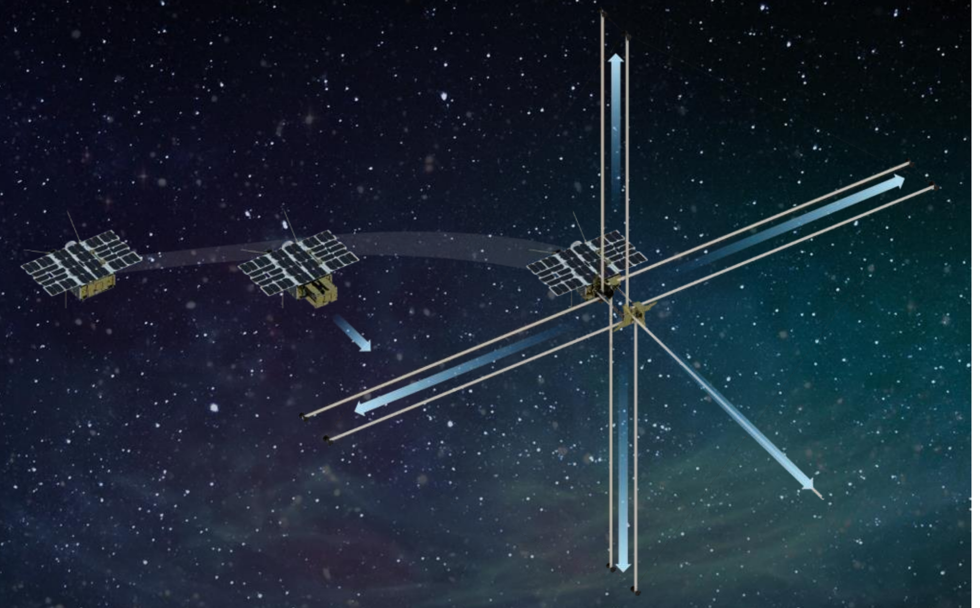
CIVIL SPACE TECH EXPO 2024

Custom Space Mechanisms and Deployable Structures

Mark Silver– MIT Lincoln Laboratory



OVERVIEW

- MIT LL has experience in the design, analysis, building, testing, and deployment of custom mechanisms and structures for space systems
- Previous work includes deployable structures and mechanisms for CubeSats and small satellites in LEO, GEO, and deep space applications

SPACE MECHANISMS

Mechanized Space Systems Can be Risky

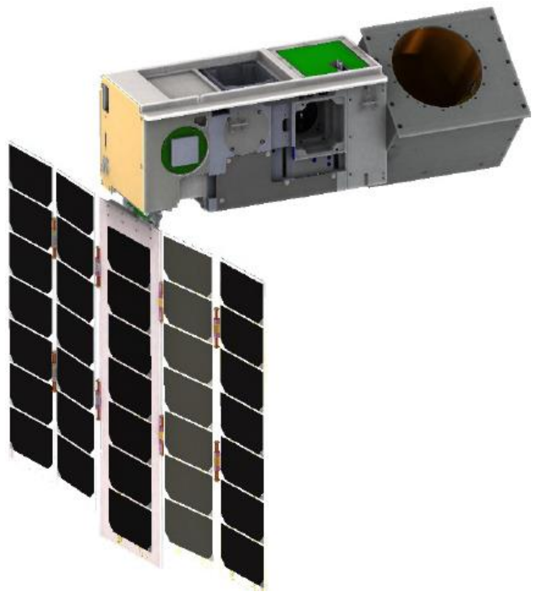
Many space missions require latches, releases, hinges, and pointing mechanisms. To operate in space, these mechanisms must be designed with many unique constraints in mind.

- Actuator designs must include significant margins to ensure they will operate under uncertain conditions
- Mechanisms must operate over a very wide range of temperatures
  - Some mechanisms may see temperatures ranging from -80°C to 150°C
- Materials and lubricants must work in vacuum and not deposit materials on neighboring surfaces through outgassing
  - Payloads with optics are especially sensitive to material outgassing

SPACE MECHANISM HERITAGE AT MIT LL

MIT LL has flown many custom space mechanisms. These can be as simple as cover release and opening mechanisms or as complex as multi-axis gimbals for precision pointing.

Examples of Past Space Mechanisms at MIT LL



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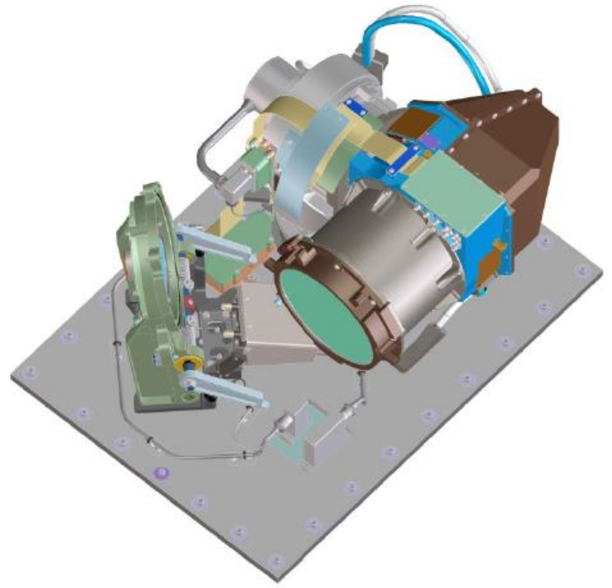

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DEPLOYABLE STRUCTURES

Enabling Big Space Payloads from Small Launch Volumes

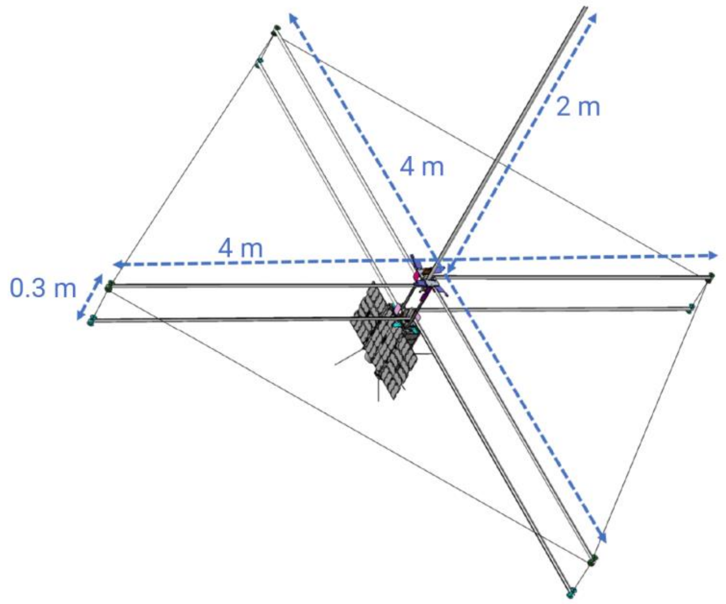
Many space missions require sensors that exceed the launch volume for the spacecraft. This can be overcome by using deployment of the sensor structures.

- Using deployable structures from small satellites can provide a cost-effective solution for many missions
- Deployable structures can be one of the riskiest parts of a space mission, but for many missions, the risk is worth the benefits
- The structures must be designed to reliably take a desired shape upon deployment
- Early prototyping and properly designed tests can reduce the risks of deployment issues

DEPLOYABLE VECTOR SENSOR 3

The deployable vector sensor antenna developed at MIT LL for the AERO program for NASA starts as a box the size of a tissue box and deploys in three dimensions to be 4 m across and 2 m tall.

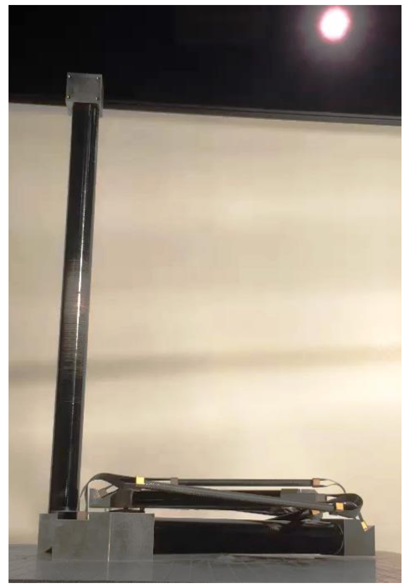
Diagram of Deployed AEROVISTA Antenna

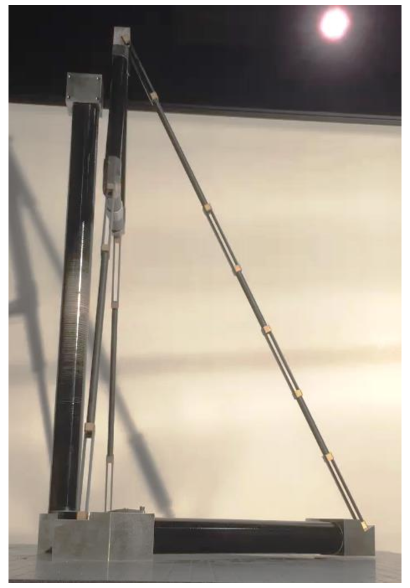


PRECISION DEPLOYABLE STRUCTURES 4

Optical imaging systems with challenging precision requirements, like the James Webb Space Telescope, can be formed with deployable structures. New advances in material technologies have been used at MIT LL to make the most precise deployable structures in the literature.

Stowed and Deployed Precision Frame





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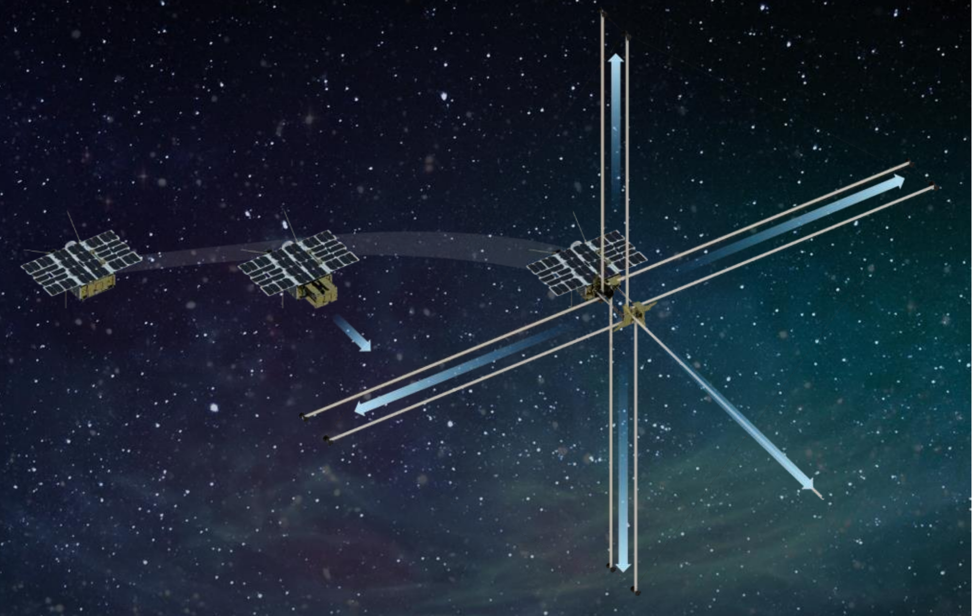

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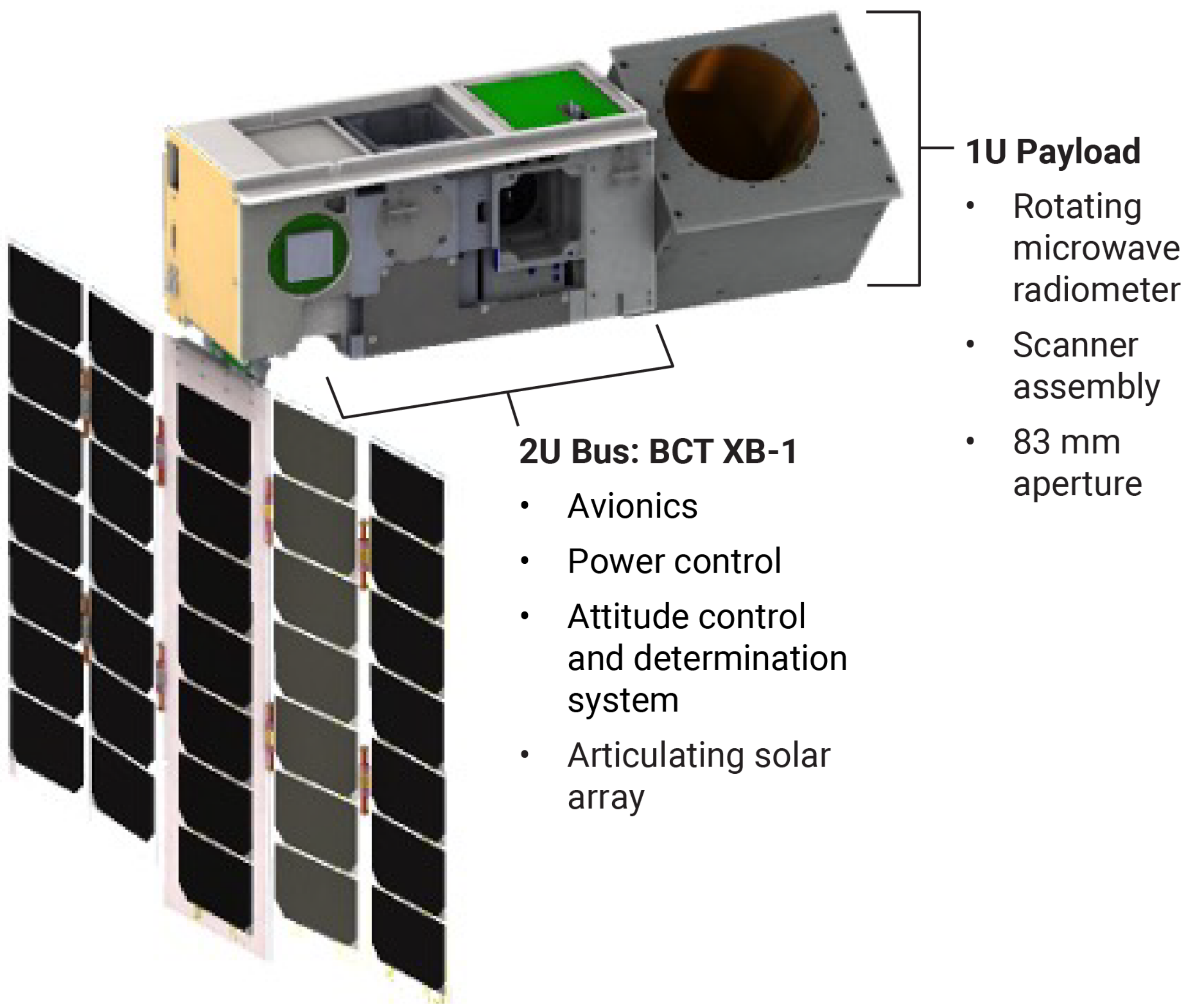
TROPICS SPINNING RADIOMETER

An Example of MIT LL's Capabilities in Space Mechanisms

TROPICS 3U CubeSat



TROPICS Spinning Radiometer Testing

The primary microwave radiometer payload continuously spins throughout the orbit of the TROPICS satellites

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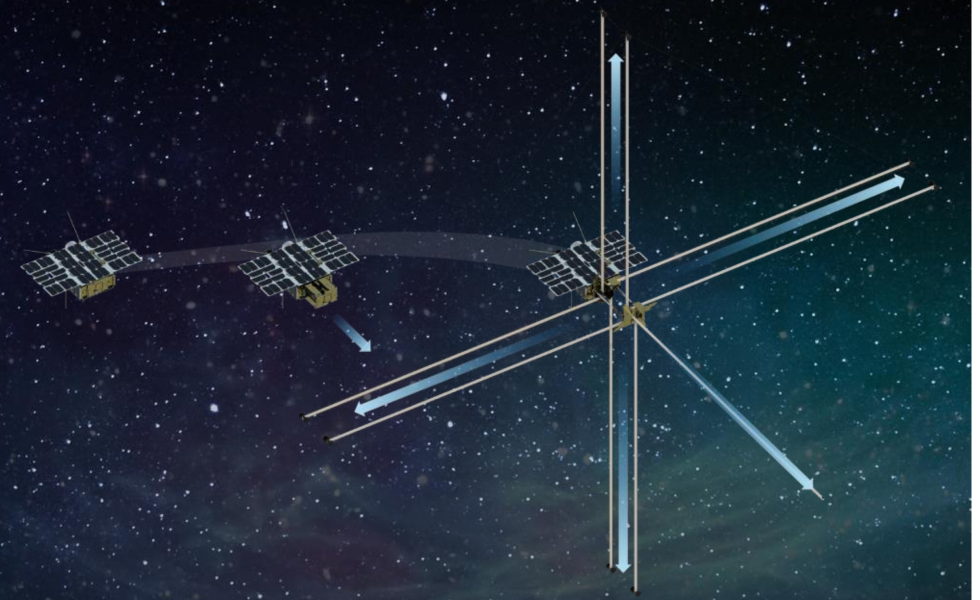

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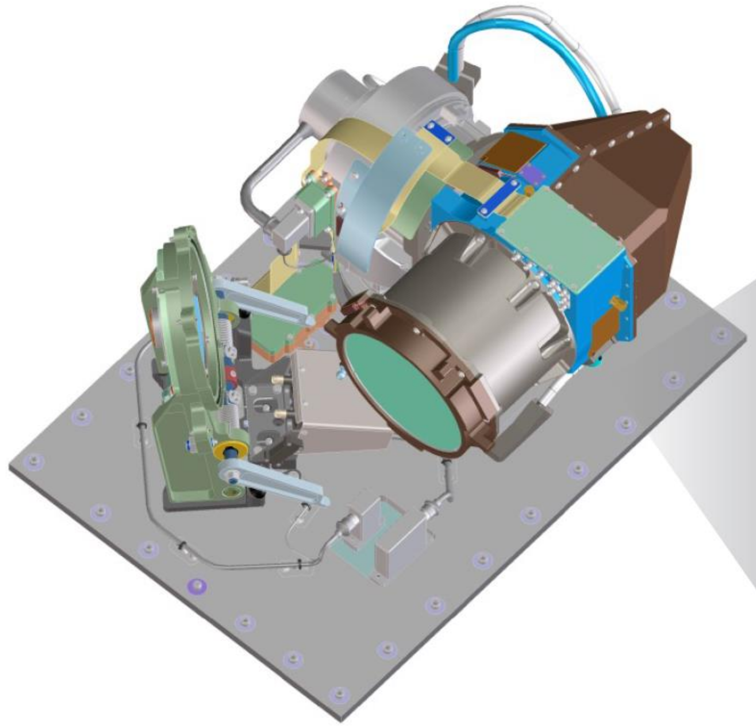
MECHANISMS FOR THE LUNAR LASER COMMUNICATIONS DEMONSTRATOR

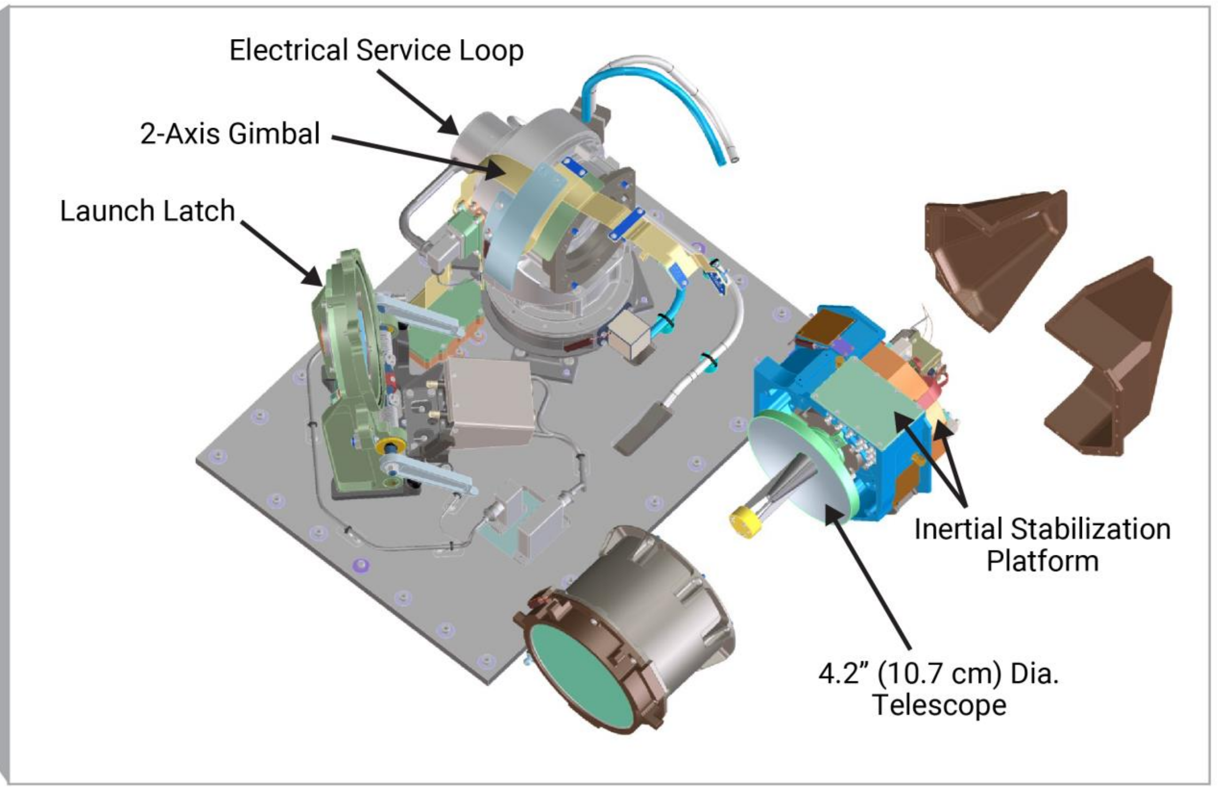
An Example of MIT LL's Capabilities in Space Mechanisms

Space Mechanism for the NASA LLCD Mission

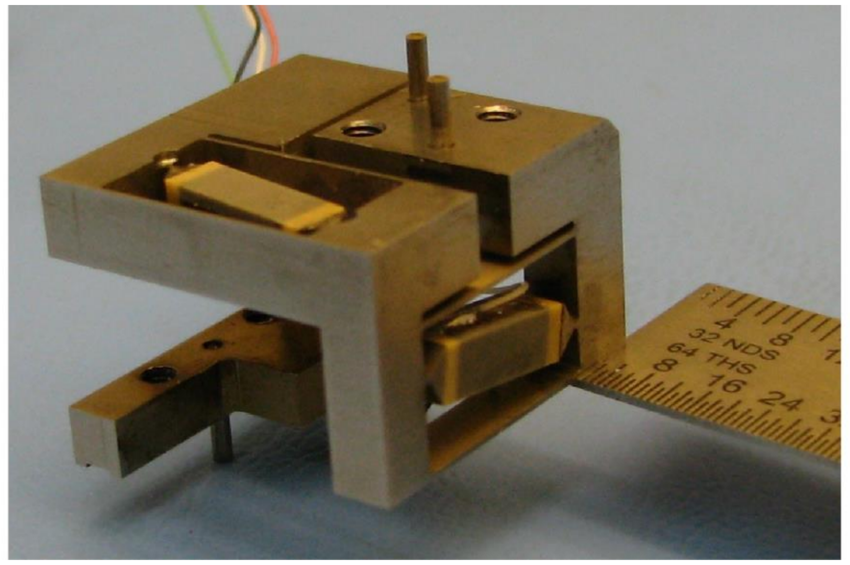
LLCD Optical Module

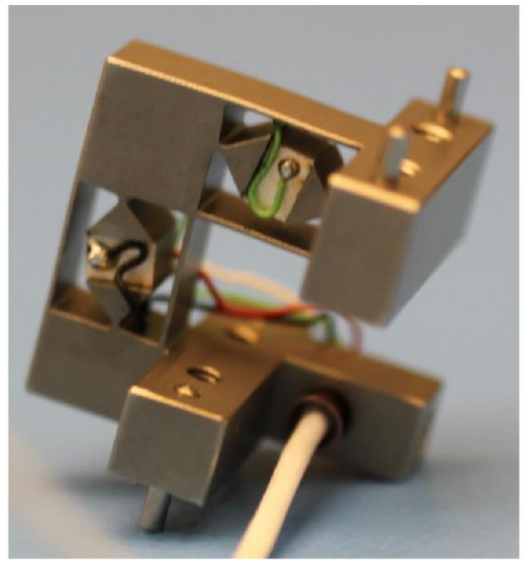


LLCD Optical Module (Exploded View) Highlighting Mechanisms



Piezo Actuator Mechanisms for the LLCD Optical Module





- Two mechanisms, one for transmit and one for receive
  - Transmit mechanism for directing laser point-ahead
  - Receive mechanism for inertial stabilization
- Each fits into a 19 × 16 × 16 mm volume
- 2 axis stage (lateral and vertical)
- Range of motion
  - Transmit 50 × 50 microns
  - Receive 12 × 12 microns
- Designed to survive launch and thermal loads
- Uses all low outgassing materials
- Relatively low lifetime requirement

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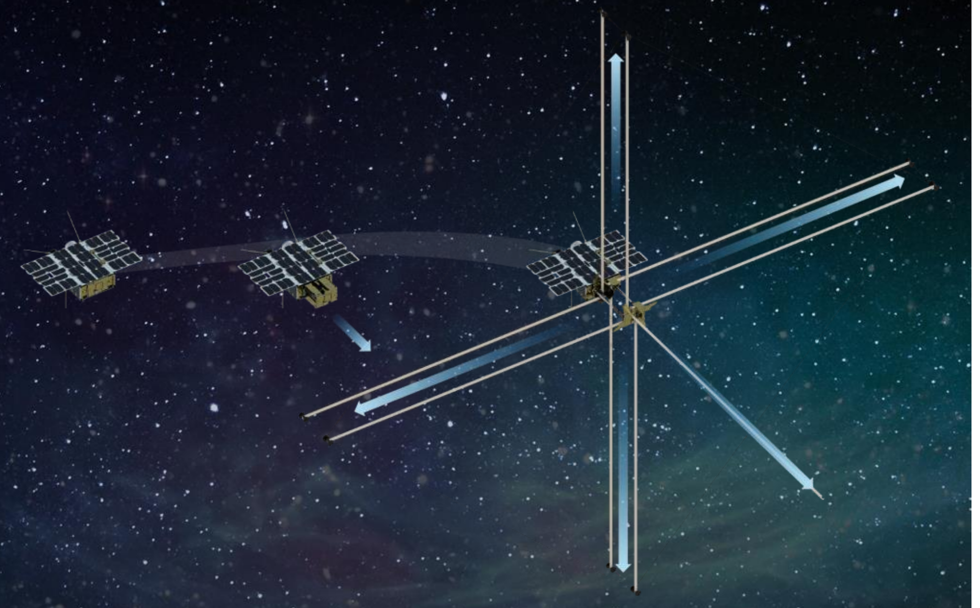

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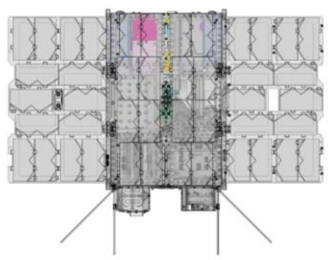
DEPLOYABLE HF ANTENNA ARRAY FOR THE AEROVISTA MISSION

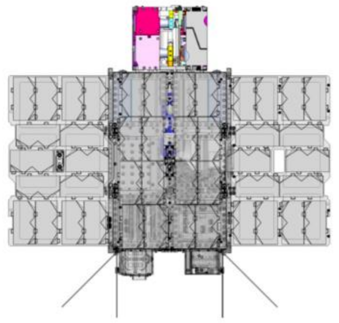
A Microsatellite-Deployable Payload for Measuring Auroral HF Radio Emissions

The AEROVISTA Antenna Deploys from the Small Satellite in Three Steps

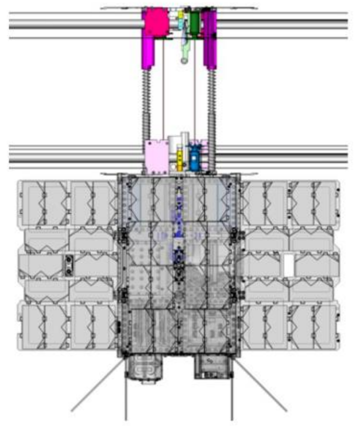
- Animation of deployment (coming from Pubs)



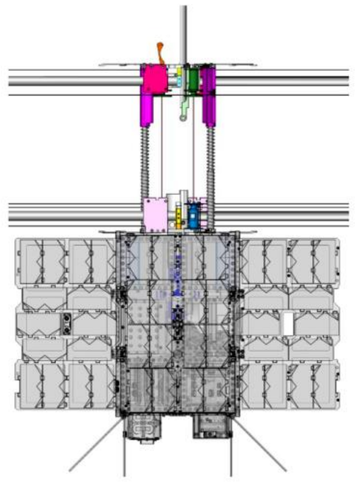
Stowed



Extended



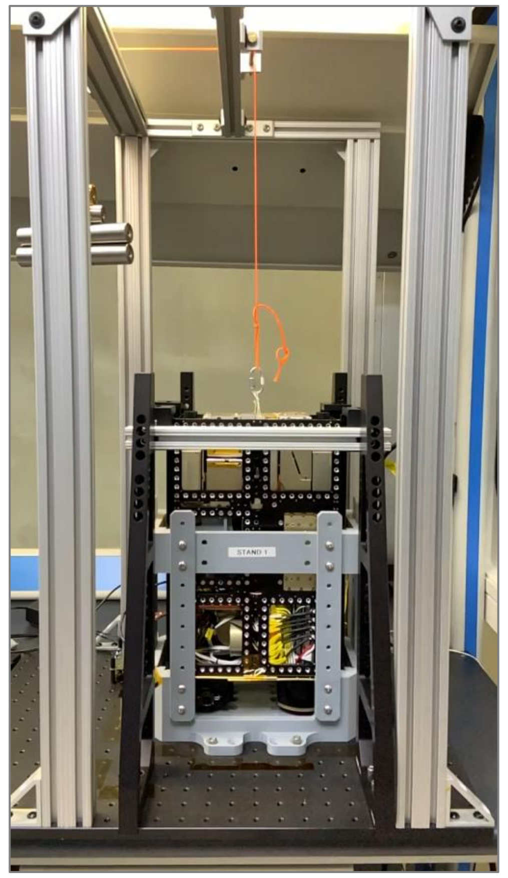
Loops Deployed



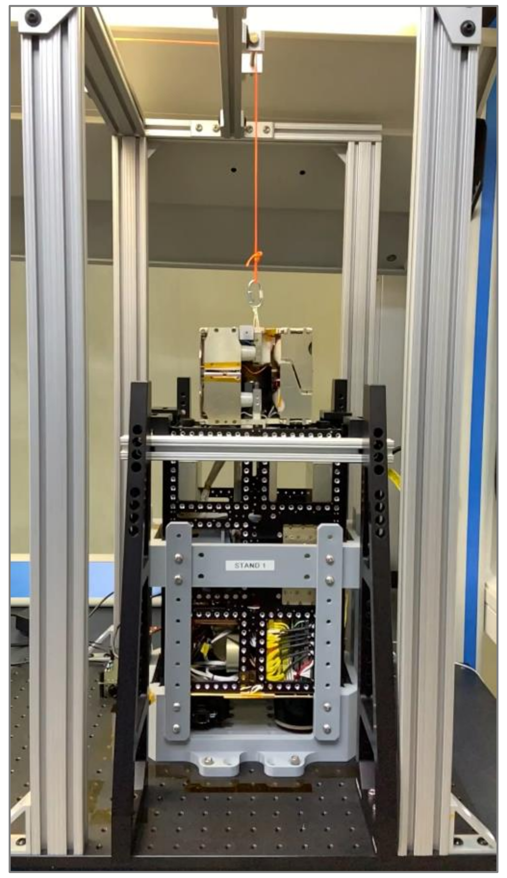
Monopole Deployed

Videos of Deployment Testing of an Early Prototype

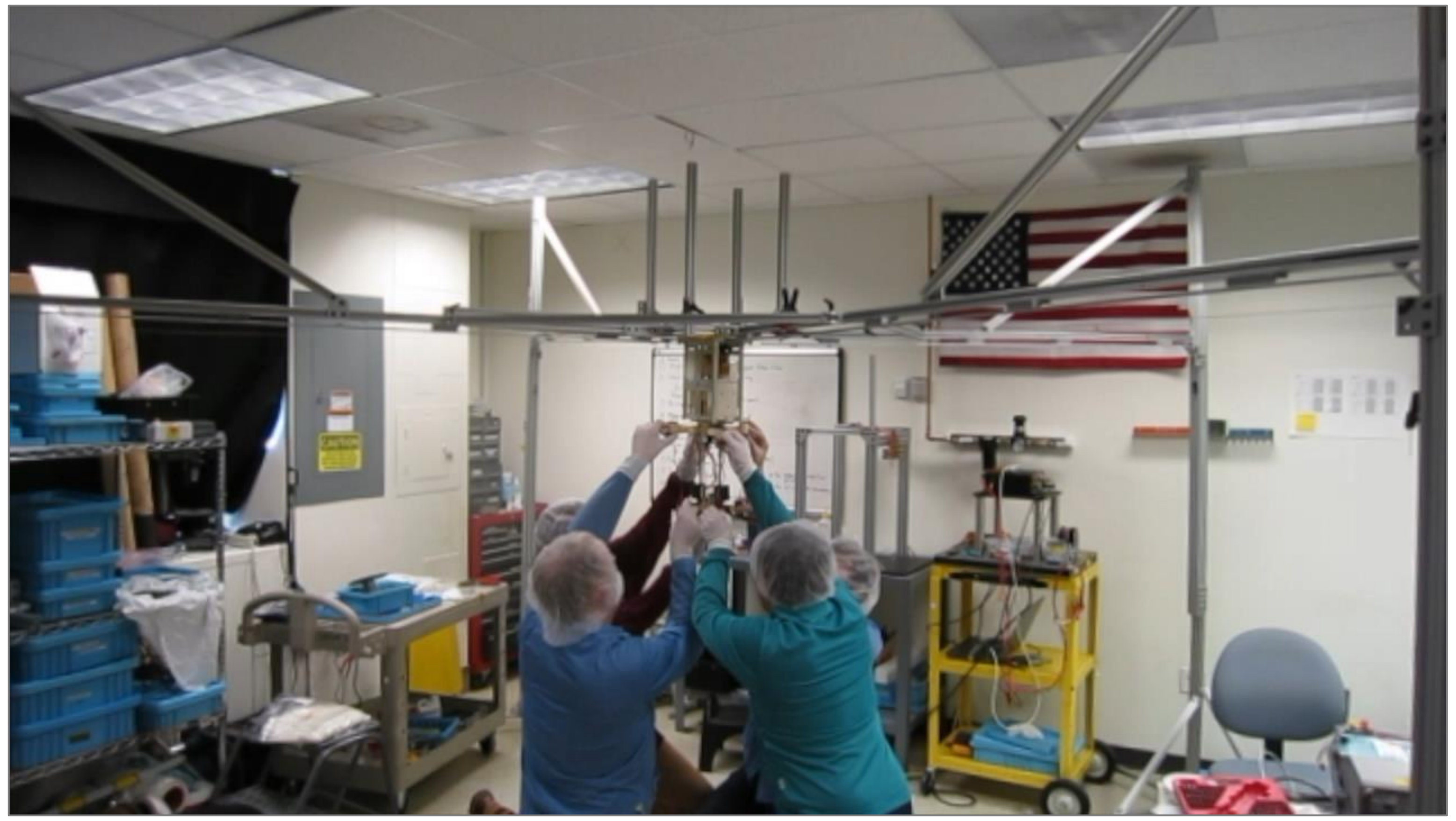
Stowed to Extended



Extended to Loops Deployed



Full Loops Deployment



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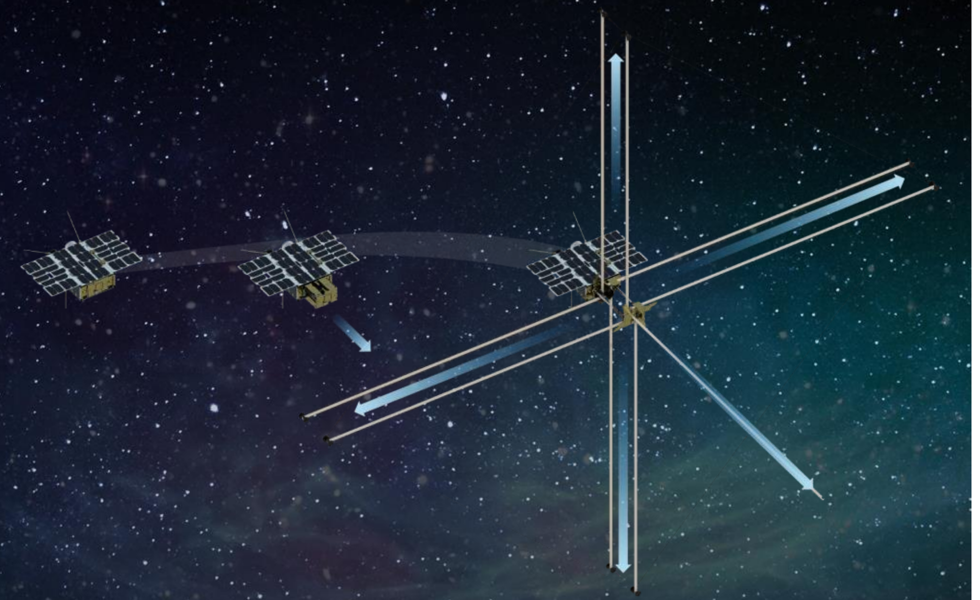

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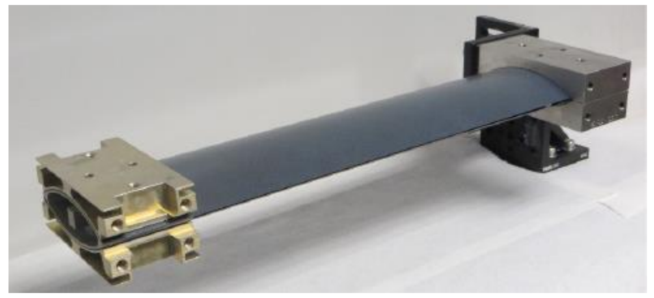
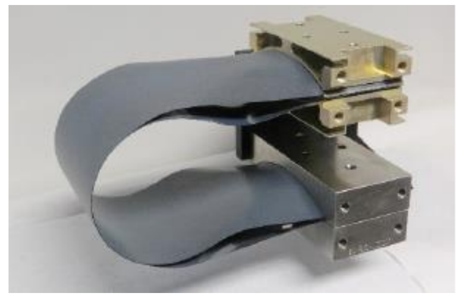
PRECISION STRUCTURAL DEPLOYMENT USING FLEXIBLE, THIN COMPOSITES

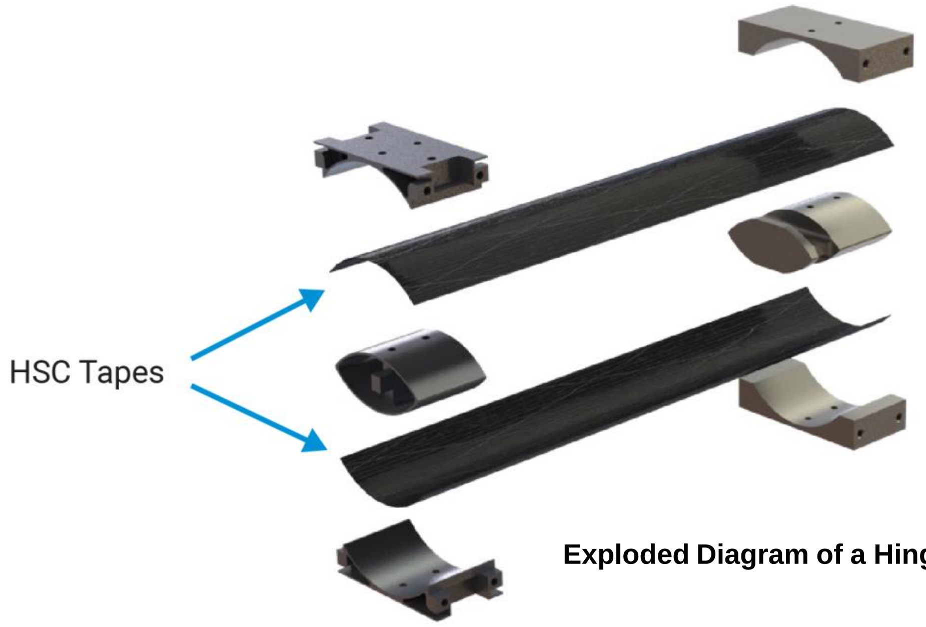
Hinge mechanisms made from thin, high strain composites (HSC) enable deployment to high shape precision



Deployed Hinge



Stowed Hinge

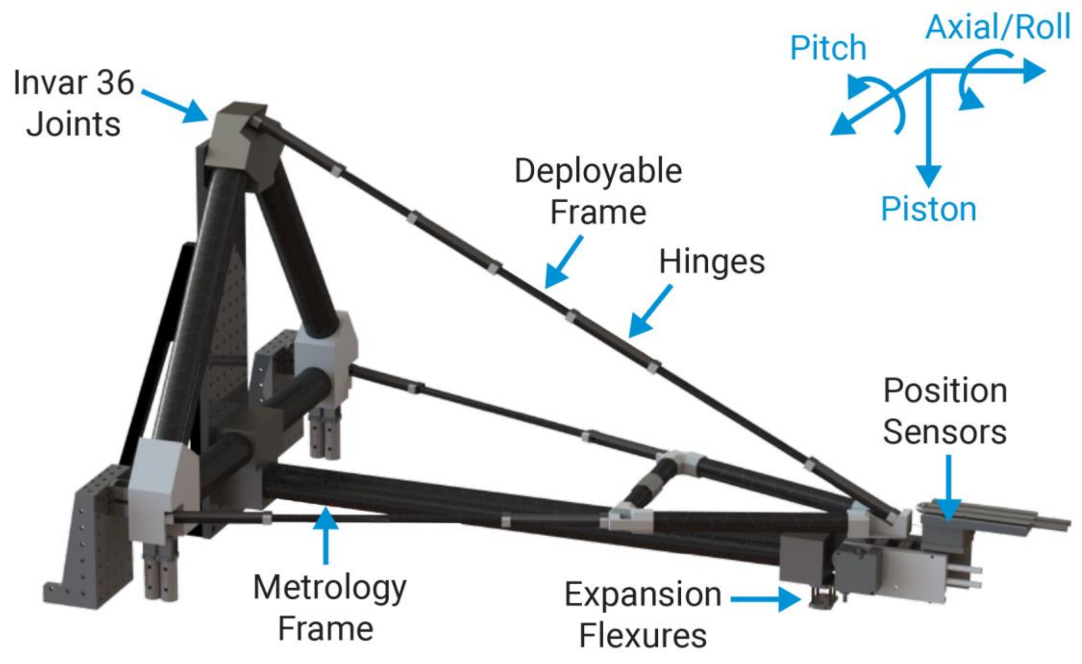


Exploded Diagram of a Hinge

HSC Hinges enable more precise deployment than the mechanisms used in the James Webb Space Telescope (JWST) Deployable Optical Test Article (DOTA)

Measurement	Hinge	Frame	JWST DOTA[1]
Piston (μm)	0.27	2.27	30
Roll (μrad)	5.83	4.01	N.A.
Pitch (μrad)	1.49	6.28	215
Axial (μm)	0.27	0.24	33

- Structures made from multiple HSC hinges enable complex deployments.
- The frame shown below is a concept metering structure for deployable space telescope



1.Reynolds, P., Atkinson, C., and Gliman, L., “Design and Development of the Primary and Secondary Mirror Deployment Systems for the Cryogenic JWST,” 37th Aerospace Mechanisms Symposium, 2004.

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