MEE 472: SENIOR CAPSTONE DESIGN SPRING 2024

Universal Adjustable Antenna Mounting System

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Student Team

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FAST. FORWARD.

Company Mentors

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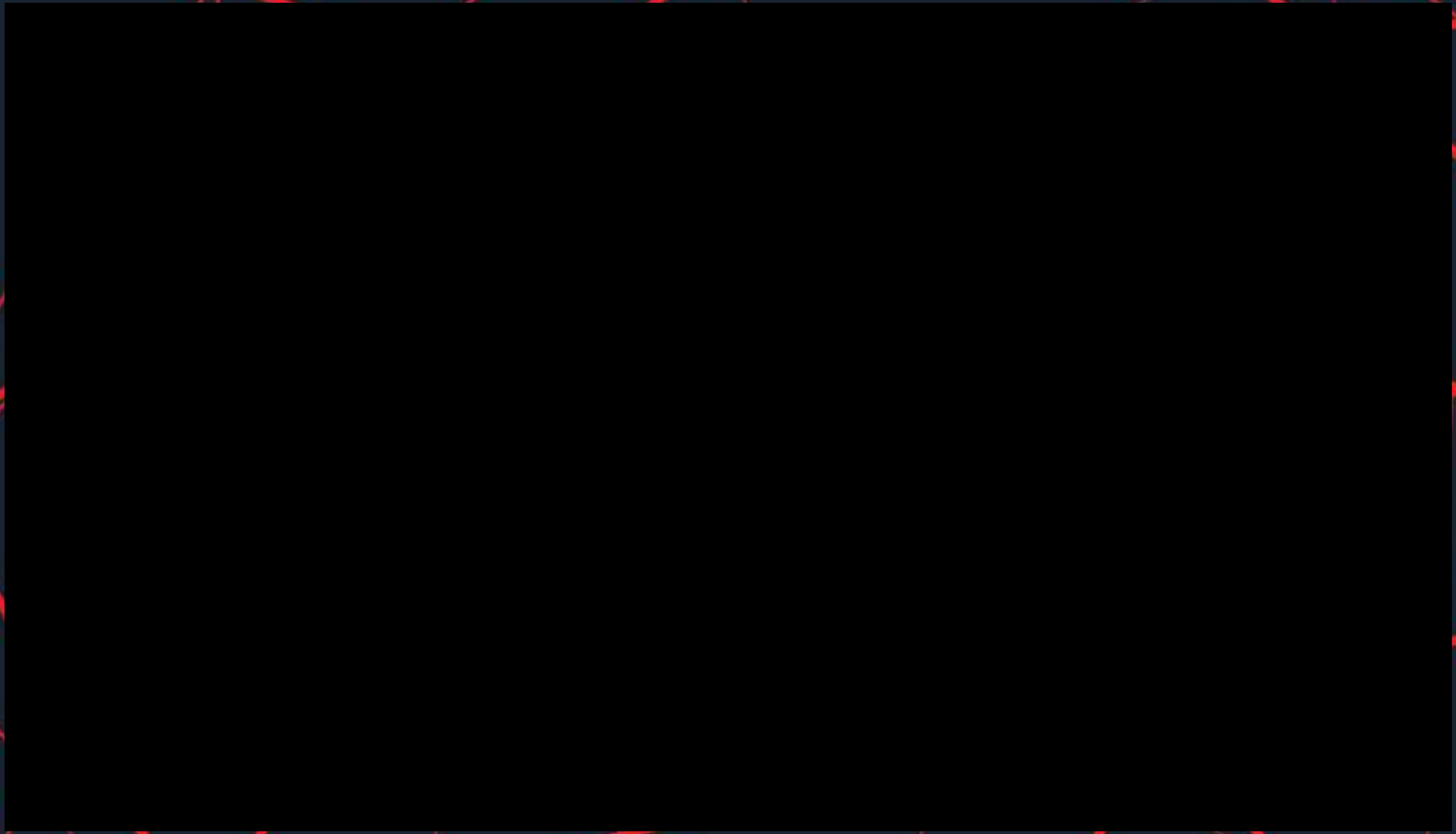


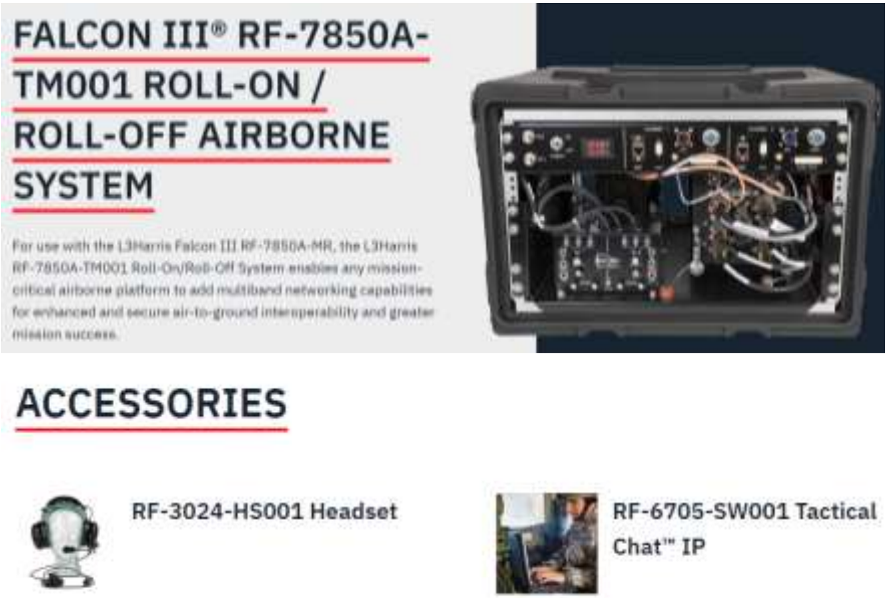
Problem

Antennas need to be installed *temporarily*, *quickly*, and *securely* onto helicopters for product demonstrations

- Flights last a few hours
- Antennas must be able to
  - Be recovered easily
  - Leave no modification to the helicopter

Current Solution:

- Zip tie antennas to the exterior of the helicopter



Project Specifications

Task: Create a universal antenna mounting system to temporarily attach to a helicopter

Reliable

- Withstands windspeeds up to 150 mph
- Secures antennas up to 10lbs
- Performs under flight weather conditions

Universal

- Mounts variety of antennas
- Attaches to various helicopters
- Functions as counterpoise for monopole antennas

User-friendly

- Installation and removal with little to no training
- Minimal parts

Sustainable

- No damage or permanent modification to helicopter/antenna
- Reusable for other helicopters

Common Helicopter for this Application

UH-1 Huey

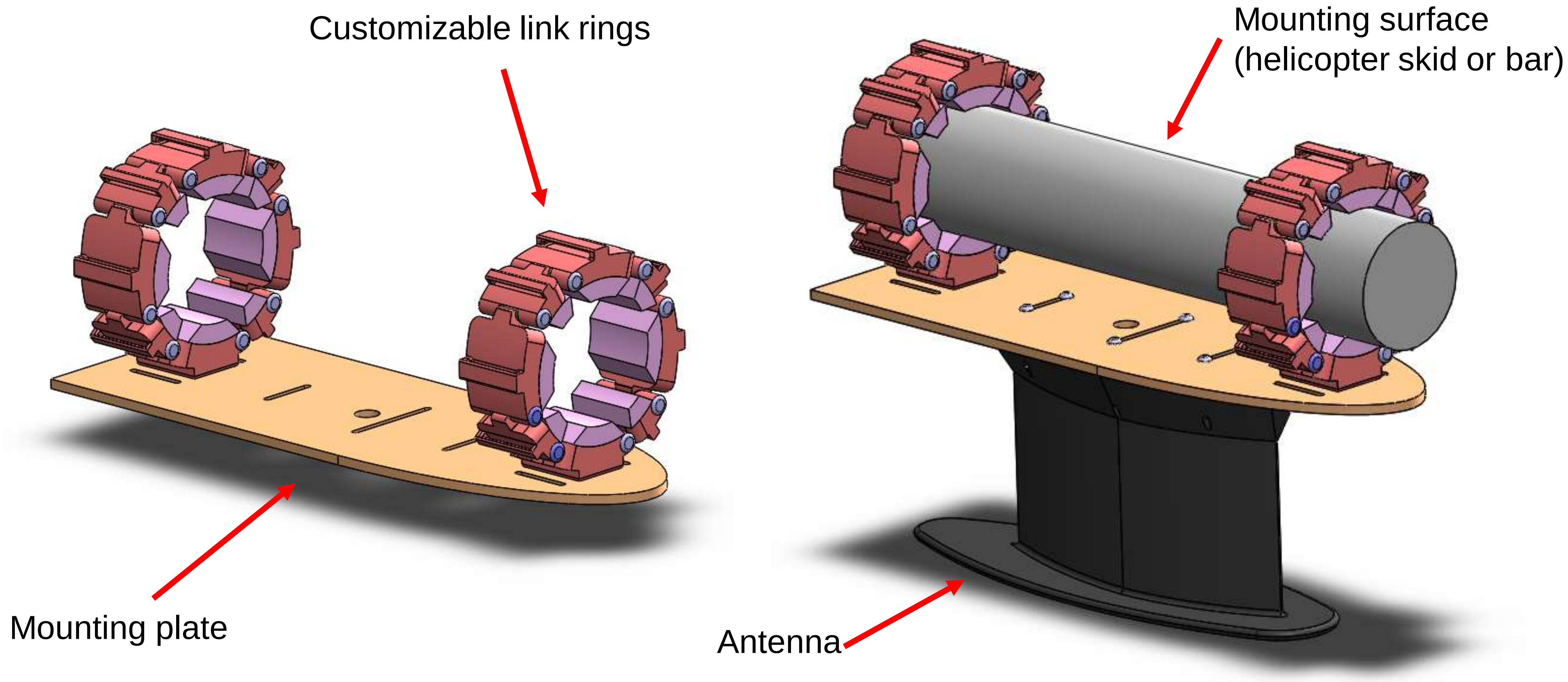
Red indicates possible attachment points for the antenna mounting system

Pugh Matrix: The Need for New Design

Selection Criteria	Current Solutions			Design Concepts for New Solutions		
	Zip-tie	Velcro strap	Custom mount	Suction cup	Modular links	Ratchet strap
Withstand up to 150 mph windspeed	1	1	2	0	2	2
Secure antennas up to 10 lbs.	2	1	2	0	1	2
User-friendly for installation and removal	2	2	0	2	0	1
Adaptable to various antennas	1	1	0	2	2	1
Adaptable to various helicopters	1	2	0	2	2	2
Secure counterpoise for monopoles	0	0	2	1	2	1
No permanent modification to helicopter or antenna	2	2	0	2	2	2
Sustainable	0	0	1	2	2	1
Limit possibility of airborne projectiles	2	2	2	1	2	2
Reliable for use case period	0	0	2	0	1	0
Economically efficient	2	2	0	2	1	2
Score for Design Selection	13	13	11	15	17	16

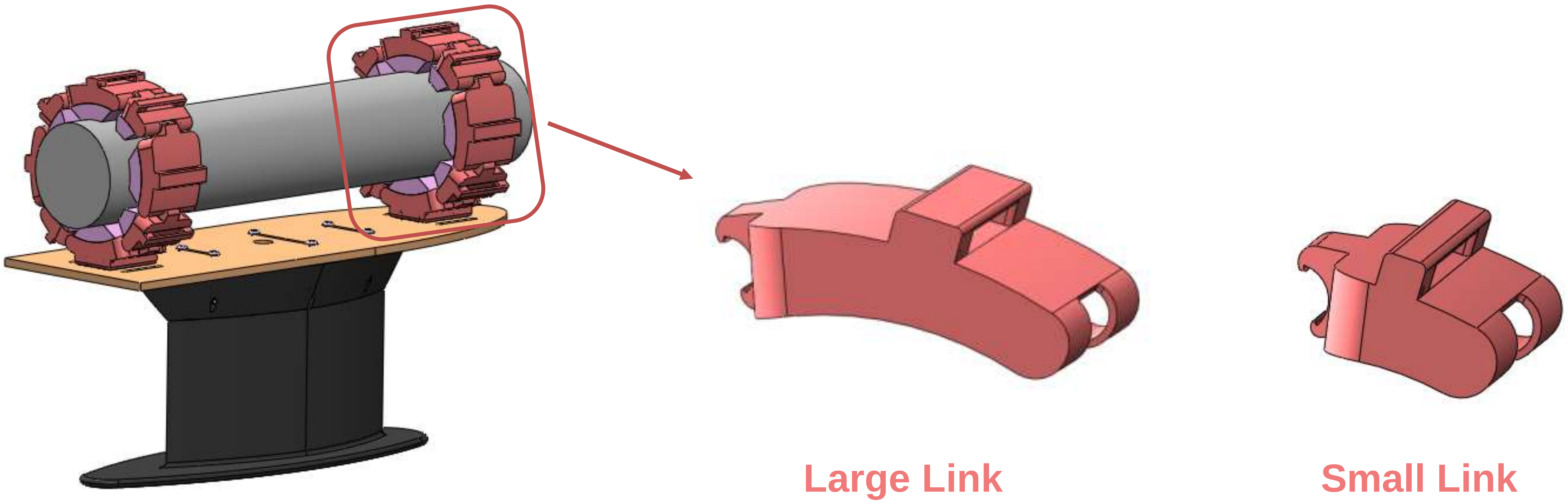
Key: **0 – Not Satisfactory**
1 – Somewhat Satisfactory
2 – Satisfactory

UAAMS Assembly



Link Ring Concept

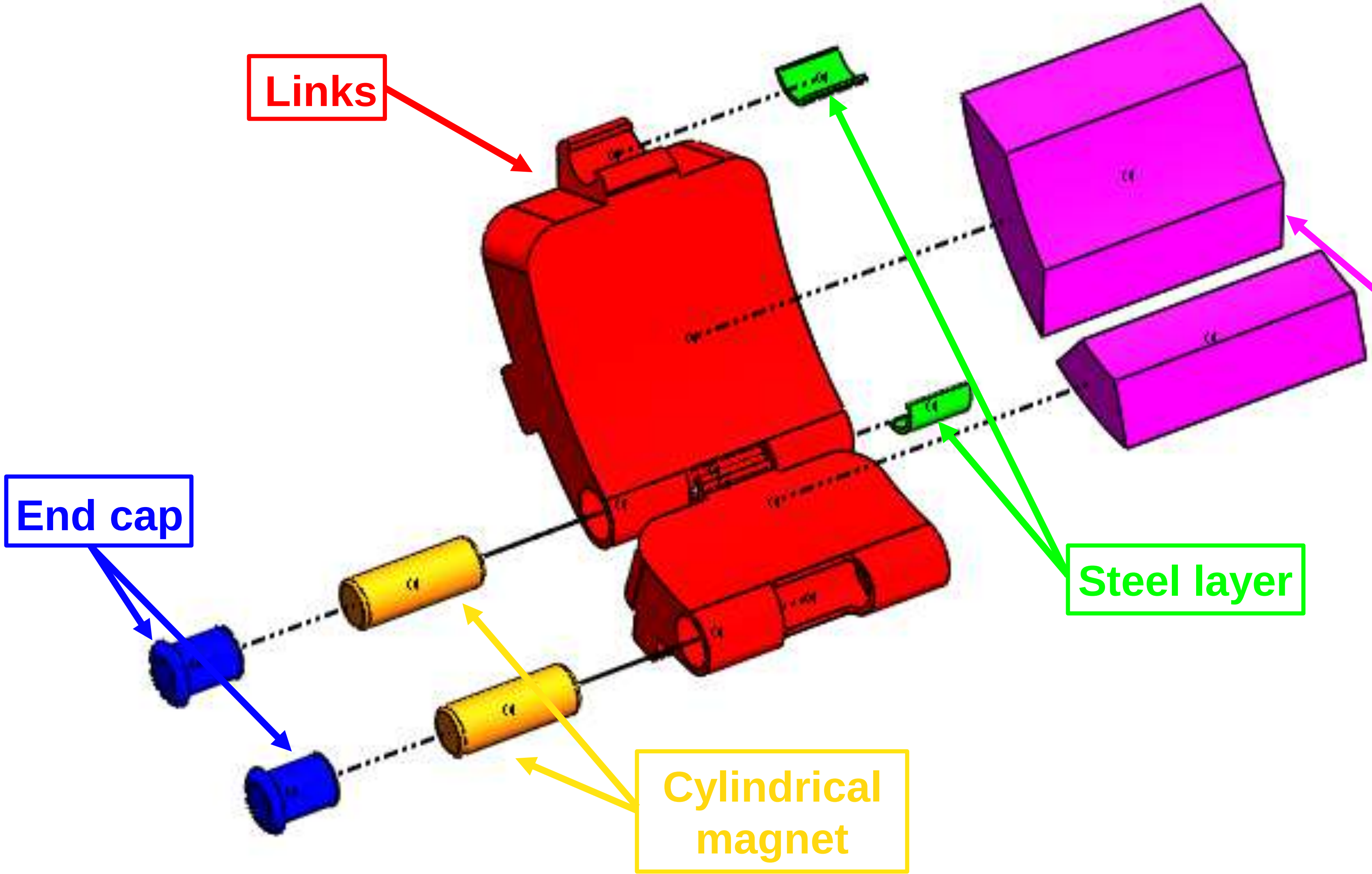
- Providing “large links” and “small links” to our client
- Magnetic attraction between adjacent links for **ease of assembly**
- Strap fed through each link **provides compressive force**
- Safety wire fed through each link as a **safety precaution**

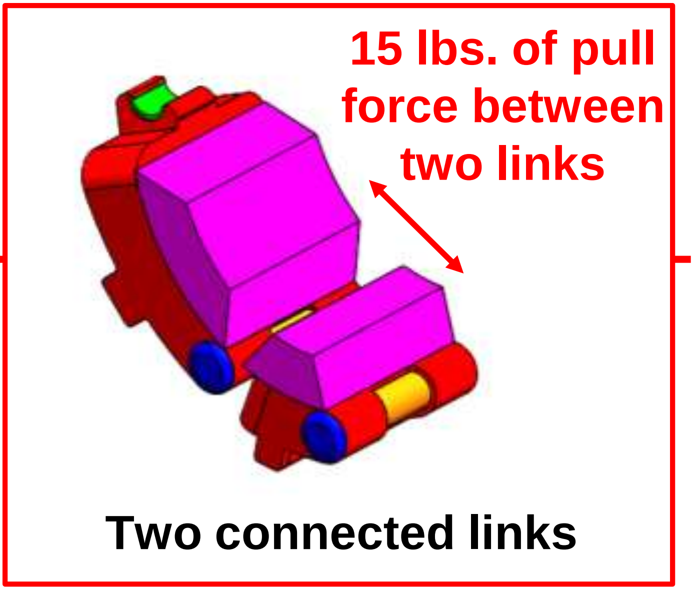


Large Link

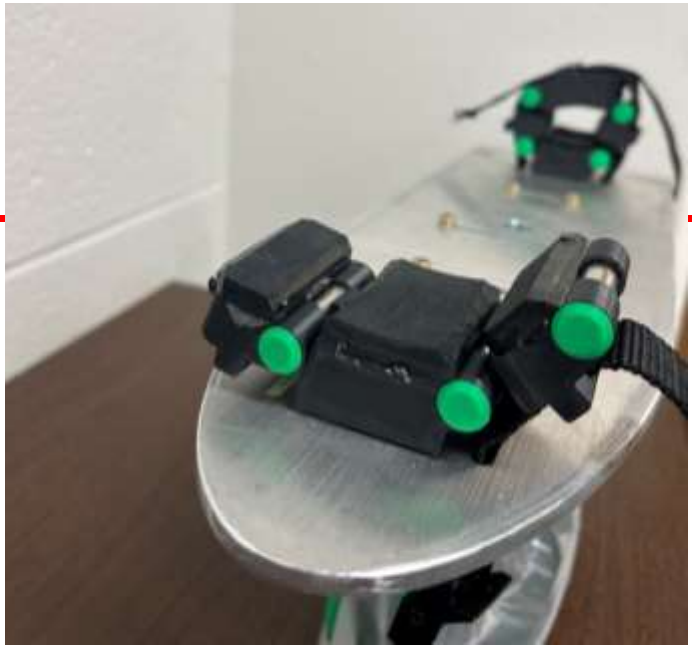
Small Link

Key Design Points



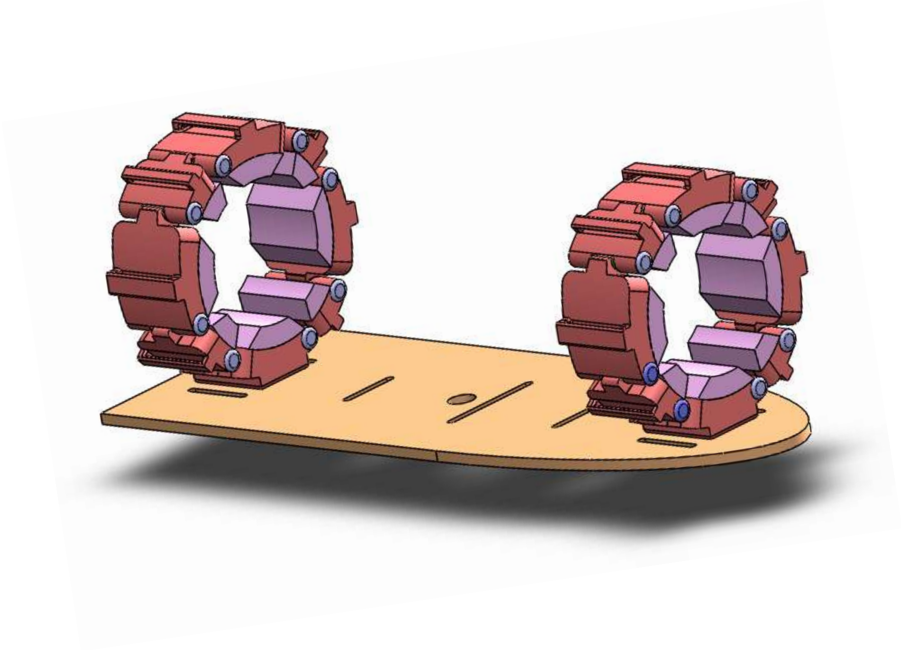


Magnets



Cost

- 10 initial UAAMS’s to be manufactured
- 16 links per UAAMS
- Cost per UAAMS: **$401.21**
- Majority of the cost is due to manufacturing
- Chosen materials are relatively cheap

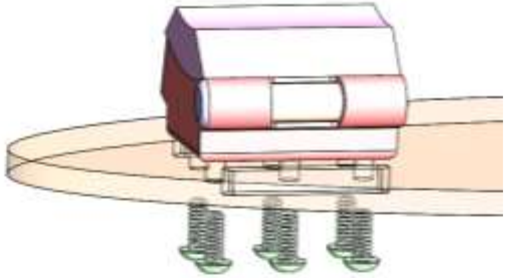


https://m.media-amazon.com/images/I/71Hb9mv7Y4L._AC_UL960_QL65_.jpg

6 Step Installation Process

1 Check parts for serviceability: structural integrity and EPDM grip wear.

2

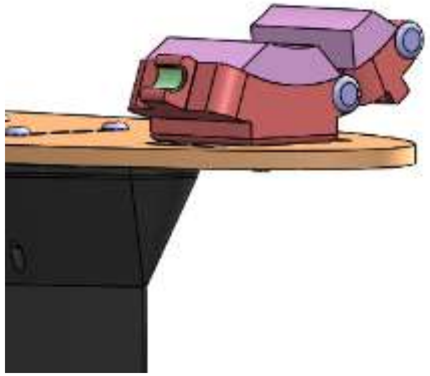


Affix mount links to mount plate

3

Affix antenna to mount plate

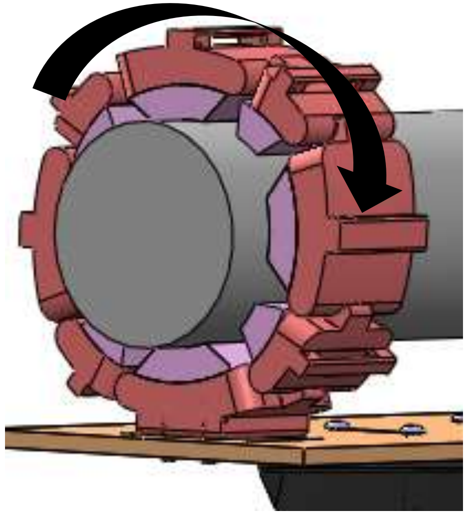
4



Magnetically assemble links to fit around helicopter attachment point

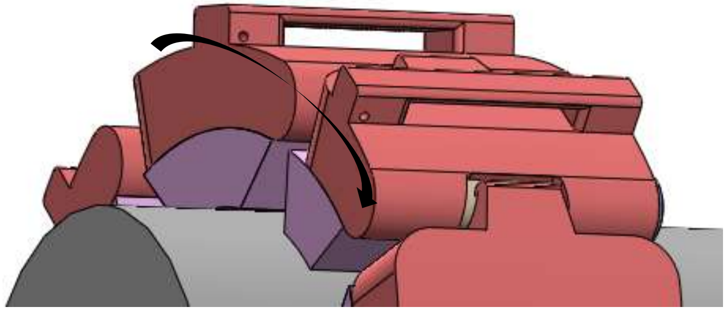
6 Step Installation Process (cont.)

5



Feed strap through loops
of links and plate and tighten

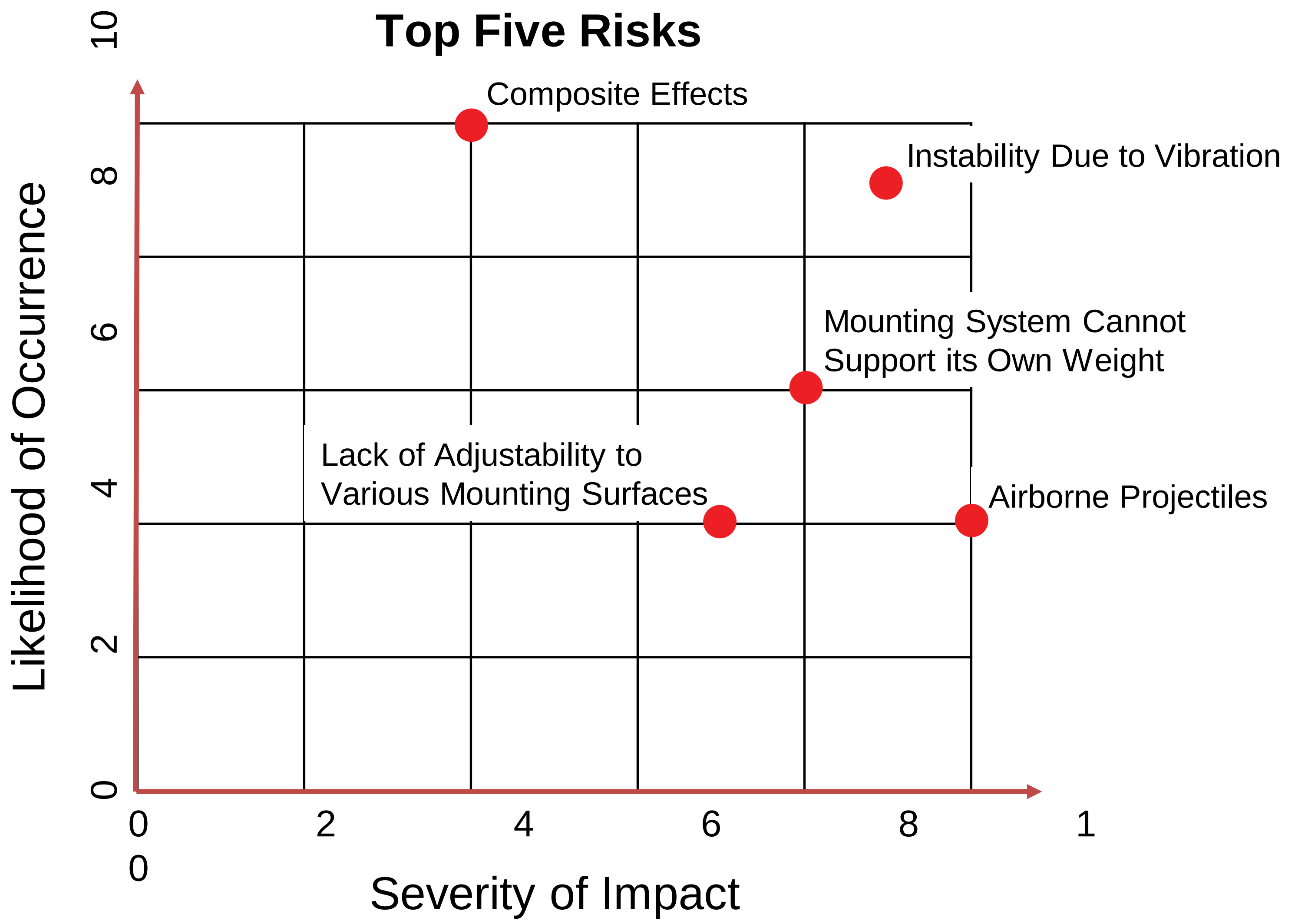
6



Feed safety wire through
side channels and secure to
safety attachment point
on helicopter

Ready for takeoff!

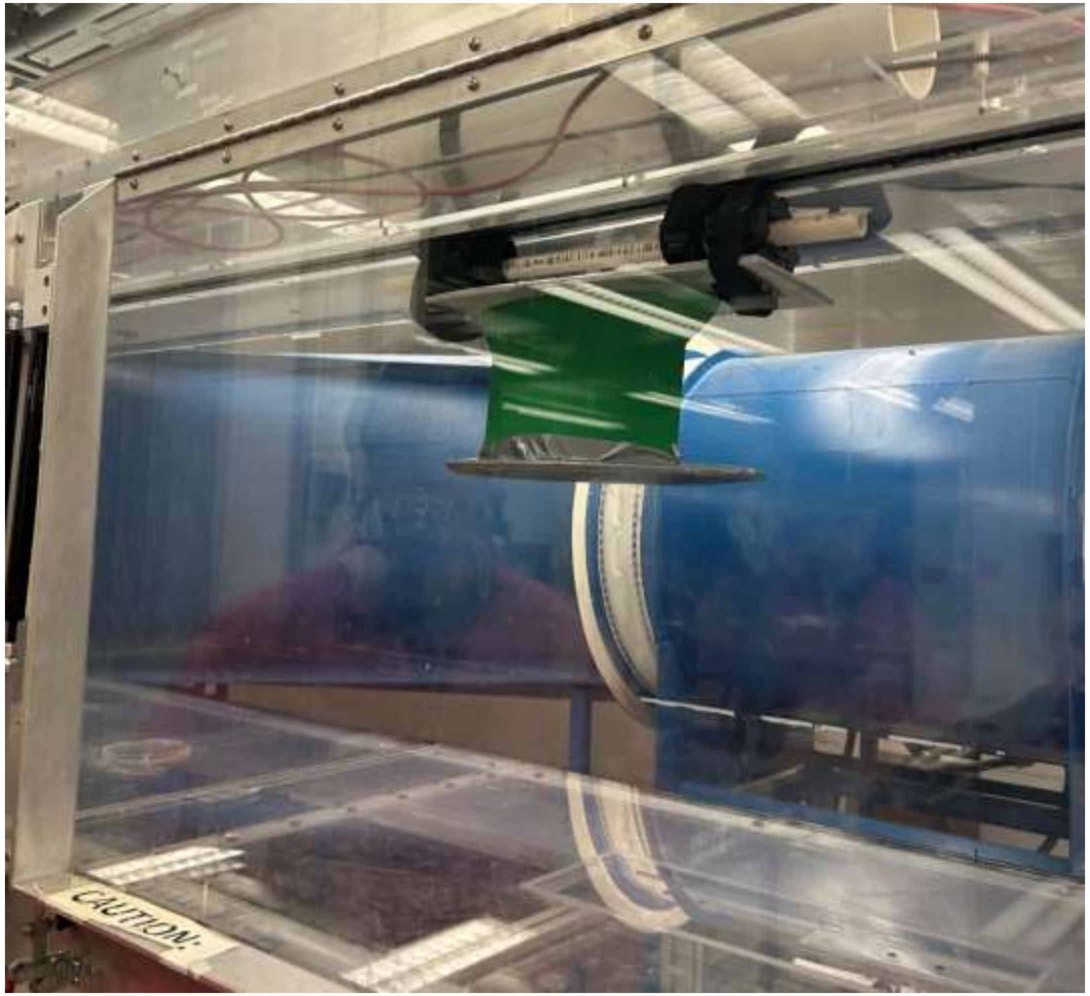
Risk Management



Wind Tunnel Test

- Mounted in low-speed closed-return wind tunnel
- Test points at 30, 40, 50, and 60 Hz (67 to 134 mph)
- Duration of 30 seconds each
- Based on MIL-STD-810H

Results: No measurable movement of the UAAMS relative to the mounting surface

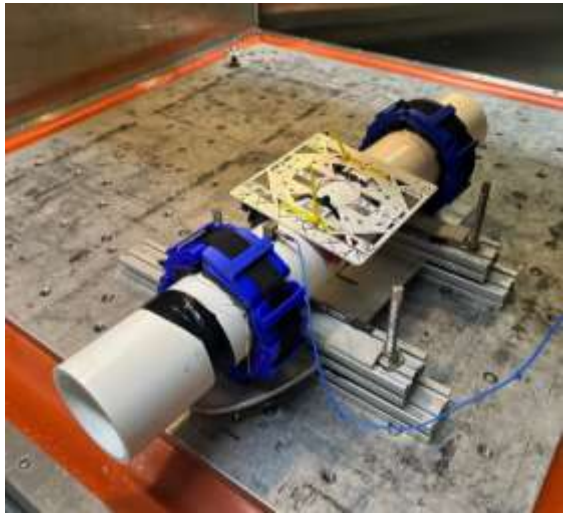


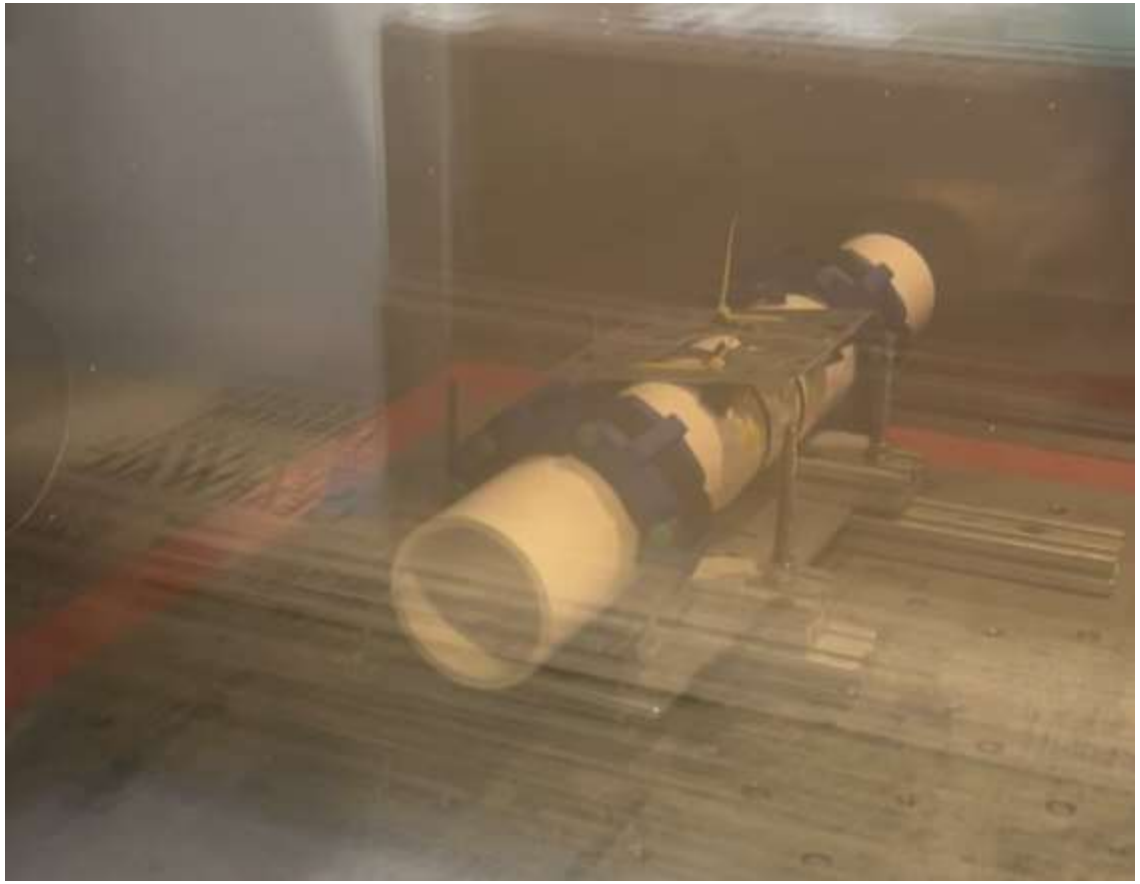
UAAMS mounted inside wind tunnel

Vibration Table Test

- Tri-axial vibration table
- Test set points at 5g’s and 7g’s
- Duration of 5 minutes each
- Based on MIL-STD-202

Results: The UAAMS can withstand random vibrations that occur in flight





UAAMS inside vibration testing system

Drone Flight Test

- The antenna was attached to a drone
- Flew up to 400 feet
- Speeds up to 35 miles per hour
- Withstood a 45-degree turn
- Provided a G force between 2.5 and 3
- Based on MIL-STD-810H

Results: No detectable motion of the antenna relative to the drone

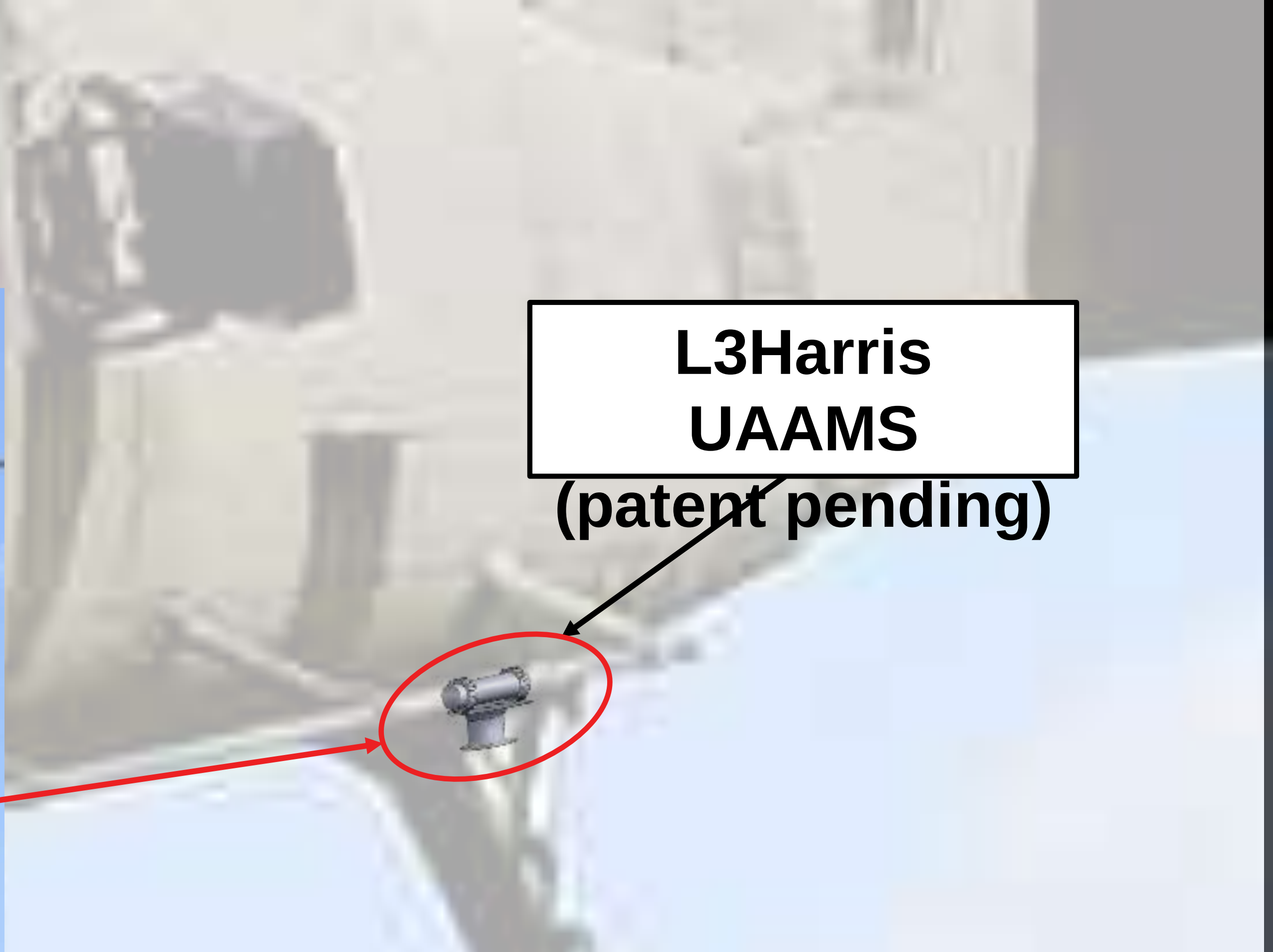
UAAMS mounted on drone

Drone changing altitude and making turns

Future Work

Conclusion

UH-60 Black Hawk



Thank you to our company mentors:
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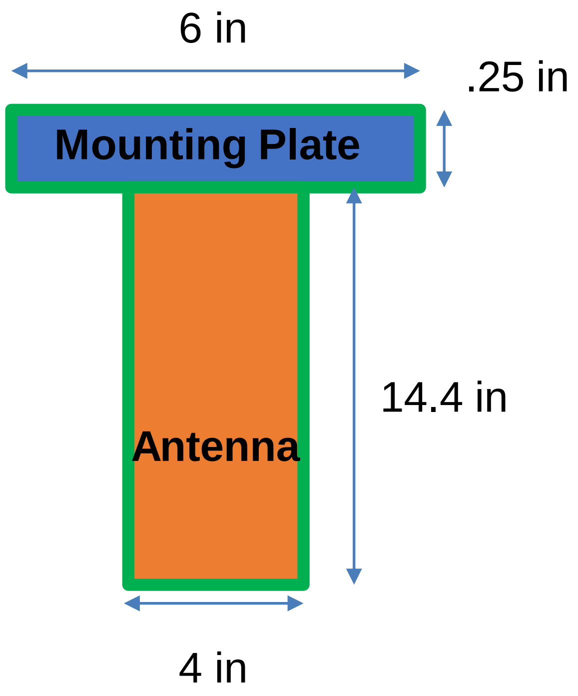
Professor Alex Deyhim, Dr. Michelle Blum, Dr. Ed Bogucz, and Dr. Mehmet Sarimurat

Design Inspirations

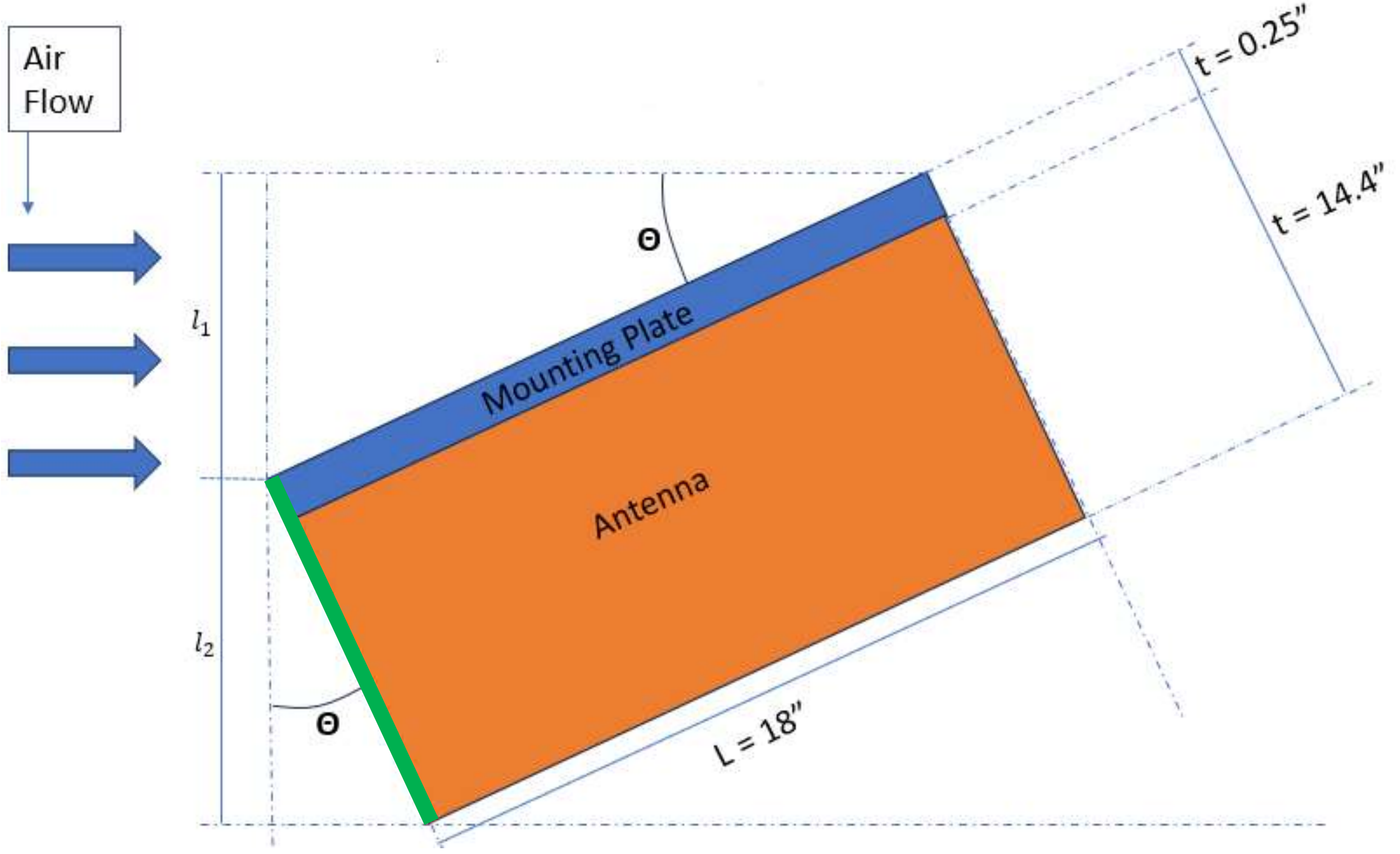
Simplified FBD for Mounting System

Front View
*Not to scale



$$A_{w,\theta=0} = (4\ in\ x\ 14.4\ in) + (6\ in\ x\ 0.25\ in) = \mathbf{59.1\ in^2}$$

Side View At Variable Tilt Angle ϴ



Drag Force Calculations

$$F_d = \frac{1}{2} C_d \rho A_w V^2$$

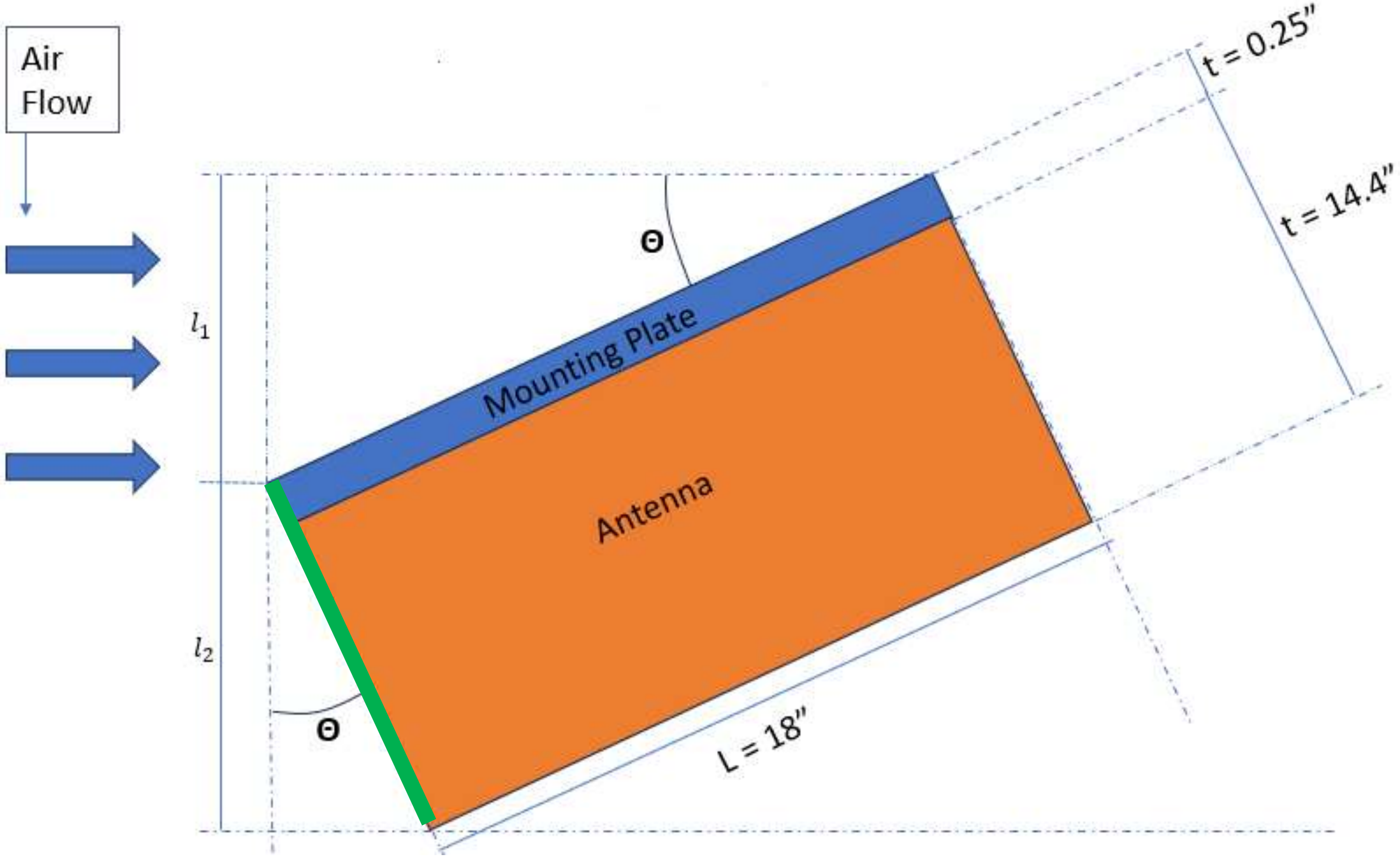
$$C_d = 1.1806$$

$$V = 67.1 \left[\frac{m}{s}\right]$$

$$\rho = 1.225 \left[\frac{kg}{m^3}\right]$$

$$A_{w,\theta=0} = 59.1\ in^2$$

Side View At Variable Tilt Angle **Θ**



Drag Calculation: Additional Details

Assumptions:

1. No holes in the plate
2. Velocity is a constant top speed of 150 mph
3. Air density is constant
4. Wind is negligible
5. Plate area is a full rectangle

Wetted Area Derivation:

$$l_1 = L\sin\theta$$
$$l_2 = t\cos\theta$$
$$L' = l_1 + l_2$$
$$L' = L\sin\theta + t\cos\theta$$
$$A_w = W * L'$$
$$A_w = W(L\sin\theta + t\cos\theta)$$

Drag Calculation: Additional Details

<u>Drag Coefficient Calculation</u>

$$\frac{L}{W} = 1 \quad C_d = 1.16$$

$$\frac{L}{W} = 5 \quad C_d = 1.20$$

$$\frac{L}{W} = \frac{18"}{5.88"} = 3.06 \qquad C_d = 1.1806$$

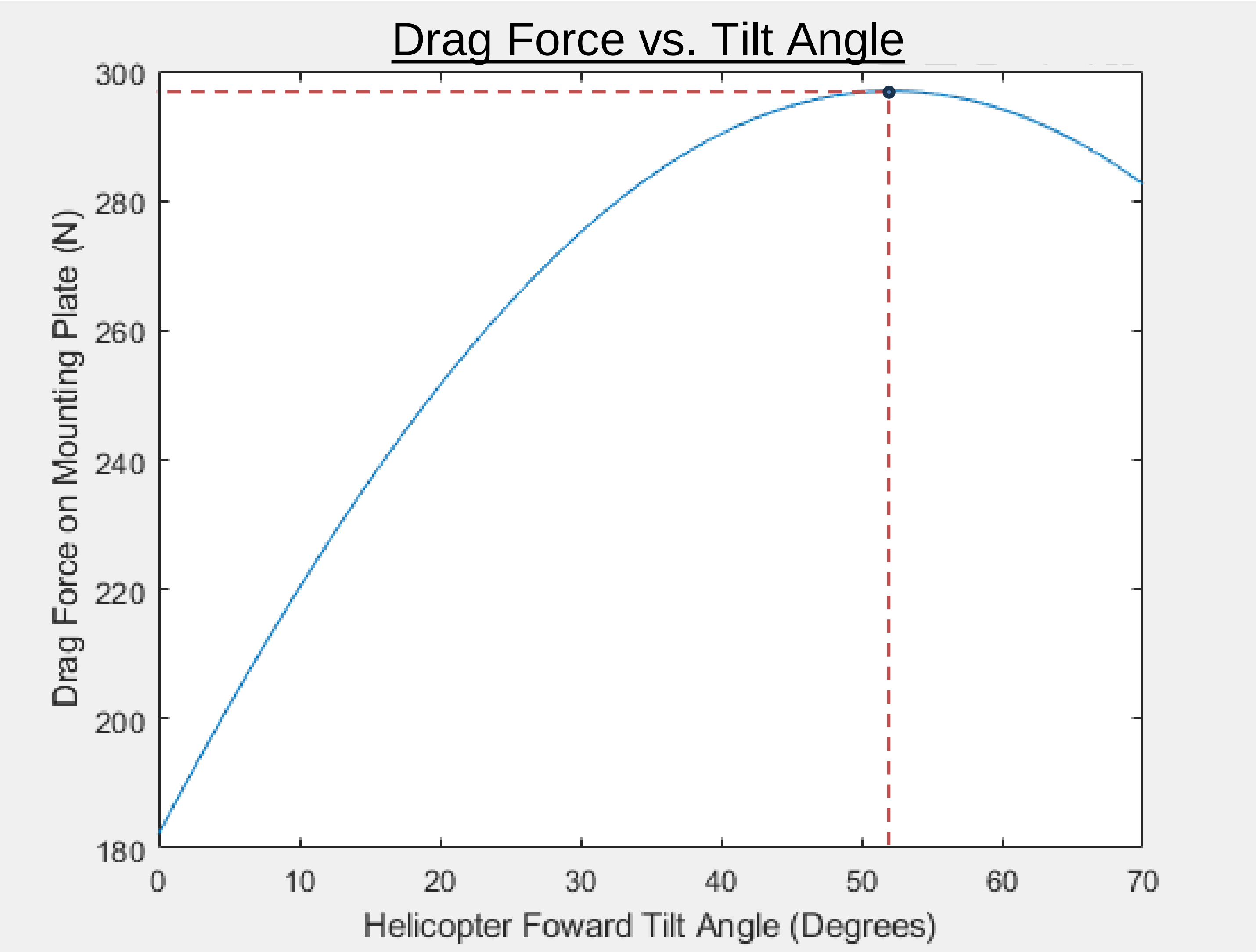
$$A_w = 0.15(0.48sin\theta + 0.37cos\theta)$$
$$= 0.072sin\theta + 0.0566cos\theta \; [m^2]$$

$$V = 150 \; [mph] = 67.1 \left[\frac{m}{s}\right]$$

$$\rho = 1.225 \left[\frac{kg}{m^3}\right]$$

$$F_d = \frac{1}{2}(1.1806)(1.225)(0.072sin\theta + 0.056cos\theta)(67.1)^2$$
$$F_d = 234.4sin\theta + 182.3cos\theta \; [N]$$

Theoretical Calculations



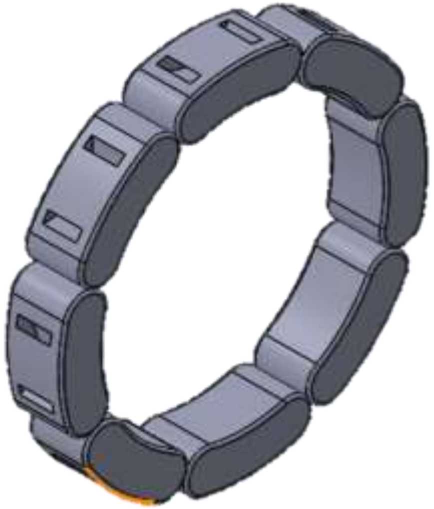
$$F_d = 234.4 sin\theta + 182.3 cos\theta \ [N]$$

Max Drag Force = 296.95 [N]
Angle at Max Drag = 52.1˚

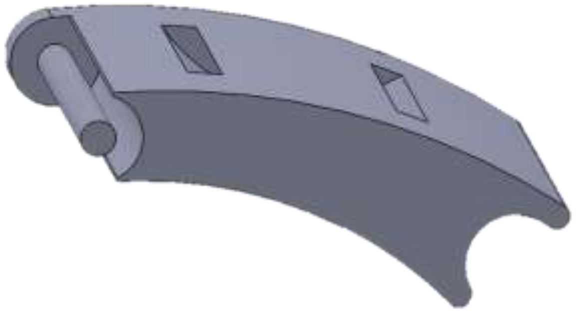
Risk Analysis and Mitigation

Failure Mode	Severity	Control Methods				RPN	Rank
		Prevention Control	Occurrence	Detection Control	Detection		
Instability due to vibration	9	**Multi-axial vibration testing**	9	Monitor the mounting system throughout the flight mission	4	324	1
Airborne projectiles	10	Designing with minimal parts that can be removed; Safety wire to catch parts; Simulation testing and experimental testing in **wind tunnel**	4	Field test with L3Harris; Appearance and torque check before takeoff	6	240	2
Lack of Adjustability to Various Mounting Surfaces	7	EPDM rubber allows links to conform to more shapes; Designing two sizes of links, limiting gap size in ring; **Testing prototype for rotational degree of freedom**	4	Before helicopter takes off, ensure the links are conforming tightly to the mounting surface	4	112	3
Mounting System Cannot Support its Own Weight	8	Specialized polymer with 3D printing to allow for complex, lighter, and stronger geometries	6	**Field test** with UAV	2	96	4
Composite Effects	6	**Field test** with UAV	10	Appearance check for fatigue failure effects before installation on helicopter	1	60	5

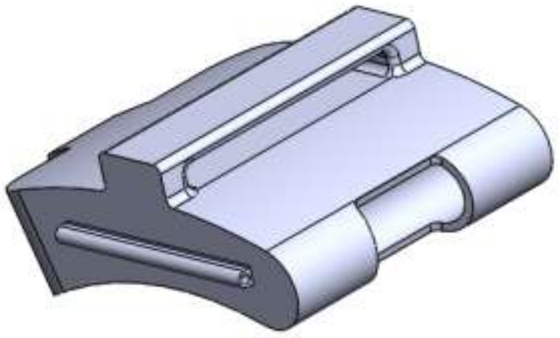
Design Progression



- Symmetric removable links
- Held together by strap

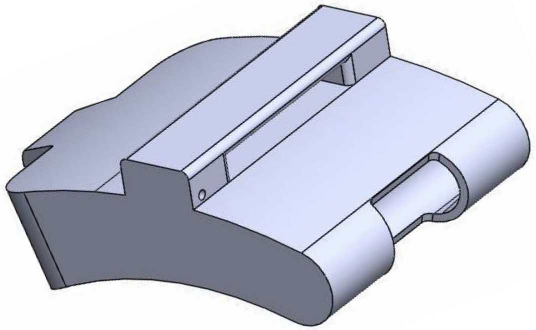


- Mating surfaces
- Addition of magnetic connection between links



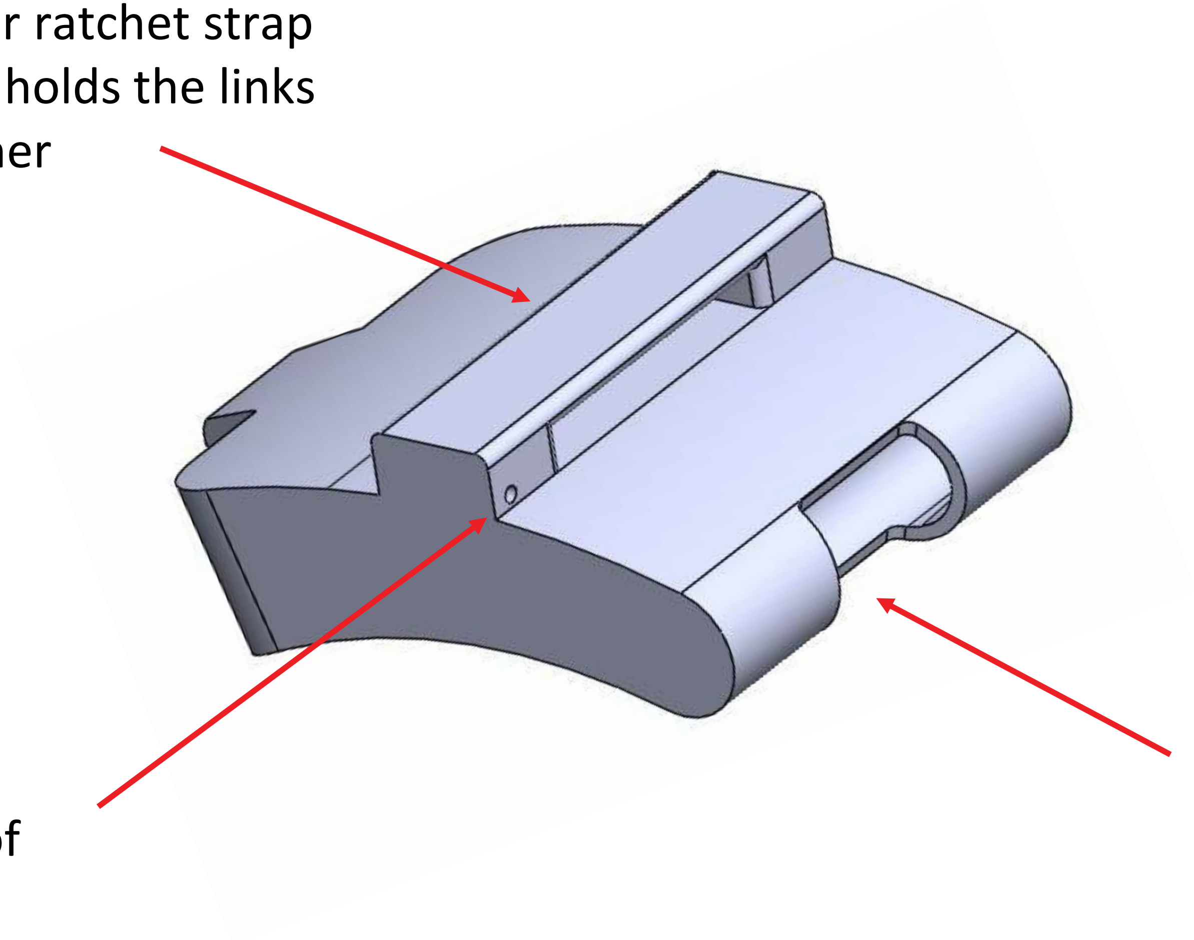
- Extrusion for strap to be fed through
- Channel for safety wire

- Safety wire channel is changed to a hole on the strap extrusion



Additional Link Features

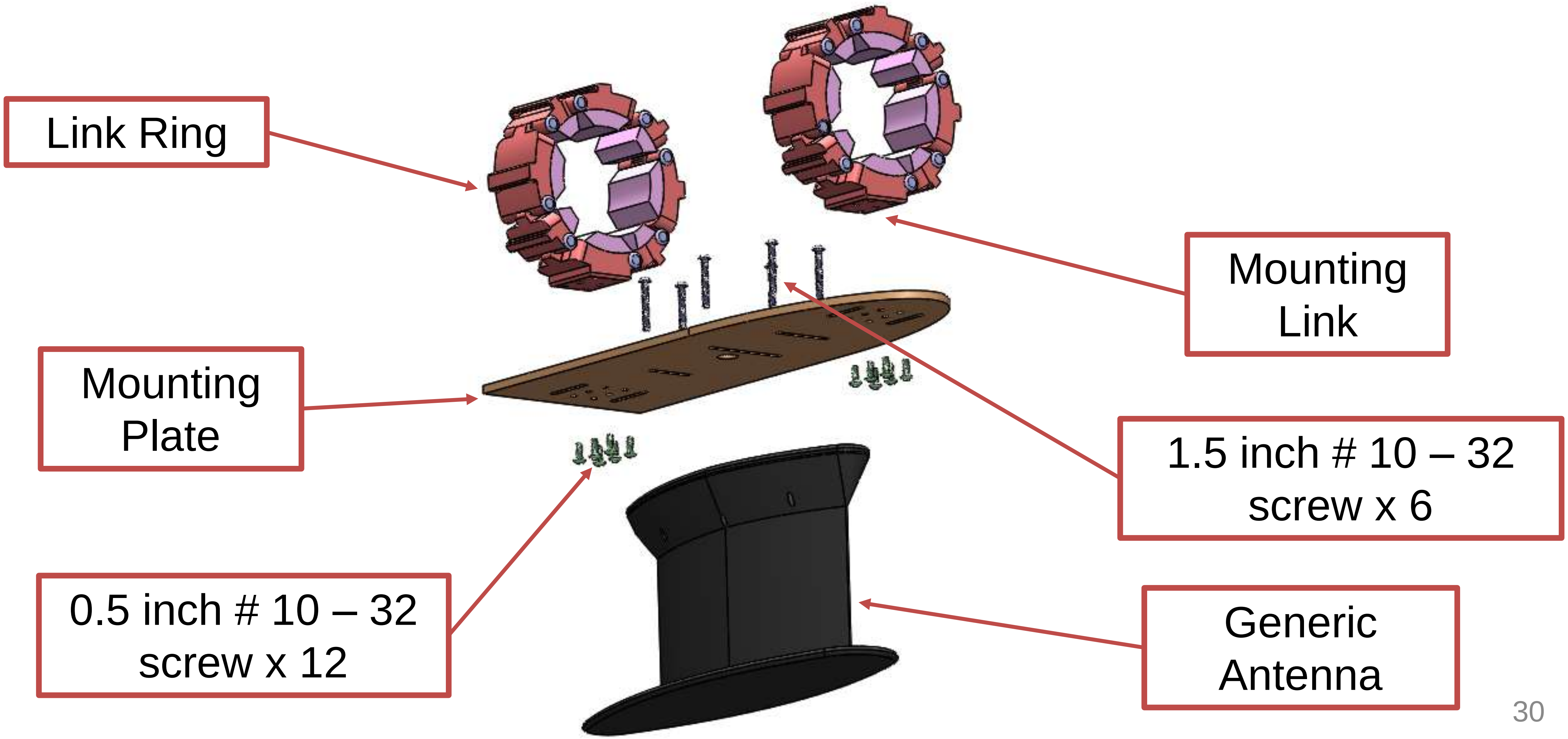
Slot for ratchet strap which holds the links together



Separate channel for safety wire to feed through each piece of the assembly

Window exposing magnet to provide a stronger connection

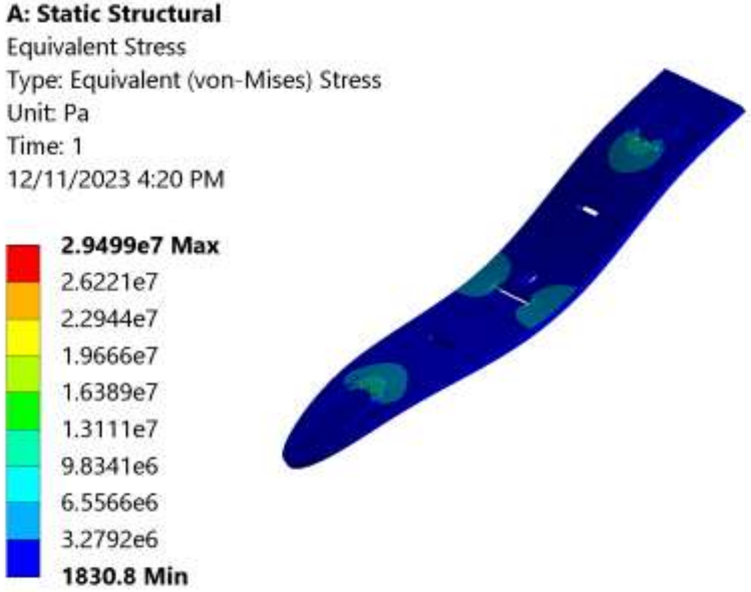
Plate to Link Connection



Timeline and Milestones

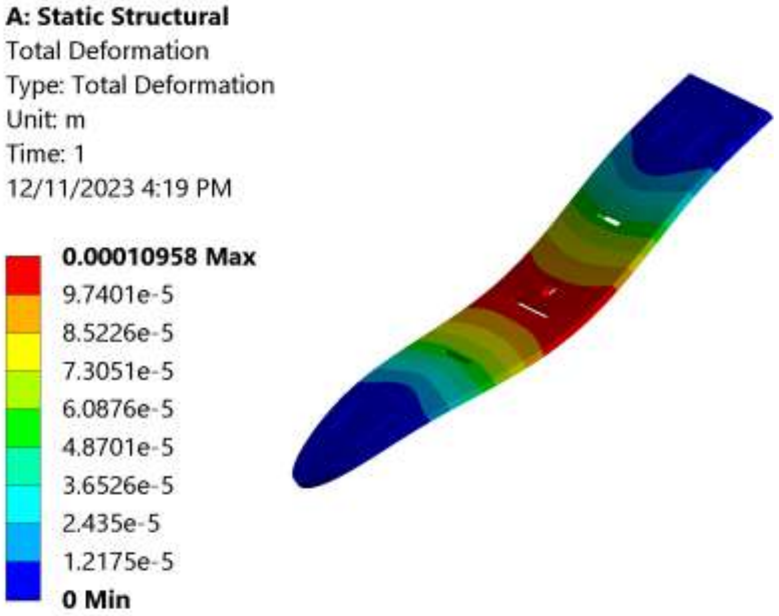
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Design Concepts									
Materials Research									
CAD Design									
ANSYS Failure Analysis									
Risk Assessment									
Prototype									
Order Materials									
Experimental Testing									
Safety Review									
Field Testing									
Finalize Design									
Instruction Sheet for Kit									

Static–Structural Simulations



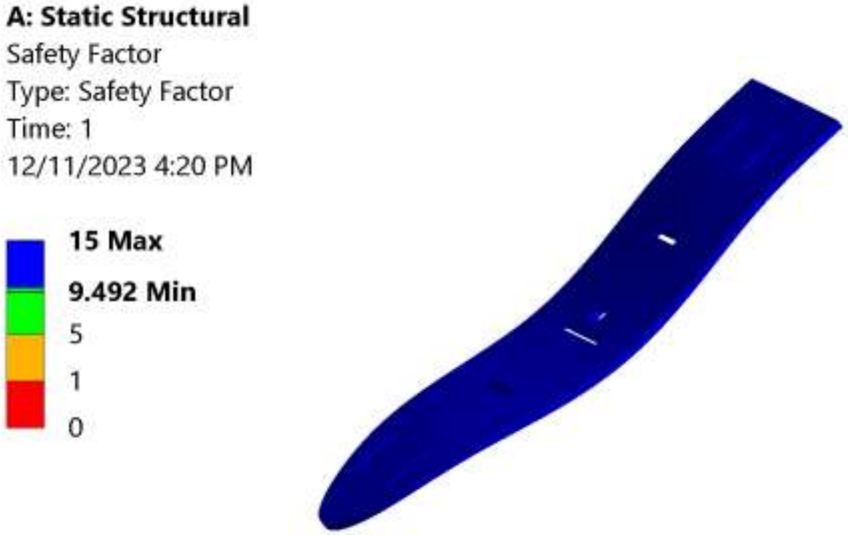
Von-Mises Stress

- Maximum = 29.5 MPa
- Stress concentration at screw holes



Total Deformation

- Maximum = 0.11 mm
- Occurs in the center of the plate



Safety Factor

- Minimum = 9.5

MIL-STD-202 Vibration Testing

Specifies frequency sweep testing (Amplitude 0.03 inches)

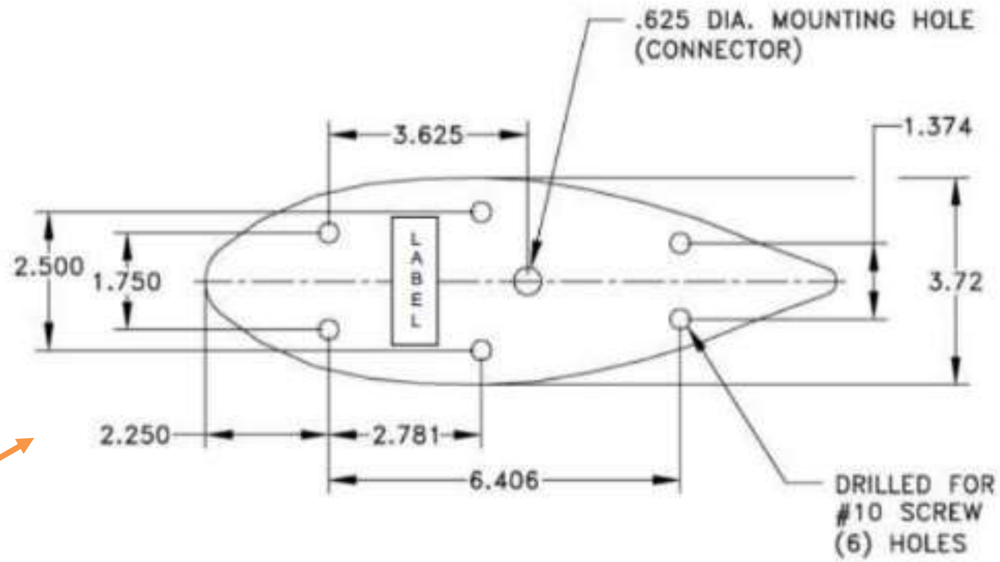
- Testing of each axis of motion for two hours
- Predominant frequencies encountered during field service:10 Hz – 55 Hz

- Previous ANSYS modal analysis will inform critical frequencies
- Results presented in table by frequency, orientation of motion, and failures observed. Maybe further expanded quantitatively by categorizing by failure size (diameter or deflection)
- Likeliest to fail between link rings and mounting plate
- Observations to be recorded during and after each test

Antenna Attachment to Mounting Plate

Antenna will be screwed onto the plate using six #10-32 screws

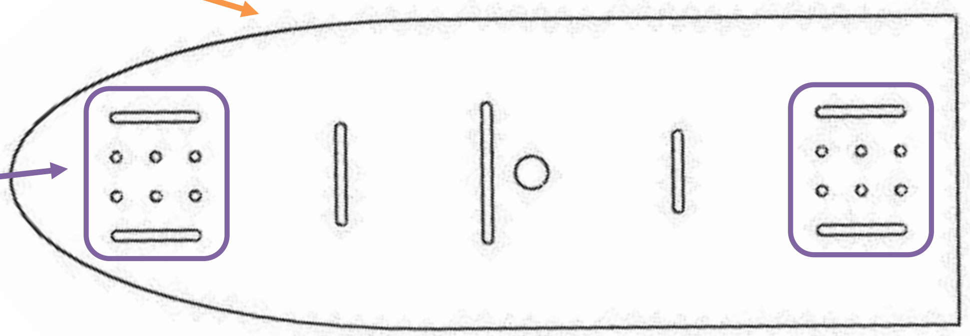
Universal mounting pattern



Source: Specifications provided by L3Harris

Our mounting plate

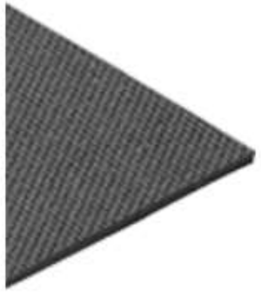
Link attachment points



Materials

ASA filament

Rigid and scratch resistant, exceptional resistance to weathering, including long-term moisture and UV exposure



High-Strength Weather-Resistant EPDM Rubber with Criss-Cross Texture

Adds friction, damping, and conformity to links

1 mm Steel Sheet

Magnetically attracted to male end of the links

1/4'' Aluminum Sheet

Lightweight mounting plate, counterpoise for monopole antenna

Materials (cont.)

Neodymium Cylinder

Lightweight and connects links together with 15lbs pull force

Thumb Ratchet

Holds mount assembly together and to the helicopter, with low profile

Epoxy Glue

Attaches EPDM layer to links

Safety Wire

Resists loosening from vibration

References

Drag coefficient

Drag coefficients for different shapes and dimensions (based on Prasuhn... | Download Scientific Diagram (researchgate.net)

Air Density

Air Density Table and Specific Weight Table, Equations and Calculator (engineersedge.com)

Shock Testing

mil-std-810h-shock.pdf (trentonsystems.com)

Wind Tunnel Testing

https://simpleflying.com/pitot-tubes/

Air Flow Calculations

Navier-Stokes Equation | Glenn Research Center | NASA

Vibration Testing

MIL-STD-202 Vibration Testing | Keystone Compliance