Magnus Ultralight Critical Design Review

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Reviewing Feedback and Design Changes

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  - Improve strength of the rotor spar attachment mechanism
  - Reduce mass
- Sphere construction →
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  - Reduce weight from original design estimate
  - Validate motor capabilities
- Landing skids →
  - Increase “wheelbase”
  - Look into 3D printing bracket out of rubbery material
- Offset fastening holes
- Add countersinks where possible

Note on Mass Estimation

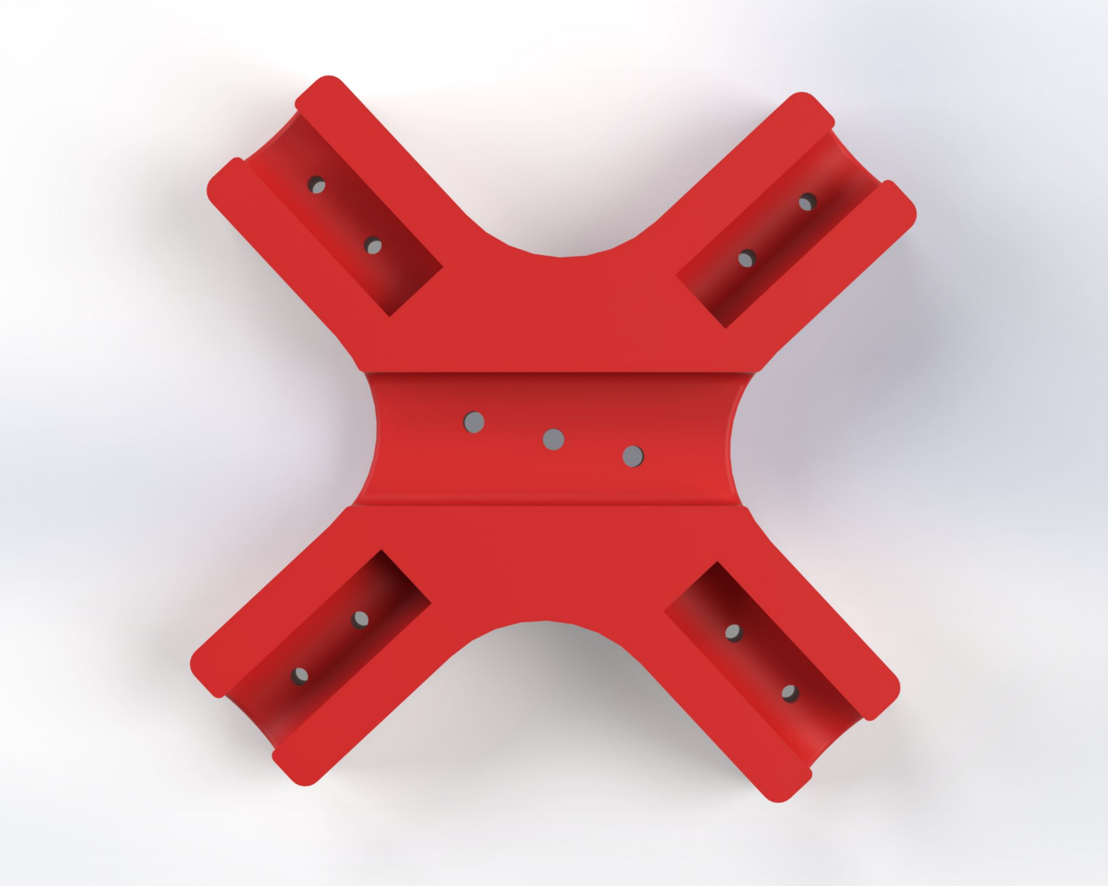
All mass estimation done by SOLIDWORKS

The accurate mass/mass density of all off the shelf components was used in the SOLIDWORKS analysis

Determined either by physical measurement or interpolation from online specifications

All custom components used the documented mass density of the expected fabrication material

Updates to Central Bracket



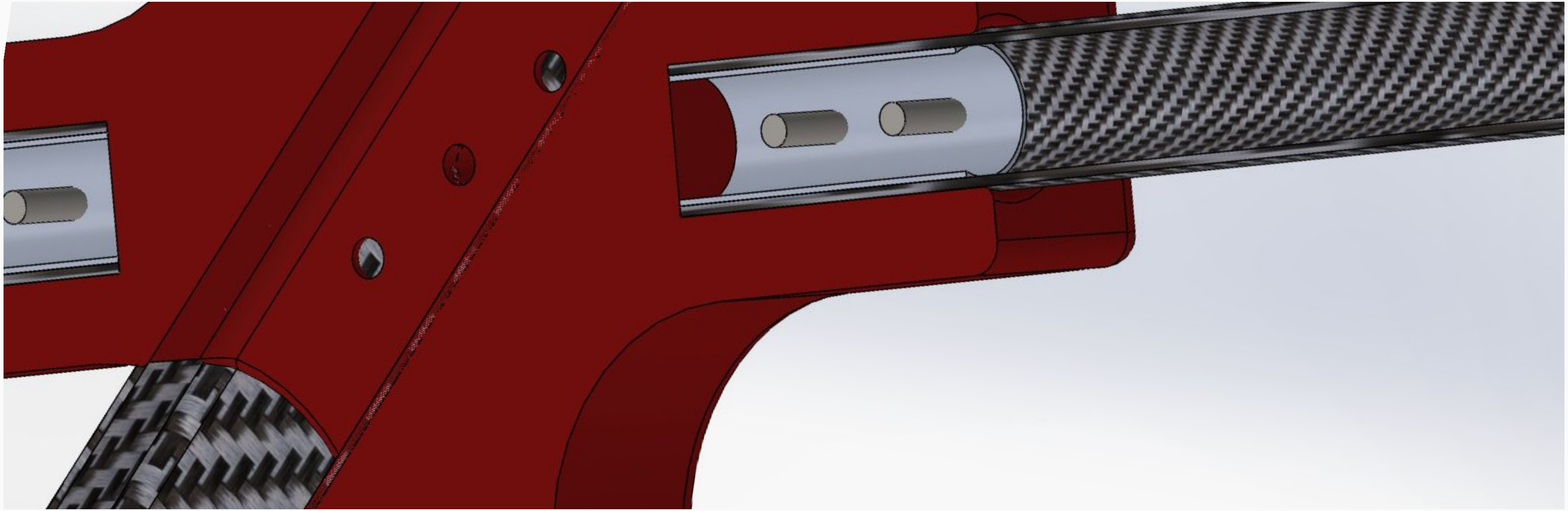
Mass reduced to 0.8 kg

Changed to cross shape

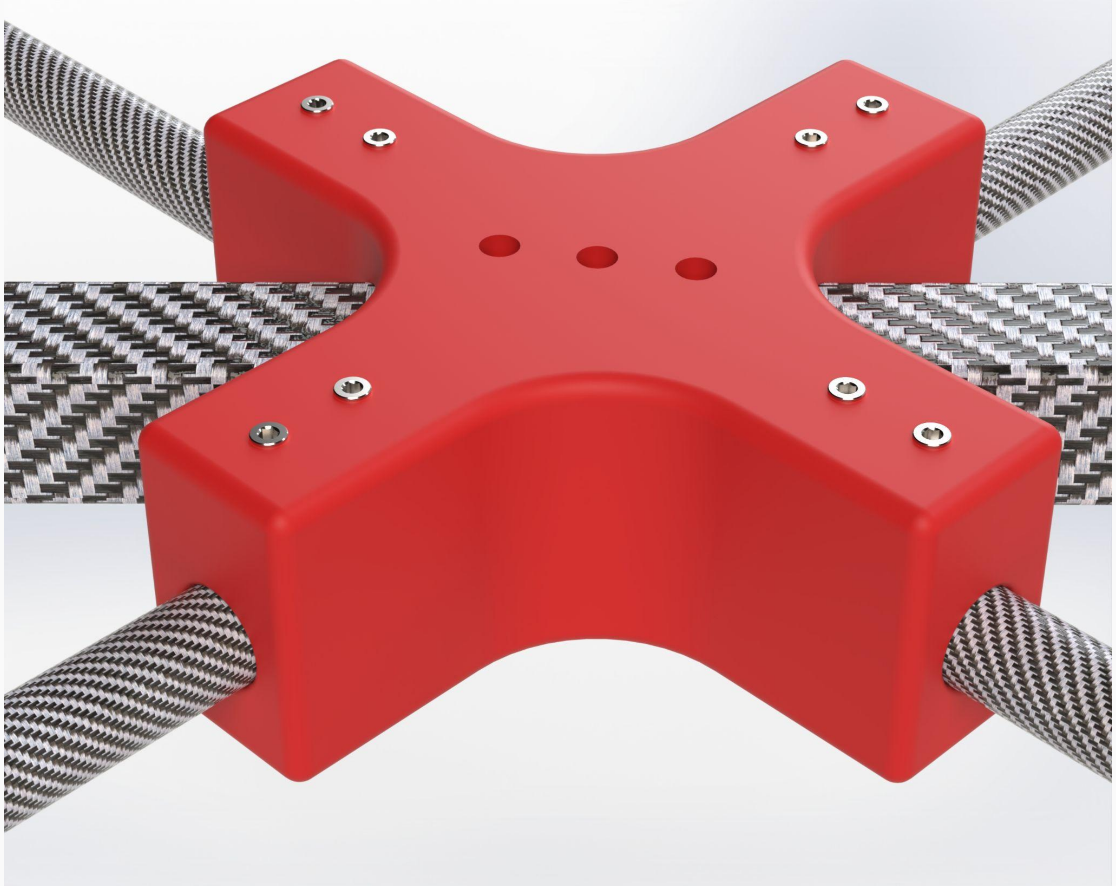
Did not go with a continuous spar design due to added mass and complicated geometry

Added aluminum insert tubes to reinforce the carbon fiber and the joint

Central Bracket Continued



Central Bracket Continued



Sphere Construction

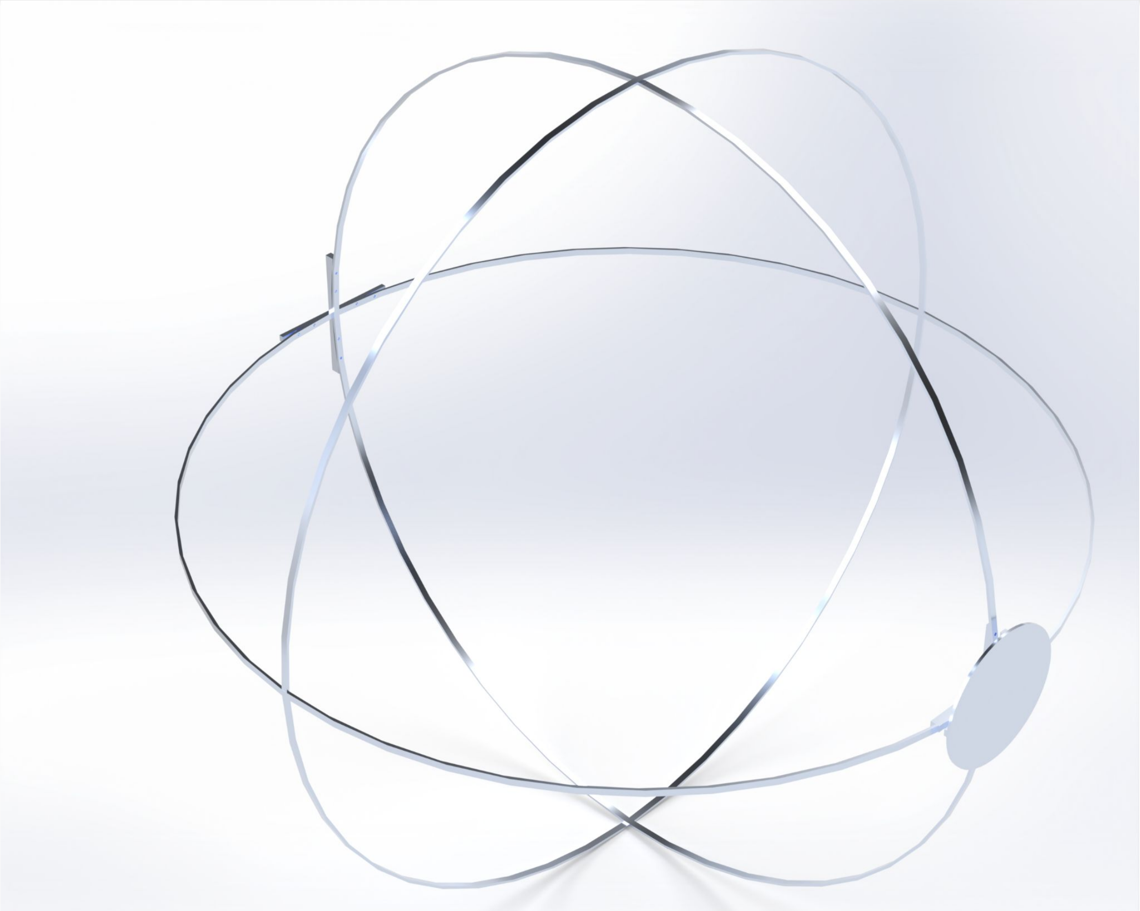
0.61 m diameter aluminum hoops

2 mm thick by 5 mm wide

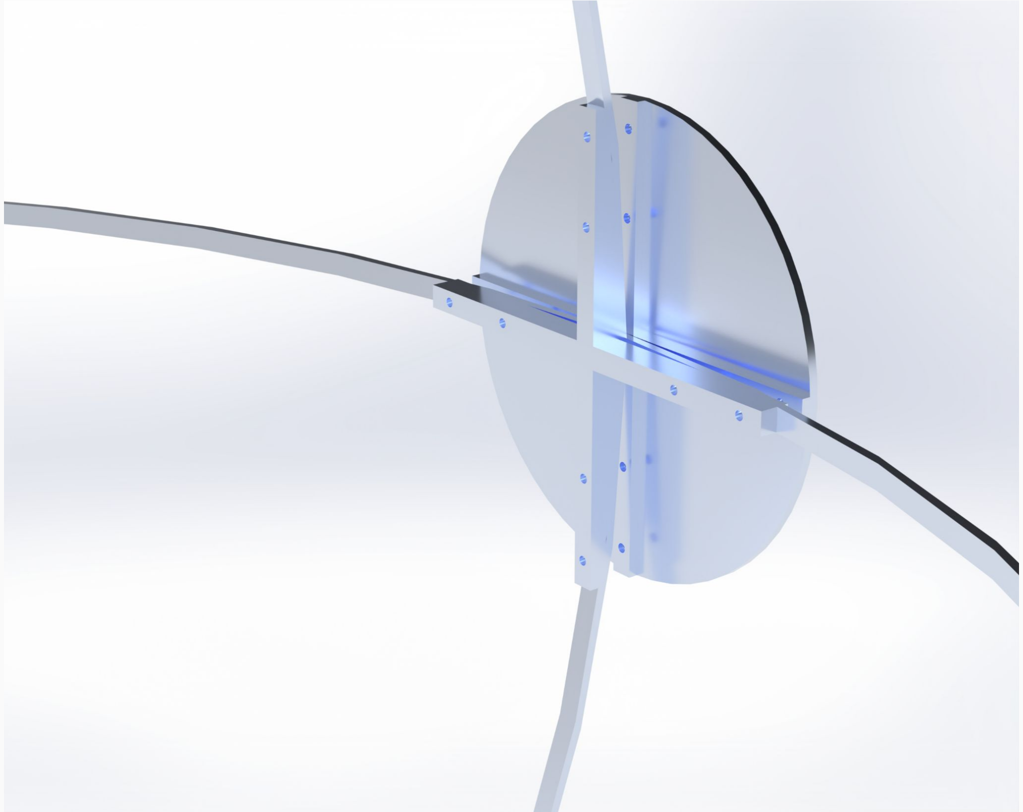
Bent into six semicircles and bolted together at ends by aluminum cross mounts

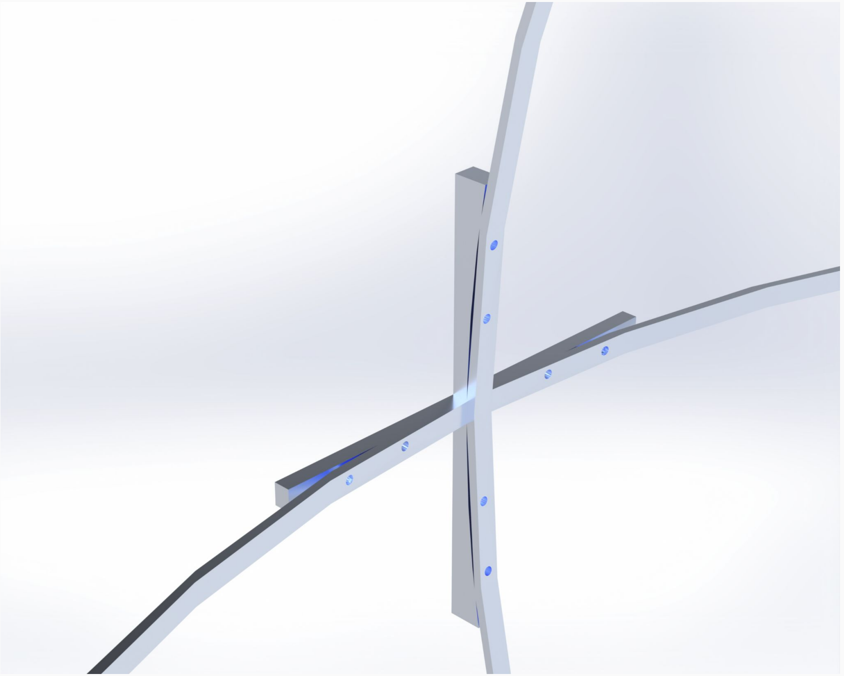
Aluminum cross mount on motor side squeezes hoops and bolts into aluminum disk that is screwed to the motor

Two screws at each node provide rigidity



Sphere Construction Continued





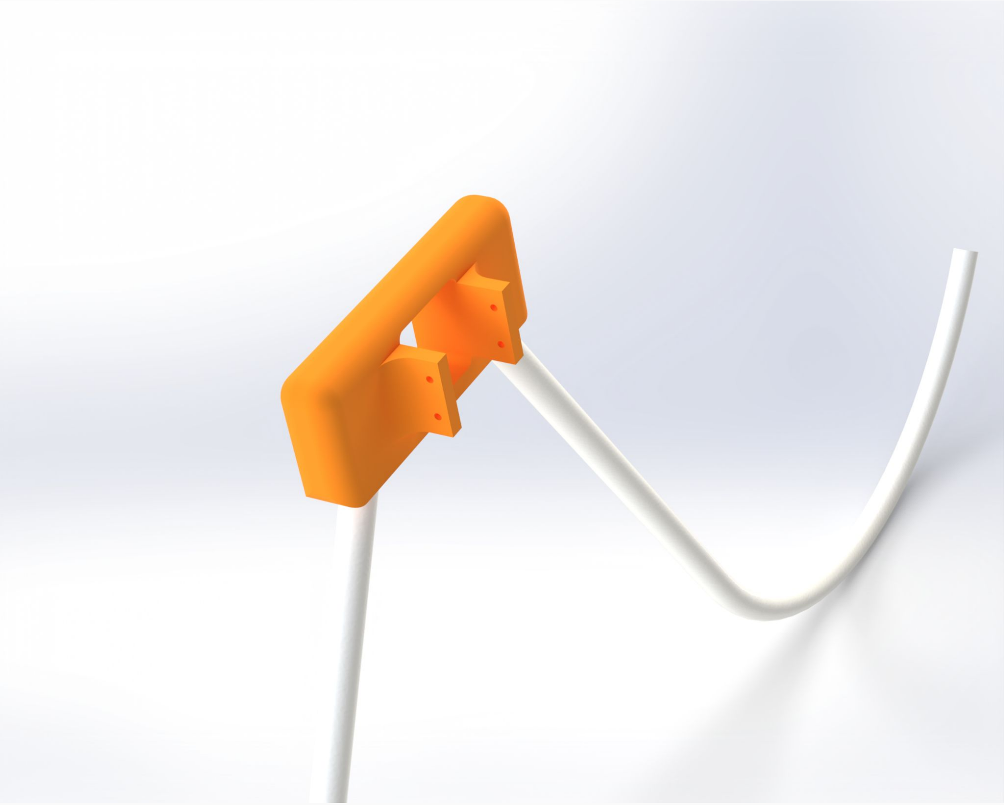
Mylar Balloon

24 inch diameter filled with helium

Mass of helium: ~25 grams

Lift generated: ~ 2.4 N

Landing Skids

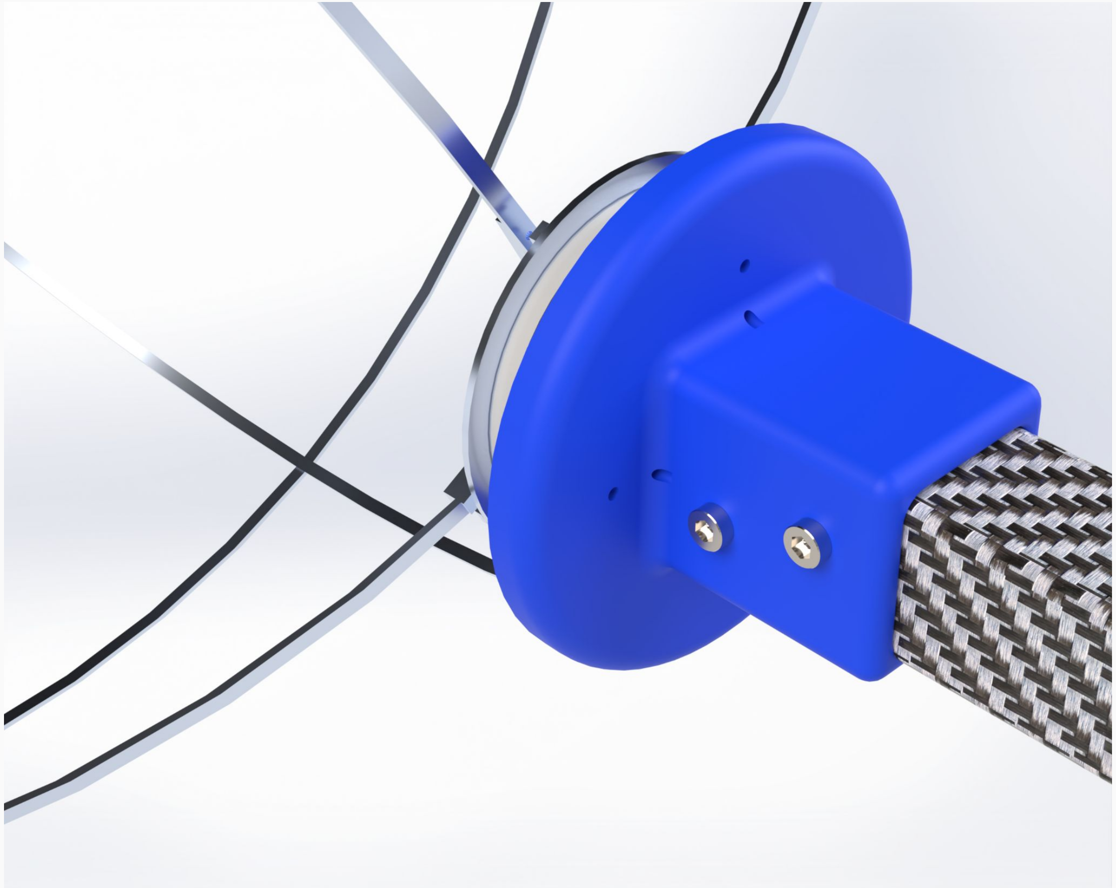


Height and width were increased

Skids will be made out of aluminum tubing for some flexibility

Looked into 3D printing out of Nylon PA-12 which would offer some flex and shock absorption → only downside is the cost of ~$200 per part

Motor Mounts

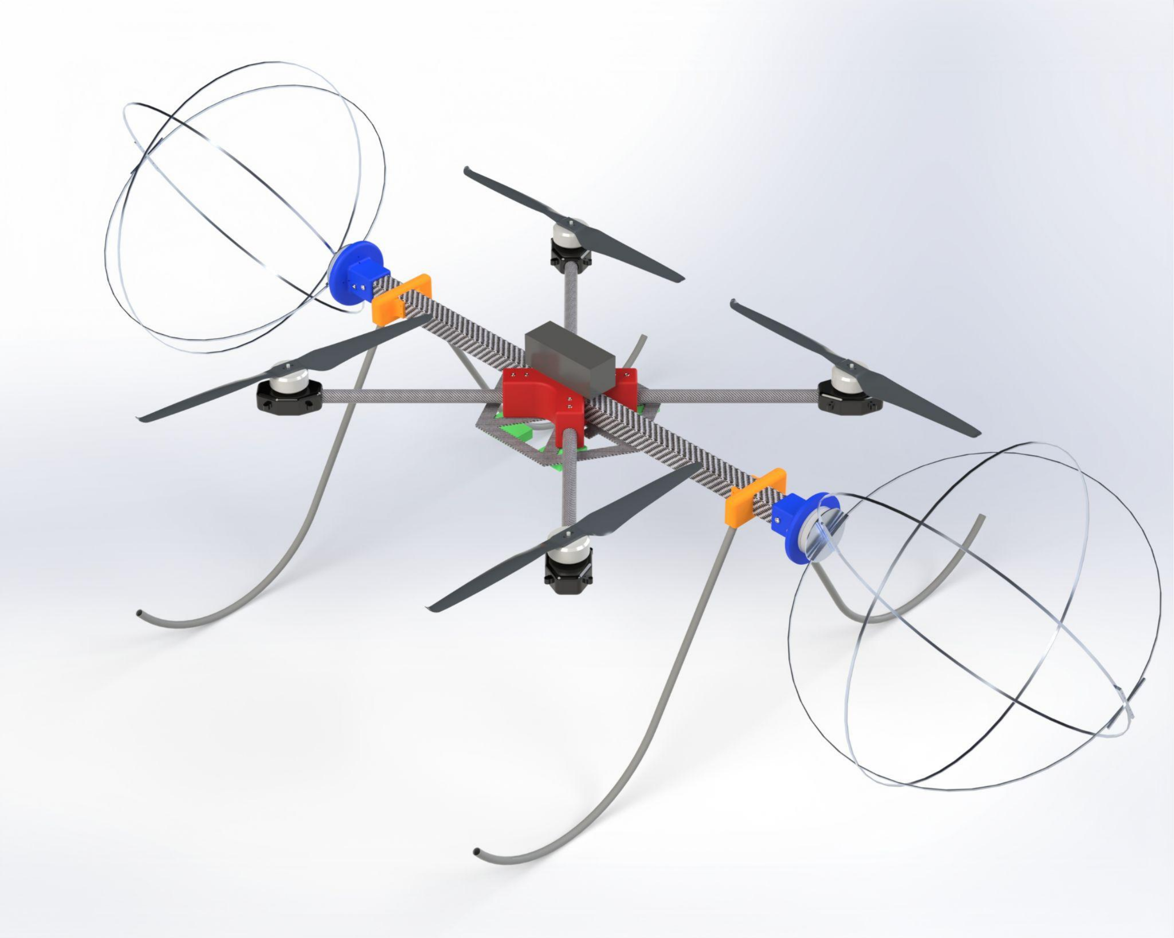


Offset holes for better torsional support

Changed orientation to allow for 3D printing

Added an aluminum plate between the motor and the sphere for mounting purposes

Full System Overview



Total Mass: 7.41 kg

Bounding box dimensions:

Length: 2.46 m

Width: 1.34 m

Height: 0.8 m

Validation of Quadcopter Parameters

Per the documentation of the SunnySky XS High Power X6212S motors, four of them in a quadcopter configuration have a max takeoff weight of 10 kg

Our mass has been reduced to 7.41 kg so we are well within this limit now

Analysis and Validation of Sphere Design

SOLIDWORKS mass estimate: 7.41 kg

Sphere diameter: 0.6 m

Rotation rate: 180 rpm → ~ 3 revolutions per second

Velocity: 10 m/s

Using the Kutta-Joukowski Lift Theorem for a Sphere and reducing by a factor of 6, we estimate that the lift generated by two spheres as given will be ~140 N

Motor Validation

GL80 motors provide a documented 2.9 Nm of peak torque and ~1.5 Nm of continuous torque

Found an article that cited this paper: Lugt, H. J. (1983). “Vortex Flow in Nature and Technology” to empirically describe the induced drag of a rotating sphere

This gave an estimated induced drag of 0.66 - 2 Nm for the range of 103 - 180 rpm

I’d like to do more research and tests on this but it seems like we are in the safe regime especially if operating closer to 103 rpm which would still theoretically provide enough lift

Other Notes

Statics analysis on square 1.5 inch central spar showed it offers the necessary support and rigidity

All 3D printed components can be sliced in half to allow for easy printing

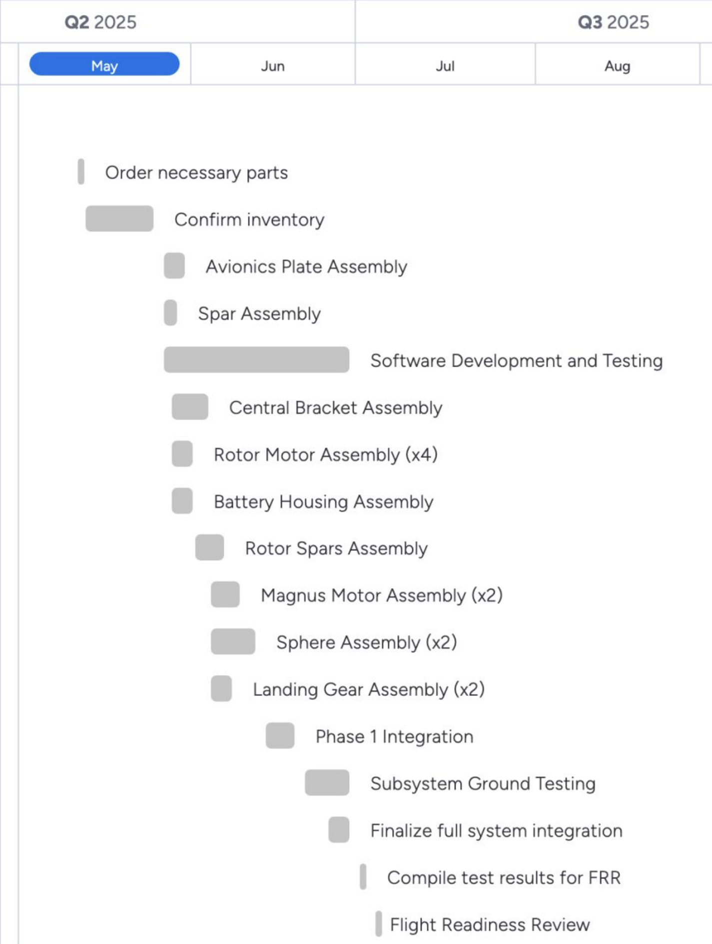
Holes were offset to increase torsional support and counterbores were added were material thickness allowed

Center of mass remains 2 cm above the lateral plane of the vehicle, so spacers will be added to the avionics to offset this → much more room to work with in the mass range

Bill of Materials							
	Part Name	**Vendor**	**Part Number**	**QTY.**	**Unit Cost**	**Total Cost**	**Applicable Link**
	Tube - Fabric - 0.875 x 0.995 x 72 Inch	Rockwest Composites	45541	2	$ 139.99	$ 279.98	https://www.rockwestcomposites.com/45541.html
	Multipurpose 6061 Aluminum Round Tube (1ft)	McMaster	9056K72	1	$ 9.63	$ 9.63	https://www.mcmaster.com/9056K72-9056K723/
	Alloy Steel Socket Head Screw, M5 x 0.8 mm, 85 mm long	McMaster	91290A105	1	$ 14.15	$ 14.15	https://www.mcmaster.com/91290A105/
	Thin-Profile Nylon-Insert Locknuts Zinc-Plated Low Strength Steel, M5 x 0.8 mm Thread Size	McMaster	90453A113	1	$ 7.86	$ 7.86	https://www.mcmaster.com/90453A113/
	Alloy Steel Socket Head Screw, M6 x 1 mm, 85 mm long	McMaster	91290A037	1	$ 17.49	$ 17.49	https://www.mcmaster.com/91290A037/
	Thin-Profile Nylon-Insert Locknuts, Zinc-Plated Low Strength Steel, M6 x 1 mm Thread Size	McMaster	90453A114	1	$ 8.57	$ 8.57	https://www.mcmaster.com/90453A114/
	Tube - Square - Fabric - 1.50 x 1.63 x 66 inch	Rockwest Composites	25498	1	$ 318.99	$ 318.99	https://www.rockwestcomposites.com/25498.html
	Multipurpose 6061 Aluminum Bar, 2 mm Thick x 5 mm Wide	McMaster	9146T11	14	$ 2.40	$ 33.60	https://www.mcmaster.com/9146T11-9146T116/
	Alloy Steel Low-Profile Socket Head Screw Hex with Recess, Black Oxide 8.8 Steel, M6 x 1mm, 60mm Long	McMaster	97050A134	8	$ 1.87	$ 14.96	https://www.mcmaster.com/97050A134/
	24 Inch Pack of 4 Sphere 4D Mylar Round Foil Party Balloon	Amazon	B0D19K9H6J	1	$ 9.99	$ 9.99	https://www.amazon.com/Sphere-Mylar-Round-Balloon-Orange/dp/B0D19K9H6J?gQT=1&th=1
						Total Cost	$ 715.22

Project Timeline Phase 1

Order necessary parts	May 12
Confirm inventory	May 13 - 26
Avionics Plate Assembly	May 27 - 30
Spar Assembly	May 27 - 29
Software Development an	May 27 - Jun 30
Central Bracket Assembly	May 28 - Jun 4
Rotor Motor Assembly (x4	May 28 - Jun 2
Battery Housing Assembly	May 28 - Jun 2
Rotor Spars Assembly	Jun 2 - 6
Magnus Motor Assembly (	Jun 4 - 10
Sphere Assembly (x2)	Jun 4 - 12
Landing Gear Assembly (x	Jun 4 - 9
Phase 1 Integration	Jun 13 - 19
Subsystem Ground Testin	Jun 20 - 30
Finalize full system integra	Jun 25 - 30
Compile test results for FI	Jul 1 - 2
Flight Readiness Review	Jul 3



Tentatively places the Flight Readiness Review on July 3

Allows for iterative testing of subsystems during assembly

Has built in buffer zones

Manufacturing Plan

Mount all 4 rotor motors t	Jun 23 - 27	Mount all 4 rotor motors to their respective spars...
Integrate rotor spars with	Jun 23 - 27	Integrate rotor spars with central bracket | Phase...
Integrate central bracket t	Jun 23 - 27	Integrate central bracket to main spar | Phase 1 I...
Attach avionics plate to ce	Jun 23 - 27	Attach avionics plate to central bracket | Phase 1...
Attach battery housing to	Jun 23 - 27	Attach battery housing to central bracket | Phase ...
Slide on and fasten landin	Jun 23 - 27	Slide on and fasten landing gear integration piece...
Attach Magnus motor mo	Jun 23 - 27	Attach Magnus motor mount assemblies to main spar ...
Attach spheres to Magnus	Jun 23 - 27	Attach spheres to Magnus motor mounts | Phase 1 In...

Provides order of integration during the June 23 - June 27 integration period
Order is defined so that all team members know which components must be assembled in what order

Next Steps

1. Final analysis on motor and propulsion system
2. Phase 2 and 3 of Project Timeline
3. Order components
4. Begin manufacturing May 27

Thank you