5 lbs
- Payload area: 10 inch^2



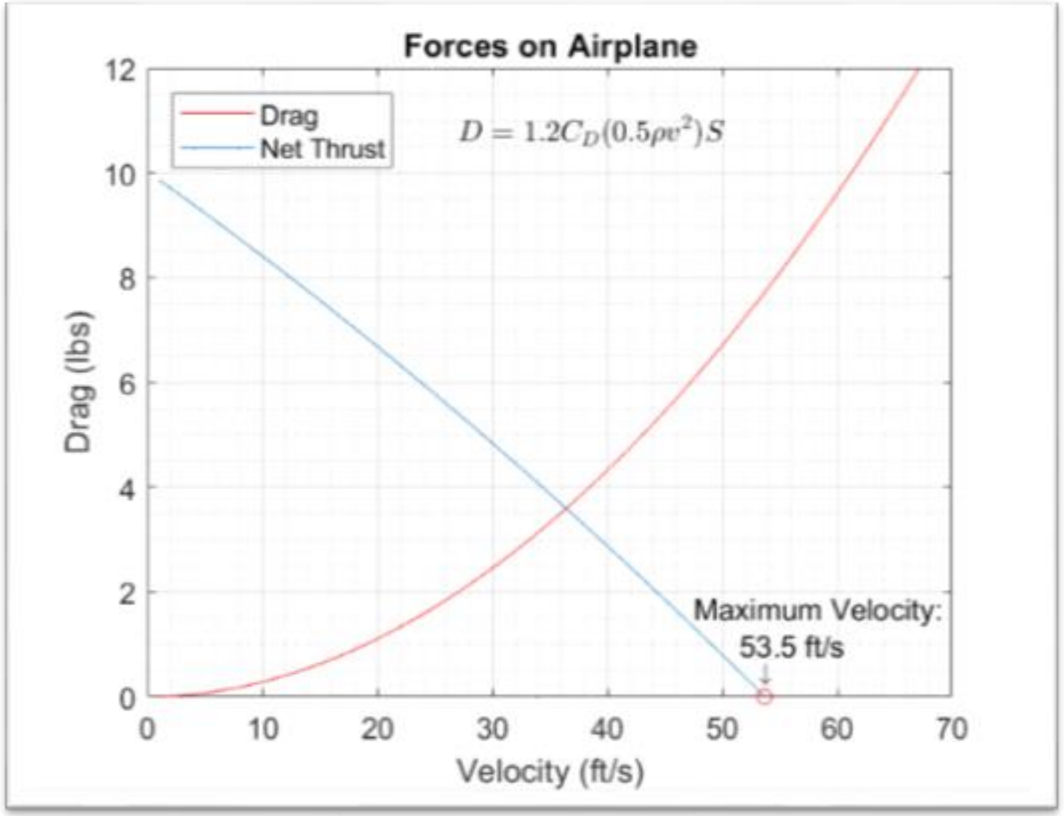


Electronics Setup

The final wiring diagram for the plane, showing the acquired parts and components to complete the circuit

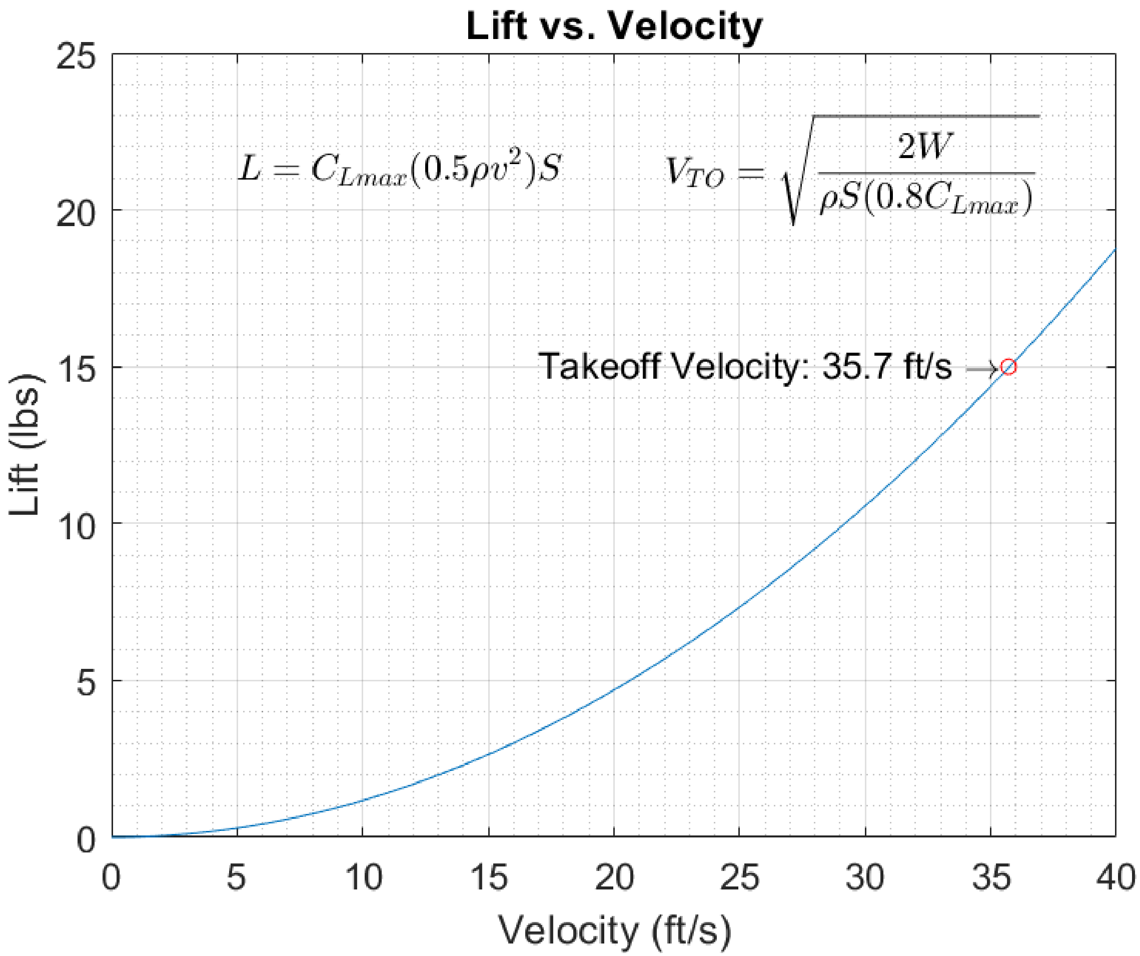
Testing

Thrust Performance Analysis



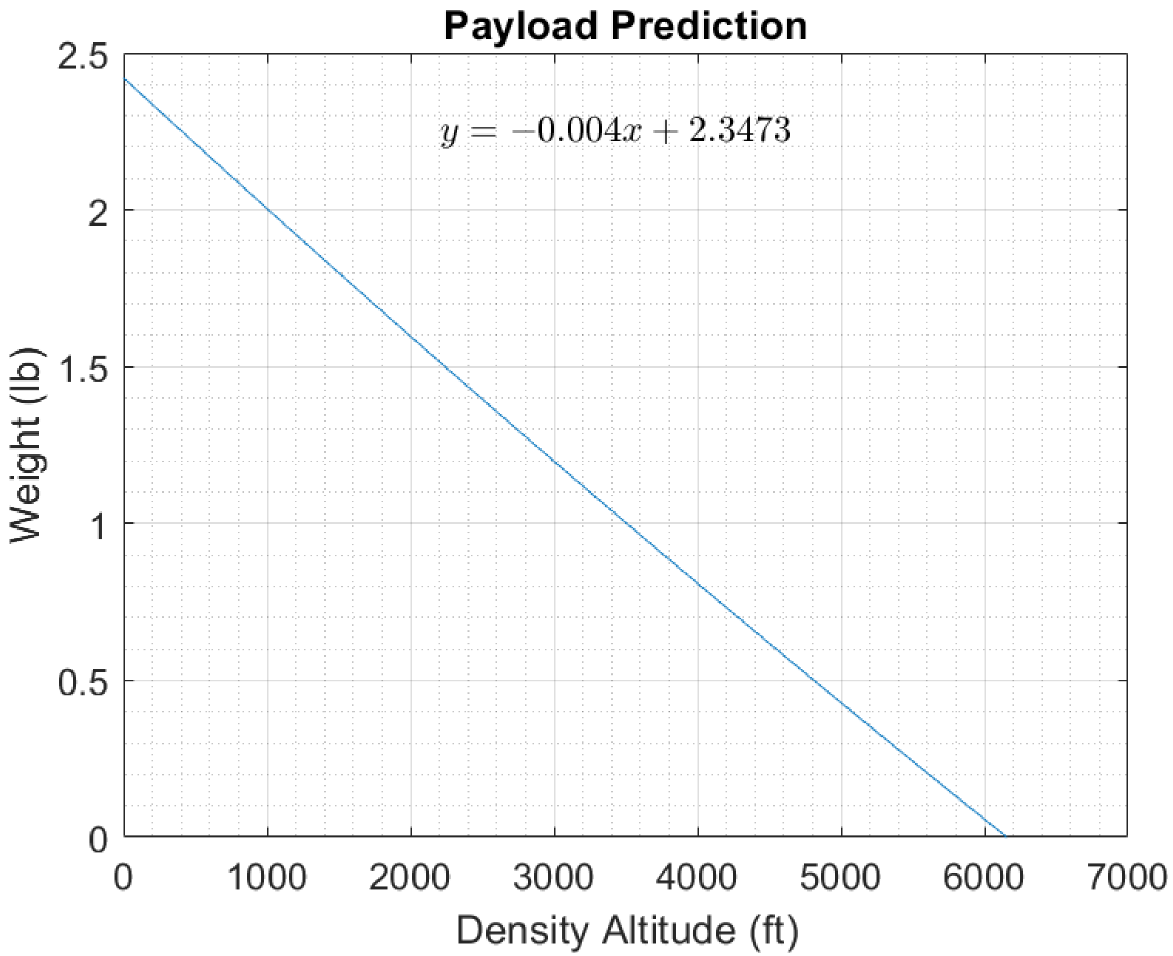
Performance Analysis: Lift

- Variables:
  - Lift (L)
  - Takeoff Velocity (V_{TO})
  - Lift coefficient (C_l)
  - Air density (ρ)
  - Velocity (v)
  - Wing area (S)
  - Weight (W)
- Yields 35.7 ft/s (24.3 mph) takeoff velocity for 15 lb plane



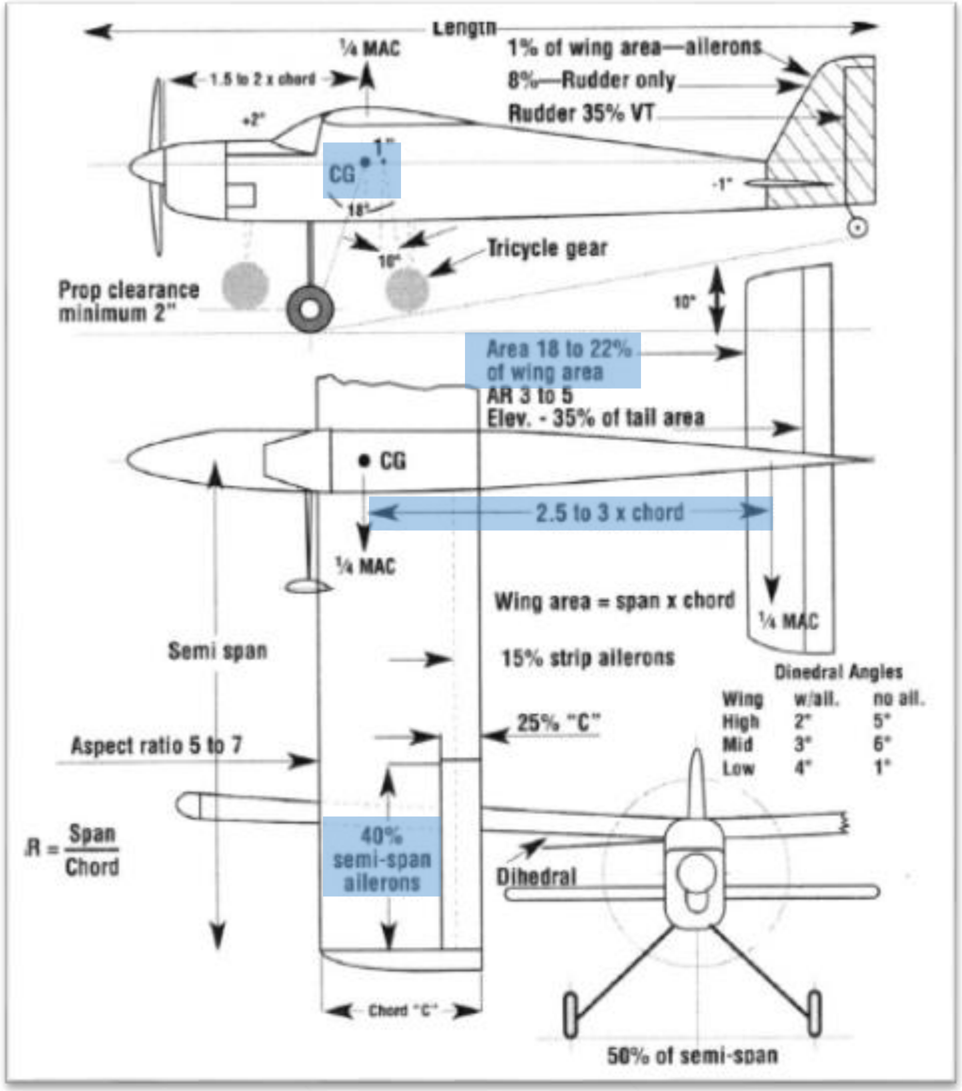
Performance Analysis: Payload

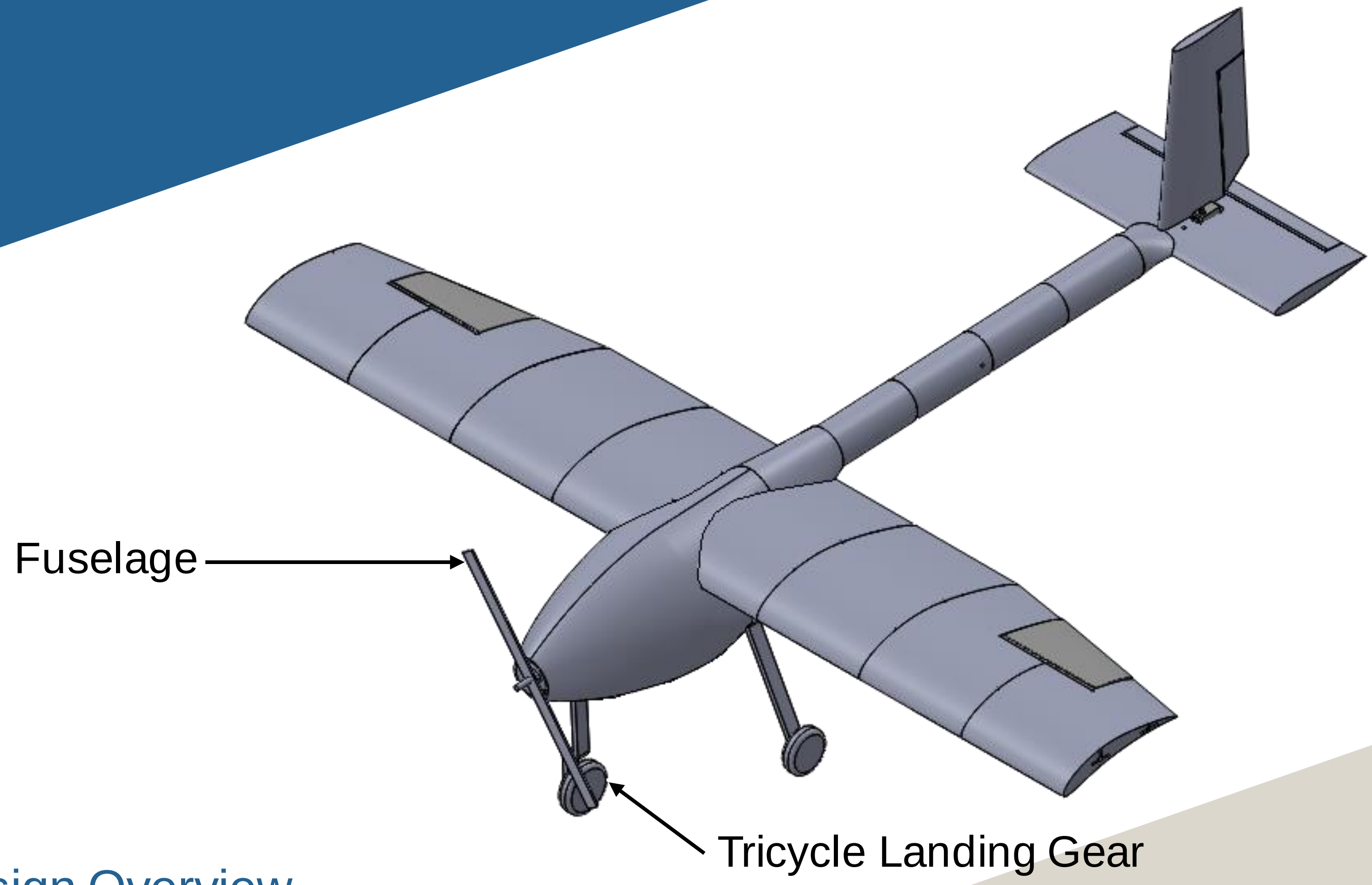
- Competition scoring based on ability to carry high payload
- For Lakeland, Florida (100 ft density altitude):
  - Max payload: 2.34 lbs



Airplane Proportions

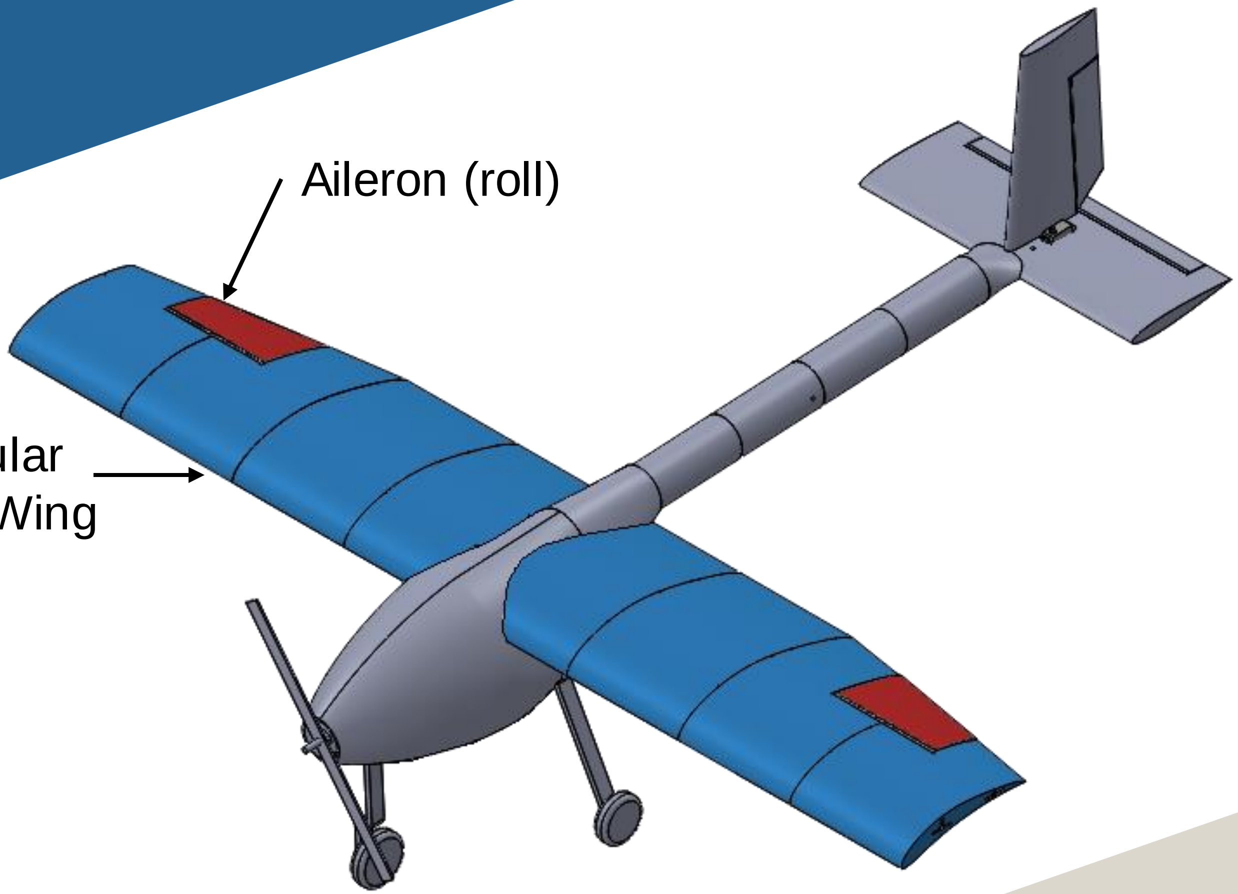
- Sized airplane using RC standards
- Wing size determines overall dimensions of airplane
- Performance sensitivities:
  - Length from wing to tail
  - Control surface area
  - Size of tail
  - Landing gear location





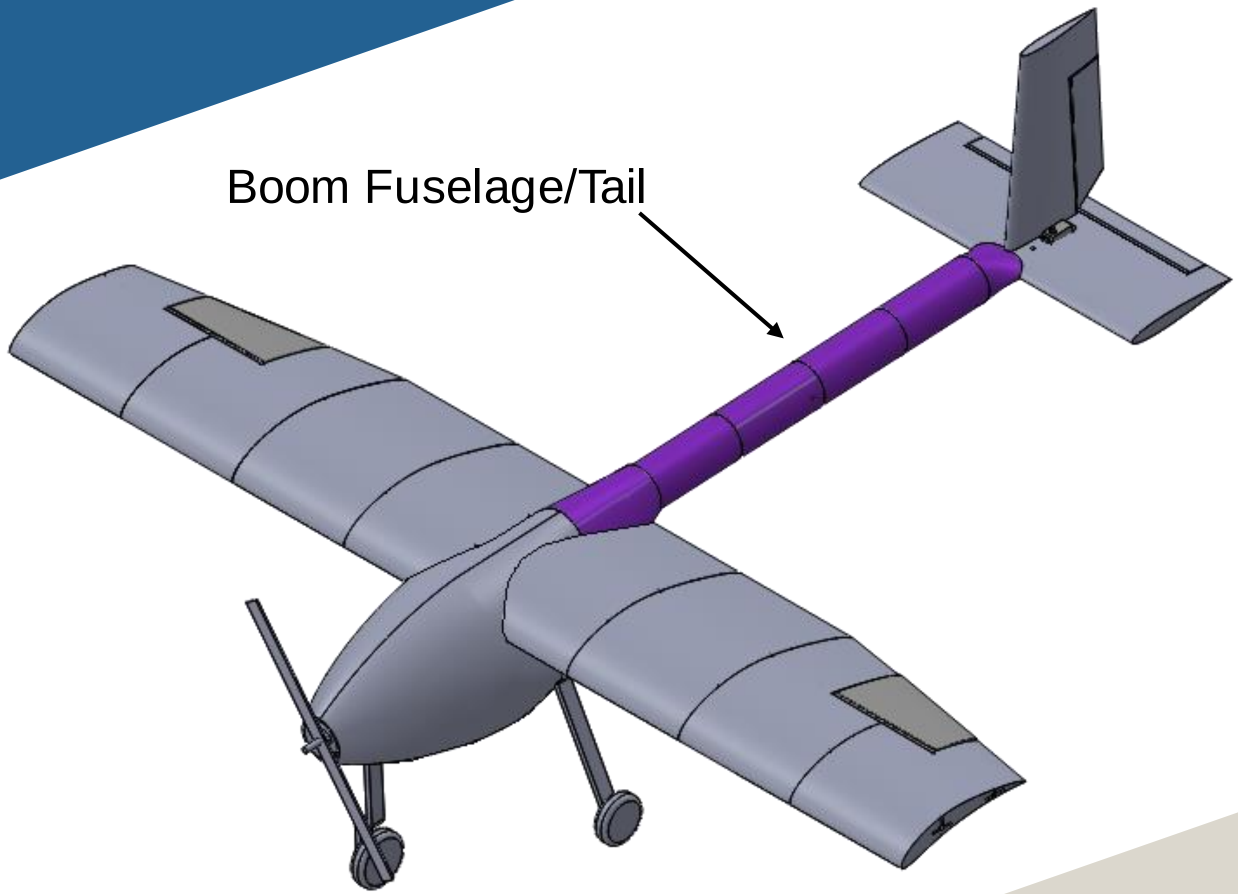
Final Design Overview

Fuselage and landing gear will not be discussed.



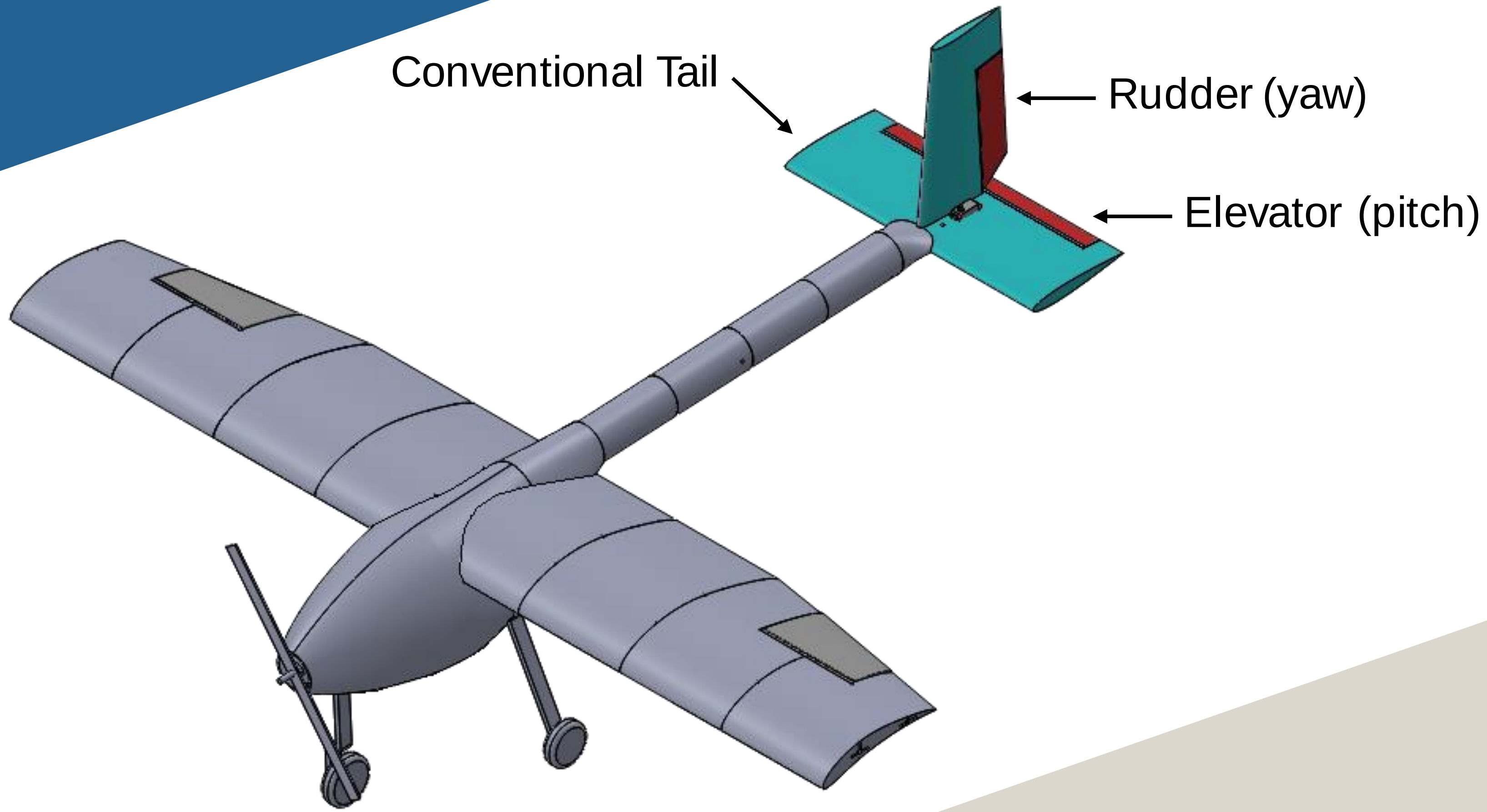
Final Design Overview

Main wing and control surfaces.



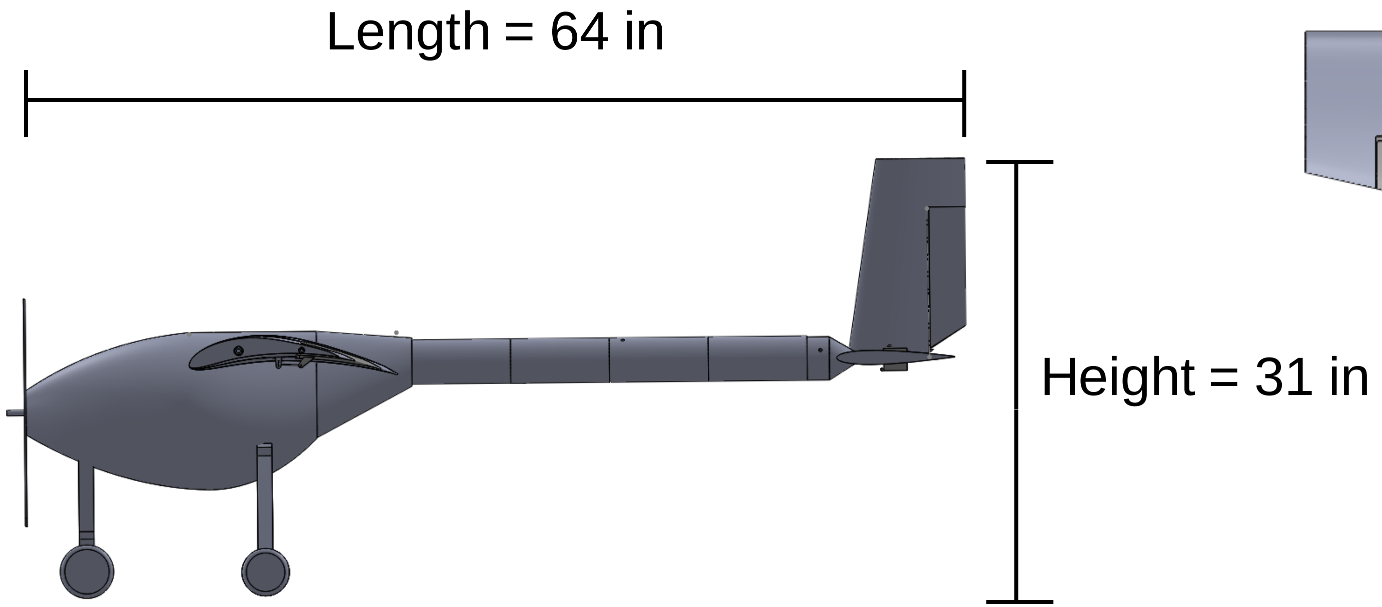
Final Design Overview

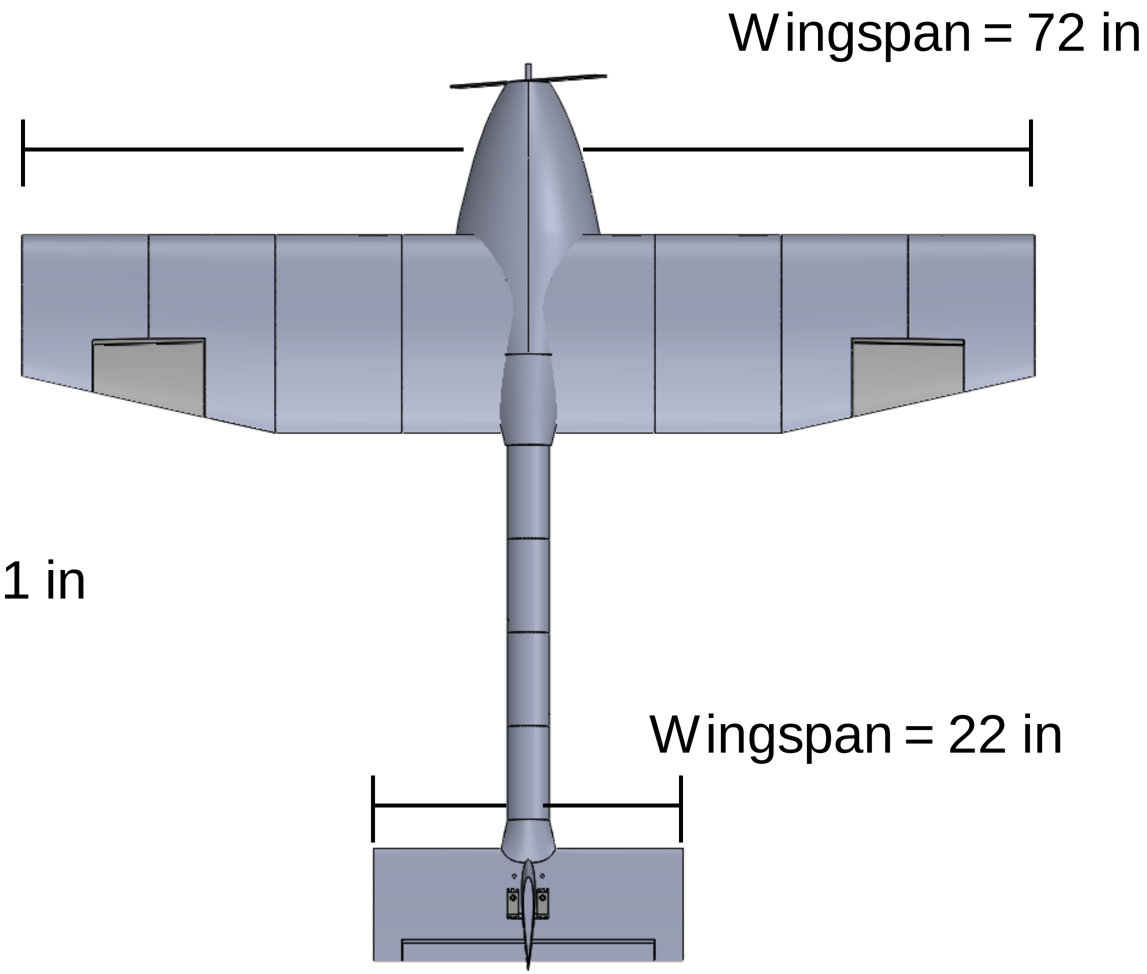
Boom connects fuselage and wing to the tail.



Final Design Overview

Conventional tail design with vertical and horizontal stabilizer.

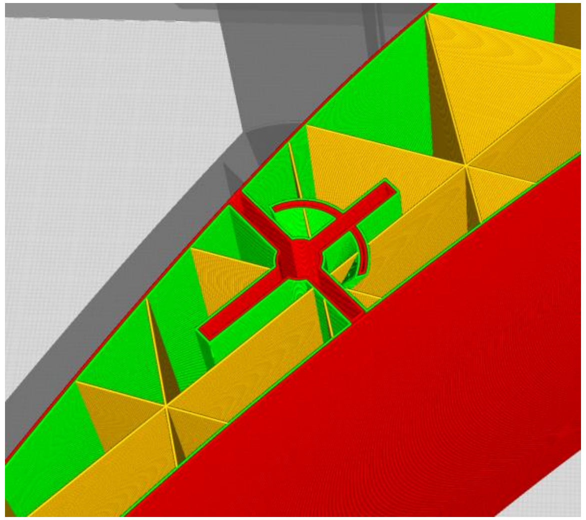


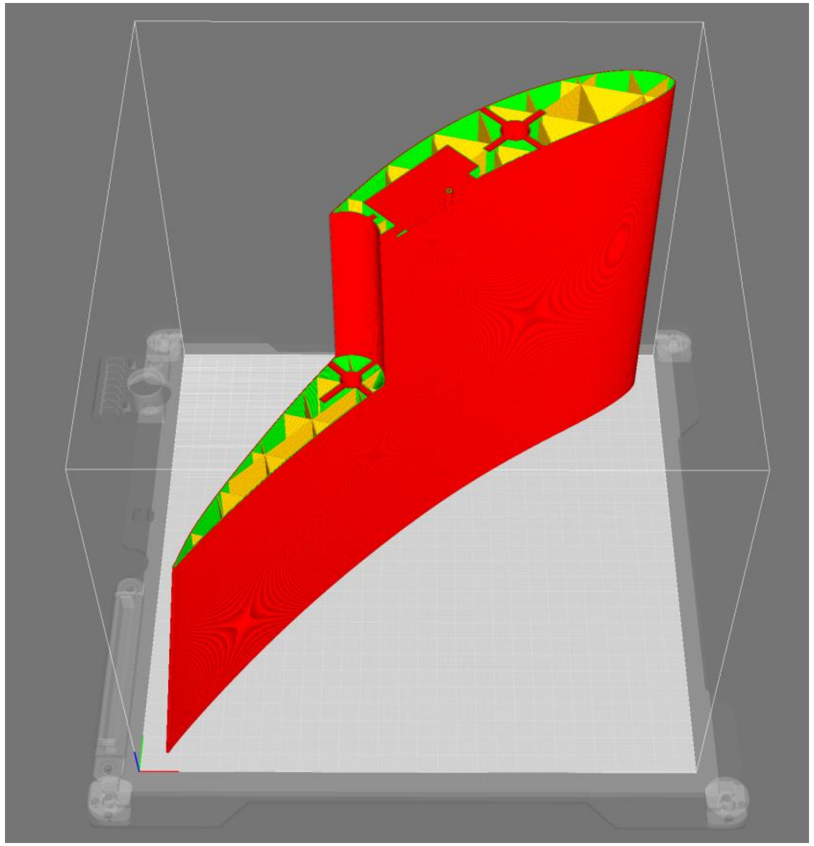


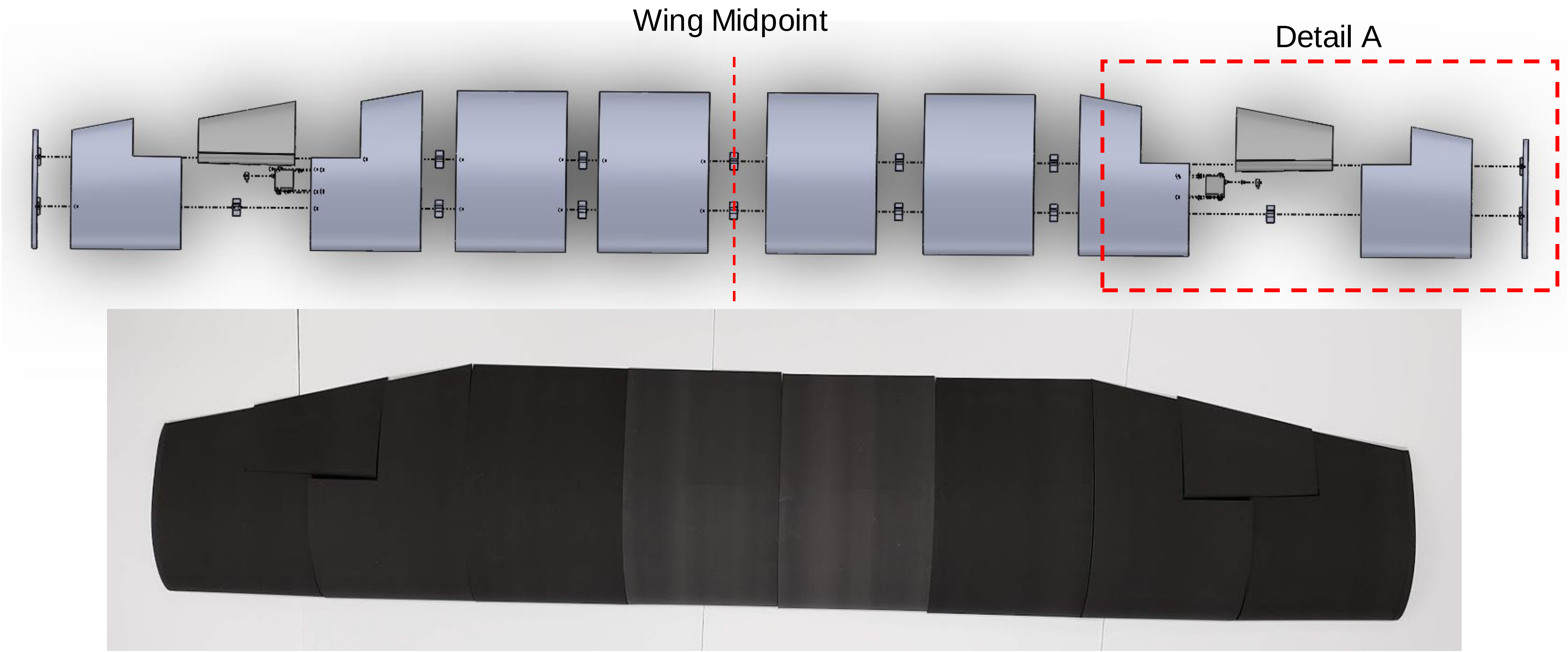
Final Design: Dimensions

3D Printing

- Designing parts to be 3D printed
  - Orientation
  - Internal structure
  - Custom supports
  - CADing in negative space
  - Looking at slice layer-by-layer



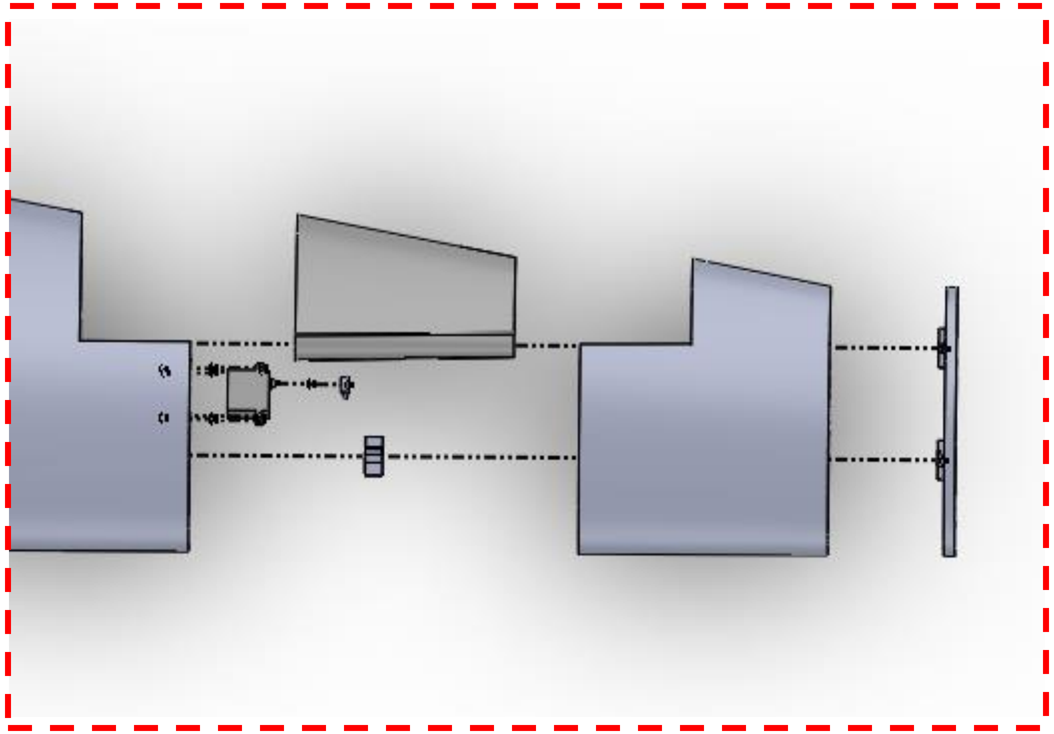


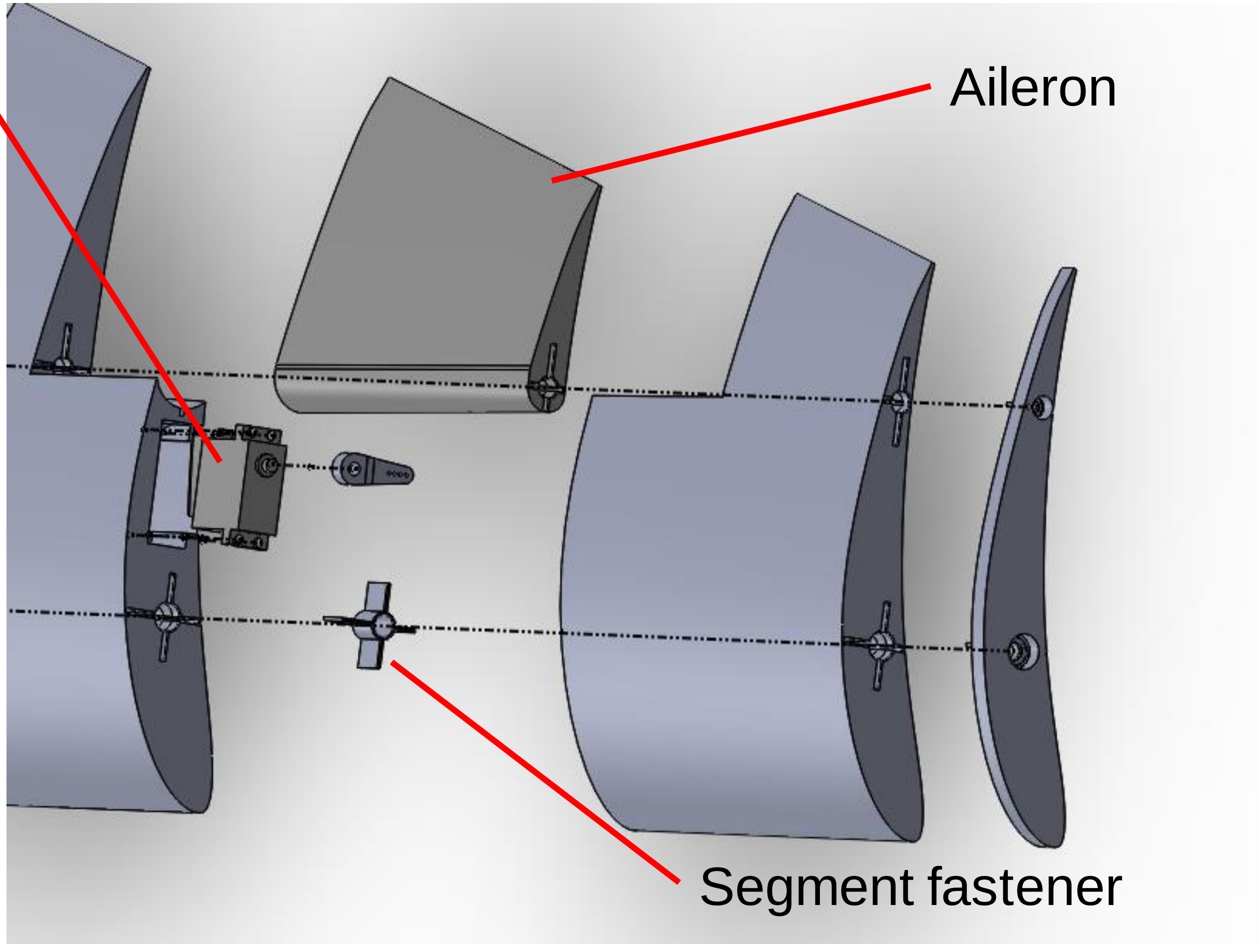


Detailed Design: Wing Assembly

The wing is comprised of eight segments, each nine inches in length, plus the ailerons and end caps.

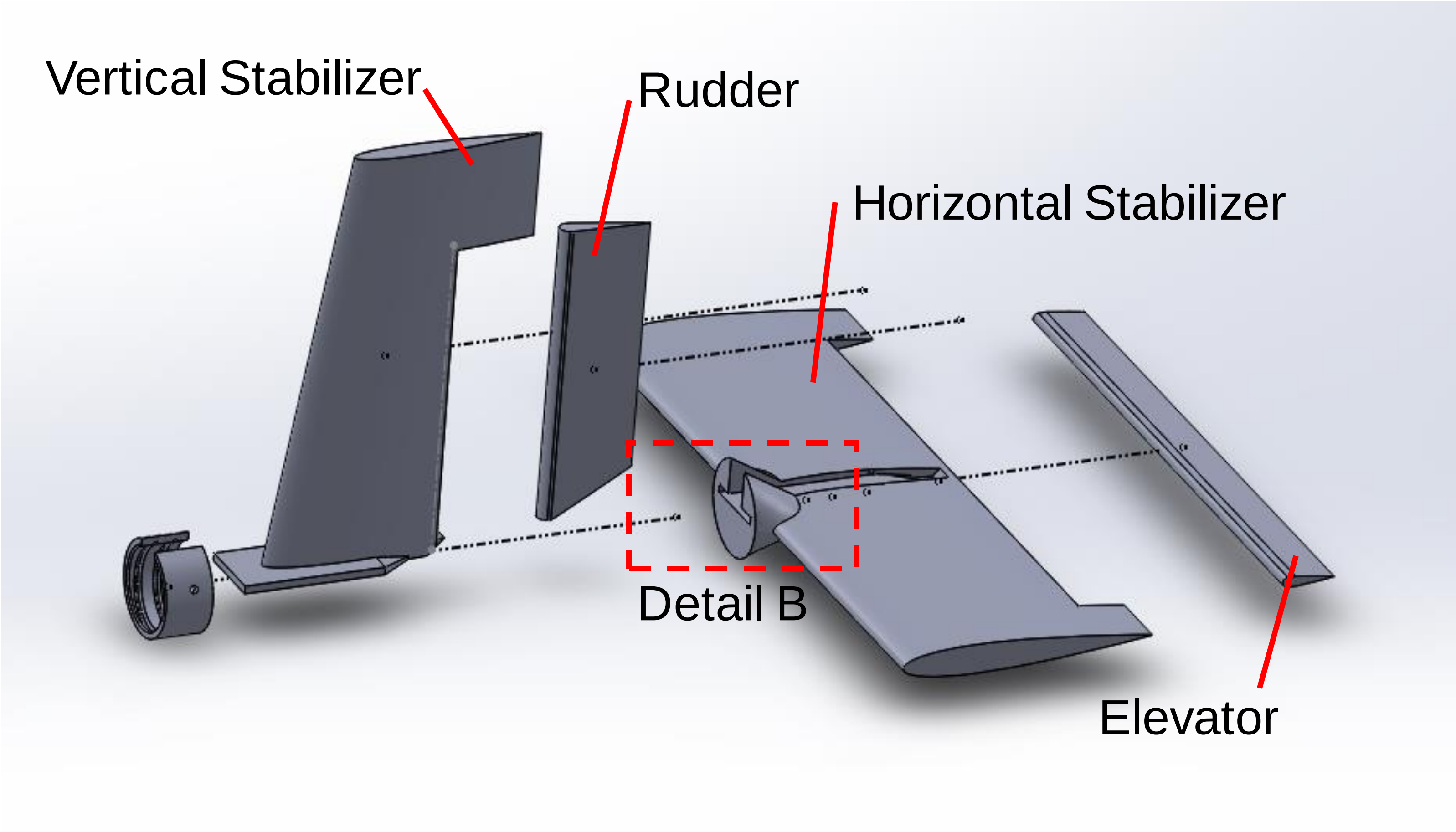
Detail A:

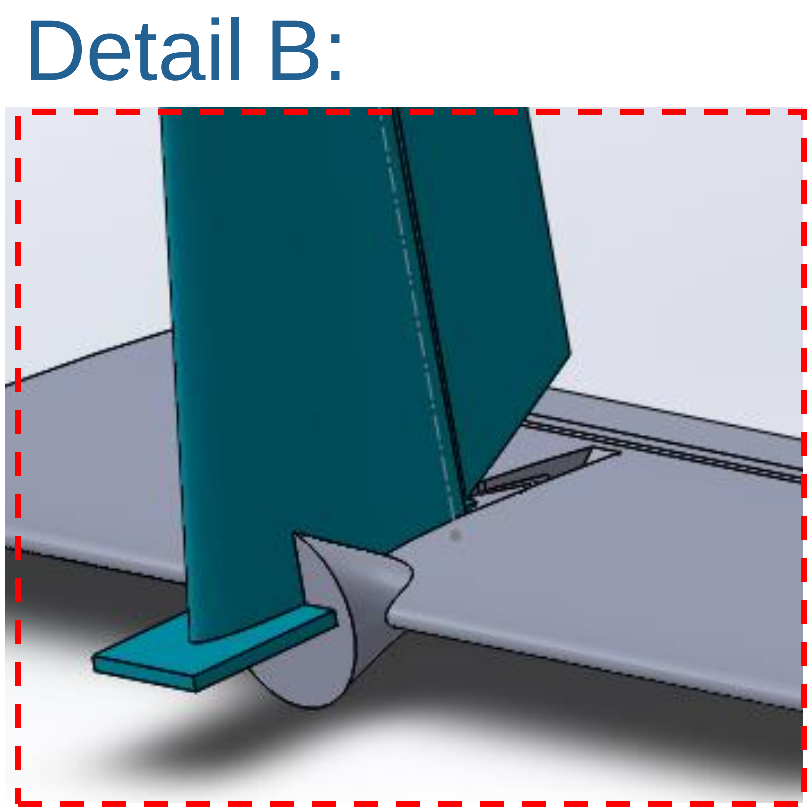




Detailed Design: Servo Motor Integration

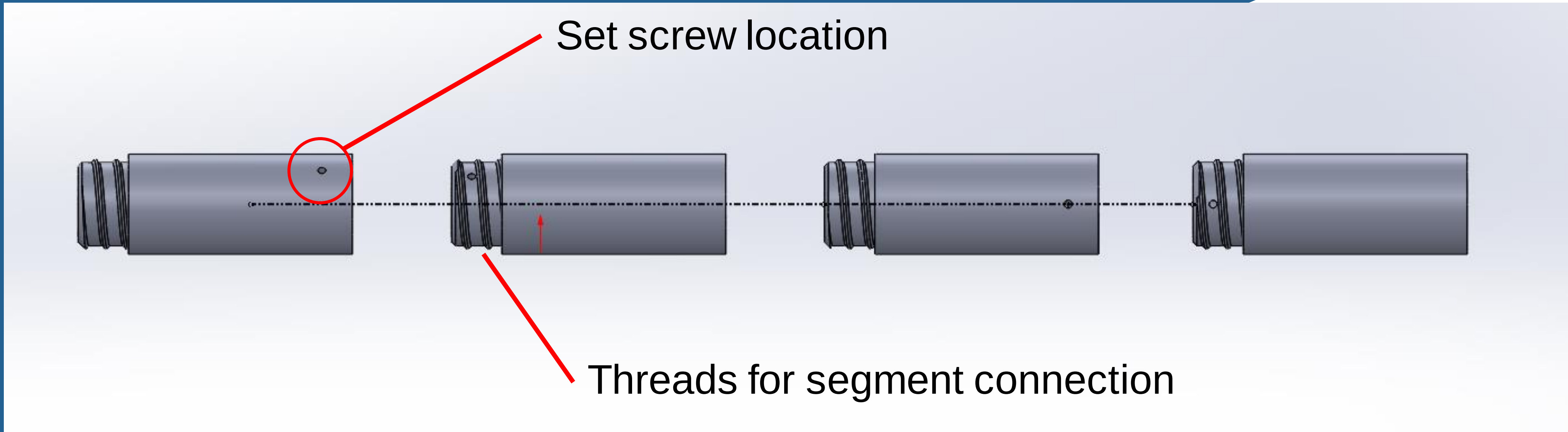
Servo motor to control ailerons is located inside of the wing, affixed between two segments.





Detailed Design: Horizontal and Vertical Stabilizer

The vertical stabilizer slides and locks into the horizontal stabilizer.

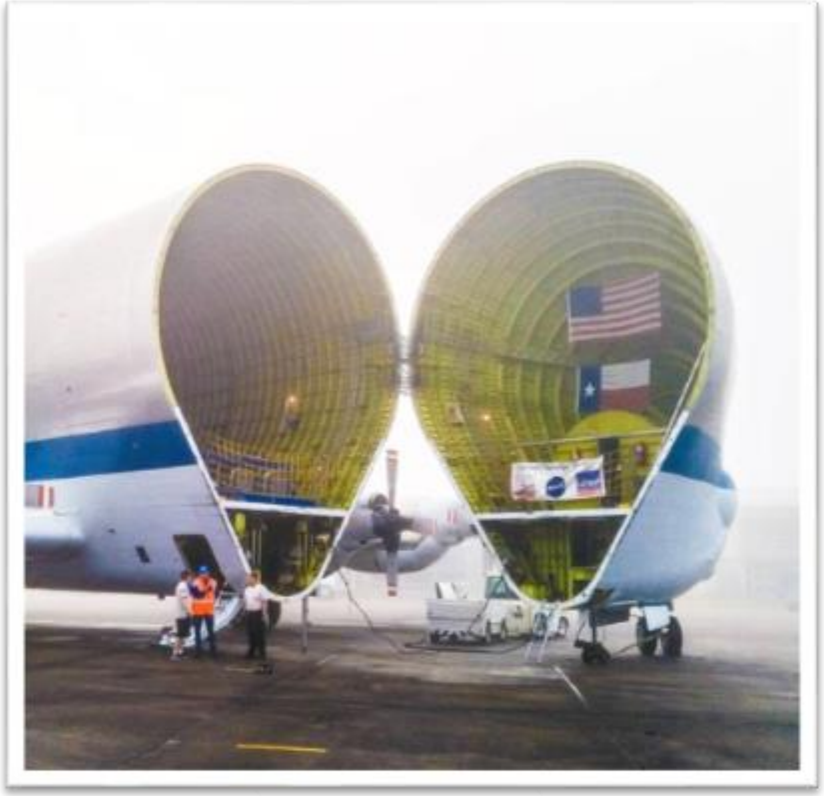


Detailed Design: Boom Tail

The fuselage connects to the tail using a boom, made of four modular segments that fasten using screw threading

Future Work

- Design mounting points for electronics
- Design guppy cargo door
- Create landing gear
- Confirm center of gravity
- 3D print remaining parts
- Initial test flight



Most Important Points

1. The goal is to design and manufacture a 3D printed airplane capable of carrying a soccer ball and one pound of steel cargo.

2. Calculations are completed that estimate airplane performance, dimensioning is also complete.

3. Wing, boom tail, and tail is 3D printed. Fuselage and landing gear is next priority.

4. The test flight of airplane will take place February 29th.

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Questions?

Backup Slides

Functional Decomp

Concept Selection

Concept Generation

Detailed Concepts

Detailed Math

Bill of Materials

Targets and Metrics

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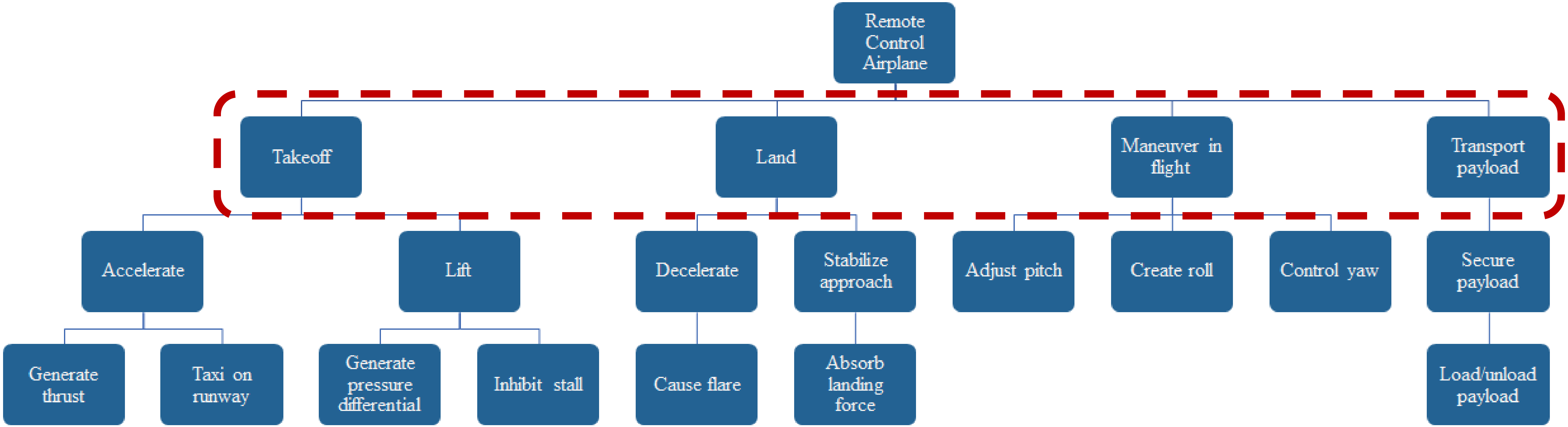
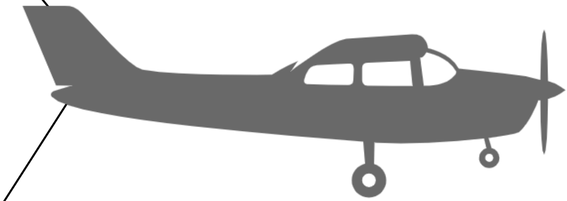
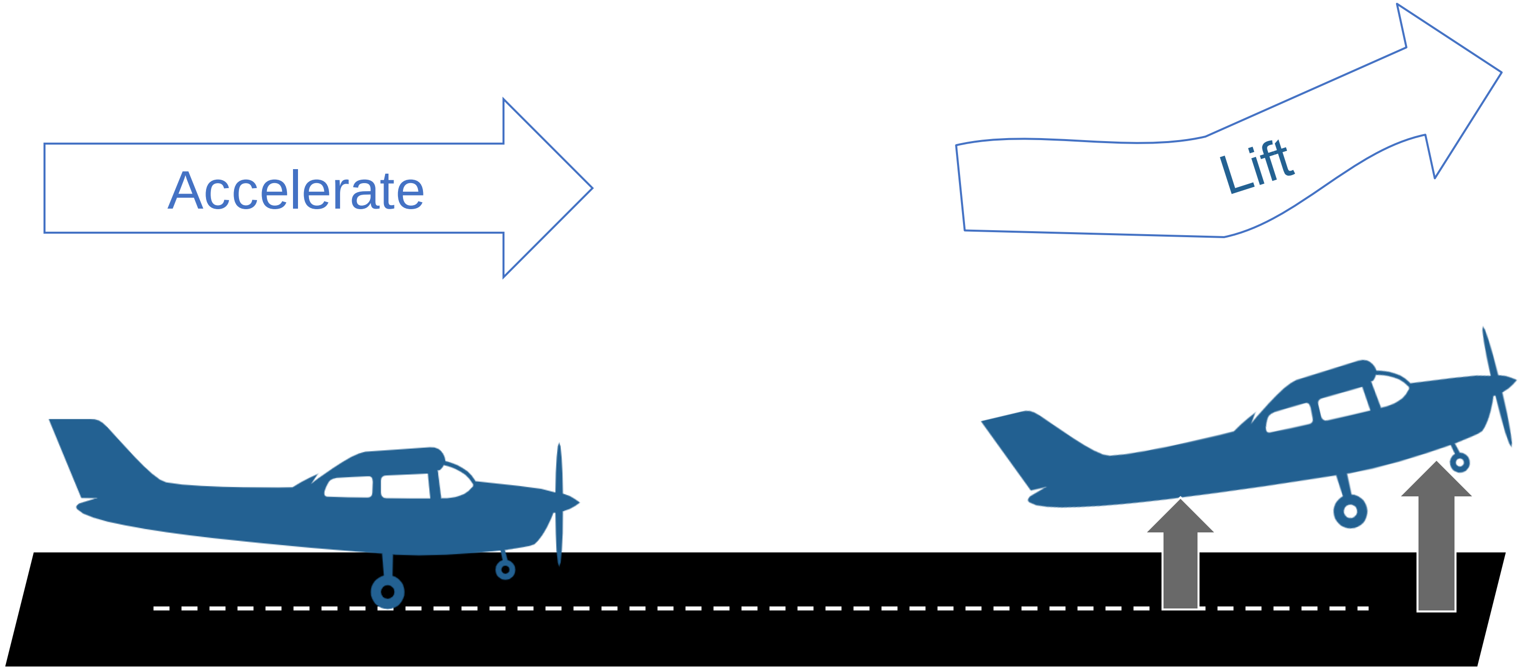
Functional Decomp Backup

Functional Decomposition



Functional Decomposition: Takeoff

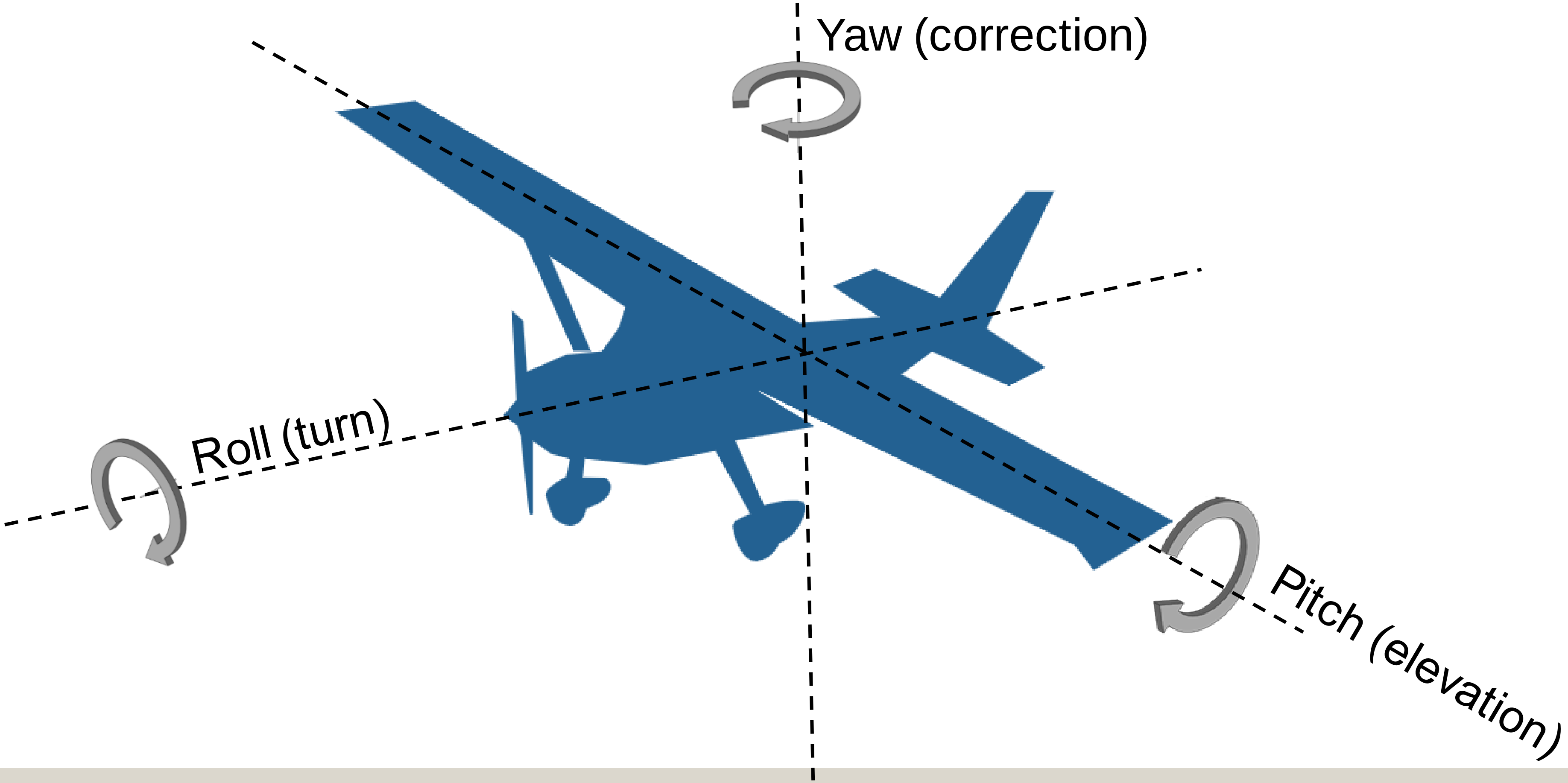




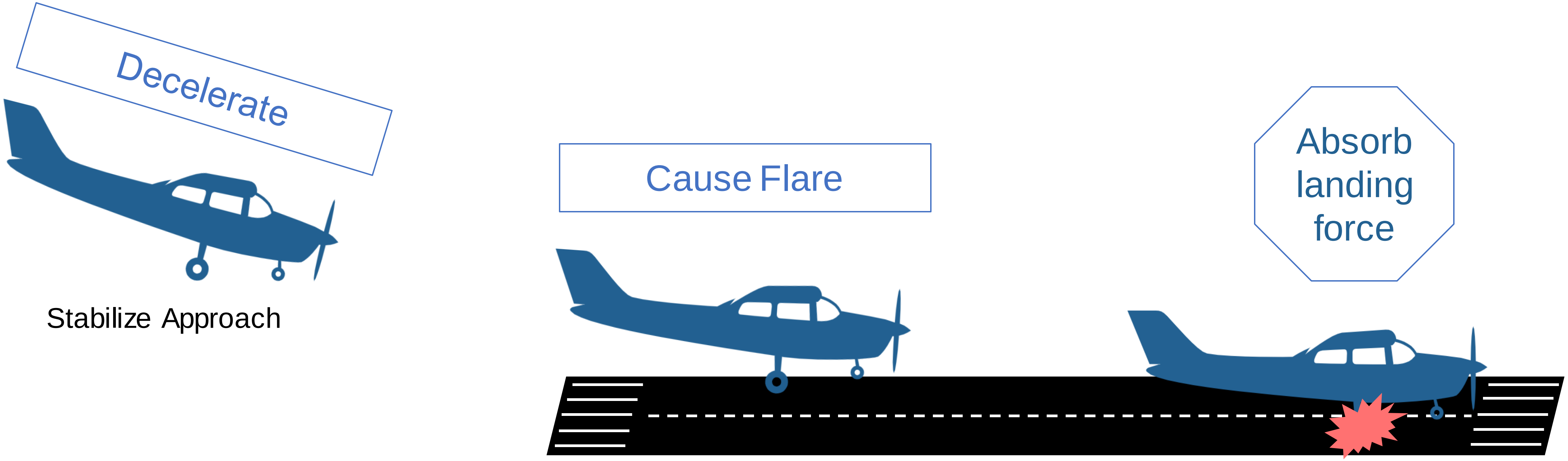
Generate Thrust
Taxi on Runway

Generate Pressure Differential
Inhibit Stall

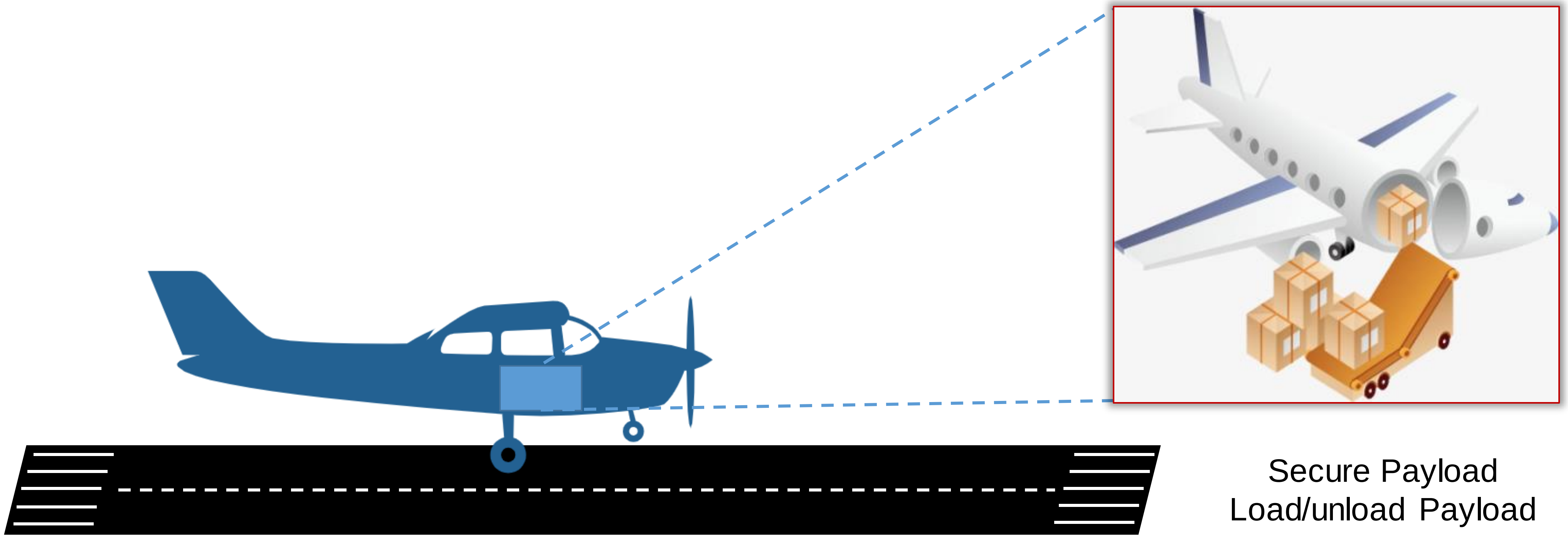
Functional Decomposition: Maneuver in Flight



Functional Decomposition: Land



Functional Decomposition: Transport Payload



Secure Payload
Load/unload Payload

Concept Selection Backup

House of Quality

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

				Column #	1	2	3	4	5	6	7	8	9	10
				Direction of Improvement	▼	▲	▲	◇	▲	◇	▼	▼	▼	▼
Row #	Weight Chart	Relative Weight	Customer Importance	Functional Requirements / Customer Requirements (Explicit and Implicit)	Weight(Lb)	Thrust (lbf)	Lift (lbf)	Drag (lbf)	Acceleration (ft/s^2)	Weight Distribution (lbf(x))	Wingspan (in)	Time to Unload Cargo (sec)	Price ($)	Manufacturing Time (sec)
1		16%	10	Fly	●	●	●	●	●	▽	●	▽	▽	○
2		10%	6	Carry Payload	●	●	●	●	●	●	○	○	▽	○
3		8%	5	Takeoff Distance	●	●	●	●	●	▽	●	○	○	●
4		8%	5	Landing	●	●	○	●	●	▽	▽	▽	○	●
5		8%	5	Cost	▽	●	▽	▽	○	○	○	▽	●	○
6		15%	9	3-D Printed	●	▽	▽	▽	●	○	●	●	●	●
7		10%	6	Flight Stability	○	▽	●	●	○	●	●	●	▽	○
8		10%	6	Payload Accesibility	▽	▽	▽	●	○	●	▽	●	▽	●
9		16%	10	Safety	●	●	▽	▽	○	○	○	●	○	▽
				Technical Importance Rating	700	629	464.5	590.3	638.7	409.7	554.8	535.5	345.2	509.7
				Relative Weight	13%	12%	9%	11%	12%	8%	10%	10%	6%	9%
				Weight Chart										

Initial Pugh Selection Chart

		Concepts						
Selection Criteria	**Concept 7**	**1**	**2**	**3**	**4**	**5**	**6**	**8**
Weight	DATUM	+	-	-	S	S	+	+
Drag		+	S	-	S	-	S	+
Wingspan		+	+	+	S	S	+	+
Time to Unload		+	-	S	S	-	+	-
Manufacturing Time		-	-	+	S	S	+	-
Cost		-	+	S	+	+	S	+
# of pluses		4	2	2	1	1	4	4
# of minuses		2	3	2	0	2	0	2

Pugh Chart 1

Eliminated Concept 2 & 5. Concept 6 becomes new datum.

Final Pugh Selection Chart

Selection Criteria	Concept 6	Concepts 1	3	4	8
Weight	DATUM	+	-	S	+
Drag		+	-	-	S
Wingspan		S	S	-	S
Time to Unload		S	-	+	-
Manufacturing Time		-	S	+	-
Cost		-	S	S	+
# of pluses		2	0	2	2
# of minuses		2	3	2	2

Pugh Chart 2

Eliminated Concept 3 & 8. Concept 1, 4, and 6 transfer to AHP.

Criteria 1 – Drag

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Concept 1	1.460	0.480	3.044
Concept 4	0.346	0.115	3.010
Concept 6	1.230	0.405	3.033
Avg Con: 3.029	Con Index: 0.015	Con Ratio: 0.028	Consistent?: **Yes**

Criteria 2 – Weight

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Concept 1	1.230	0.405	3.033
Concept 4	0.346	0.115	3.010
Concept 6	1.460	0.480	3.044
Avg Con: 3.029	Con Index: 0.015	Con Ratio: 0.028	Consistent?: **Yes**

Analytic Hierarchy Process

Overview of drag and weight criteria

Criteria 3 – Wingspan

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Concept 1	0.790	0.260	3.033
Concept 4	0.320	0.106	3.011
Concept 6	1.946	0.633	3.072
Avg Con: 3.039	Con Index: 0.019	Con Ratio: 0.037	Consistent?: **Yes**

Criteria 4 – Time to Unload

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Concept 1	0.790	0.260	3.033
Concept 4	0.320	0.106	3.011
Concept 6	1.946	0.633	3.072
Avg Con: 3.039	Con Index: 0.019	Con Ratio: 0.037	Consistent?: **Yes**

Analytic Hierarchy Process

Overview of wingspan and time to unload criteria

Criteria 5 – Manufacturing Time

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Concept 1	0.273	0.091	3.000
Concept 4	1.364	0.455	3.000
Concept 6	1.364	0.455	3.000
Avg Con: 3.000	Con Index: 0.000	Con Ratio: 0.000	Consistent?: **Yes**

Criteria 6 – Cost

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Concept 1	1.853	0.574	3.230
Concept 4	0.427	0.140	3.049
Concept 6	0.897	0.286	3.133
Avg Con: 3.137	Con Index: 0.069	Con Ratio: 0.132	Consistent?: **No**

Analytic Hierarchy Process

Overview of manufacturing time and cost criteria

AHP Criteria Weights and Consistency Check

	Weighted Sum Vector	Criteria Weight	Consistency (Con)
Drag	2.840	0.369	7.697
Wingspan	1.387	0.212	6.554
Time to Unload	0.607	0.097	6.268
Weight	1.044	0.156	6.711
Manufacturing Time	0.962	0.143	6.739
Cost	0.159	0.024	6.591
Avg Con: 6.760	Con Index: 0.152	Con Ratio: 0.122	Consistent?: **No**

Analytic Hierarchy Process

Overview of criteria weights

[Final Rating Matrix]^T			
Selection Criteria	Concept 1	Concept 4	Concept 6
Drag	0.480	0.115	0.405
Weight	0.405	0.115	0.480
Wingspan	0.260	0.106	0.633
Time to Unload	0.260	0.106	0.633
Manufacturing Time	0.091	0.455	0.455
Cost	0.574	0.140	0.286

X

Criteria Weights {W}	
	Weight
Drag	0.369
Weight	0.212
Wingspan	0.097
Time to Unload	0.156
Manufacturing Time	0.143
Cost	0.024

=

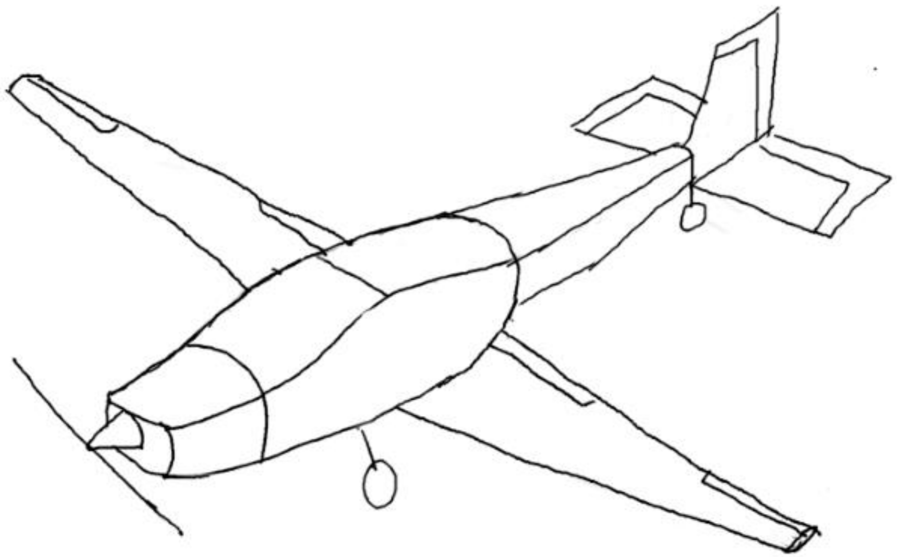
	Alternative Value
Concept 1	0.355
Concept 4	0.162
Concept 6	0.483

Analytic Hierarchy Process

Overview of final selection matrix

Selected Concept: Concept Six

- Tapered Wings
- Low wing location
- Tricycle with tail wheel
- LW PLA
- Conventional tail



Concept Generation Backup

Modular Connections	3D Materials	Propeller Size	Propeller Pitch	Number of Blades	Landing Gear	Landing Gear Mechanism	Landing Gear Suspension	Wings	Wing Location	Wing Orientation	Aileron/Flaps	Motor	Fuselage	Electronics add ons	Battery	Tail
Compression	PLA	Large Prop	Large Pitch	2 Blade	Tricycle with Front Wheel	Fixed	Fixed	Elliptical	Low Wing	Uniform Leading Edge	Plain	Low kv Rating	Flying boat	Speed Densor	High Battery Capacity	Conventional
Formfit	ABS	Small Prop	Small Pitch	3 Blade	Tricycle with Tail-Wheel	Retractable	3D Printed Flexible	Tapered	Mid Wing	Swept	Split	High kv Rating	Double booms	Gyroscope	Low Batter Capacity	T-Tail
Glue	LW-PLA			4 Blade	Four Wheels		Metal Fleible	Rectangular	High Wing		Slotted		Symmetric from side view	Camera	Higher Ampacity	Cruciform
Fasteners	TPU				Ski-Plane		Shocks	Inverted			Fowler		SubSonics	Illumination	Appropriate C rating	Dual
Japanese glue free joints	PP							Winglets			Double-Slotted Fowler		Super Sonic	Extra Battery		Triple
T-joint glued form fit								Triangular			Junkers		High capacity sub sonic	Special Speed Controller		V
Soldering											Gouge		High manurability super sonic			Inverted V
											Fairey-Youngman					Inverterd Y
											Zap					Twin
											Krueger					Boom
											Gurney					High Boom
											Leading Edge Droop					Multiple-plane tail
											Handley-page					

Concept Generation

Excel table which combined morphological chart and crap shoot method to generate 100 concepts

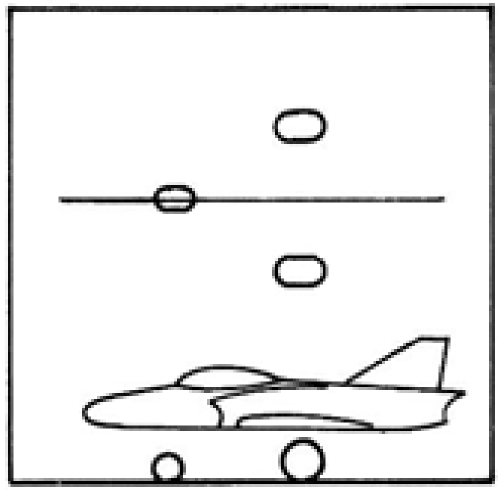
Concept Generation

Concept Generation Chart

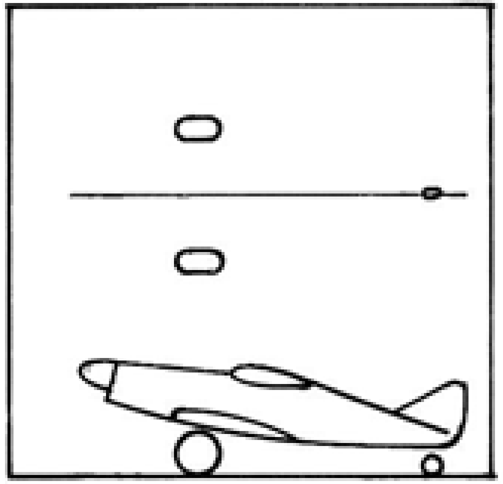
3D Material	Landing Gear	Wings	Wing Location	Aileron/Flaps	Fuselage	Tail
PLA	Tricycle with Front Wheel	Elliptical	Low Wing	Plain	Flying boat	Conventional
ABS	Tricycle with Tail-Wheel	Tapered	Mid Wing	Split	Double booms	T-Tail
LW-PLA	Four Wheels	Rectangular	High Wing	Slotted	Subsonic	Cruciform
					High Capacity Subsonic	Triple
						Twin
						Boom
						High Boom

Concept Generation

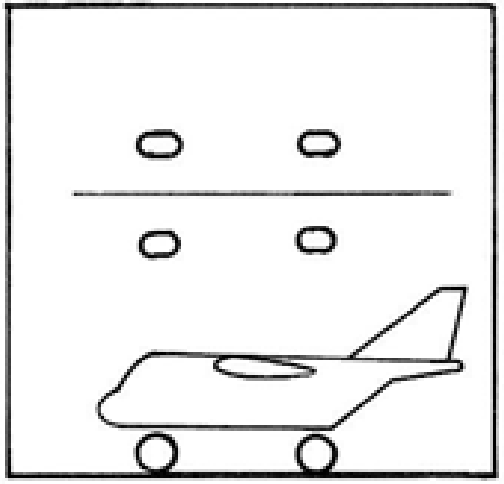
Landing Gear Configuration



Tricycle with Front Wheel



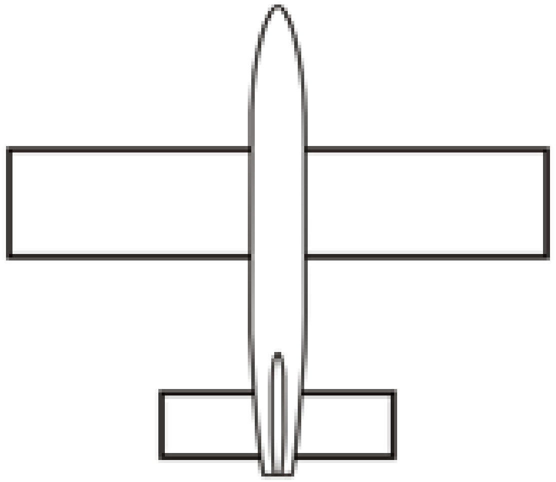
Tricycle with Tail Wheel



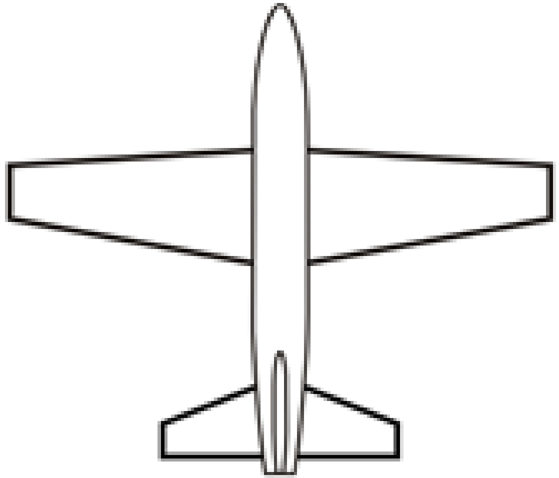
Four Wheel

Concept Generation

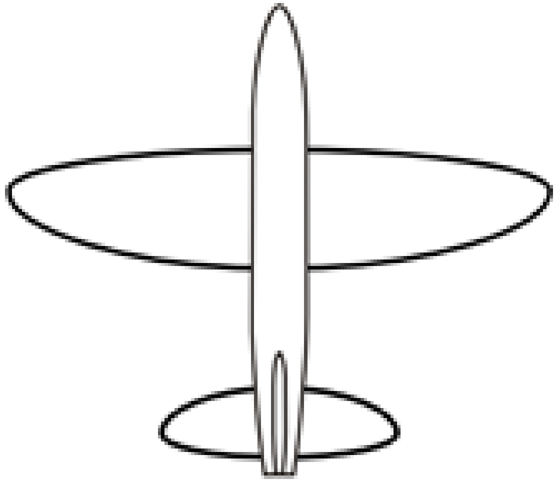
Wing Planform



Rectangular



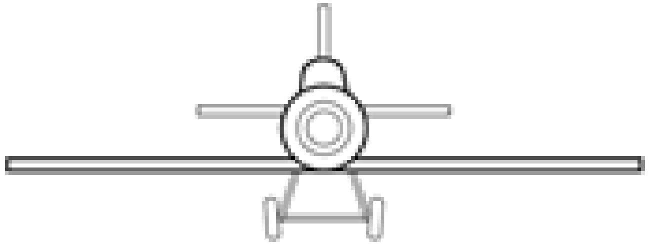
Tapered



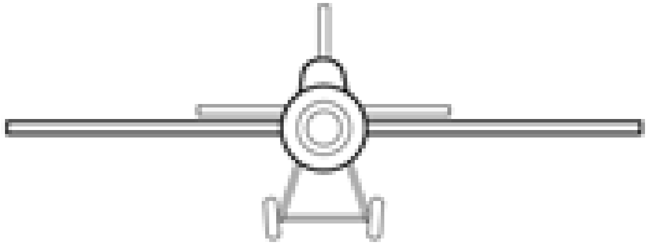
Elliptical

Concept Generation

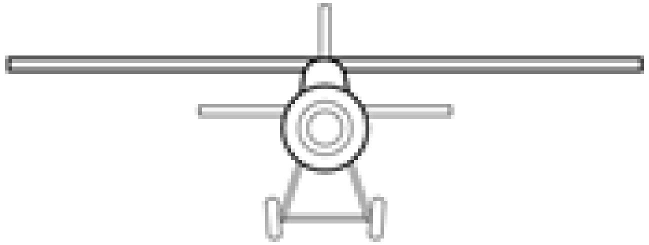
Wing Location



Low Wing



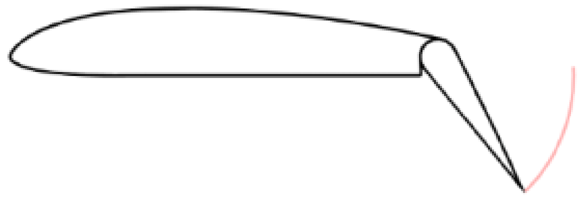
Mid Wing

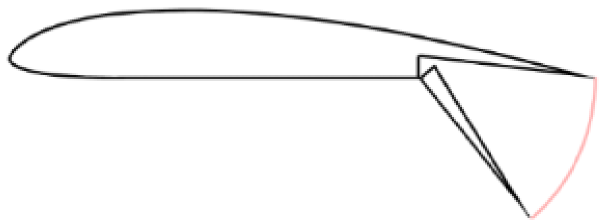


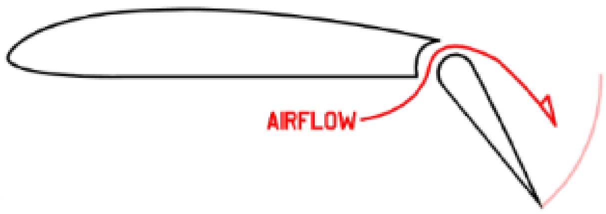
High Wing

Concept Generation

Aileron and flaps







Plain Flap

Split

Slotted

Concept Generation

Fuselage


Subsonic

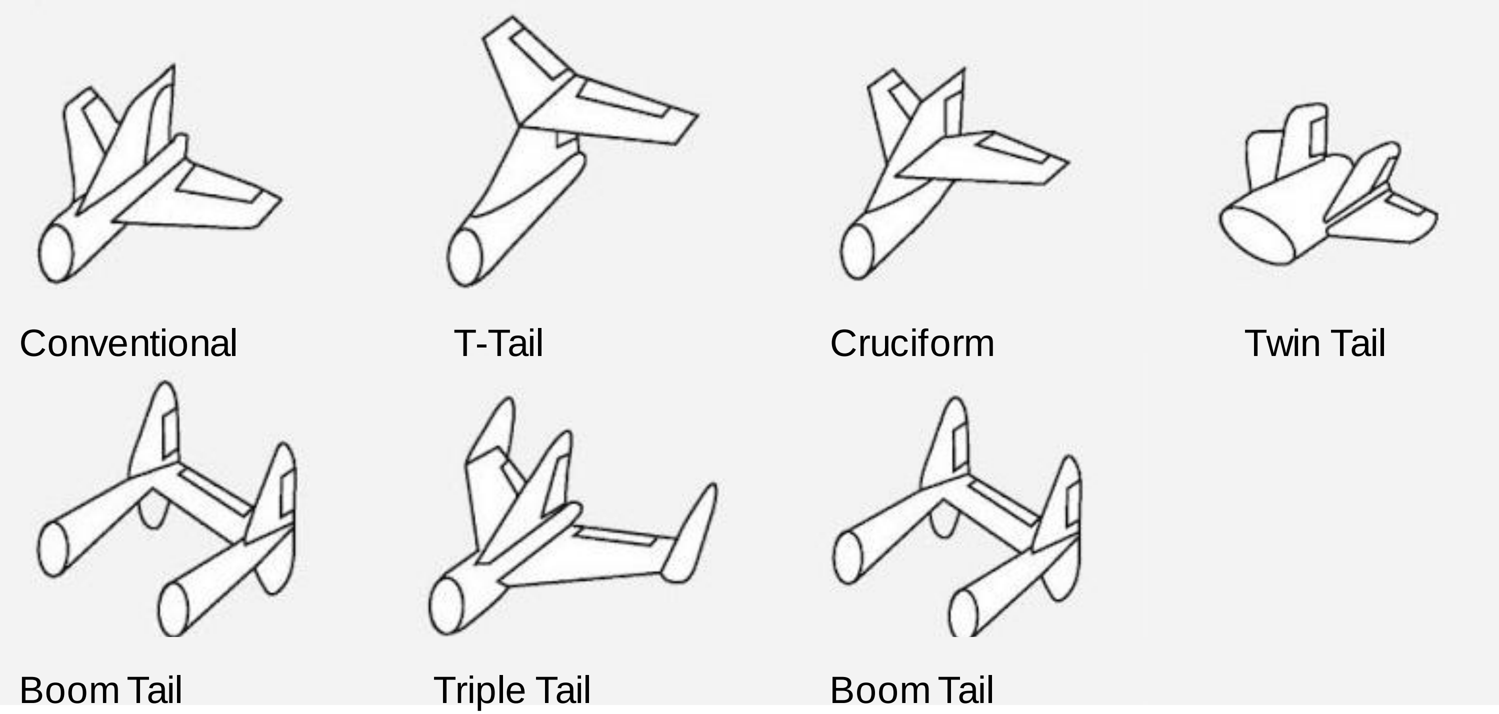

High Capacity Subsonic


Flying Boat


Double Boom

Concept Generation

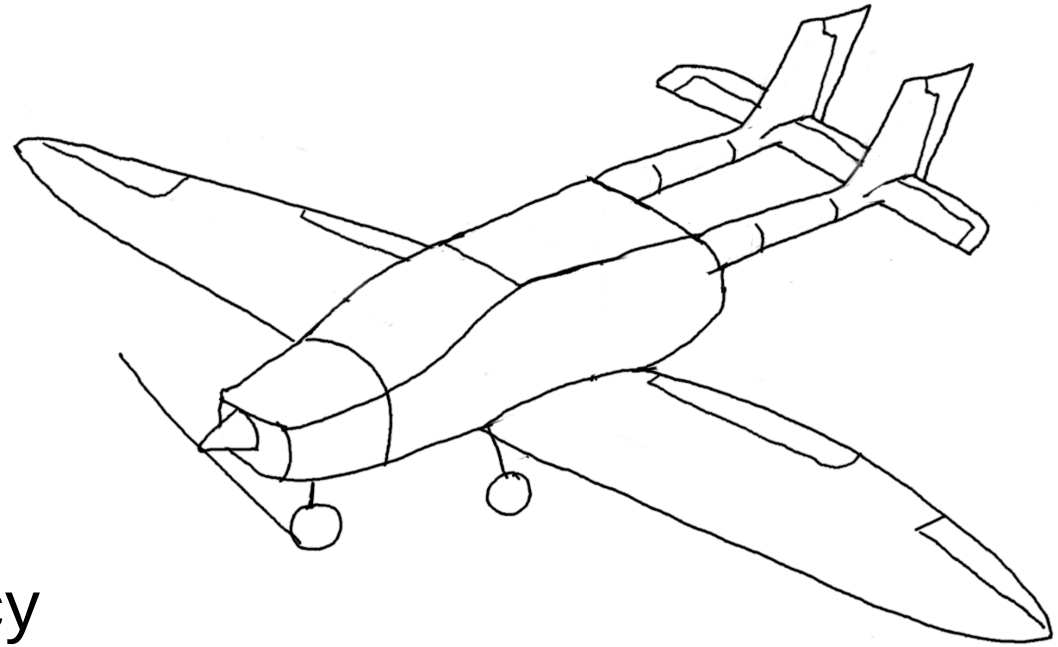
Tail Configuration



Detailed Concept Backup

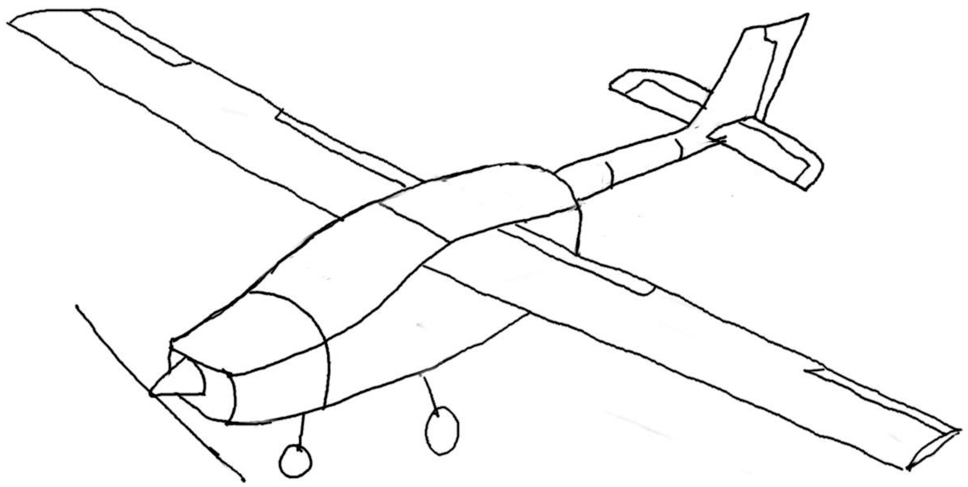
Concept One

- Elliptical shaped wings most efficient
- Reduce wing load
- Tricycle with singular wheel
- Split ailerons give more redundancy
- Boom tail reduces fuselage weight



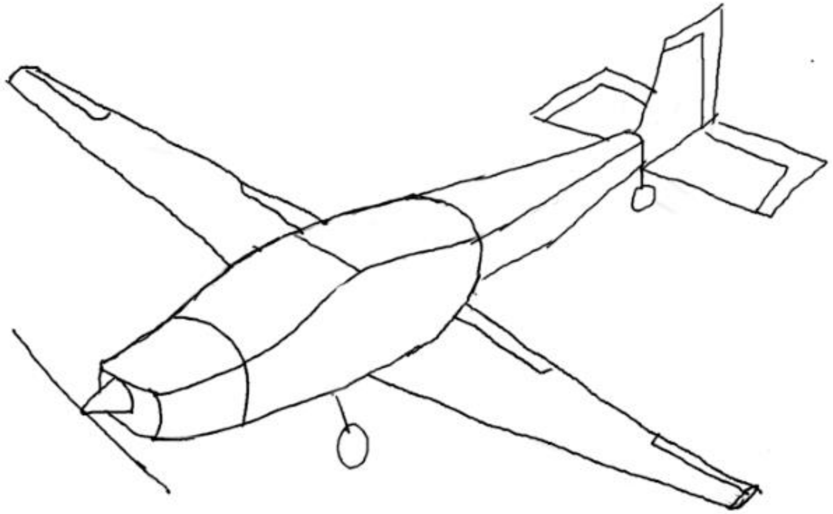
Concept Four

- Light weight PLA
- Slotted flap increases lift and decreases drag
- Rectangular wing is the least efficient design



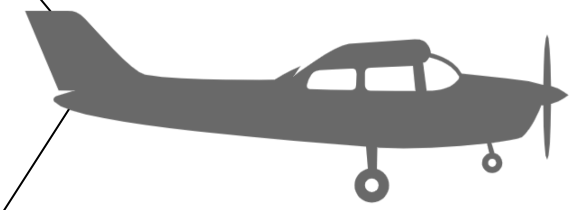
Concept Six

- Positive angle of attack
- Increase the lift
- Conventional Tail
- Light weight
  PLA



Detailed Math Backup

Takeoff Calculation



Takeoff Ground Distance: $S_G = \int_0^{V_{TO}} \frac{V\,dV}{a} = \frac{1}{2}\int_0^{V_{TO}} \frac{dV^2}{a}$

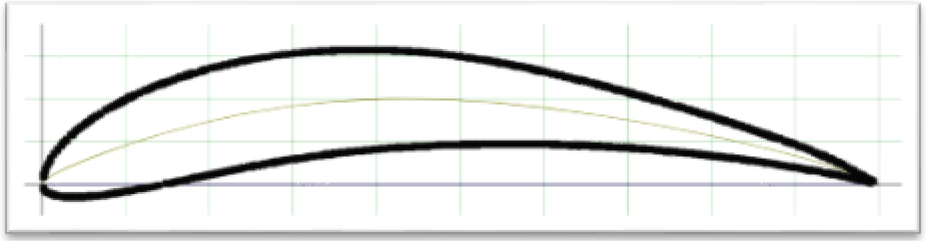
Takeoff Velocity: $V_{TO} = 1.2\,V_{stall} = 1.2\sqrt{\frac{W_{TO}}{S_{ref}}\frac{2}{\rho C_{L_{max}}}}$

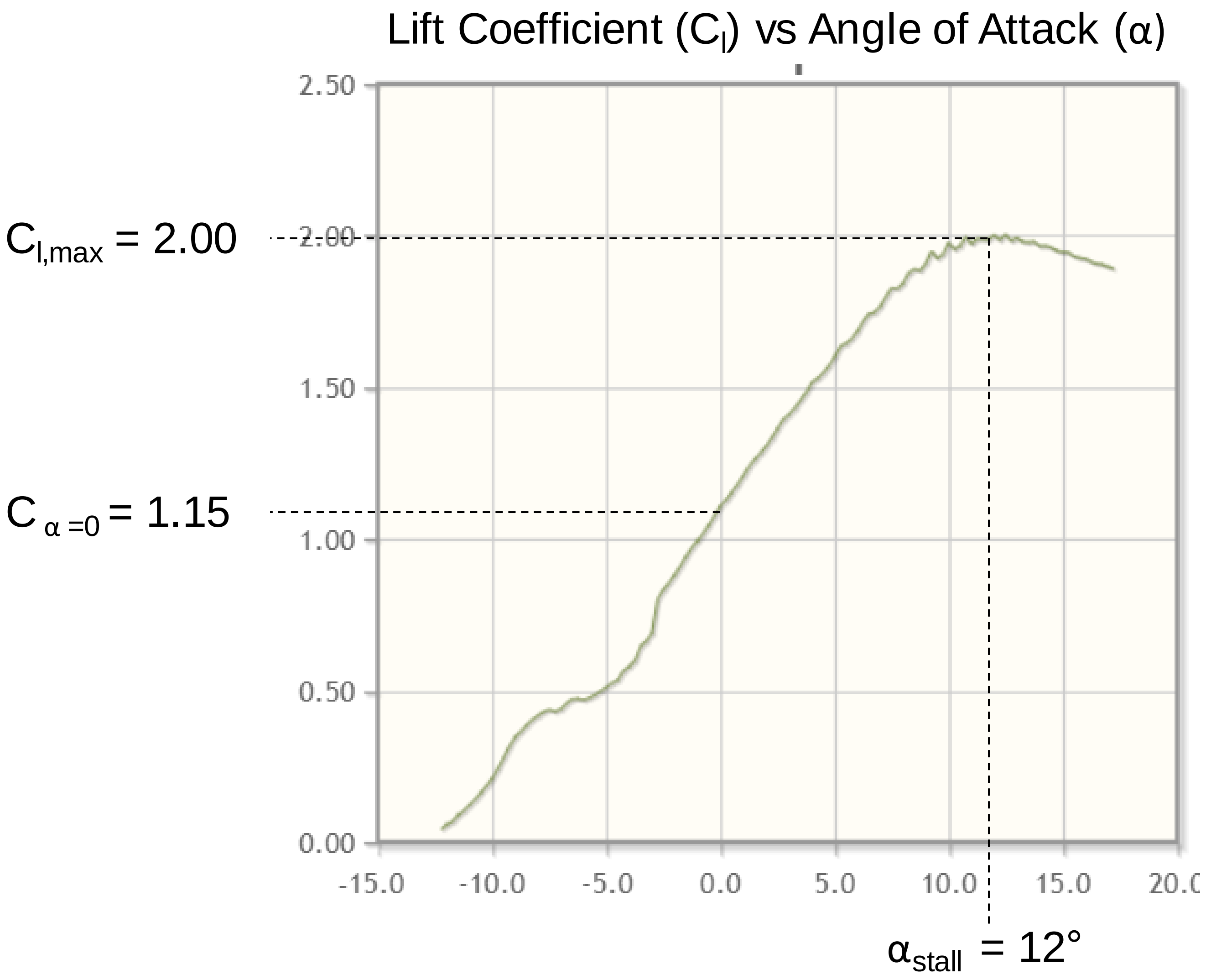
Command Window

```
For an airplane with 15.000 lb weight, 72.000 in wingspan, and 14.000 in chord length
yields 7.000 ft^2 wing area, 5.143 aspect ratio, and 34.286 oz/in^2 wing loading

The required velocity for take off is 34.441793 ft/s or 23.483034 mph

The required ground distance for take off considering thrust is 32.506 ft
The above doesnt include drag, and thrust is a rough estimate at 8.500000 in the calculation

The required ground distance traveled for take off considering lift and drag is 49.665579 ft
fx >>
```

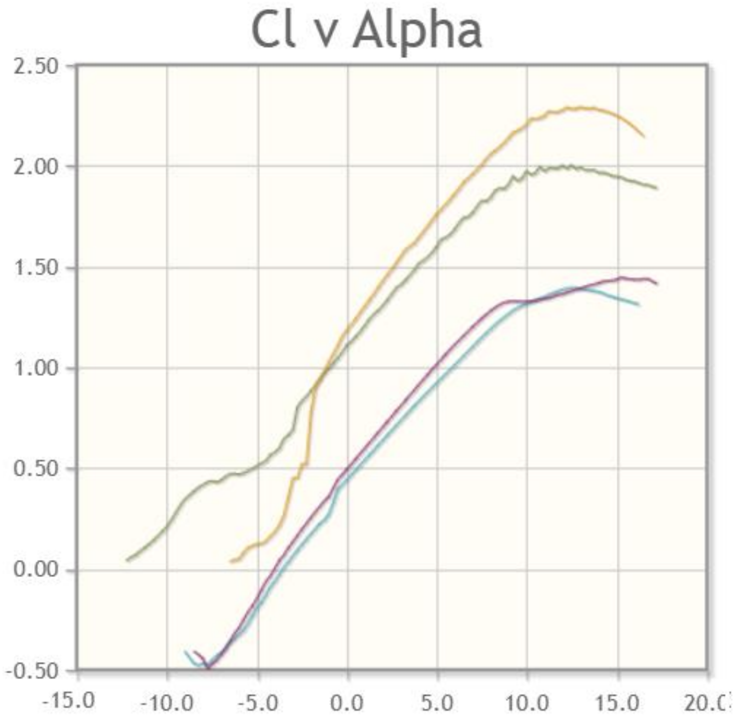
Airfoil Selection

- Selected the Eppler E423
- Satisfies targets for lift coefficient and stall angle of attack
- Designed as a heavy lift UAV airfoil

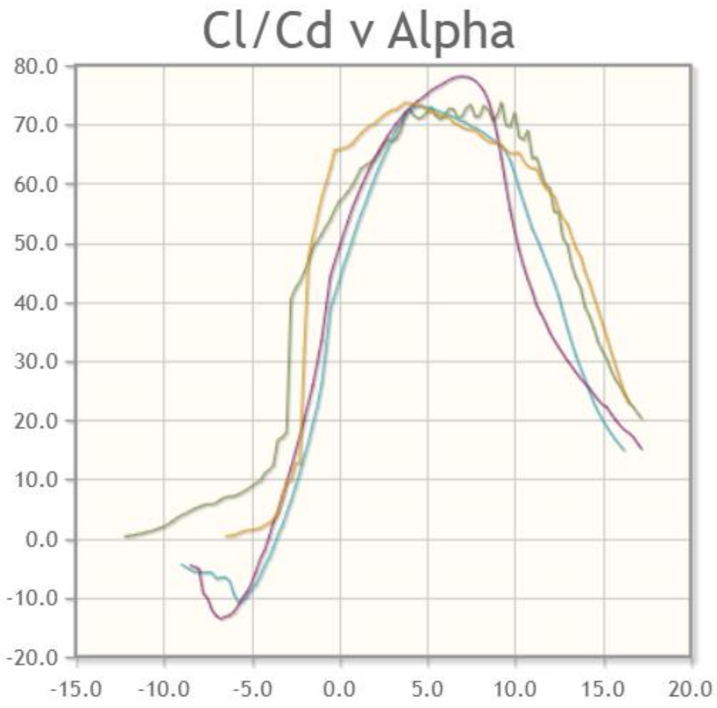




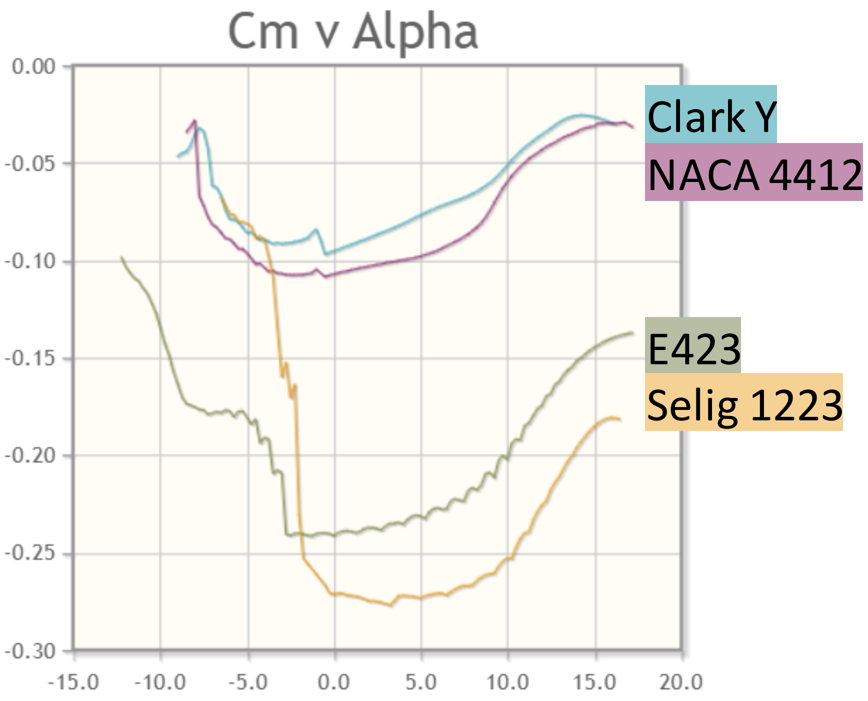
Airfoil Selection



Compare lift coefficient



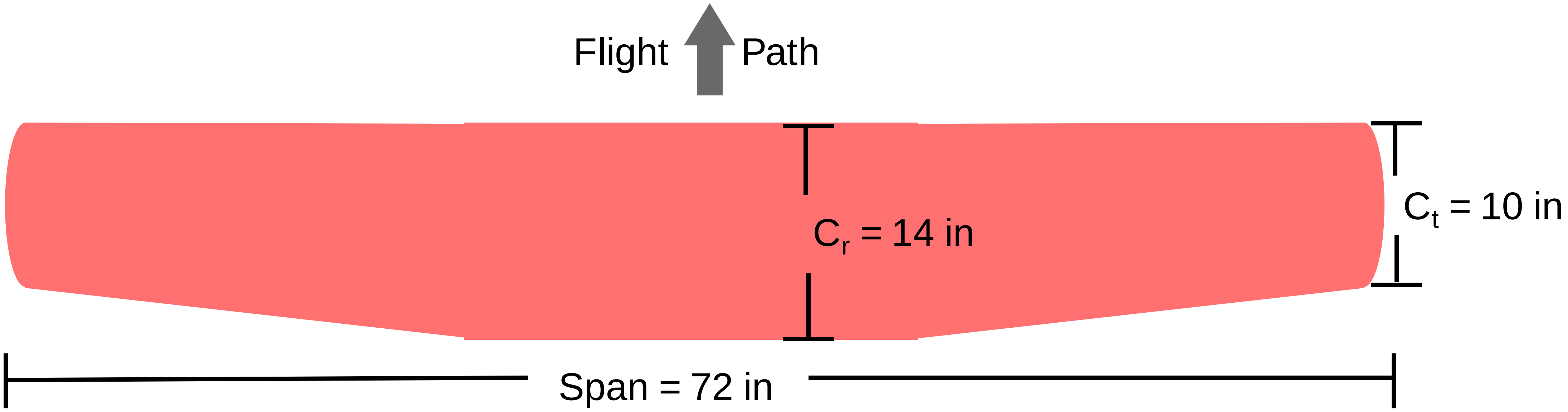
Compare lift-to-drag ratio



Compare moment coefficient

FAMU-FSU Engineering

Wing Sizing



- Produces takeoff distance of 49.6 ft at 23.4 mph
- Wing loading of 34.3 oz/in^2 and aspect ratio of 5.1

Bill of Materials Backup

Item No.	Items Purchased with Grant Money	$ / Unit	Qty	Price	Price w/ Tax
1	SAE Competition Registration	$1,100.00	1	$1,100.00	$ 1,100.00
2	Onxy 22.2V 63 4000mAh 30C LiPo Battery, EC5 connector	$ 76.39	2	$ 152.78	$ 164.24
3	Futaba R2006GS 6-Channel S-FHSS Receiver	$ 39.99	1	$ 39.99	$ 42.99
4	Onyx LiPo Charge Protection Bag	$ 8.99	1	$ 8.99	$ 9.66
	Item 2, 3, 4 with $30 off discount				$ (30.00)
5	E-flite Prop Adapters: Power 90	$ 17.09	1	$ 17.09	$ 18.20
6	E-flite X-Mount/Hardware: Power 90/110/160	$ 14.24	1	$ 14.24	$ 15.17
7	APC 18x8 Thin Electric Propeller	$ 11.13	1	$ 11.13	$ 11.85
	Item 5, 6, 7, shipping and handling				$ 15.40
8	Al 6061 Spar 0.37"x0.035"x0.305"	$ 9.94	2	$ 19.88	$ 39.76
9	Al 6061 Spar 0.25"x0.035"x0.18"	$ 9.73	2	$ 19.46	$ 38.92
	Item 8 and 9 shipping and handling				$ 21.96
10	Colorfabb Light Weight PLA 0.75kg roll	$ 30.91	6	$ 185.46	$ 185.46
	Item 10 Shipping				$ 43.20
11	Colorfabb Light Weight PLA 0.75kg roll	$39.60	5	$198.00	$198.00
				Total	$ 1,874.81

Purchasing Log

	Items	Category	$ / Unit	Qty	Retail Price	Price	Wt. / Unit [oz]	Total Wt. [oz]	Dimensions / Specs	Source	Purchased/Printed	Need By Date	Received	Completition Percentage	Completed
Electronics	FlightLine RC 5055-390kV Brushless Motor	Propulsion	Legacy	1	$59.99	$0.00	14.460	14.460	3.14" x 1.97 "	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	E-Flite Power 90 Brushless Outrunner Motor 325Kv	Propulsion	Legacy	1	$129.99	$0.00	15.800	15.800	diameter: 2.21" length: 2"	Link	No	11/27/2019	10/25/2019	100.00%	YES
	ADMIRAL 6s, 4000 mAh, 40 C, 22.2 V Battery	Power	Legacy	1	$79.99	$0.00	21.090	21.090	5.51" x 1.77" x 1.65"	Link	No	11/27/2019	9/6/2019	100.00%	YES
	Spare Battery	Power	$79.99	1	$79.99	$79.99	21.090	21.090	5.51" x 1.77" x 1.65"	Link	No	11/27/2019		92.31%	NO
	Prop Adapters: Power 90	Fastener	$8.55	2	$17.09	$17.09			6mm propeller adapter for E-flite 90 motor	Link	10/31/2019	11/27/2019		76.92%	NO
	X-Mount/Hardware: Power 90, Motor mounting hardware	Fastener	$14.24	1	$14.24	$14.24	0.120	0.120	3.90" x 2.40" x 0.49"	Link	10/31/2019	11/27/2019		92.31%	NO
	Futaba 6J 6-Channel S-FHSS System	Control	Legacy	1	$179.99	$0.00	-	-	4.8" x 10.2 x 16"	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Futaba R2106GF 6-Channel S-FHSS Micro Receiver	Control	$29.99	1	$29.99	$29.99	0.140	0.140	1.5" x 0.85" x 0.40"	Link	No	11/27/2019		92.31%	NO
	ZTW GECKO 85A ESC WITH 8A SBEC WITH XT-60 CONNECTOR	Control	Legacy	1	$49.36	$0.00	2.650	2.650	2.59" x 1.29" x 0.62"	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Hitec HS-311 Plastic Gear Standard Servo	Control	$8.99	7	$62.93	$0.00	1.510	10.570	1.57" x 0.78" x 1.44"	Link	No	11/27/2019		92.31%	NO
	Red Arming Plug	Safety	$6.47	1	$6.47	$6.47	0.130	0.130	0.28" x 0.50" x 0.5"	Link	No	11/27/2019		92.31%	NO
	SAE 2019 Power Limiter V2 regular class 1000W	Safety	Legacy	1	$75.00	$0.00	0.720	0.720	0.5" x 0.5" x 2.00"	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Cell Meter Battery Capacity Checker	Safety	$8.99	1	$8.99	$8.99	1.760	1.760	3.26" x 0.98"	Link	10/28/209	11/27/2019	10/30/2019	100.00%	YES
														0.00%	
3D Printing	Ailerons	Wing		2		$0.00		0.000	The $/unit and unit weight will be determined once the airplane CAD is created. It is assumed all these parts will be printed with the Light Weight Polylactic Acid.	N.A	No	11/27/2019		69.23%	NO
	Flap	Wing		2		$0.00		0.000		N.A	No	11/27/2019		61.54%	NO
	Hinges	Wing		4		$0.00		0.000		N.A	No	11/27/2019		61.54%	NO
	Support Spar	Wing		2		$23.58		0.000		Link	No	11/27/2019		61.54%	NO
														0.00%	
	Cargo Bay	Fuselage		1		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Nose Cone	Fuselage		1		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Electronics Bay	Fuselage		1		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Hinges	Fuselage		4		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
														0.00%	NO
	Elevator	Tail		2		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Rudder	Tail		1		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Vertical Stabilizer	Tail		1		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Horizontal Stabilizer	Tail		1		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
	Hinges	Tail		4		$0.00		0.000		N.A	No	1/6/2020		61.54%	NO
Landing Gear	Dubro Super Lite Wheels 3"	Wheel	Legacy	2	$8.99	$0.00	0.244	0.488	OD = 3" ID axle = 0.178"	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Sullivan SkyLite Wheel w/Aluminum Hub 4-1/2"	Wheel	Legacy	2	$38.66	$0.00	2.230	4.460	OD = 4.5" ID axle= 1.6"	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Dubro Axle Shaft	Fastener	Legacy	2	$6.79	$0.00	1.200	2.400	OD = 0.1875" Length axle= 2"	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Dubro Tail Wheel Assembly	Fastener	$3.99	1	$3.99	$3.99	0.176	0.176	For 1" dubro tail wheel	Link	No	11/27/2019		92.31%	NO
	Dubro Tail Wheel 1"	Wheel	$2.48	1	$2.48	$2.48	0.680	0.680	OD = 1" for tail wheel assembly	Link	No	11/27/2019		92.31%	NO
	[Shocks, if needed]											1/6/2020		15.38%	
	[Shocks accessories, if needed]											1/6/2020		15.38%	
Cargo	Size Five Soccer Ball	Cargo	$15.00	1	$15.00	$15.00	15.000	15.000	100% Butylene Size 5 ball (official size)	Link	No	11/27/2019		92.31%	NO
	Velcro Bands	Fastener	$0.53	4	$2.10	$2.10	0.200	0.800	General Purpose Peel & Stick	Link	No	11/27/2019		92.31%	NO
	Steel Plates	Cargo	Legacy	6	$8.35	$0.00	16.000	96.000	A36 Steel Plate	Link	Legacy	11/27/2019	9/6/2019	100.00%	YES
	Metal Screw	Fastener	$0.20	6	$1.18	$1.18	0.071	0.423	#8 x 1-1/2 in. Phillips Flat Head Plated Sheet Metal Screw	Link	No	11/27/2019		92.31%	NO
Testing	Flite Test Water-Resistant Foam Board By Adams	Prototype	$2.99	10	$2.99	$29.90	4.021	40.212	L = 20" W = 30" thick = 3/16"	Link	No	11/27/2019		92.31%	NO
	Gorilla Glue Hot Glue Sticks	Prototype	$0.13	30	$3.97	$3.97	0.149	4.480	8" tall multipurpose temp range	Link	No	11/26/2019		92.31%	NO
	Polylactic Acid	Filament	$0.33	3	$20.99	$0.00	105.900	317.700	35.3 Oz	Link	Sponsered	11/1/2019	9/26/2019	100.00%	YES
	Acrylonitrile Butadiene Styrene	Filament	$0.20	5	$18.99	$0.00	176.500	882.500	35.3 Oz	Link	Sponsered	11/1/2019	9/26/2019	100.00%	YES
	Flexible	Filament	$0.50	2	$26.99	$0.00	70.600	141.200	35.3 Oz	Link	Sponsered	11/1/2019	9/26/2019	100.00%	YES
	Light Weight Polylactic Acid	Filament	$1.09	2	$57.79	$54.00	52.800	105.600	26.4 Oz	Link	9/6/2019	11/1/2019	9/20/2019	100.00%	YES
	Loctite Gel Control 4g Super Glue	Fastener	$10.64	2	$2.98	$2.98	0.280	0.560	0.14 Oz	Link	No	11/1/2019		92.31%	NO
	APC Electric Propeller 16x8E	Propulsion	$8.42	1	$8.42	$8.42	1.830	1.830	Diameter = 16" Pitch = 8"	Link	10/30/2019	11/1/2019	11/1/2019	100.00%	YES
	APC Electric Propeller 18x8E	Propulsion	$11.13	1	$11.13	$11.13	3.030	3.030	Diameter = 18" Pitch = 8"	Link	10/31/2019	11/1/2019		92.31%	NO
	APC Electric Propeller 18x10E	Propulsion	Legacy	1	$11.13	$0.00	2.570	2.570	Diameter = 18" Pitch = 10"	Link	Legacy	11/1/2019	11/1/2019	100.00%	YES
	Door Hinge	Thrust Test	$1.34	1	$1.34	$1.34	0.700	0.700	3-1/2 in. Satin Brass Square Corner Door Hinge	Link	10/2/2019	11/1/2019	10/2/2019	100.00%	YES
	Poplar Board	Thrust Test	Legacy	1	$4.71	$0.00	17.000	17.000	1 in x 4 in	Link	Legacy	11/1/2019	10/2/2019	100.00%	YES

Bill of Materials

	Items	Category	Qty	Retail Price	Price	Total Wt. [oz]	% Complete	Completed
Electronics	FlightLine RC 5055-390kV Brushless Motor	Propulsion	1	$59.99	$0.00	14.460	100.00%	YES
	E-Flite Power 90 Brushless Outrunner Motor 325Kv	Propulsion	1	$129.99	$0.00	15.800	100.00%	YES
	ADMIRAL 6s, 4000 mAh, 40 C, 22.2 V Battery	Power	1	$79.99	$0.00	21.090	100.00%	YES
	Spare Battery	Power	1	$79.99	$79.99	21.090	92.31%	NO
	Prop Adapters: Power 90	Fastener	2	$17.09	$17.09		76.92%	NO
	X-Mount/Hardware: Power 90, Motor mounting hardware	Fastener	1	$14.24	$14.24	0.120	92.31%	NO
	Futaba 6J 6-Channel S-FHSS System	Control	1	$179.99	$0.00	-	100.00%	YES
	Futaba R2106GF 6-Channel S-FHSS Micro Receiver	Control	1	$29.99	$29.99	0.140	92.31%	NO
	ZTW GECKO 85A ESC WITH 8A SBEC WITH XT-60 CONNECTOR	Control	1	$49.36	$0.00	2.650	100.00%	YES
	Hitec HS-311 Plastic Gear Standard Servo	Control	7	$62.93	$0.00	10.570	92.31%	NO
	Red Arming Plug	Safety	1	$6.47	$6.47	0.130	92.31%	NO
	SAE 2019 Power Limiter V2 regular class 1000W	Safety	1	$75.00	$0.00	0.720	100.00%	YES
	Cell Meter Battery Capacity Checker	Safety	1	$8.99	$8.99	1.760	100.00%	YES

Bill of Materials: Electronics

	Items	Category	Qty	Retail Price	Price	Total Wt. [oz]	% Complete	Completed
3D Printing	Ailerons	Wing	2		$0.00	0.000	69.23%	NO
	Flap	Wing	2		$0.00	0.000	61.54%	NO
	Hinges	Wing	4		$0.00	0.000	61.54%	NO
	Support Spar	Wing	2		$23.58	0.000	61.54%	NO
							0.00%	
	Cargo Bay	Fuselage	1		$0.00	0.000	61.54%	NO
	Nose Cone	Fuselage	1		$0.00	0.000	61.54%	NO
	Electronics Bay	Fuselage	1		$0.00	0.000	61.54%	NO
	Hinges	Fuselage	4		$0.00	0.000	61.54%	NO
							0.00%	NO
	Elevator	Tail	2		$0.00	0.000	61.54%	NO
	Rudder	Tail	1		$0.00	0.000	61.54%	NO
	Vertical Stabilizer	Tail	1		$0.00	0.000	61.54%	NO
	Horizontal Stabilizer	Tail	1		$0.00	0.000	61.54%	NO
	Hinges	Tail	4		$0.00	0.000	61.54%	NO

Bill of Materials: 3D Printing

	Items	Category	Qty	Retail Price	Price	Total Wt. [oz]	% Complete	Completed
Landing Gear	Dubro Super Lite Wheels 3"	Wheel	2	$8.99	$0.00	0.488	100.00%	YES
	Sullivan SkyLite Wheel	Wheel	2	$38.66	$0.00	4.460	100.00%	YES
	Dubro Axle Shaft	Fastener	2	$6.79	$0.00	2.400	100.00%	YES
	Dubro Tail Wheel Assembly	Fastener	1	$3.99	$3.99	0.176	92.31%	NO
	Dubro Tail Wheel 1"	Wheel	1	$2.48	$2.48	0.680	92.31%	NO
	[Shocks, if needed]						15.38%	
	[Shocks accessories, if needed]						15.38%	

Bill of Materials: Landing Gear

	Items	Category	Qty	Retail Price	Price	Total Wt. [oz]	% Complete	Completed
Cargo	Size Five Soccer Ball	Cargo	1	$15.00	$15.00	15.000	92.31%	NO
	Velcro Bands	Fastener	4	$2.10	$2.10	0.800	92.31%	NO
	Steel Plates	Cargo	6	$8.35	$0.00	96.000	100.00%	YES
	Metal Screw	Fastener	6	$1.18	$1.18	0.423	92.31%	NO

Bill of Materials: Cargo

	Items	Category	Qty	Retail Price	Price	Total Wt. [oz]	% Complete	Completed
Testing	Flite Test Water-Resistant Foam Board	Prototype	10	$2.99	$29.90	40.212	92.31%	NO
	Gorilla Glue Hot Glue Sticks	Prototype	30	$3.97	$3.97	4.480	92.31%	NO
	Polylactic Acid	Filament	3	$20.99	$0.00	317.700	100.00%	YES
	Acrylonitrile Butadiene Styrene	Filament	5	$18.99	$0.00	882.500	100.00%	YES
	Flexible	Filament	2	$26.99	$0.00	141.200	100.00%	YES
	Light Weight Polylactic Acid	Filament	2	$57.79	$54.00	105.600	100.00%	YES
	Loctite Gel Control 4g Super Glue	Fastener	2	$2.98	$2.98	0.560	92.31%	NO
	APC Electric Propeller 16x8E	Propulsion	1	$8.42	$8.42	1.830	100.00%	YES
	APC Electric Propeller 18x8E	Propulsion	1	$11.13	$11.13	3.030	92.31%	NO
	APC Electric Propeller 18x10E	Propulsion	1	$11.13	$0.00	2.570	100.00%	YES
	Door Hinge	Thrust Test	1	$1.34	$1.34	0.700	100.00%	YES
	Poplar Board	Thrust Test	1	$4.71	$0.00	17.000	100.00%	YES

Bill of Materials: Testing

Sum total from each column	Value
Total # of parts	130
Total retail value of parts	$1,052.99
Total expense to T513 (some parts were sponsored or reused from last	$316.84
Total weight of parts (units: lb)	107.896
Total weight of electronics (units: lb)	5.533
Total weight of airplane components so far (units: lb)	4.847
BoM Progress Tracking	**Value**
# of parts left to order and/or 3d print	27
# of parts at 100% completion	19
# of parts in BoM	49
Total BoM % completion	39%

Bill of Materials: Project Progress

Targets and Metrics Backup

Function	Metric	Target	Method of Validation	Tools for Validation
Accelerate				
Generate Thrust	Force	10 lbf	Experimental	Force Gauge/ Scale
	Propeller Size	14in - 18in	Physical Experiment and Computations	Test sized propellers to determine maximum thrust and compare against DriveCalc program
	Electric Motor Rating Kv Ratting	390 Kv Rating	Given by Manufacture	Manufacture Validated
	Electric Motor Maximum Power	950W	Experimental	Apply current and measure voltage with a voltmeter
	Propulsion System Battery Voltage	22.2 V	Experimental	Voltmeter
Taxi on Runway	Angular Steering for Front Wheel	-60° to 60°	Experimental	Attach to front wheel, test total rotation, and record time

Targets and Metrics

Function	**Metric**	**Target**	**Method of Validation**	**Tools for Validation**
Accelerate				
Apply Throttle	Velocity for Takeoff	30 mph	Theoretical Calculations	MATLAB, PropCal 3. 0
	Ground Distance for Takeoff	Less than 100 ft	Theoretical and Experimental	MATLAB and flight testing
	Propulsion system battery capacity	4000 mAh	Given by manufacturer	Manufacturer Validate d
	Propulsion System battery duration	10 minutes	Theoretical Calculations	Determined by current drawn by propulsion system
	Power limiter top limit	1000 W	Competition Requirement	Manufacturer Validated

Targets and Metrics

Lift				
Generate Pressure Differential	Angle of Attack	2-5 Degrees	Database Comparative Analysis	xlfr5
	Coefficient of Lift	Greater than 1.0	Theoretical Calculations	MATLAB
	Coefficient of Drag	Less than 1.0	Theoretical Calculations	MATLAB
	Wingspan	60 – 120 in	Experimental and Theoretical Calculations	Prototyping, Solid works simulations, and MATLAB
	Wing Loading	10 –20 oz/ft^2	Finite Element Analysis	MATLAB, SOLIDWORKS Simulation
Structure	Gross-take-off weight	Less than 55 lbs	Theoretical Calculations, Physical Experimentation	SOLIDWORKS Simulation, digital scale
Inhibit Stall	Stall Speed	Greater than 30mph	Theoretical Calculation	MATLAB simulation
	Stall Angle of Attack	Greater than 25 Degrees	Experimentation	Flight testing and XLFR5

Targets and Metrics

Function	Metric	Target	Method of Validation	Tools for Validation
Decelerate				
Reduce throttle	Velocity for Landing	Less than 30mph	Theoretical calculations and experimentation	MATLAB, Prop Calc 3.0, testing motor and flight testing
Engage Flaps	Time to deploy	1 Second	Experimental	Stopwatch
	Angle of flaps	0°- 30°	Computer simulation	SOLIDWORKS Simulations
Stabilize approach				
Absorb Landing Force	Force	2x Weight (lbf)	Theoretical	MATLAB and FEA

Targets and Metrics

Function	Metric	Target	Method of Validation	Tools for Validation
Maneuver in Flight				
Servo Motors	Servo Motor Angular Speed	0.17 sec per 60 degrees	Given by Manufacture	Manufacturer Validated
	Angular Pitch Position	-60° to 60°	Experimentally Test	Attach to control surface, test total rotation, and record time
	Angular Roll Position	-60° to 60°	Experimentally Test	Attach to control surface, test total rotation, and record time
	Angular Yaw Position	-60° to 60°	Experimentally Test	Attach to control surface, test total rotation, and record time

Targets and Metrics

Function	Metric	Target	Method of Validation	Tools for Validation
Secure Cargo				
Load/Unload Payload	Time	2 Minutes	Human	Load/unload payload from cargo area with hands
Carry Payload	Force	5 lbf	Experimental	
	Radio System Battery Current Capacity	1000 mAh	Rule Requirement	Manufacturer Validated
	Radio System Battery Time Duration	6 min	Theoretical Calculations	Determined by current drawn by controller
Controller				
Radio Control System	Wavelength Frequency	2.4 GHz	Competition Require ment	Manufacturer Validated
	Electronic speed controller continuous current	85 A	Given by Manufacturer	Manufacturer Validated

Targets and Metrics