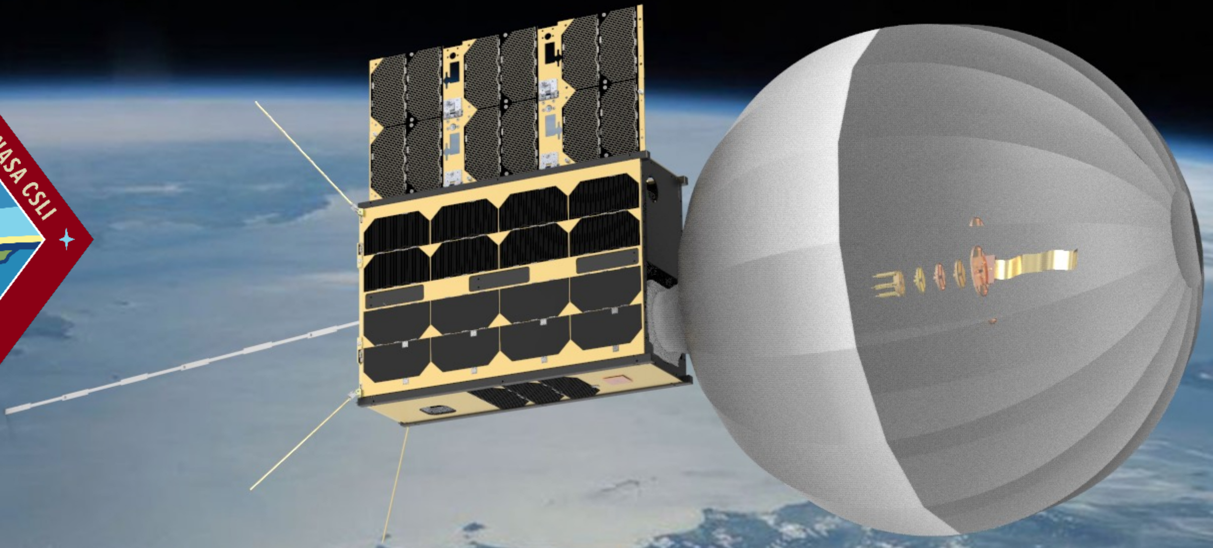
CATSAT: A 6U Inflatable antenna technology demonstrator mission

Arizona

FREEFALL AEROSPACE

Rincon Research Corporation

An Employee-Owned Company



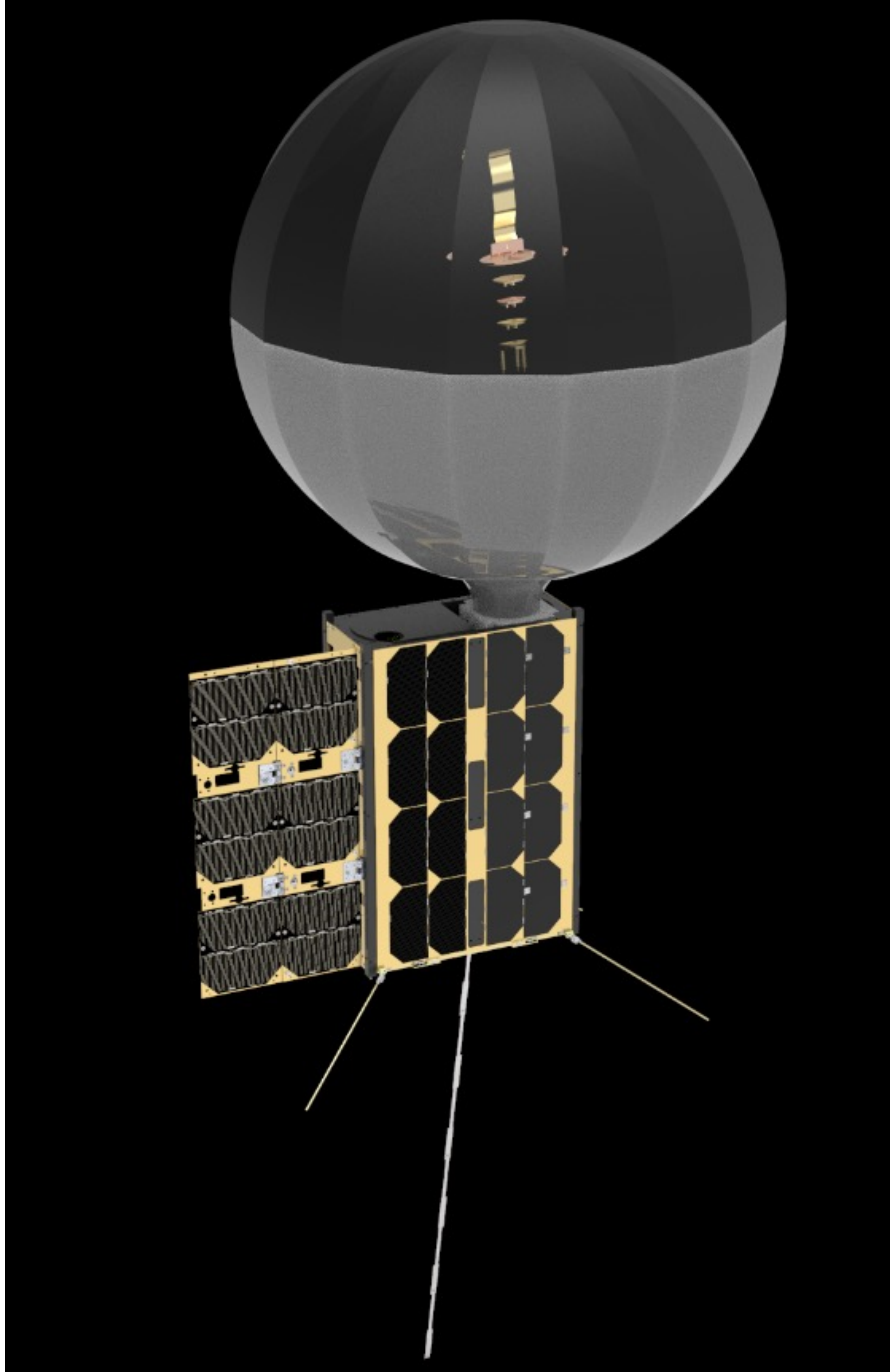
Mission Description

6U CubeSat technology demonstrator mission

- To be launched on NASA's ElaNa 43 mission.
- Launch NET August 2022 on board Fire-Fly Black Alpha.
- Sun synchronous orbit at 550 km.
- Nominal mission lifetime: 6 months.

Payload

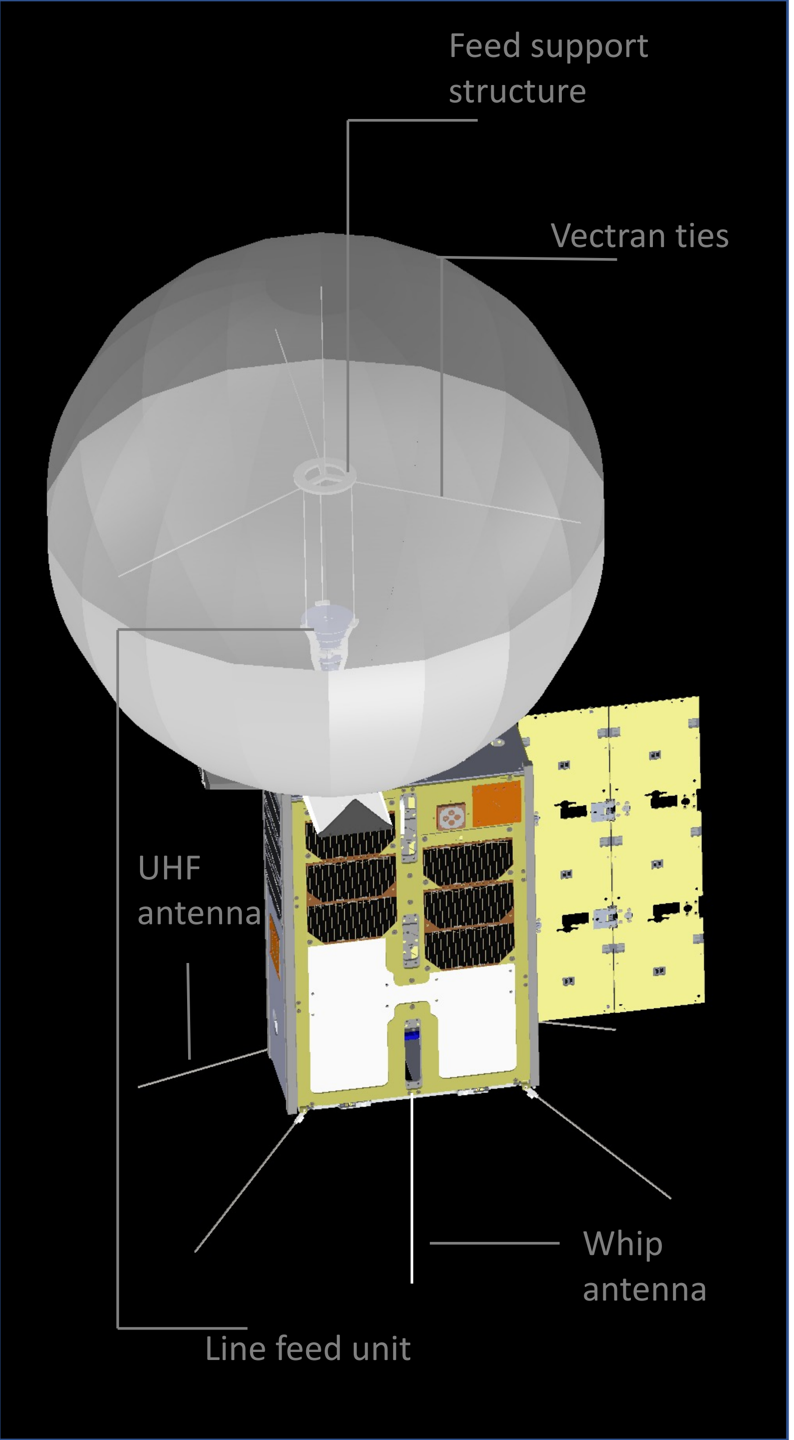
- X-band inflatable antenna system - 1.5U
- HF whip antenna deployment system - 0.1U
- Instrumentation module - 1U
  - HD Cameras, FPGA processor, SDR
- Metrology camera system – 0.5 U

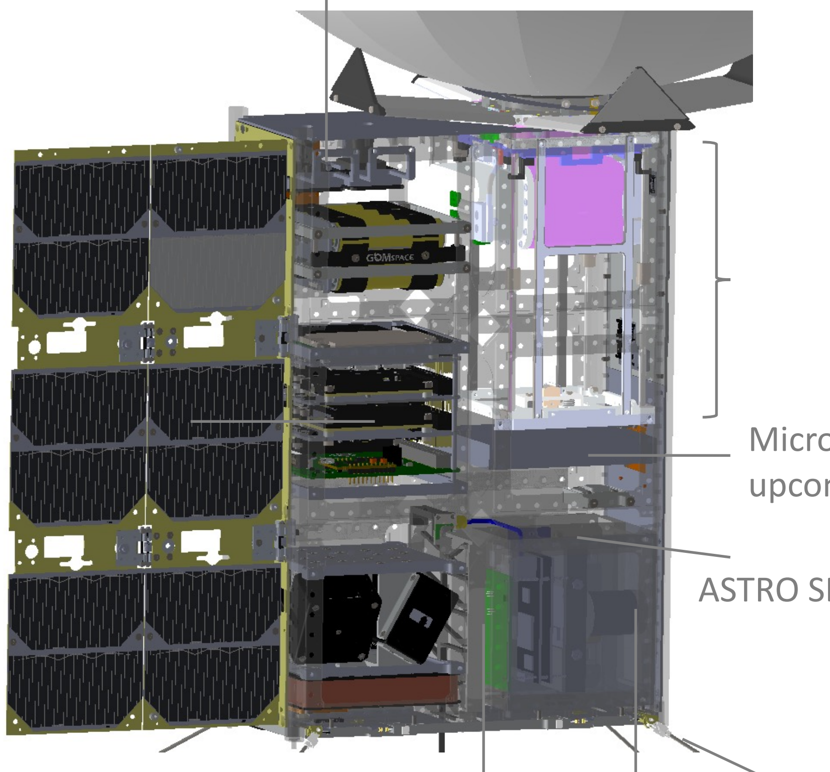


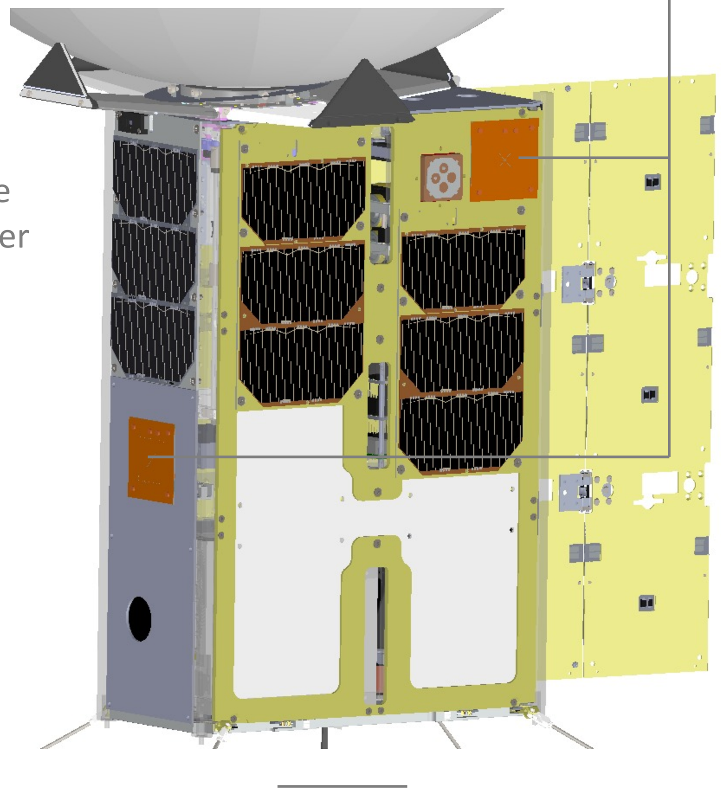
Science/Technology Traceability Matrix

Science/Technology Questions	Objective	Measurement Requirement	Mission Requirement
How can low power, high data rate communications be achieved with a Small Satellite?	Demonstrate a deployable, high gain antenna	Relay high definition images from orbit in near real time	• Orbital platform • High Def Camera imaging system • Inflatable, 0.5m reflector • X band data link • ~550 km, sun synchronous orbit • $\geq$1 month
How does the structure of the ionosphere vary from day to night?	Measure ionospheric structure along the terminator	Monitor multiple HF WSPR beacons above the ionosphere	• Orbit along terminator • >550 km altitude • $\geq$1 month

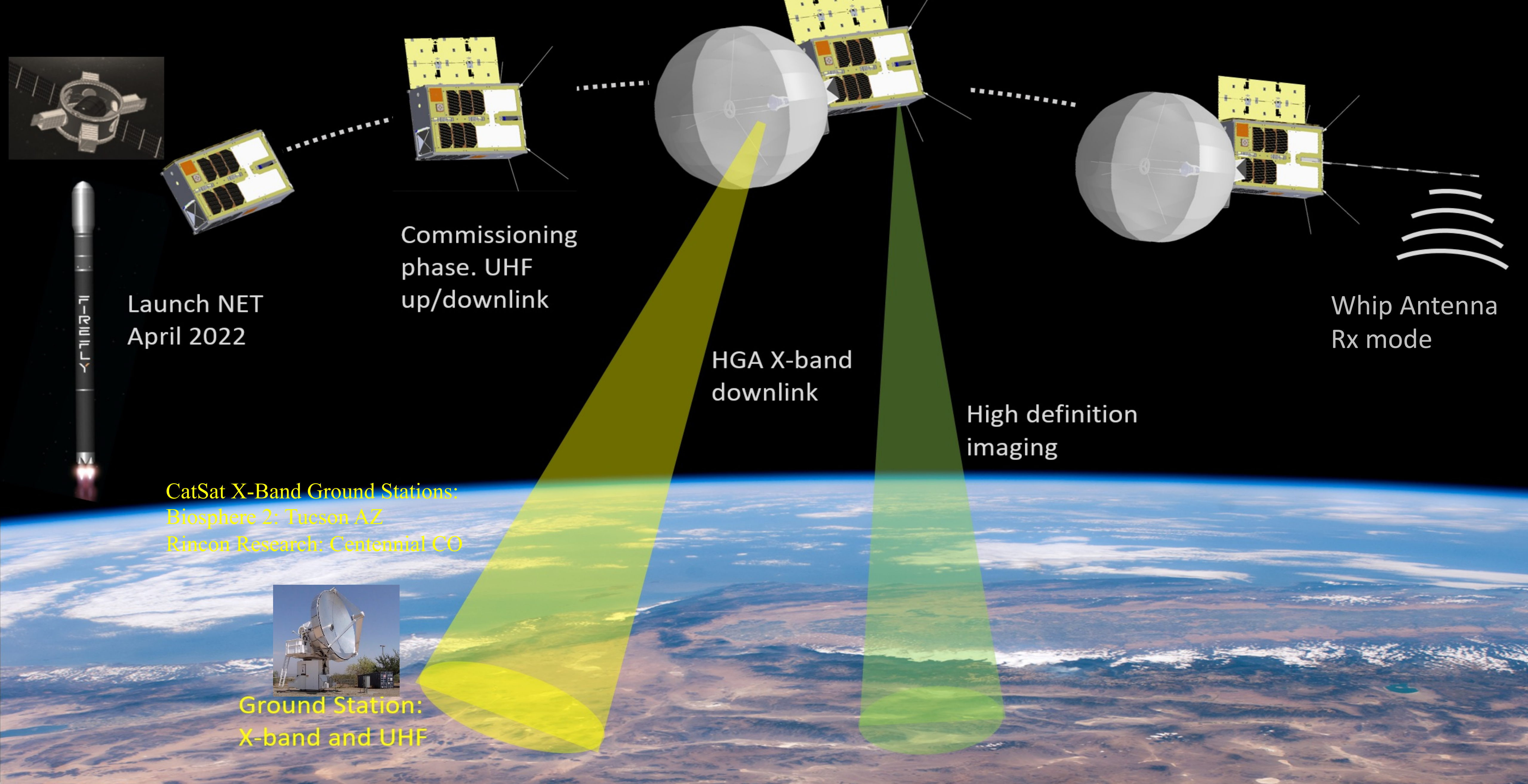
6U CubeSat System Overview





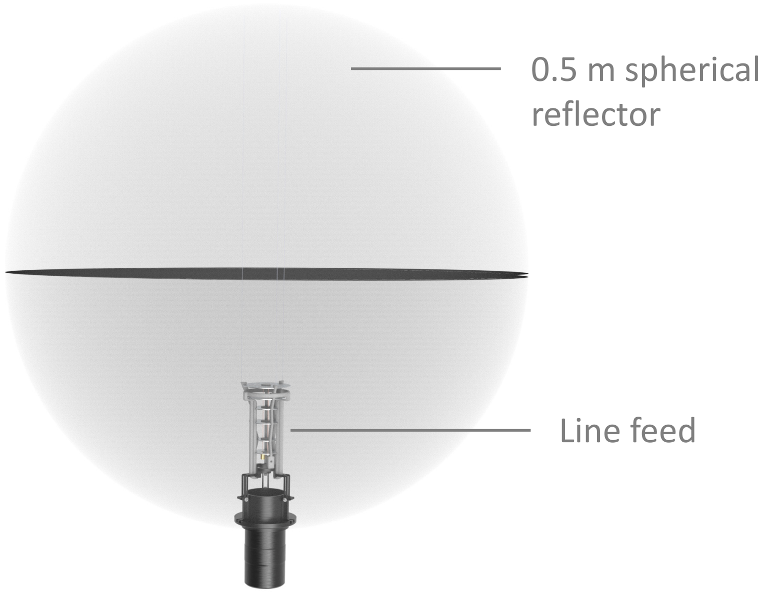


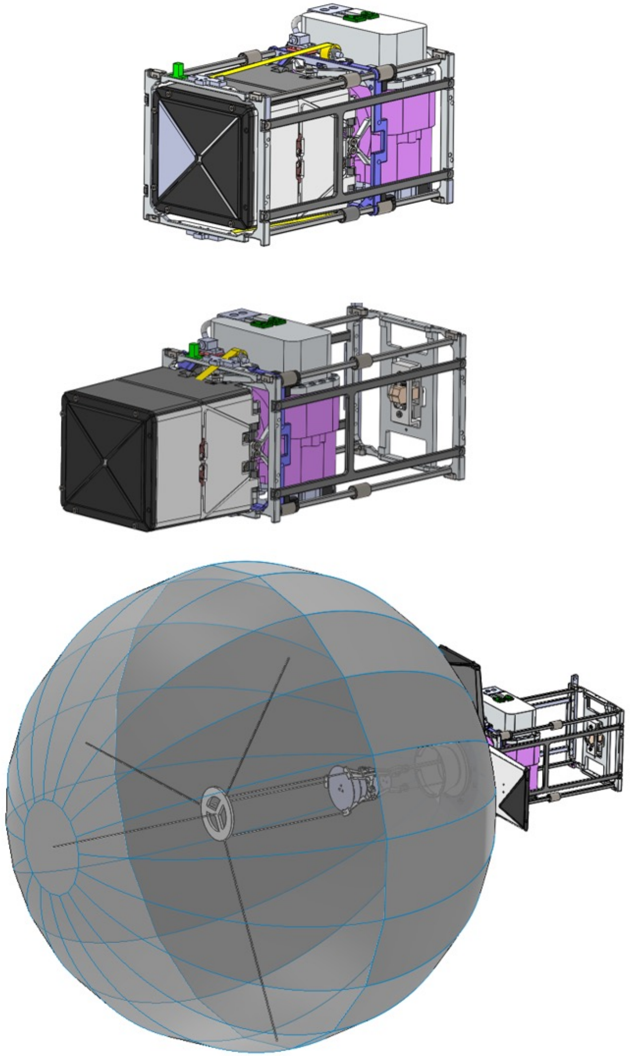
Concept of operation



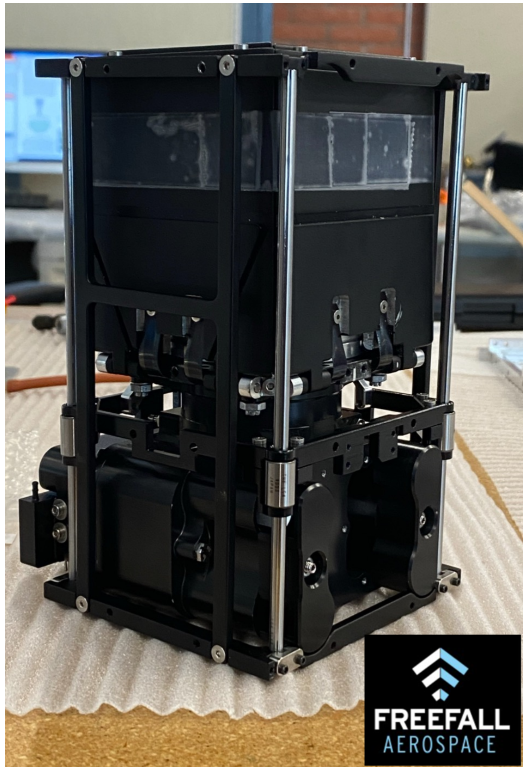
Spherical Inflatable Antenna

Arecibo observatory



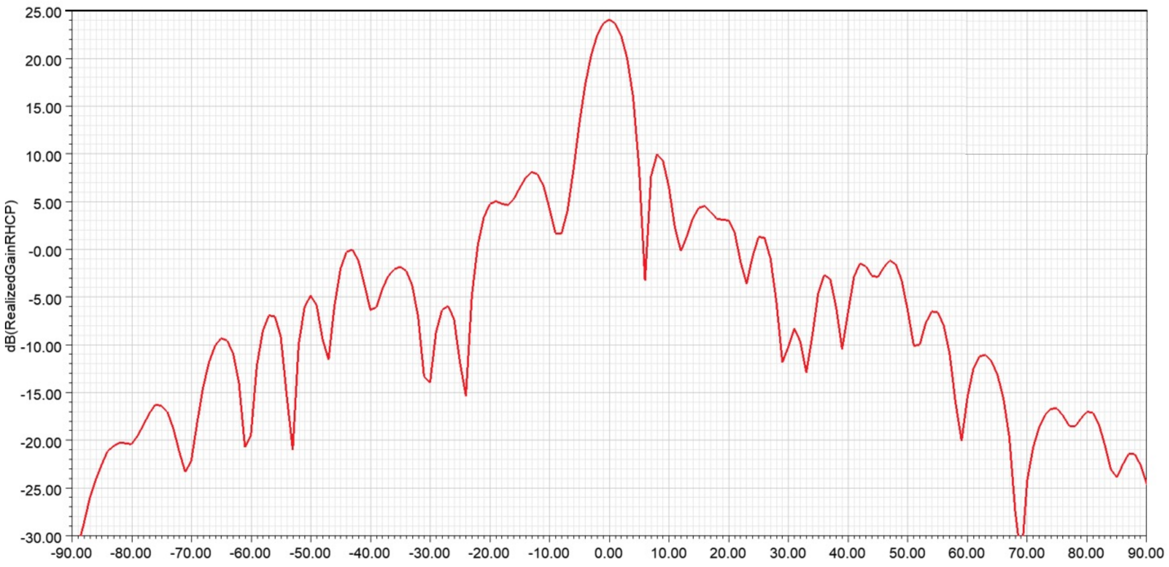


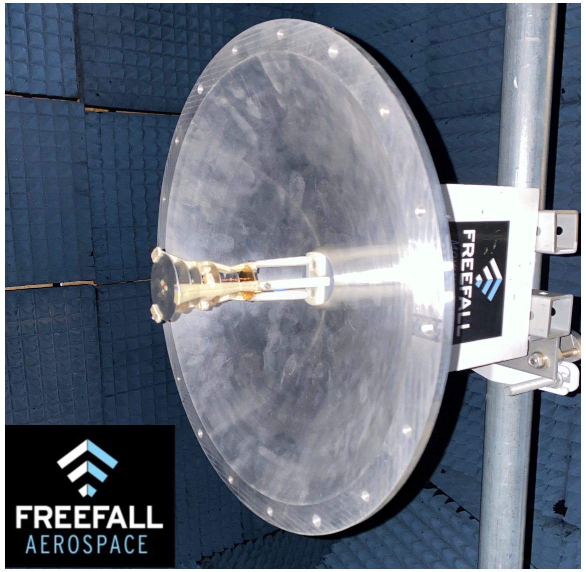
1.5 U System

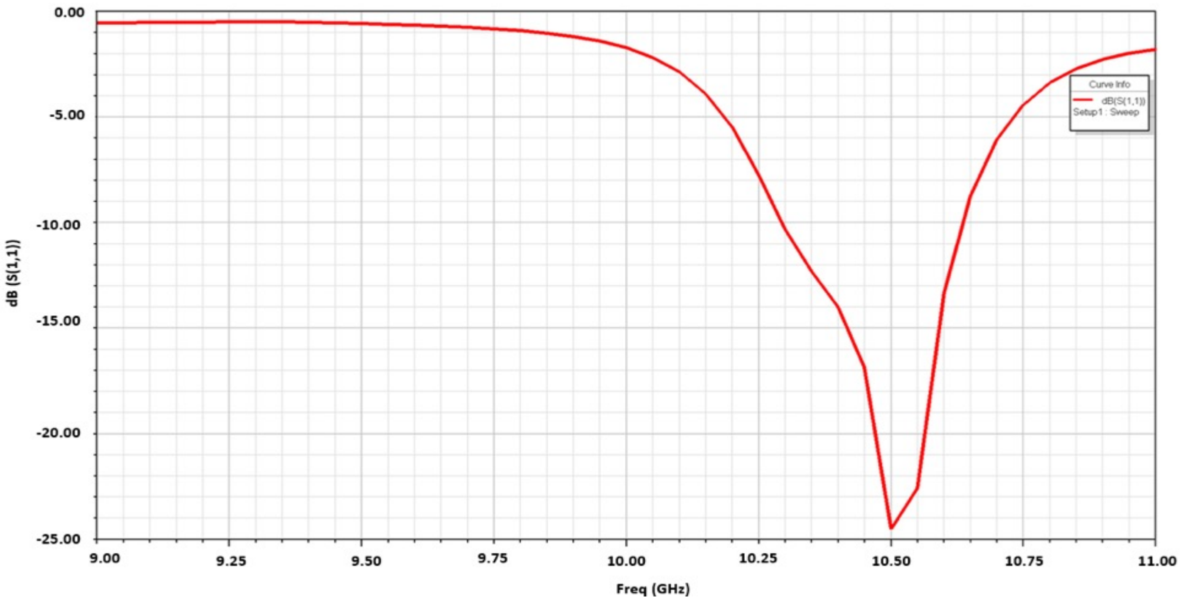


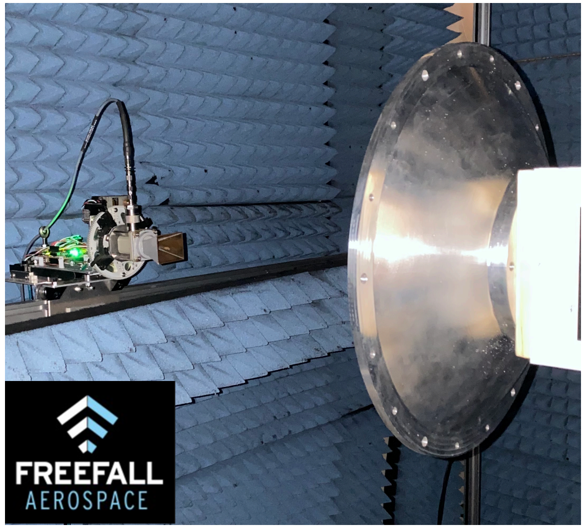
Engineering prototype

Line feed – field measurements



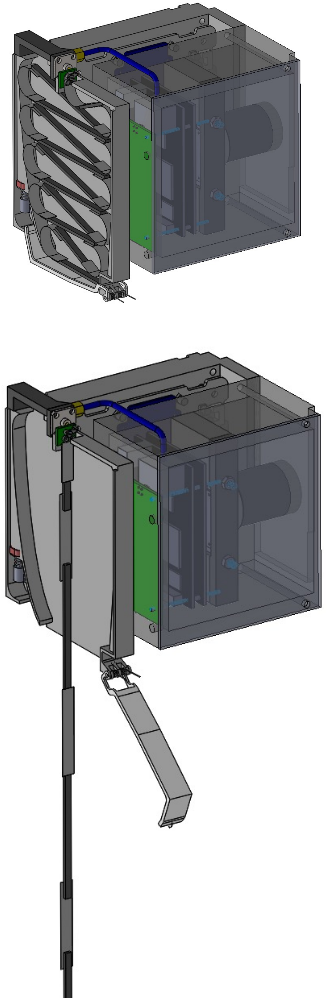


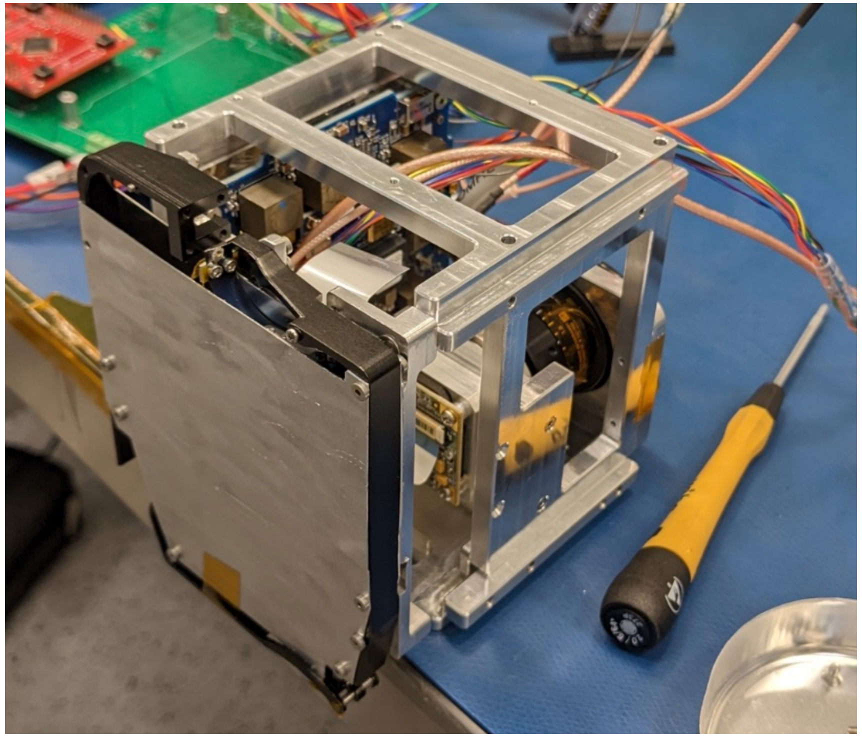




HF Whip Antenna

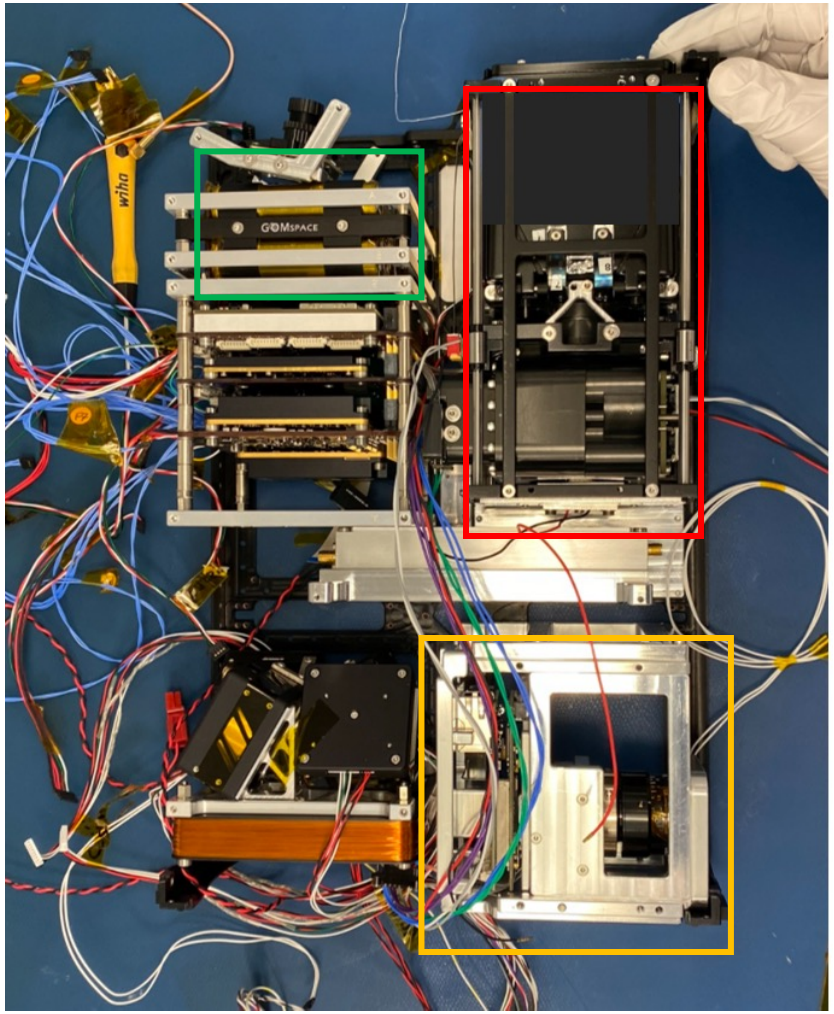
- Probe diurnal variation in the Ionosphere.
- A 0.6 m whip antenna deployed from a 0.1U packaging system.
- Listens to Weak Signal Propagation Reporter (WSPR) from Amateur radio stations.
- Probes from above Ionosphere.
- Aim to generated 3D Ionosphere ray tracing along terminator.

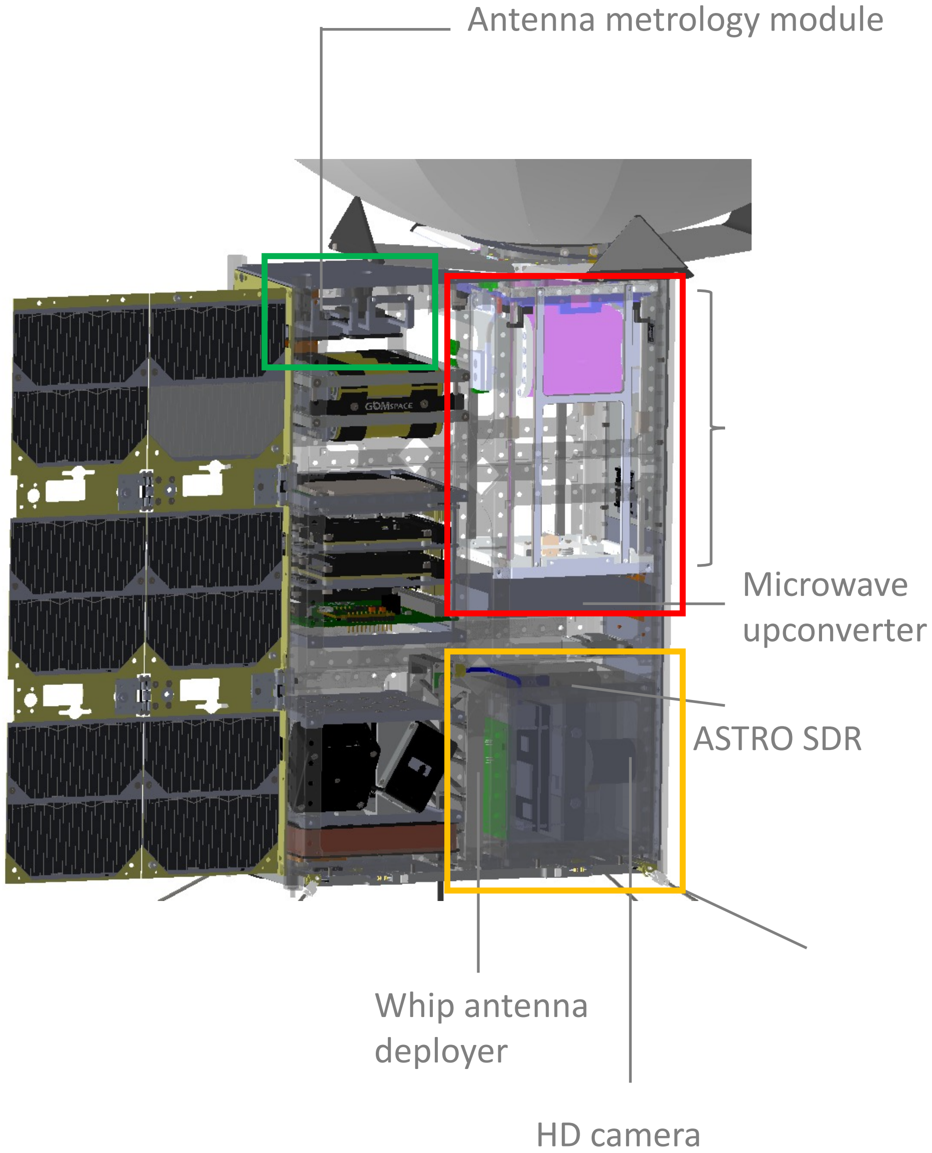




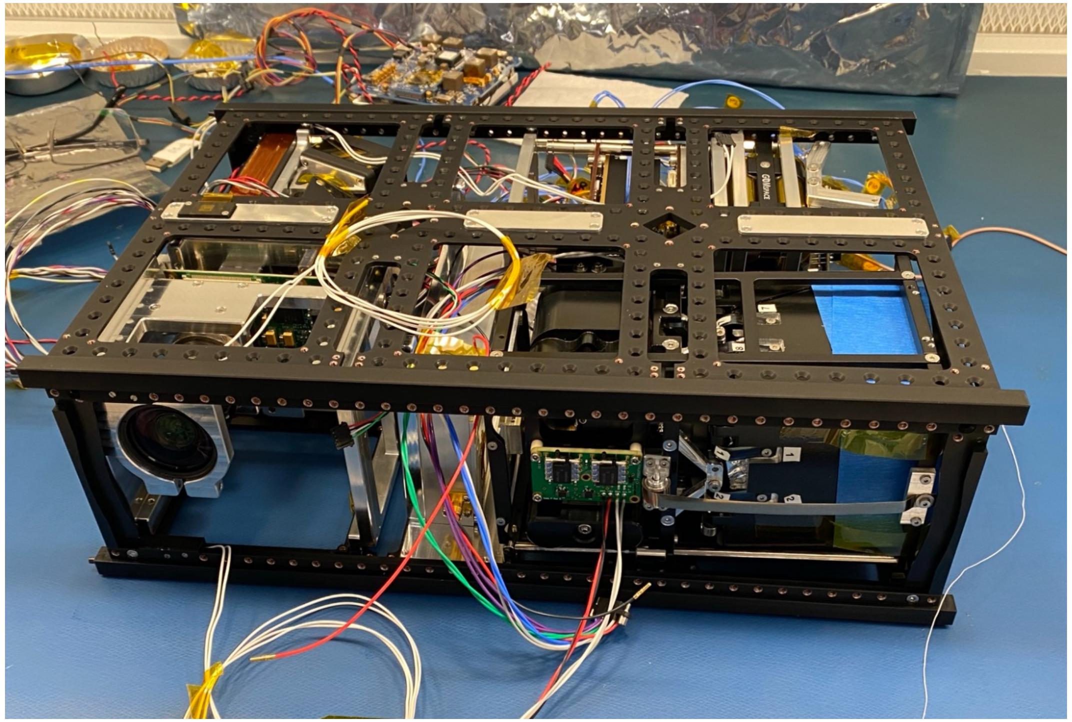
Antenna deployment system

6U CATSAT Flight Hardware Integration

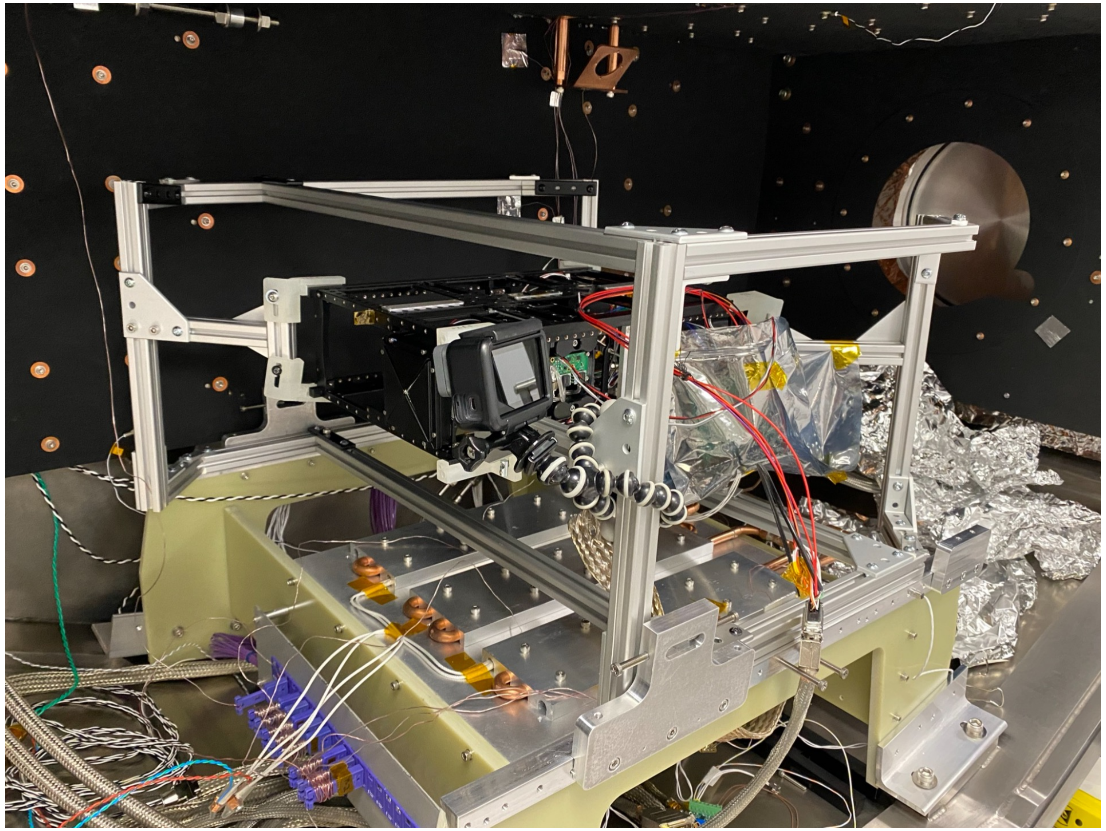




6U CATSAT Flight Hardware TVAC testing

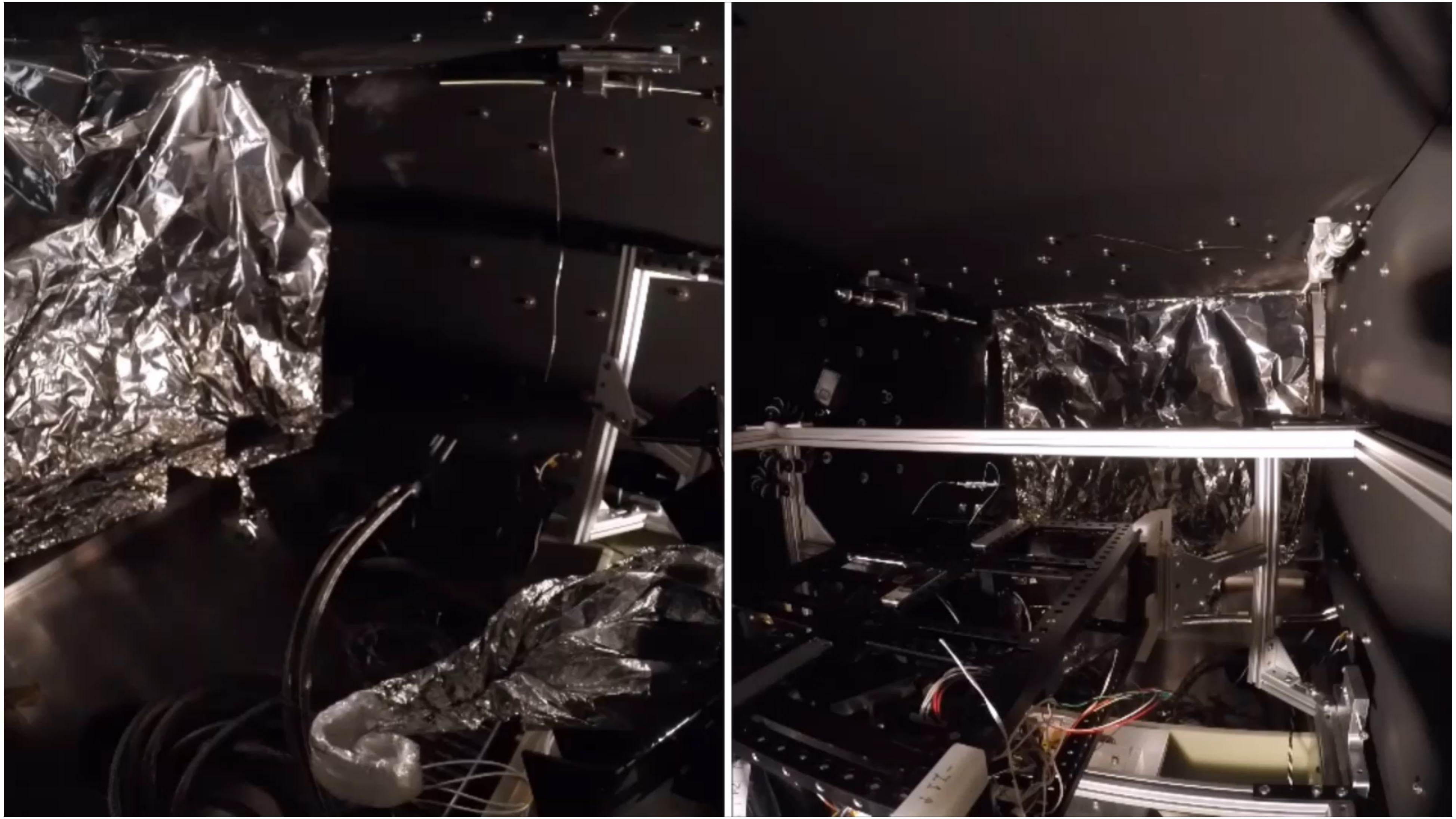


Integrated 6U system



Assembly in TVAC chamber

6U CATSAT Flight Hardware TVAC testing



Orbit lifetime assessment model

Estimated LEO lifetime in years

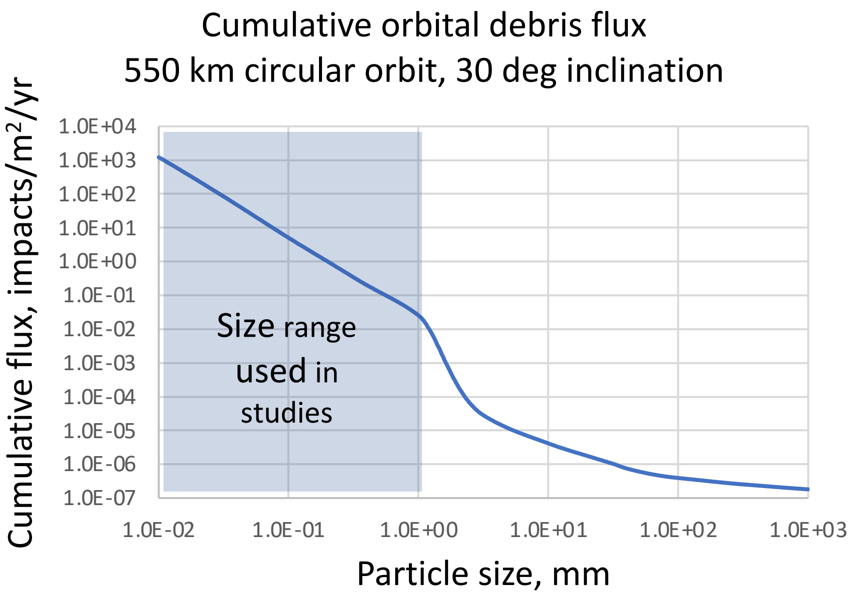
CubeSat Platform	Mass (kg)	Ballistic Coefficient	Lifetime in years			
			500 km	550 km	600 km	650 km
6U	9	20.83	2.00	3.75	11.94	24.48
12U	12	27.78	2.45	4.56	14.52	28.98
16U	16	37.04	3.07	6.53	17.24	
12U	20	46.30	3.64	11.43	25.10	
16U	24	55.56	4.10	13.49	27.87	
16U	25.8	59.73	4.31	14.12	29.31	

NASA ORDEM 3.1

Atmospheric Model - NRLMSISE2000

Drag coefficient ~ 2.2

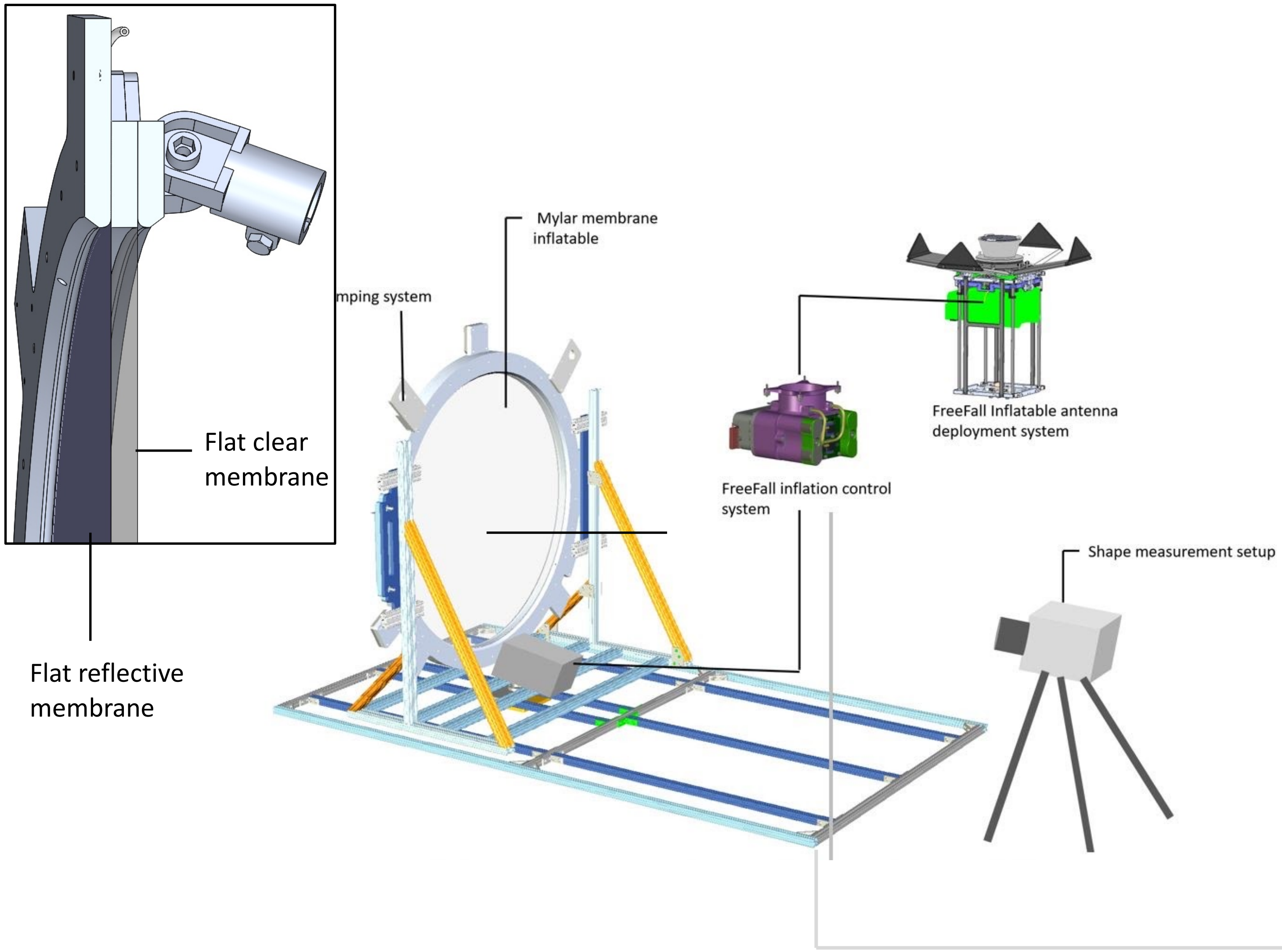
Orbit inclination: 30 degrees

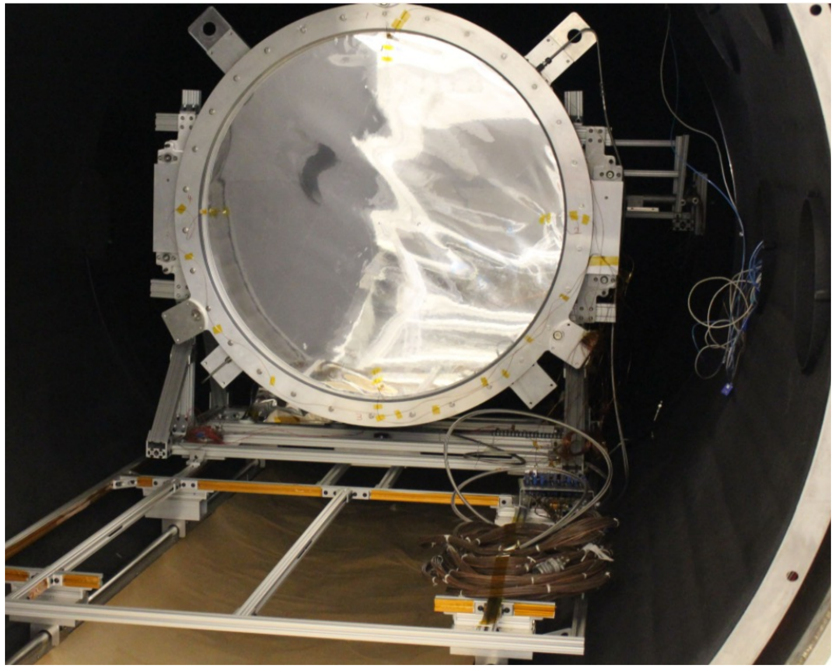


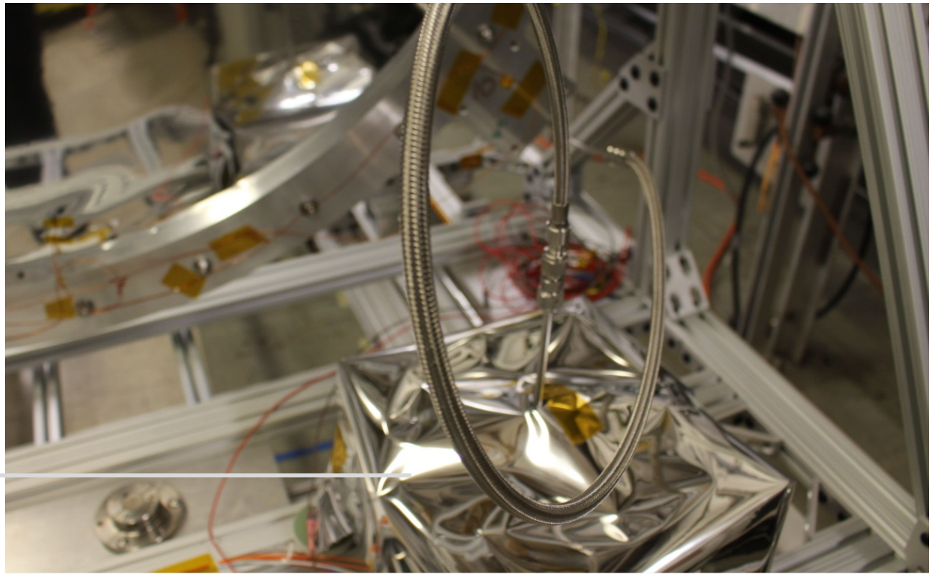
Lifetime sensitivity analysis conducted with respect to:

- Low Earth Orbit altitude and inclination (circular).
- Launch year.
- Gas composition (Helium, Nitrogen, Carbon dioxide, Argon studied).
- Membrane material.
- Membrane thickness.

Inflation control system TVAC test setup – Northrop Grumman







TVAC – Shape measurement and leak-rate analysis

- The inflation control system was able to maintain required ΔP in response to controlled punctures on the membrane surface.
- Measured leak rate of the inflatable under nominal TVAC conditions: 12 Pa/hr (0.0017 PSI/hr)
- Estimate lifetime based on leak rate: ~ 5 months (over pressure state), ~8 months (nominal pressure state). True lifetime between 5-8 months as we switch between these states.
- Inflated shapes repeatable with a 10 µm precision

Conclusion

Integrated CATSAT system

- CATSAT aims to establish the efficacy of inflatable systems in LEO.
- Flight data to be used to validate lifetime assessment models and RF performance.
- Paves the way for further enhancements including membrane Rigidization and feed steering.

Thank you!

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