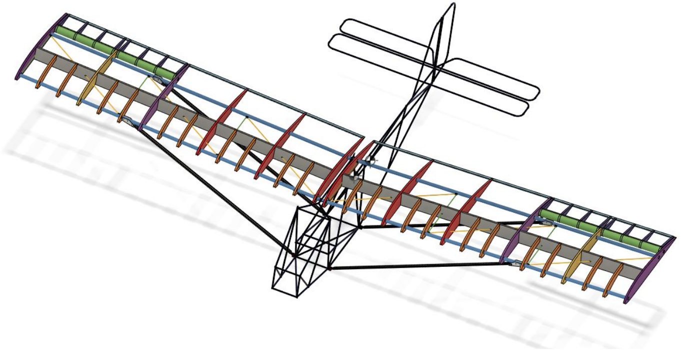
Flight Club Aerospace

8/11/21 Design Review



Mission

Description	Symbol	Value	Units	Comments
Maximum Speed	V_{max}	55	knots	AC 103-7 section 20
Cruise Speed	V_c	46	knots	
Lift at Cruise		569.02	lbf	
Stall Speed	V_{stall}	24	knots	AC 103-7 section 21
Cruise Altitude		2500	ft	
Maximum Load Factor		3.8	"g" (but technically unitless)	FAR Sec. 25.337
Minimum Load Factor		-1.5	"g" (but technically unitless)	FAR Sec. 25.338
Safety Factor		1.5	N/A	The Ultimate Factor of Safety for Aircraft and Spacecraft – Its History, Applications and Misconceptions
Max Range		132.34	miles	See "Fuselage" tab

Weight - Independent Variables

- 254 lb empty weight (legal limit)
- Maximum take-off weight: 569 lb
- V1 is gas-powered with max fuel weight 30 lb (5 gallons)

Description	Symbol	Value	Units	Comments
Maximum Takeoff Weight	W_{TO}	503	lb_f	
Maximum Takeoff Weight	W_{TO}	228.12	kg	To be used in Truss Analysis Equasions
Projected Empty Weight	W_E	254	lb_f	Based on FAR part 103 restrictions
Battery Weight	W_B	74	lb_f	
Crew Weight	W_C	170	lb_f	AC 103-7 section 21A
Payload	W_P	5	lb_f	Camera, Dorritos, licorice, etc...
Projected Useful Load	W_U	175	lb_f	Crew weight + payload
Wing Loading	W/S	2.6198	lb_f/f^3	Takeoff weight/wing surface area
Maximum Wing Loading	W/S_{max}	14.93	lb_f/f^3	Takeoff weight*maximum load factor*safety factor/wing surface area
Wing Weight	W_W	100	lb_f	Total weight of both wings

Wing Physics - 1

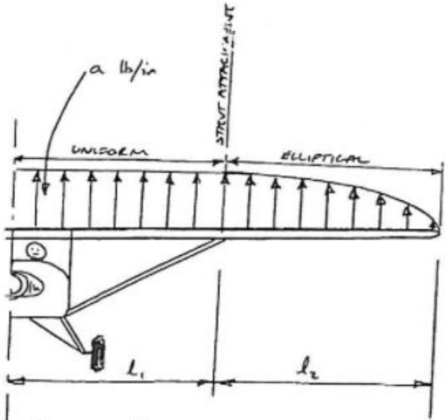
Wingspan		32.000	ft
Wing Chord	C	6.000	ft
Dihedral Angle		3.000	degrees
Wing Reference Area	S	192.000	ft^2
Wing Reference Area	S	17.837	m^2
Wing Aspect Ratio	AR	5.333	N/A
Leading Spar OD		2.000	in
Leading Spar Thickness		0.065	in
Aft Spar OD		2.000	in
Aft Spar Thickness		0.065	in
Spar Spacing (center to center)		43.312	in

Wing Physics - 2

Chord Width	W_c	0.711	ft	
Cruise Reynolds Number	$R_{e\text{-cruise}}$	375158.000	N/A	
Cruise Lift Coefficient	$C_{L\text{-cruise}}$	0.424	N/A	
Cruise AOA	α_{cruise}	[0, 0.25]	degrees	Based off Clark Y airfoil, reynold's number of 500K (rounded up), Ncrit=9
Drag Coefficient at Cruise	$C_{D\text{-cruise}}$	0.00654] (Contested)	N/A	Based off Clark Y airfoil, reynold's number of 500K (rounded up), Ncrit=10, AOA [0, 0.25] degrees || Independent XFLR5 testing shows a Cd of 0.019 at AOA 0.25
Stall Reynolds Number	$R_{e\text{-stall}}$	183166.779	N/A	
Stall Lift Coefficient	$C_{L\text{-stall}}$	1.343	N/A	
Stall AOA	α_{stall}	[11.75, 12.00]	degrees	Based off Clark Y airfoil, reynold's number of 200K (rounded up), Ncrit=9
Drag Coefficient at Stall Cl	$C_{D\text{-stall}}$	[0.02935, 0.03069]	N/A	Based off Clark Y airfoil, reynold's number of 200K (rounded up), Ncrit=10, AOA [11.75, 12.00] degrees

Schrenk Approximation (Lift Distribution)

1. Strut (or Wire) Braced Wing
1. STRUT BRACED WING



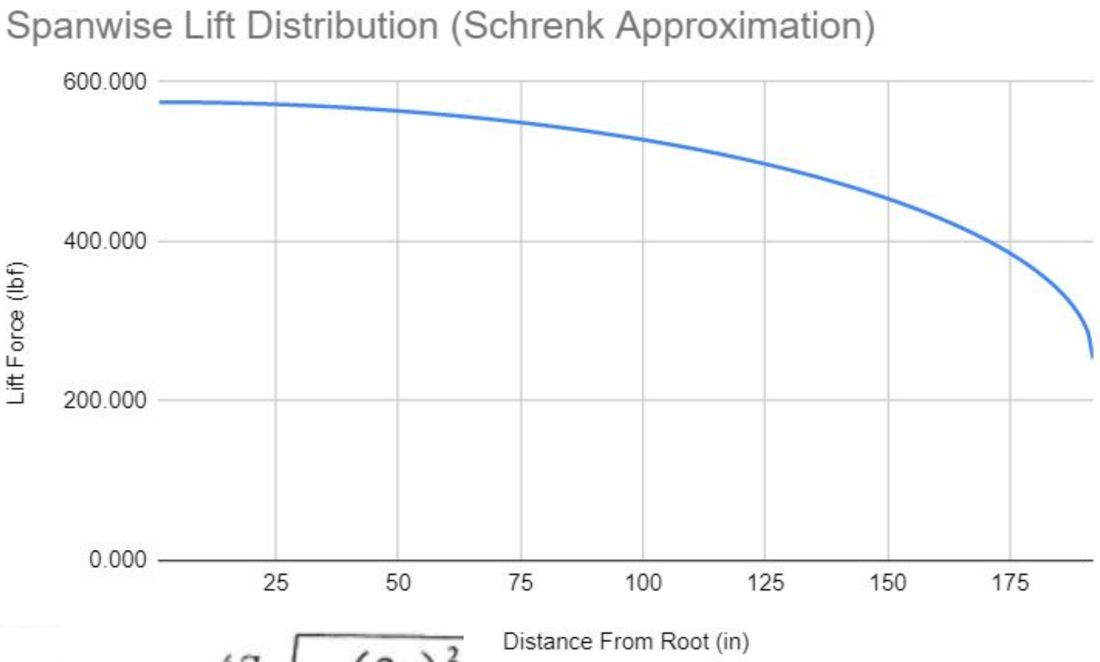
LIFT = nW

AREA OF UNIFORM LOADING = $a \times l_1$

AREA OF ELLIPSE = $\frac{\pi}{4} a l_2$

TOTAL AREA = $\frac{\pi}{4} a l_2 + a l_1 = \frac{nW}{2}$

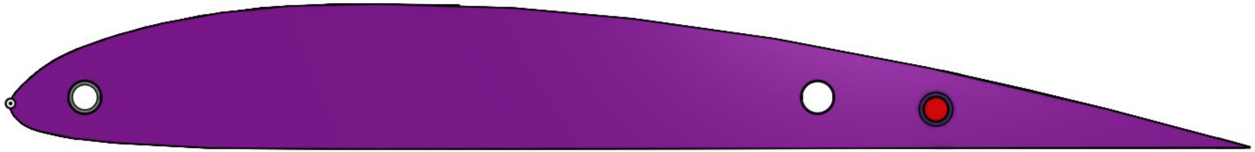
$a = \left[\frac{nW}{2}\right] / \left[l_1 + \frac{\pi}{4} l_2\right]$ lb/in



$$\text{Ellipse Height} = \frac{4S}{\pi b}\sqrt{1-\left(\frac{2y}{b}\right)^2}$$

Wing Design

Ribs



Clark Y - 6 ft Chord

XPS Foam with fiberglass epoxied with micro glass bubbles

Aluminum spar caps to help take the load

“False” ribs to keep up the fabric

Rib Testing

Structure

Spars: 2” x 0.065” 6061 T6 Aluminum

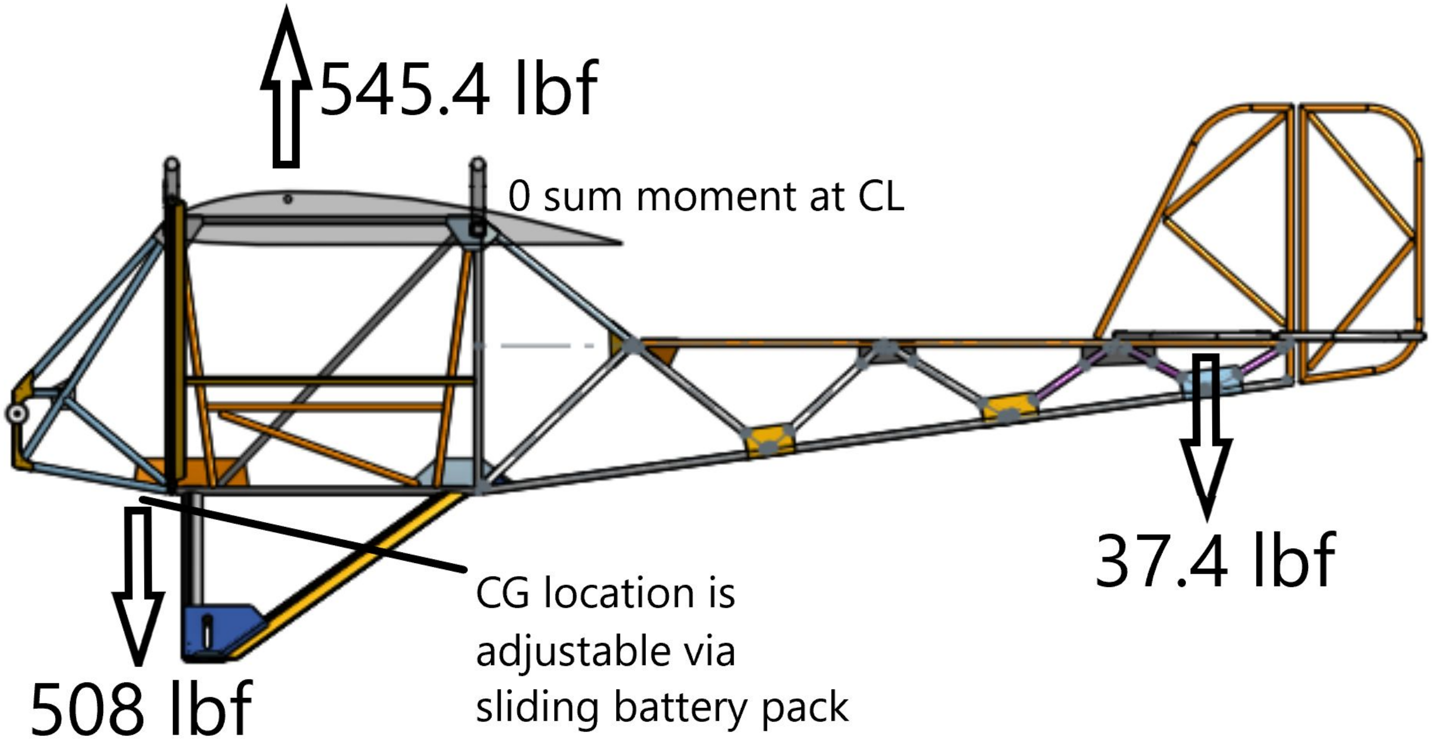
Cross Struts: 0.55”x 0.032” 6061

Gusseted with Cherrymax 3/16” rivets

Mostly Done!

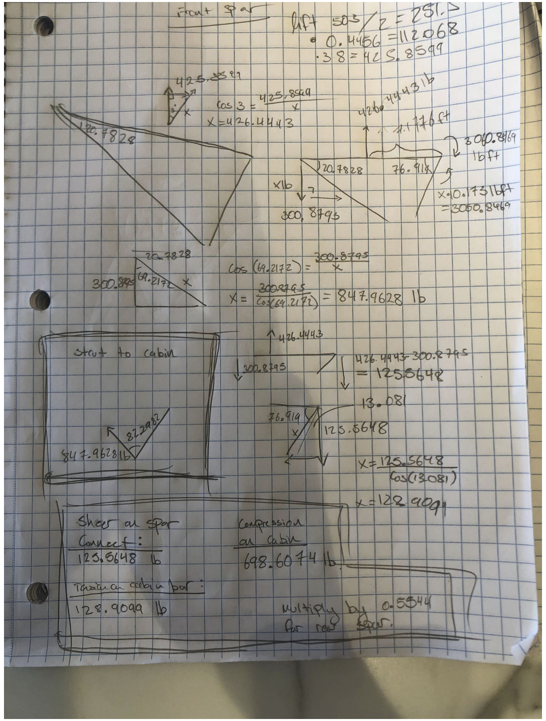
Truss Physics

Identifying initial forces.



Calculating Strut Location - 1

We calculated compression and column buckling inboard of spar.



Buckling strength of spar

$$u(x) = \frac{\pi^2 10000000 i}{(12x)^2} \{-16 \le x \le 0\}$$

How much compression spar will be under

$$c(x) = k \cdot 3.8 \cdot \tan\left(90 - a(x)\right) \cdot \frac{1592.8983}{\mathrm{abs}(x)} \{-16 \le x \le 0\}$$

Percent of lift bearing done by main spar (percent of lift bearing done by rear spar = 1 - k

$k = 0.4456$

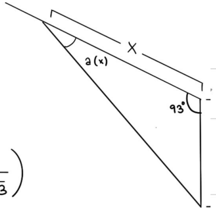
0

according to law of cosines:

$$l(x) = \sqrt{x^2 + 10.543 - 6.494 \cdot x \cdot \cos 93}$$

according to law of sines:

$$a(x) = \sin^{-1}\left(\frac{3.247 \sin 93}{\sqrt{x^2 + 10.543 - 6.494 \cdot x \cdot \cos 93}}\right)$$



Area moment of innertia

$$i = \frac{\pi\left(D^4 - (D - 2p)^4\right)}{64}$$

$i = 0.166963971849$

Dimensions of spar (D=outer diameter, p=thickness)

$D = 2$

0 2

$p = 0.058$

0 2

Calculating Strut Location - 2

We calculated the greatest tension caused by moment on the spar and compared it to the tensile yield strength.

Intermediate step used to find moment

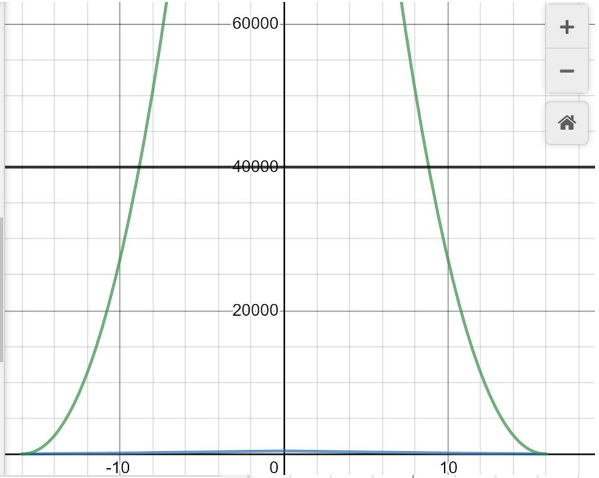
25
$$f(x) = \int_{-16}^{-\mathrm{abs}(x)} g(t)\,dt$$

26
How much tension the spar will have at the strut intersection (the point of greatest moment)

27
$$h(x) = 12\,\frac{\frac{D}{2}\int_{-16}^{-\mathrm{abs}(x)} f(v)\,dv}{i}$$

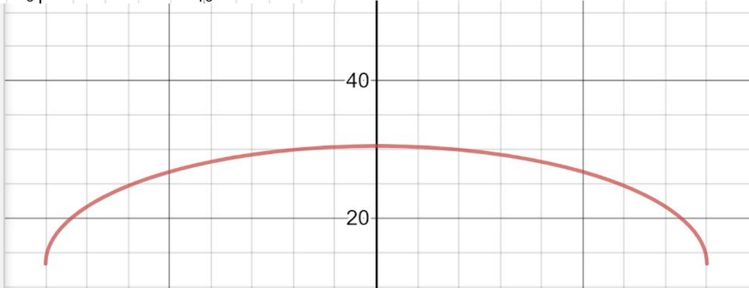
28
Yield tensile strength

29
$$o(x) = 40\,000$$



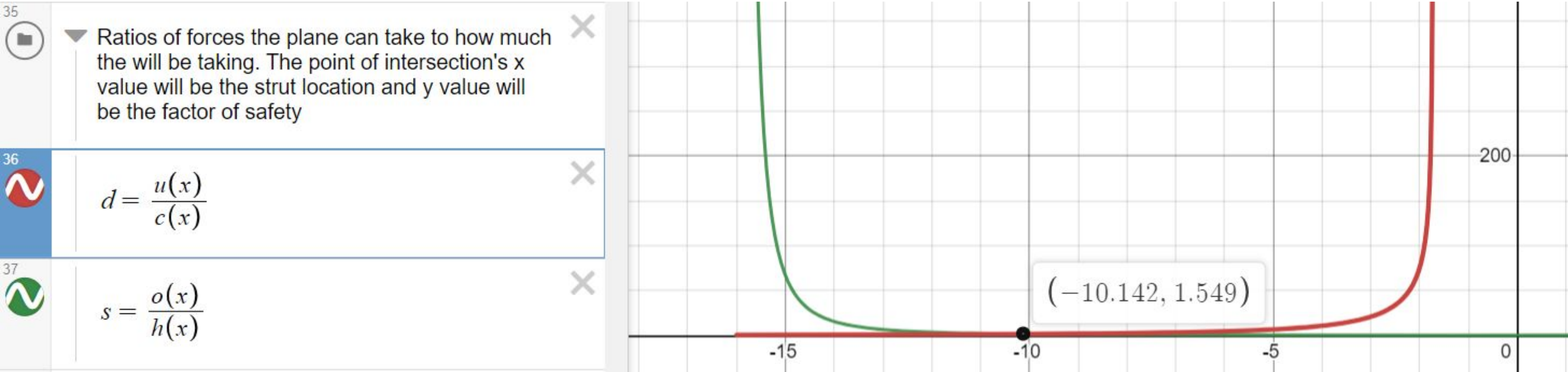
11
Lift coefficient using the Schrenk approximation

12
$$g(x) = k \cdot 3.8 \cdot \frac{2801.34\left(.3627\,\frac{\frac{6+\frac{4\cdot 192}{\pi\cdot 32}\sqrt{1-\left(\frac{2x}{32}\right)^2}}{2}}{32\cdot 6}\right)}{2}$$

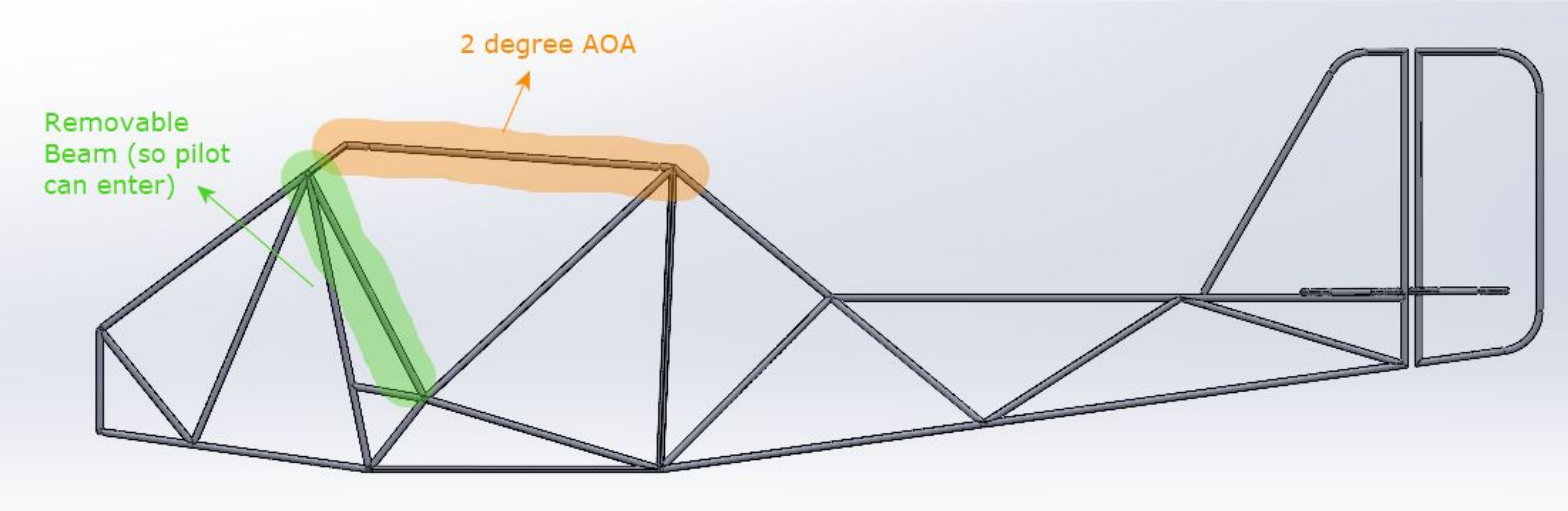


Calculating Strut Location - 3

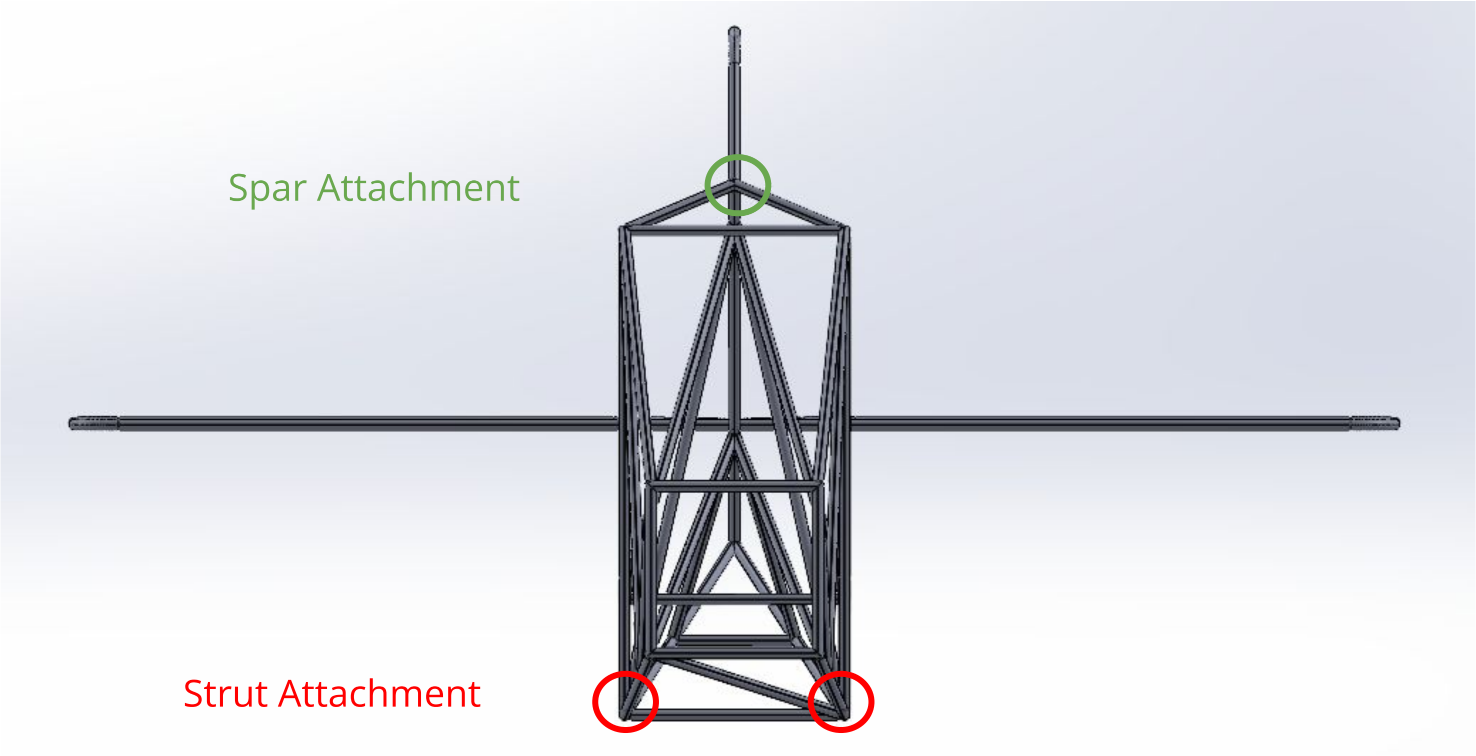
- Compared the (column buckling of our spar/the compression inboard of spar) and the (tensile yield strength of our spar/the greatest tension caused by moment on the spar) ratio
- X value of the intersection point= the optimal distance from the fuselage to the strut attachment point
- Y value = the factor of safety at that point
- Creates the optimal factor of safety for both tension and compression.



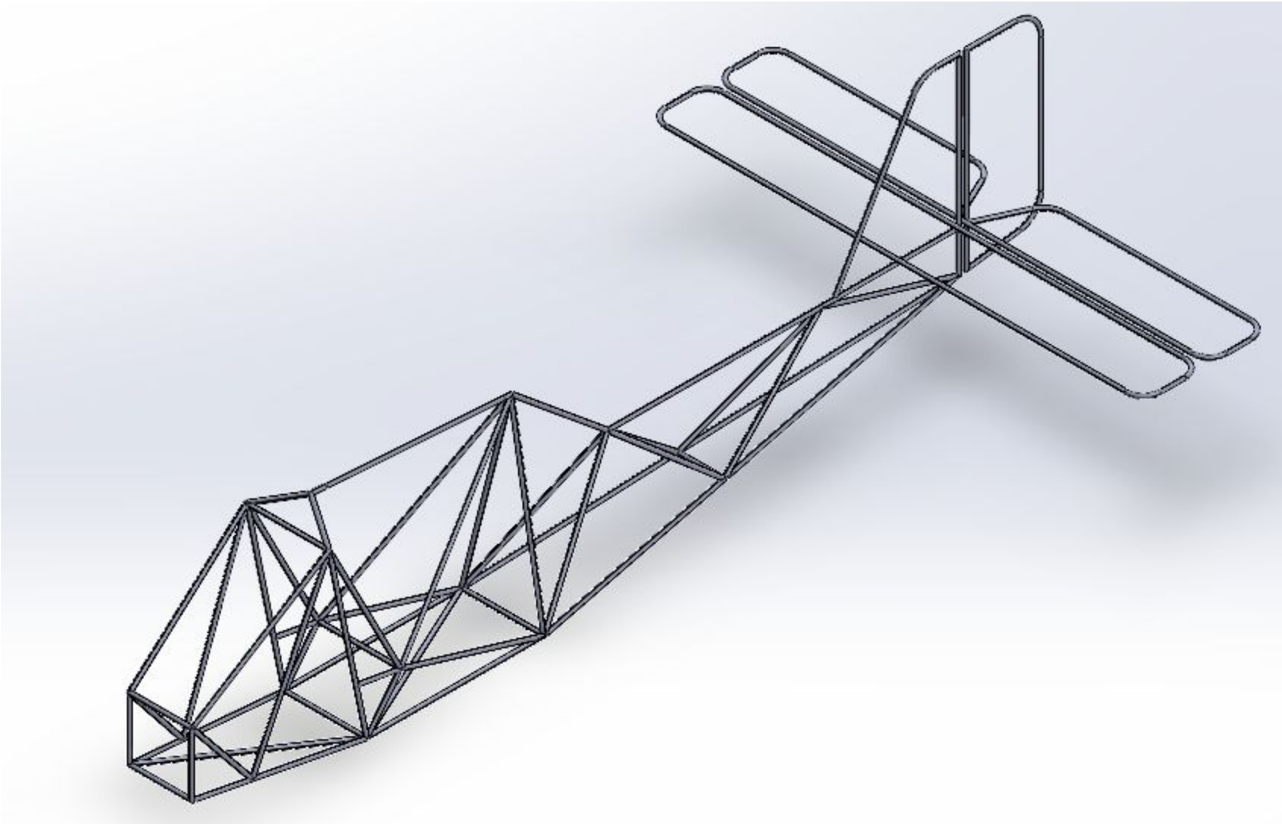
Truss Design - 1



Truss Design - 2



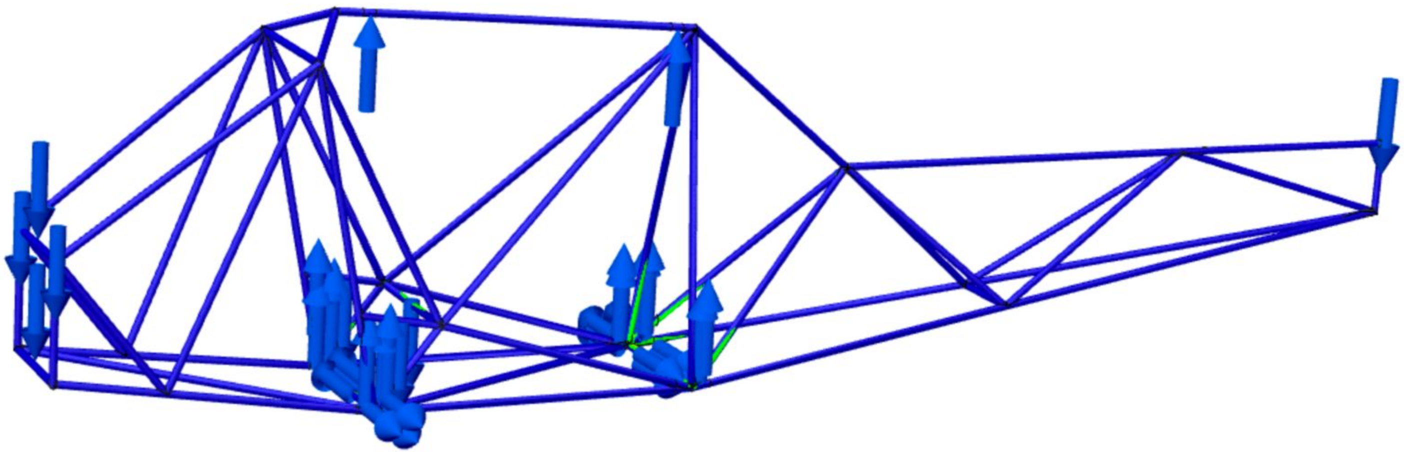
Truss Design - 3



1” x 0.058” 6061 T6 Aluminum

Gussets: Steel (so we can bend it)

Truss Simulations



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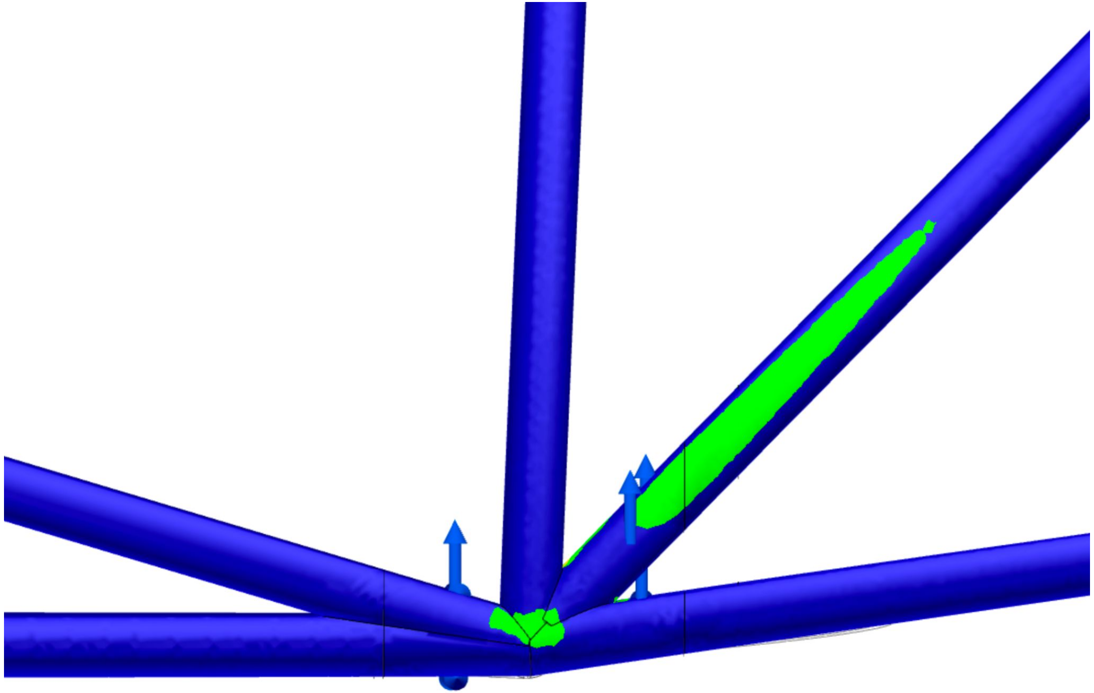

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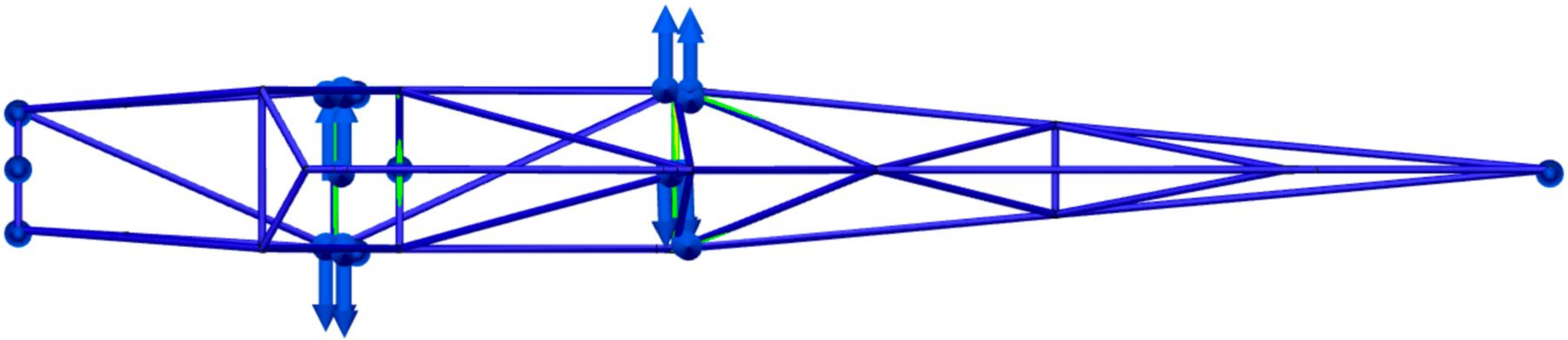


Tail + Static Stability

Tail Volume Coefficient

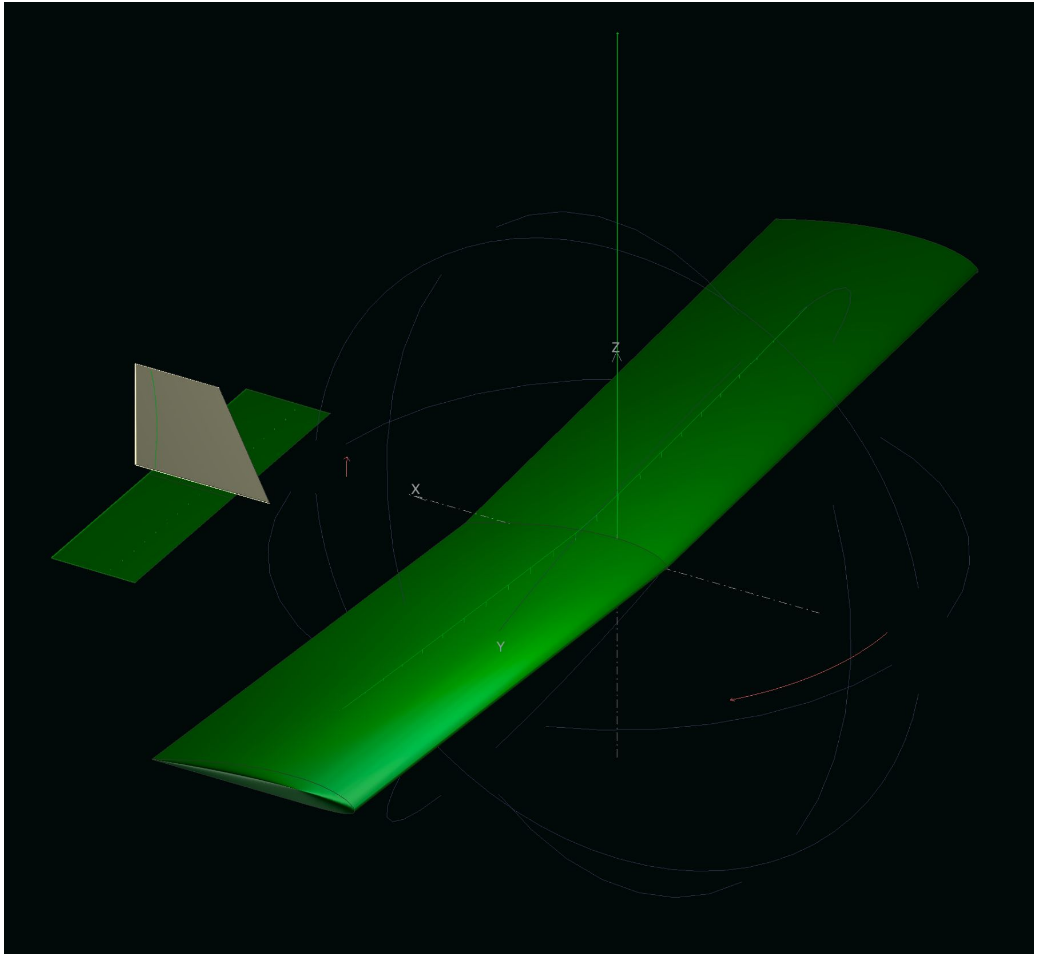
- $S_H = (V_H \times S_W \times m.a.c.) / L_H$

- Using V_H (0.34) from Piper J-3 Cub:
  - $S_H = (0.34 \times 192\ ft^2 \times 6\ ft) / 13\ ft = \sim 30.1\ ft$ (really big)

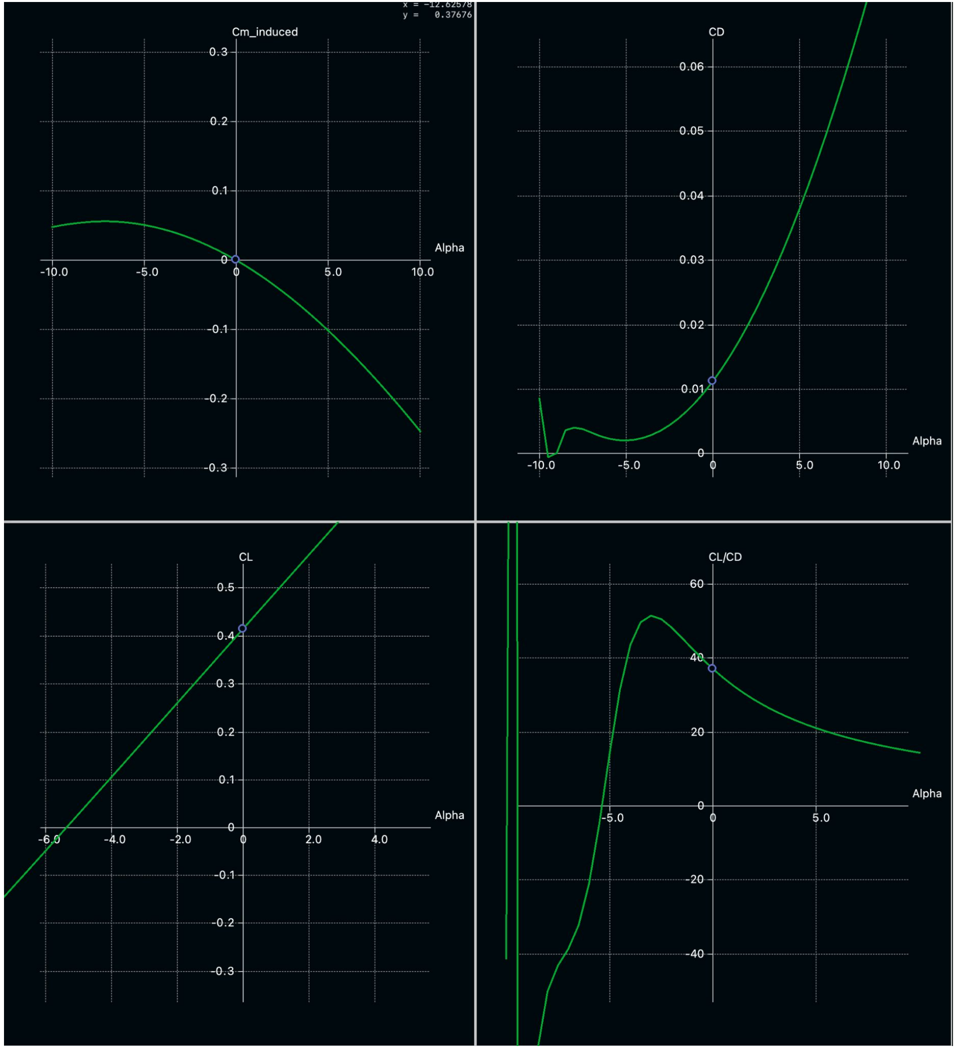
- Typical homebuilt $V_H = 0.5$:
  - $S_H = (0.5 \times 192\ ft^2 \times 6\ ft) / 13\ ft = \sim 44.3\ ft$ (massively oversized)

XFLR5

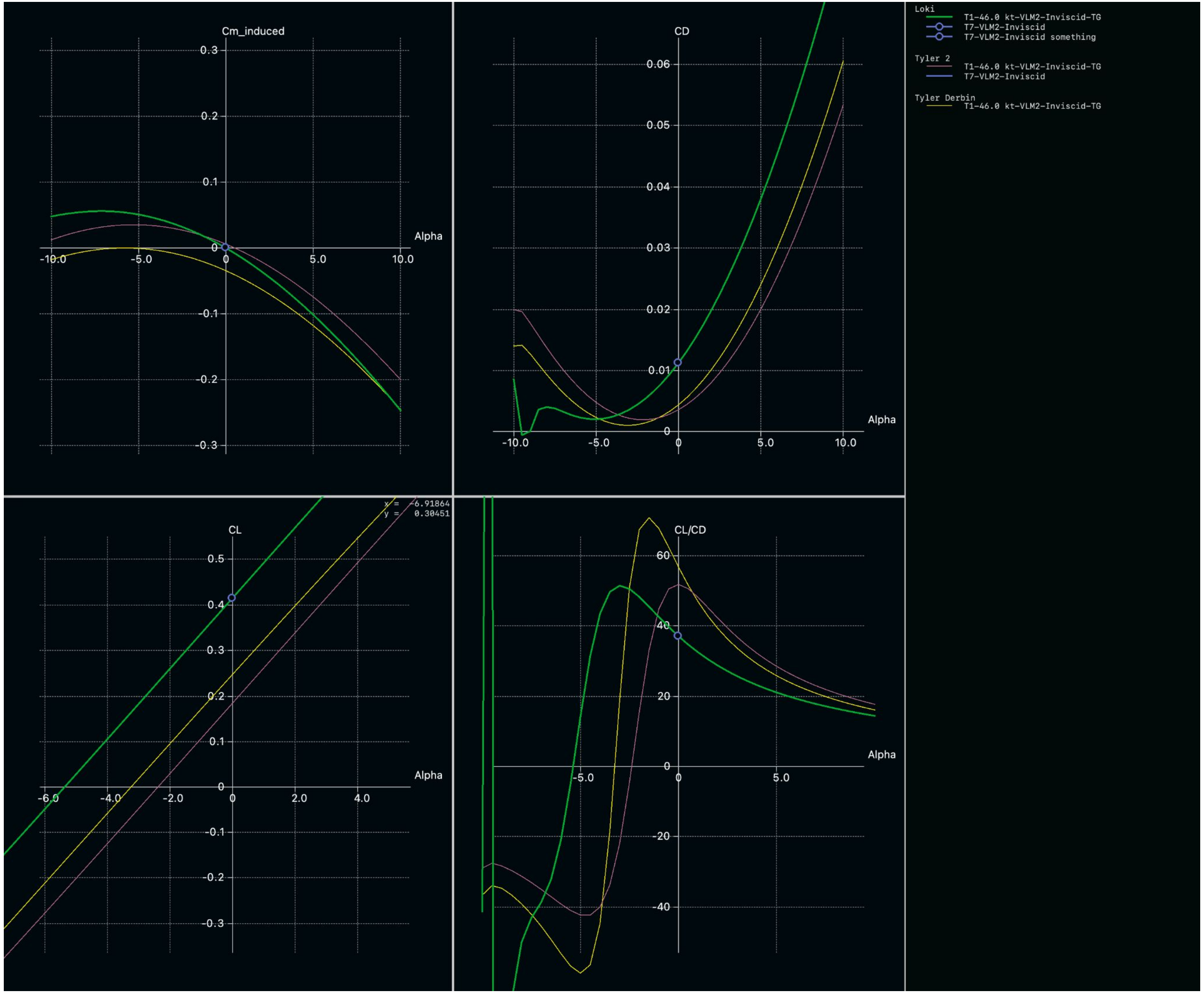
- 2.5 ft x 10 ft (25 ft^2)
- -0.3° AOA
- 0.258 tail volume coefficient



Current Design (Loki)



Loki vs Tylers



CG Calculator

https://docs.google.com/spreadsheets/d/1QXmaBWWRDz4BI3gv-acK8mFDM79IXPg8rVR1Yl0DeKg/edit#gid=2001226050

Required CG: 0.245” in front of QC

Current CG: 6.2” in front of QC

Engine

Drag

$$C_D = C_{D\,min} + (C_L^{\,2} / (pi \cdot AR \cdot e))$$

$$D = ½ \cdot p \cdot V^2 \cdot S_{ref} \cdot C_D$$

Drag				
Minimum Drag Coefficient	C_D min	0.04		Searey CD_min (General Aviation Aircraft Design textbook pg 756)
Oswald Efficiency Factor	e	0.70		https://www.grc.nasa.gov/www/k-12/airplane/induced.html
Cruise Lift Coefficient	C_L cruise	0.41		XFLR5
Drag Coefficient	C_D	0.06		
Drag Force	D	80.76	lbf	

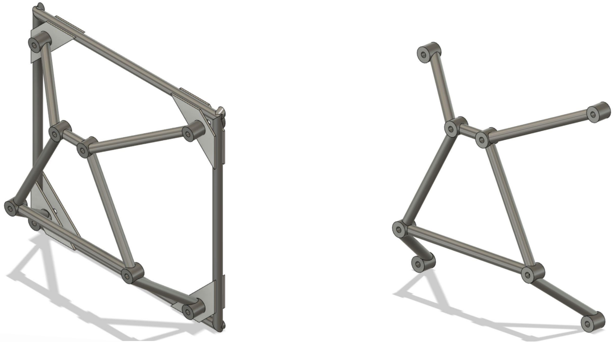
Polini Thor 202

- Two stroke
- Liquid Cooled
- 33 hp
- 200 pounds of thrust
- 37 pounds

Engine Data

Description	Value	Unit	Comments
Max Thrust	200	lbf	Polini Thor 202
Average gph	2	G/h	Average from Forum
Oil Content in Fuel	2.5	%	
Total Fuel	5	G	
Effective Fuel	4.88	G	
Max Range	132.34	miles	Assuming Cruise Speed

Motor Mount

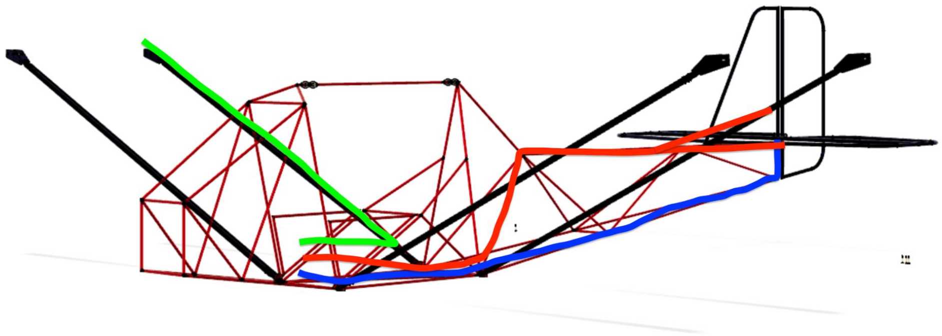


- The top design is our old design made of the same pipe as the fuselage and welded together.
- The bottom design is our new mount made of c-channels that mount flush with the nose.
- The reason we re-designed the mount was because we switched to gusseting and the first design was overly complicated.
- The main downside with the new design is the motor will be 4.5 inches closer to the CG.

Control System

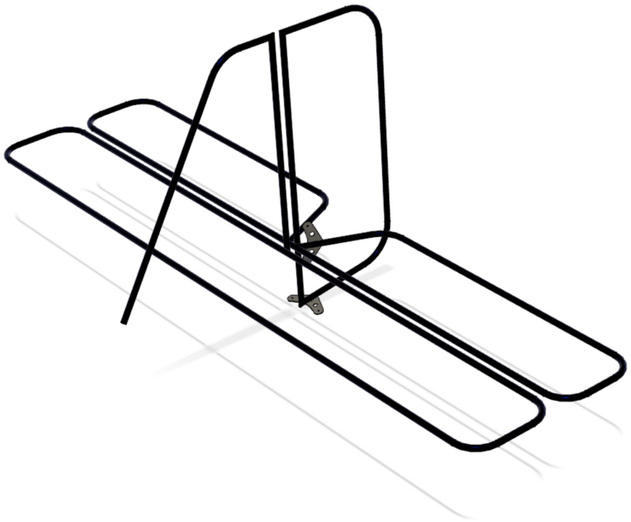
Cable-Controlled

- 3/32" 7x19 galvanized steel cable
- Copper Nicopress sleeves
- MS20219-1 Phenolic Pulleys
- Making own Nylon fairleads



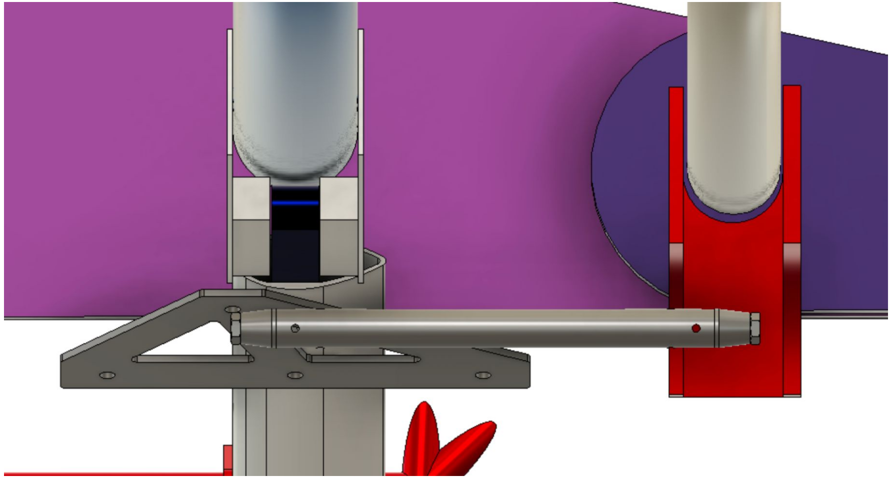
Rudder/Elevator Bellcranks

- ⅛" Aluminum



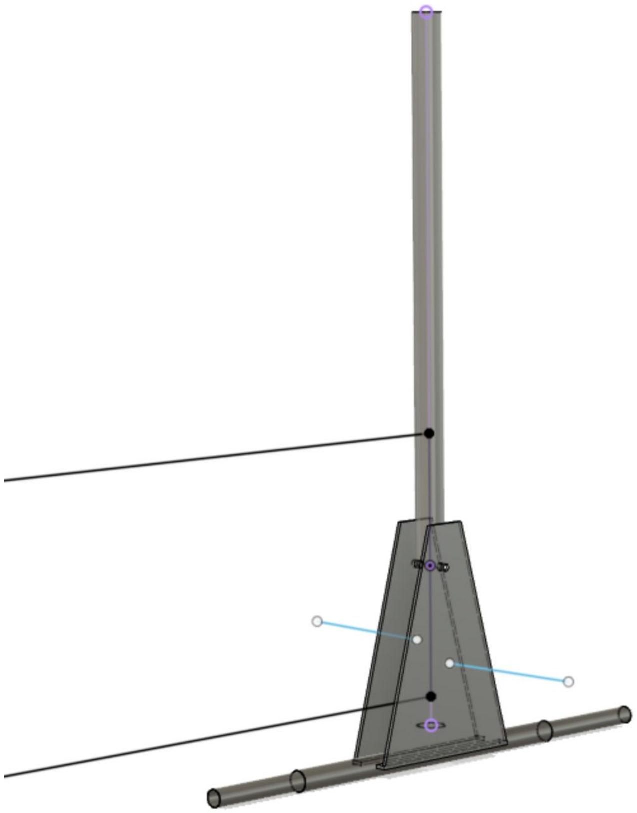
Aileron

- ⅛" steel bellcrank
- Push-pull tube: ⅝" OD pipe with threaded inserts on both ends (to connect to rod ends)
- 1/16" aluminum push-pull tube to torque tube attach



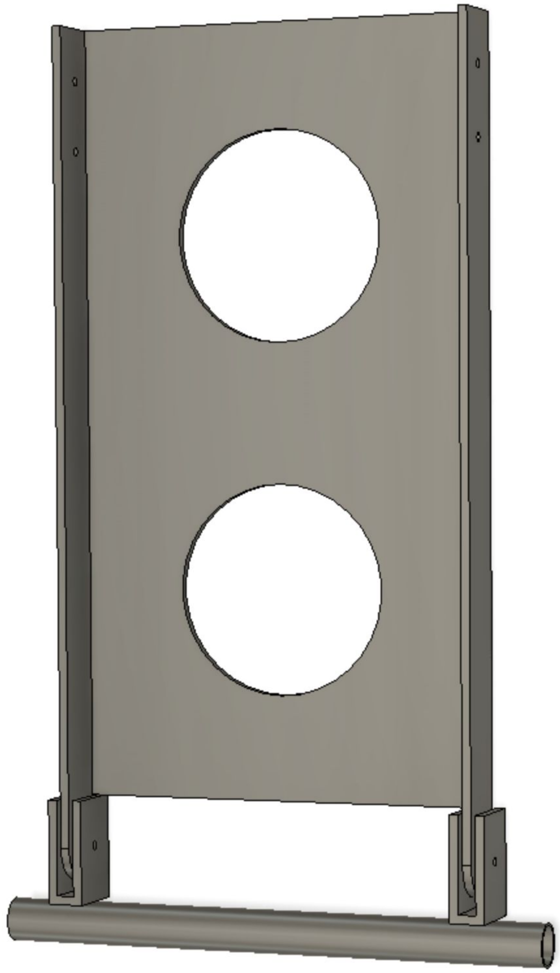
Control Stick

- ⅛” aluminum sheets + 1” OD aluminum pipe
- Mounted on floor of nose



Rudder Pedals

- ⅛” aluminum, sheet



Landing Gear

Landing Gear Physics

Used basic kinematic equations to find force on landing

Speed at Landing		27	knots	Assumption by Physics Team
Angle at Landing		0.12	radians	Assumption by Physics Team
Verticle Landing Vector		3.17	knots	
Vector on Rear Tail Wheel		191.14	lb	Assuming 10% of total weight
Angle from Line(Front to Back landing gear) to ground (on ground)		0.17	radians	Not exact, need to update after finish CAD
Verticle vector on Rear Tail Wheel		188.24	lbf	
Angle from ground to bottom empannage Beams		0.16	radians	
Distance of Landing		4.1	inches	Distance between bottom of slot to top
Acceleration at Landing		25.13	knots/sec^2	
Acceleration at Landing		12.93	m/s^2	To be used in Truss Analysis calculations

Landing Gear Physics cont.

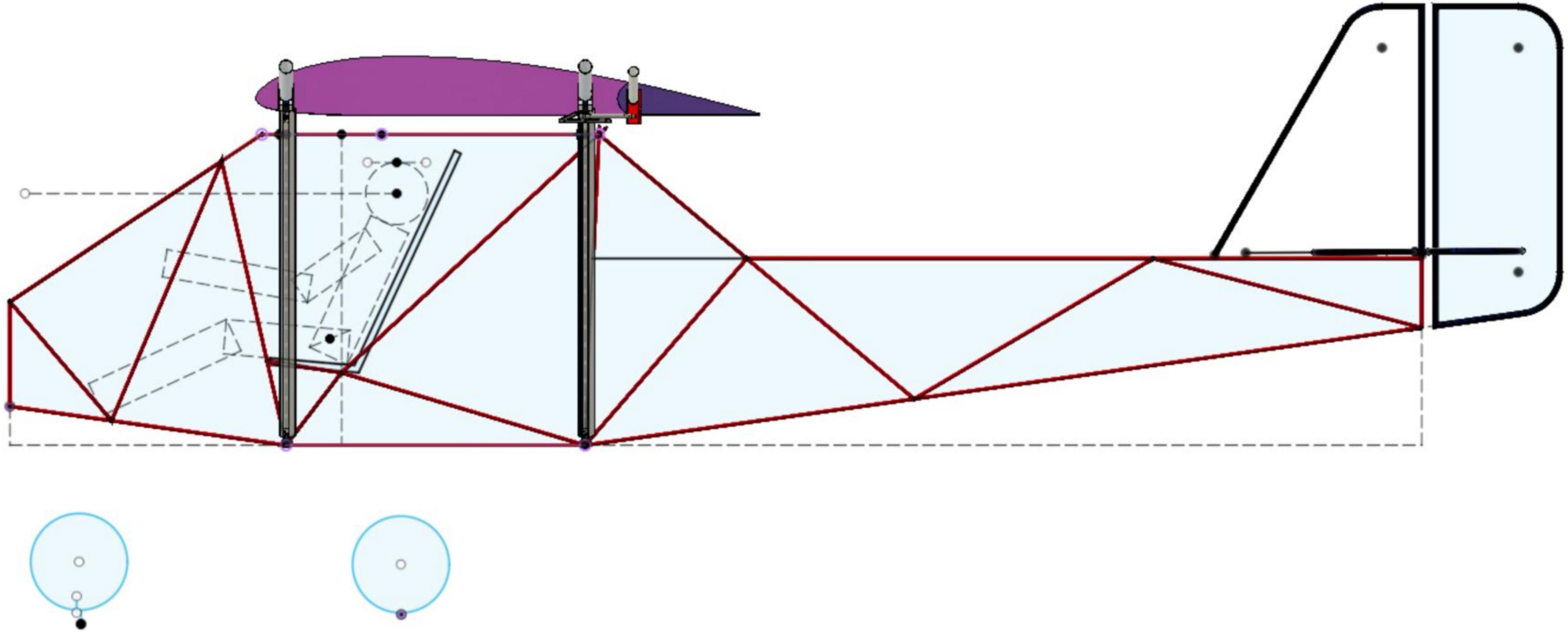
Then, used the force to check if our struts could take the weight

Beam	Length (in)	Column buckling (lbf)	Max tension tolerable (PSI)	Forces at landing C/T (lbf)	Forces at landing PSI	Forces at 3.8 g (-=T, +=C)	Forces at -1.5 g (-=T, +=C)	K	Pi	Area moment of innertia (in^4)	Safety Factor C
Landing gear vertical beam	29.5	39847.9139		2,541		2,541		0.9	3.141592654	0.2846	15.6819810

Using column buckling equations:

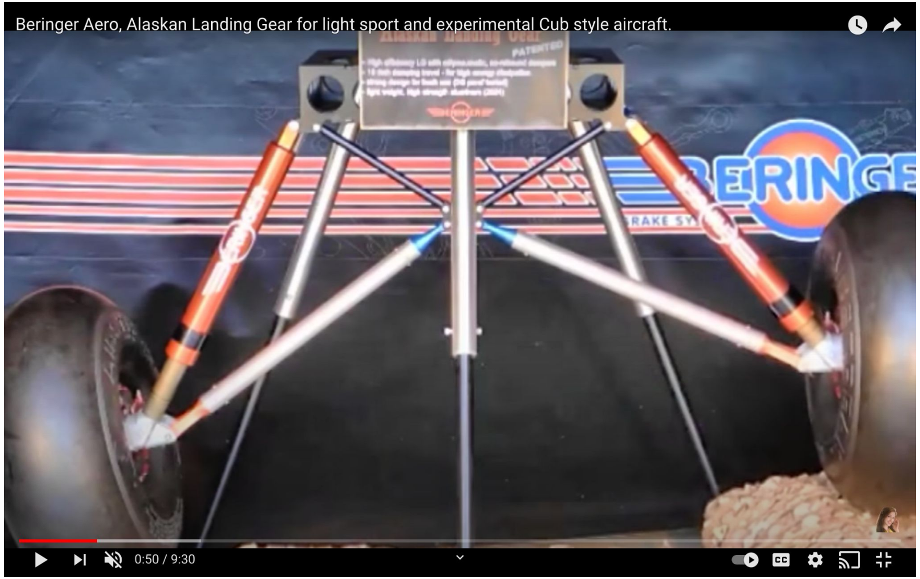
$$F = \frac{\pi^2 EI}{(KL)^2}$$

Trike Configuration



Landing Gear Attach

- Tricycle arrangement
- Rubber pucks
- No welding - attached with gussets



Black Max Landing Gear Kit

https://drive.google.com/drive/folders/1-fEPRJgm5izc7_tjbXStEDB6-VrwqTQb

2 wheels brake independently, 2 master cylinders on control stick

Safety

BRS & Harness

- Ballistic Recovery System:
  - Aerolite 103 BRS
  - NOT installing immediately
- Safety Harness:
  - https://www.aircraftspruce.com/catalog/appages/rvcrowres-llwo.php?clickkey=436169
  - 5 point Y harness

Safety Harness

https://www.aircraftspruce.com/catalog/appages/rvcrowres-llwo.php?clickkey=436169

5 point Y harness

Questions:

1. Check drag calculations + range + endurance + consumption
2. Our gusset calculations seem to be VERY off
    a. Are there better equations? Are we dealing with it wrong?
3. How should we go about deciding beam thickness/gusset thickness?
    a. Simulations work but they get less accurate when we put in rivets/bolts
4. Make the gussets? Bend them around?
    a. How much do we need to design and how much are we eyeballing day of construction?