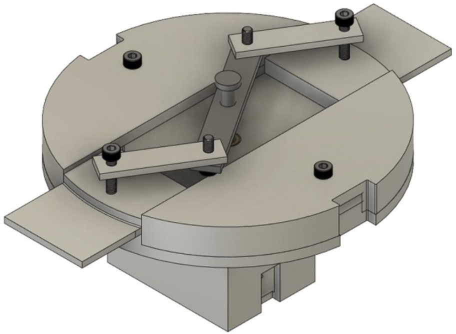
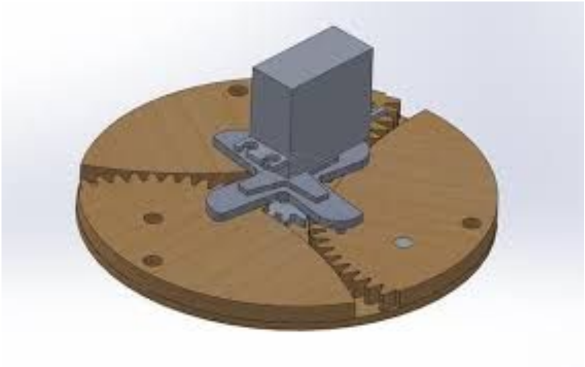
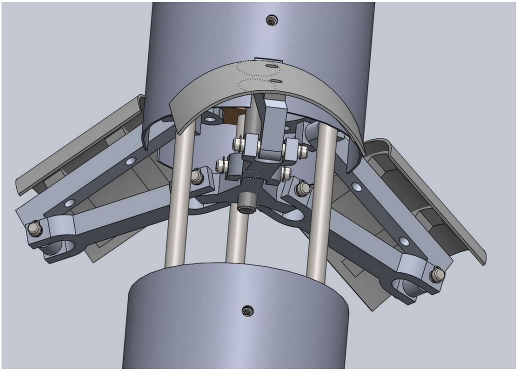
Air Brakes

What are Air Brakes?

- A mechanism that upon actuation, creates a large amount of drag to slow down the rocket
- Suddenly creates a large amount of area outside the rocket which creates drag
- Applications:
  - Reaching target altitude with accuracy
  - Drag separation



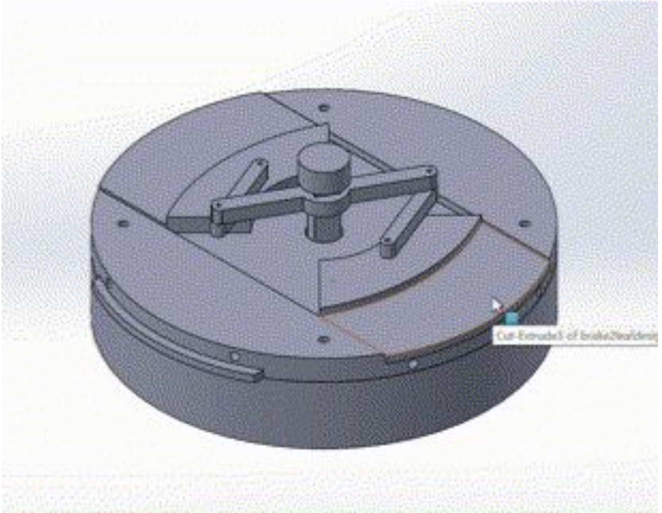


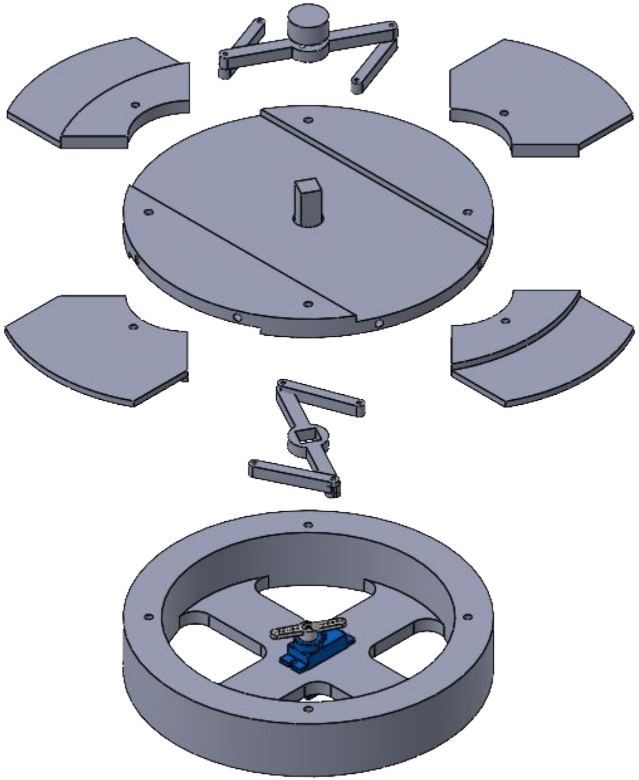


Functional Requirements

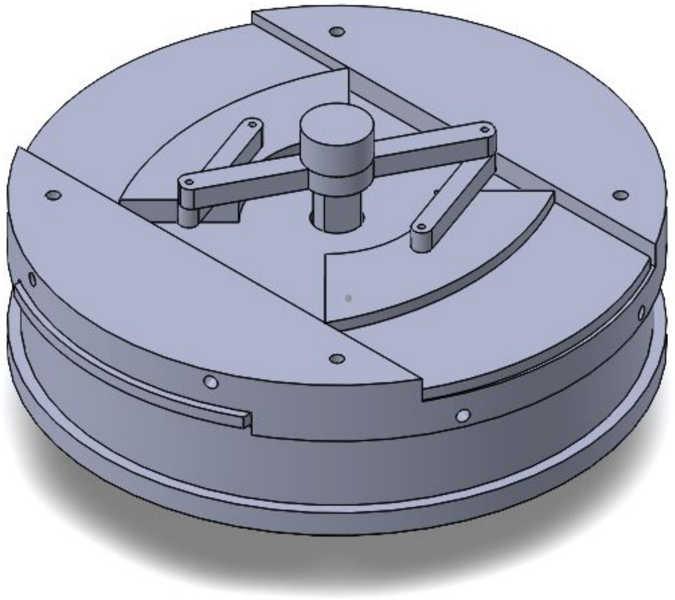
- **Actuation Time:** Transition from fully retracted to fully extended within 0.5 seconds
- **Predictability:** Produce a **predictable** amount of drag when fully extended
- **Purpose on Booster:** Cause drag separation
- **Purpose on Sustainer:** Reach target altitude with accuracy (prevent overshooting)
    - Note: Avionics will be creating a feedback control loop to determine when to extend air brakes

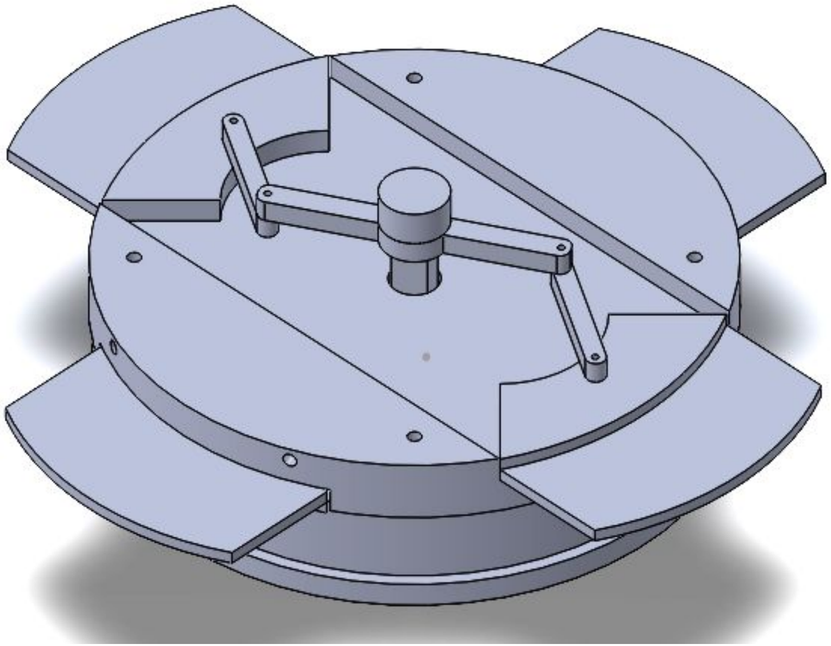
CAD



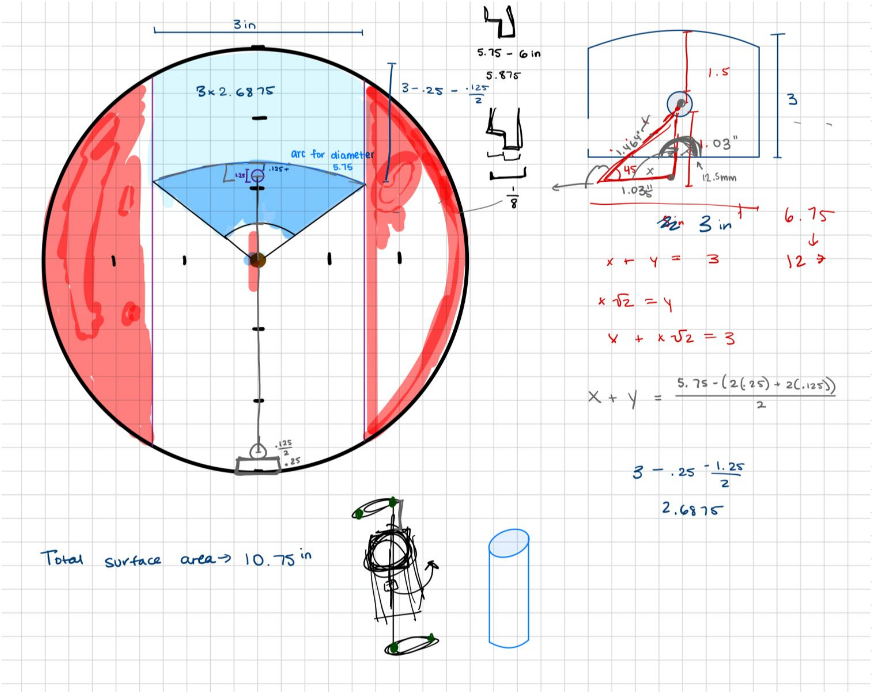


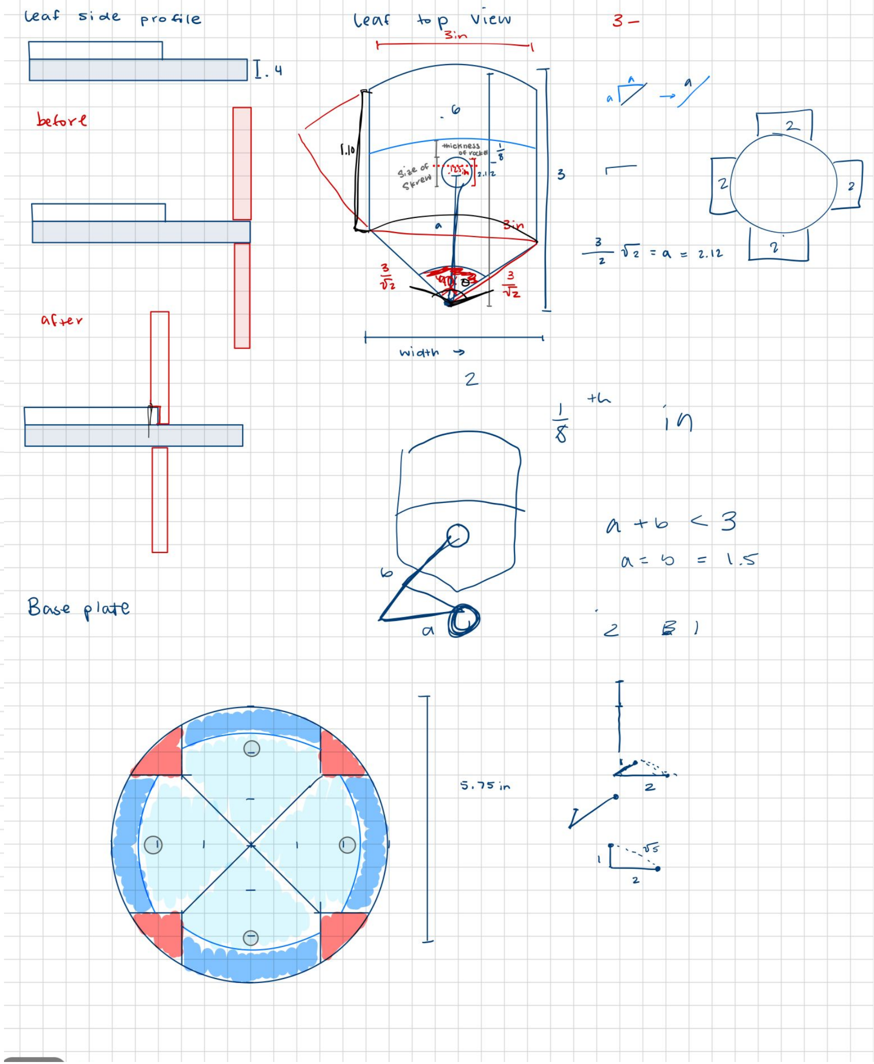
CAD



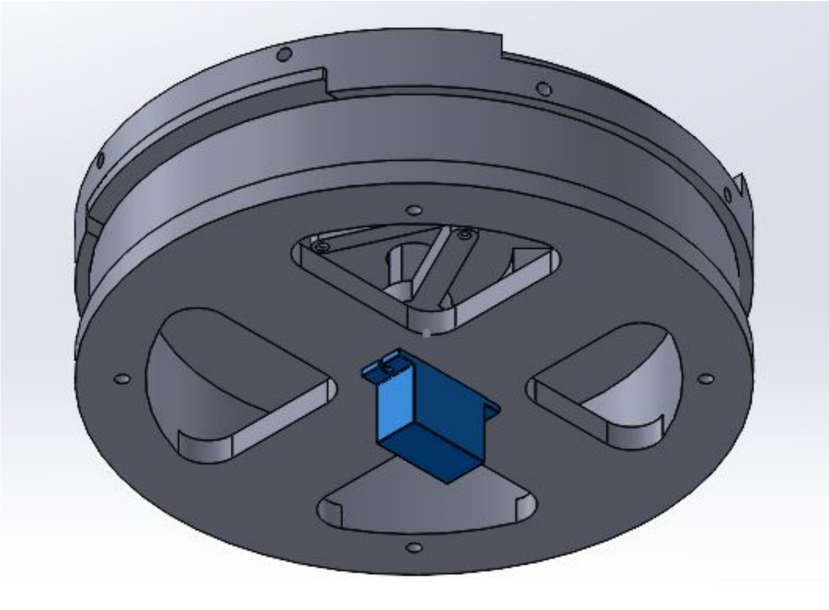


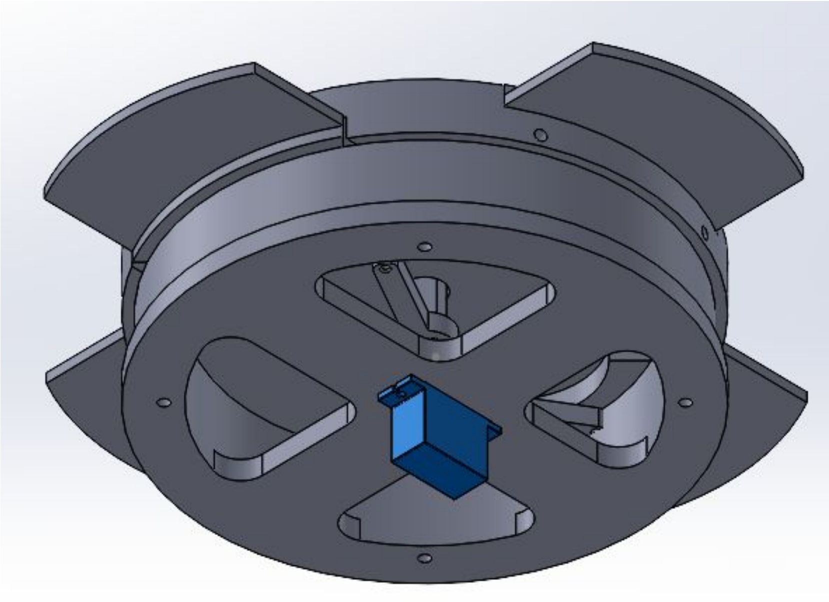
Design


3in
3x2.6875
arc for diameter 5.75
5.75 - 6 in
5.875
3 - .25 - .125/2
1/8
1.5
3
1.03"
12.5mm
45
1.03"
3 in
6.75
12
x + y = 3
x√2 = y
x + x√2 = 3
x + y = 5.75 - (2(.25) + 2(.125)) / 2
3 - .25 - 1.25/2
2.6875
Total surface area → 10.75 in


leaf side profile
before
after
Base plate
leaf top view
3in
.6
thickness of rocket
Size of screw
1.10
3
width →
3/√2
3 -
3/2 √2 = a = 2.12
2
1/8 th in
a + b < 3
a = b = 1.5
5.75 in

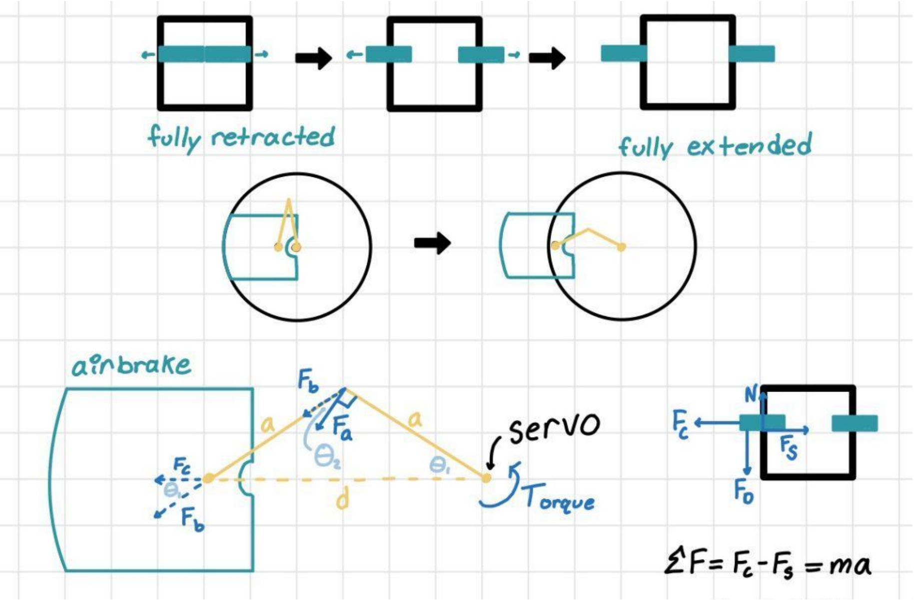
CAD Pt. 2





Torque Calcs

- Plate experiences **resistance** to moving outward (deployment) due to **friction** with opening (**drag force** = normal force)

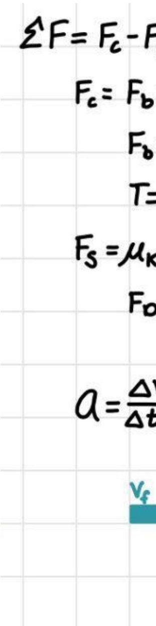


$$T=\left(m\frac{2\Delta x}{\Delta t^2}+\mu_K\frac{1}{2}\rho C_D V^2 A\right)\frac{4a^4\sqrt{\frac{4a^2}{d^2}-1}}{\left(2a^2d-d^3+2a^2\right)}$$

Inputs

- Mass of plate
- Distance extended
- Time to extend
- Coefficient of friction
- Air density
- Coefficient of drag
- Velocity at deployment
- Area of plate
- Length of servo arms
- Distance airbrake is extended

Results: 9.5 Nm = 1345 oz-in

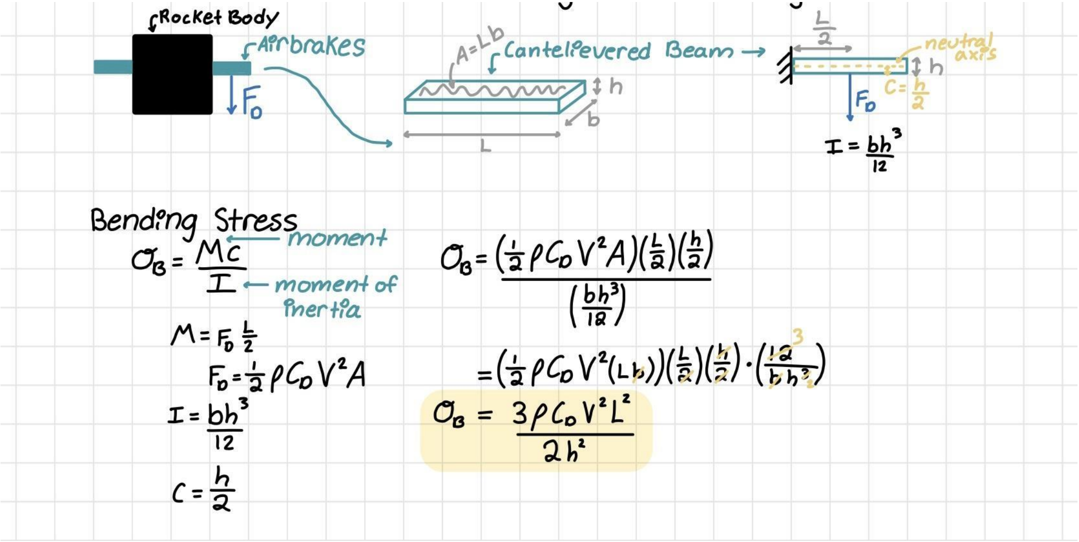


Possible Servo:

- **Torque: 1435 oz-in**
- **Size (LxW): 4.26 x 3.42 in**

Material Selection

- Finding the **Bending Stress** in the plate due to **Drag Force** when plate is fully extended



Inputs:

- Coefficient of Drag (plate): 1.9
- Air Density: 0.0765 lb/ft^3 (sea level)
- Velocity at Deployment: 400 ft/s
- Length of Plate: 3in
- Thickness of Plate: 0.25in

Results

- **Bending Stress: 7.9 MPa**

Yield Strength of Materials:

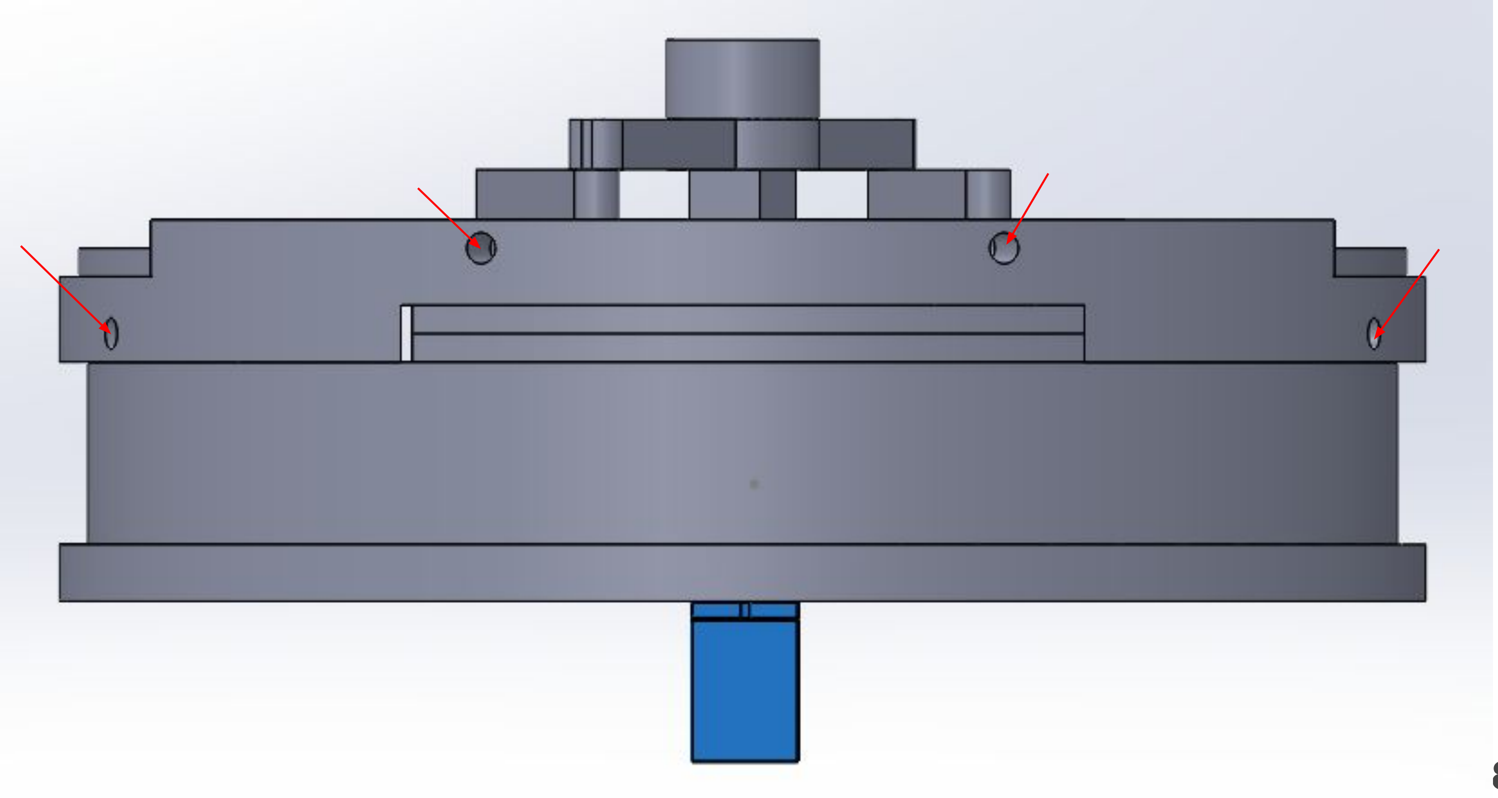
- **Aluminum 6061-T6: 241 MPa**
- PLA: 26 MPa (homogenous)

Air Brakes Mass Breakdown

	Part	Mass (lbs)		Part	Mass (lbs)
Booster	Servo	0.032	Sustainer	Servo	0.032
	Leaf (x4)	0.044 (0.176)		Leaf (x4)	0.044 (0.176)
	Base plate	0.088		Base plate	0.088
	Total:	**0.296**		**Total:**	**0.296**
Total:			**0.592**		

Integration

8-32 screws



Manufacturing

- Tests will be done to determine necessary materials and if all components can be 3D printed
- If needed almost all components can be machined out of aluminum

Possible Failure Modes

Failure Mode	Probability	Severity	Mitigation
Air brakes fail to deploy (sustainer)	Low	Medium	Choose servo with sufficient torque
Air brakes fail to deploy (booster)	Low	Medium	Choose servo with sufficient torque
Deformation or structural failure of plates	Low	Medium	Choose material and thickness to withstand sufficient bending stress
Structural failure of mission package tube at air brakes	Medium	High	Choose sufficient thickness of material within mission package tube and size of screws