

# Novel Deployable Sunshade for a Formation-Flying Telescope

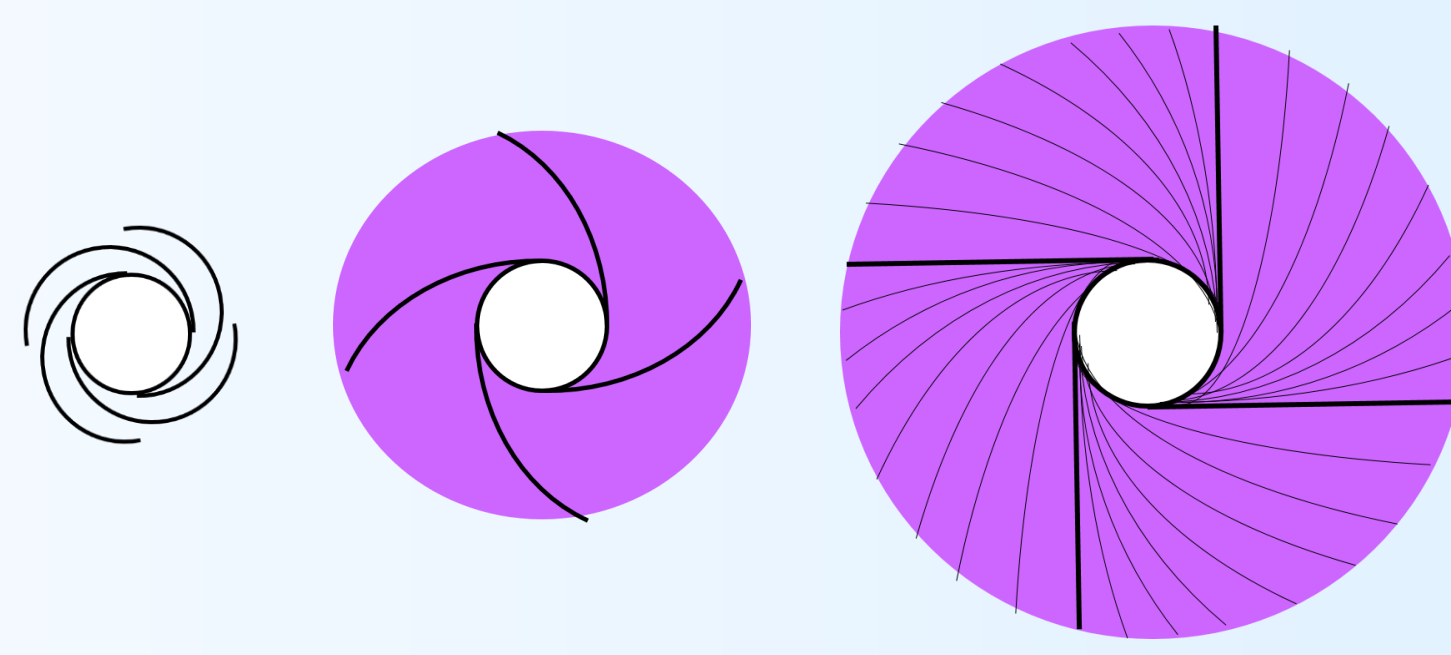
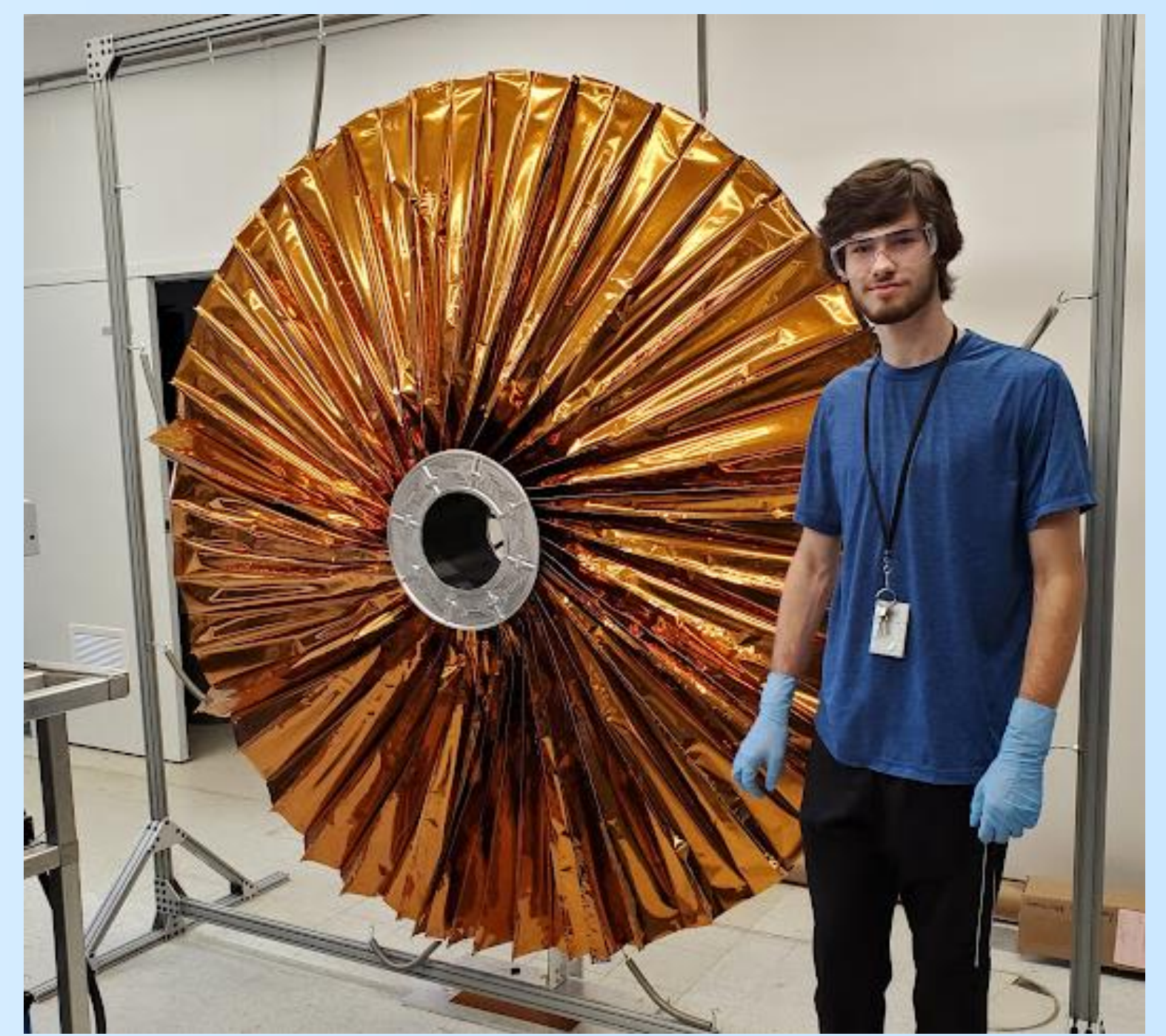
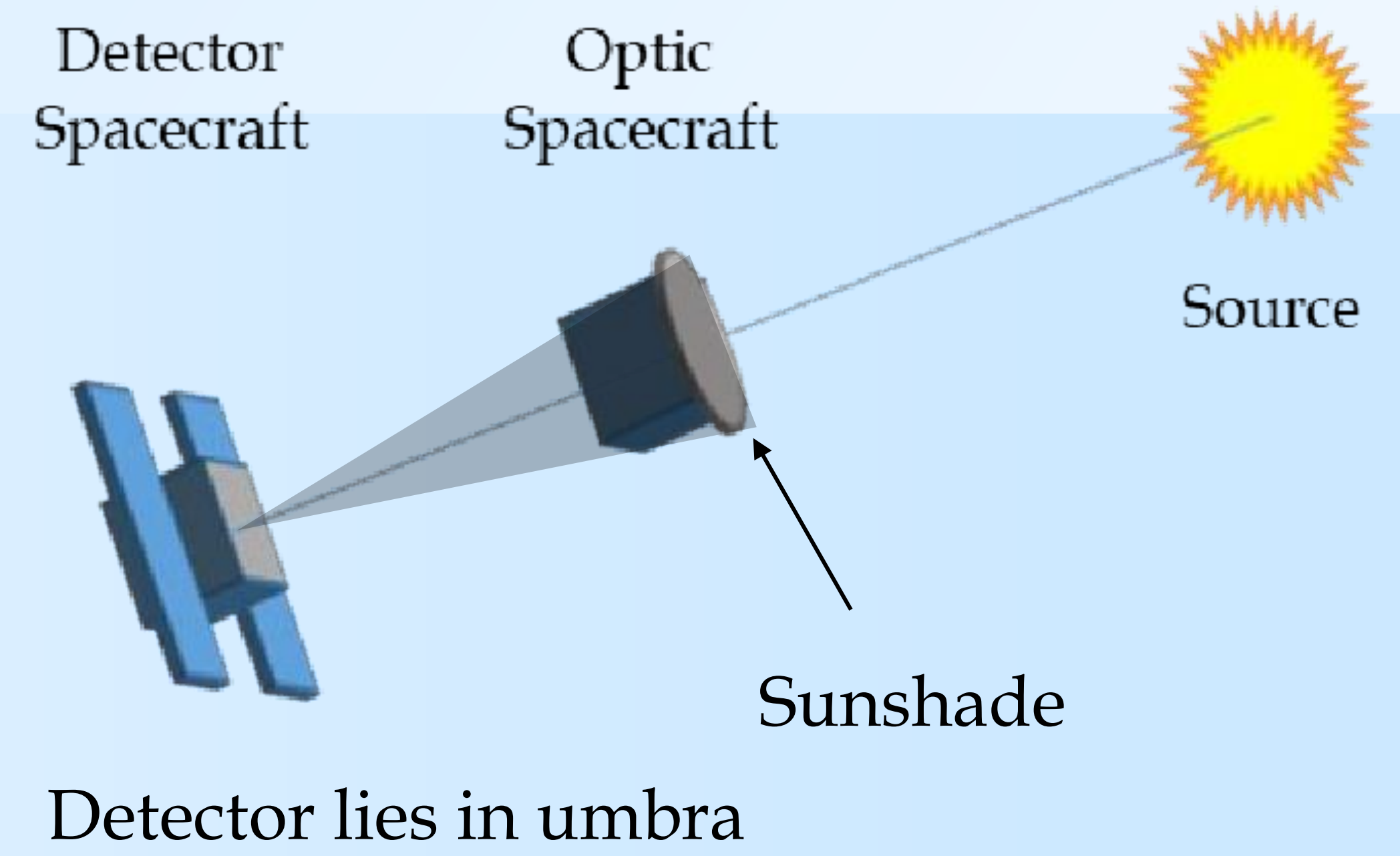
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### Motivation/Problem Statement:

- Design and build a meter-class sunshade that can stow into a compact package and deploy from a CubeSat or SmallSat.
- Enables an ultrahigh angular resolution EUV telescope or an externally occulted coronagraph.
- Science detector is placed in umbra of sunshade to improve signal to noise ratio.
- Shade can also be mounted on a boom for single spacecraft missions

### Project Summary:

- Deployable sunshade is based on folding paper party decoration.
  - Cellular structure creates strong, rigid form.
  - Instead of folding flat, the cellular fan is wrapped around a central hollow core to accommodate a focusing optic.
  - Imbedded spring ribs deploy the cellular fan into a large disk.
- Shade is constructed of thermal blanket materials and is sewn together rather than glued.
- Design bears some resemblance to JPL starshade, but is a much simpler design
  - JPL design includes pantograph-like mechanical structure and motors to drive deployment.



### Overview

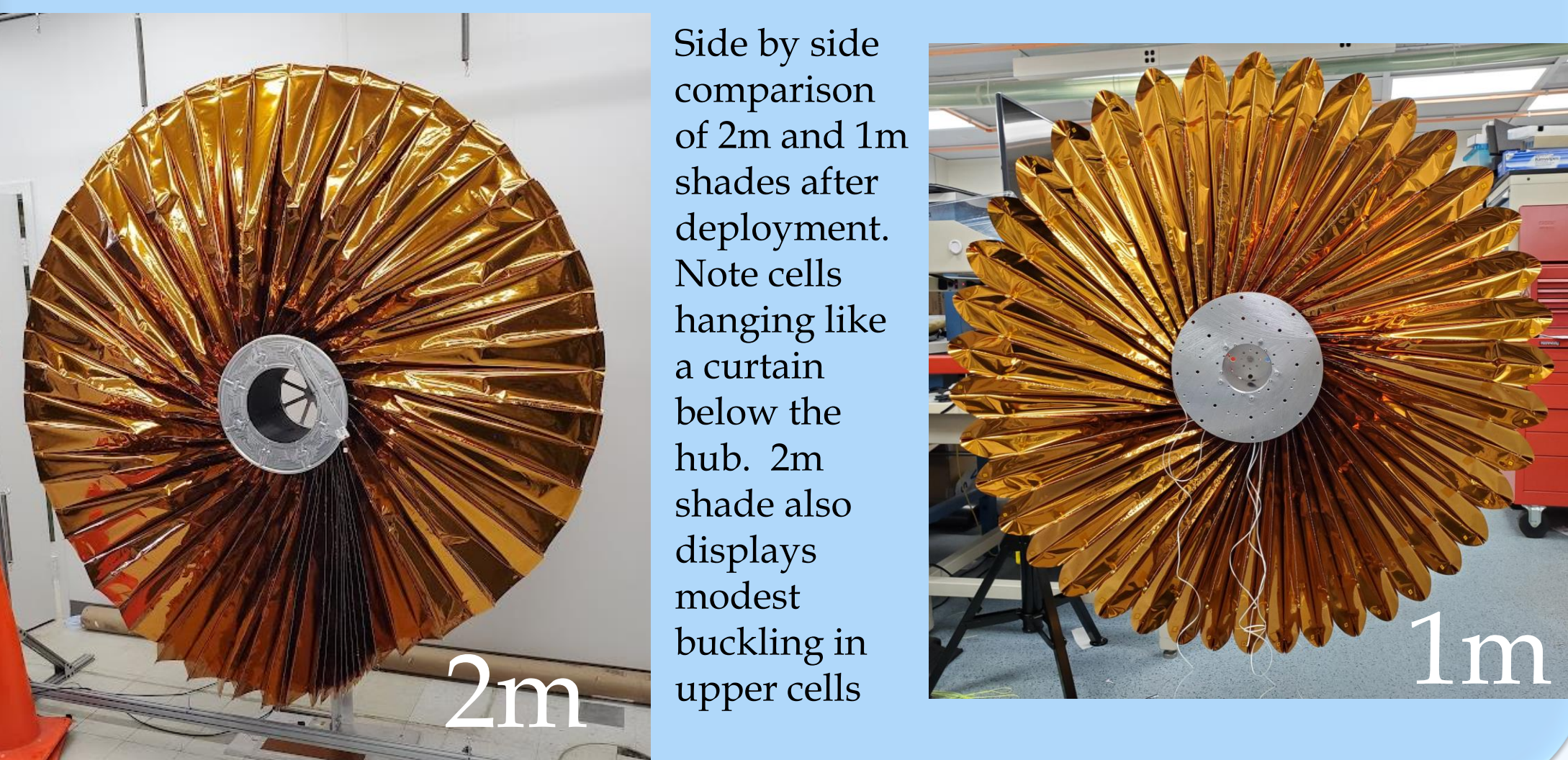
- FY21: Initial proof of concept.
  - Fabricated 1m units from both polyester film and kapton film.
  - Conducted thermal testing of kapton unit at atmospheric pressure
- FY22: Fabricated a 1m diameter kapton shade and subjected it to environmental testing.
  - Vibration testing
    - 3 axes GEVS
  - Thermal-Vacuum Testing
    - -50C to +90C, 4 cycles
    - Successful deployment at -50C
- FY23:
  - Scaled shade to 2m diameter, which is the size needed for intended mission concept
  - Revised deployment mechanism, method of hub attachment and stowing method.
- FY24:
  - We have proposed to subject the 2m shade to environmental test. Our goal is to achieve TRL6 for the 2m shade.

### Scale Shade to 2m

Length and width of the cells was doubled whereas the film thickness was held at 2 mils. Similarly, the expansion wires were held at 0.029" diameter because the 1.0 m shade had excessive expansion energy. Two issues were identified:

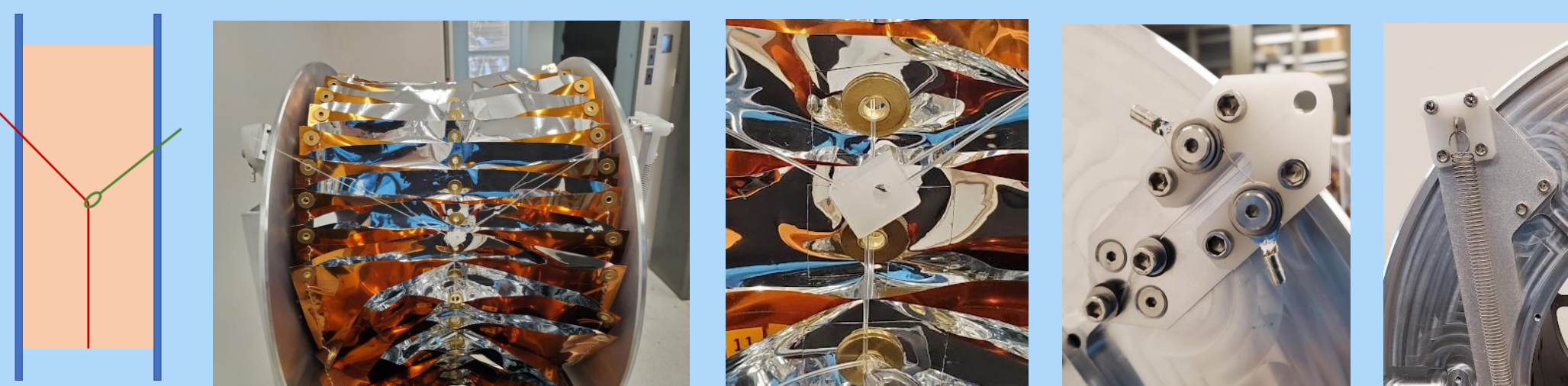
- Existing spring wires were too weak to deploy shade under full gravity. Shade deployed ~90% but wires had insufficient force to lift some cells.
- Cell size was too large relative to thickness of film, resulting in slight buckling of cells.

Both issues would likely not be relevant in zero gravity, but both must be addressed to demonstrate successful operation on Earth.



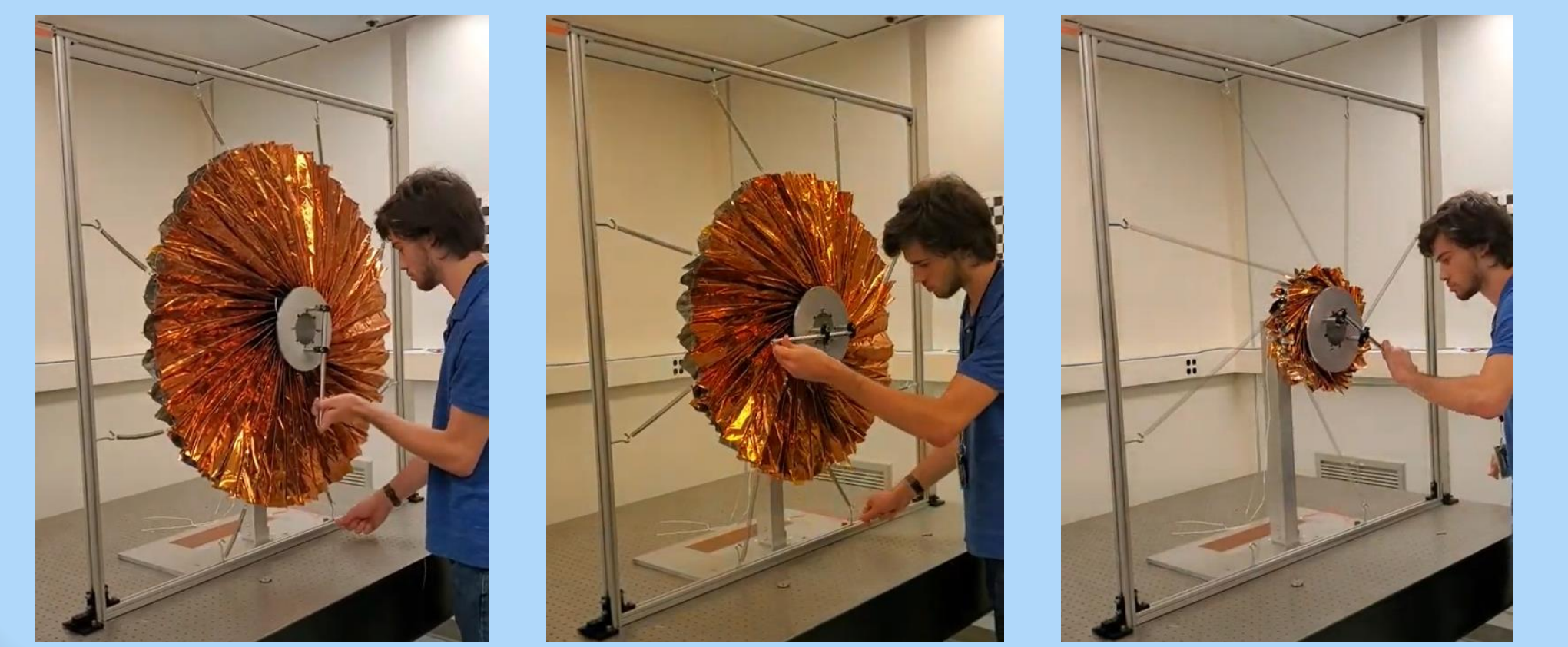
### Deployment Mechanism

A "slipstring" deployment method was developed at the end of FY22. During FY23 this method was updated to a flight qualifiable design and revised to ensure no elements of the device remained in the path of the shade during deployment. A restraining line winds around the stowed pack, passes through a restraining bead, which redirects the nylon line to the hub flange where it passes over a nichrome heater wire. To deploy the shade, the heater is activated, which melts the nylon restraint line. The bead is attached to an extension spring which retracts the bead out of the shade's expansion path. The deployment mechanism is simple, relying only spring forces and a simple low voltage heater circuit.



### Stowing Fixture

The shade stowing procedure has proved to be challenging and has undergone improvements each year of the project. Stowing the shade places a great deal of strain on the shade, imposing shear forces on the flat leaves of film from which the shade is constructed. Uneven distribution of the shear forces results in tearing of the film near seams. In FY23 we developed a method for stowing the shade that distributes the shear forces evenly. The shade is mounted in a frame with extension springs attached at a minimum of 8 points along its perimeter. The shade is then wound onto the hub by rotating the hub. The springs ensure uniform packing of the shade and thus minimizes shear forces in the pack.



Unit	FY21 Prototype	FY21 SN001	FY21 SN002	FY22 SN003	FY23 SN004
Deploy Diam.	0.60 m	1.0 m	1.0 m	1.0 m	2.0 m
Stow Diam.	9 cm	25 cm	21.5 cm	27.5 cm	40.6 cm
# Cells	40	48	40	40	40
Mass of shade	154 g	420 g	537 g	740 g	2000 g
Edge style	Stairstep	Stairstep	Stairstep	Flower Petal	Smooth
Type of Film	Polyester	Polyester	Kapton	Kapton	Kapton
Film thickness	2 mil	2 mil	2 mil	2 mil	2 mil
Stitching	Polyester	Fiberglass	Fiberglass	Fiberglass	Fiberglass
# hub anchors	4 (10%)	4 (8.3%)	4 (10%)	5 (12.5%)	40 (100%)
# spring wires	0	0	40	80	80
Wire length	N/A	N/A	0.30 m	0.45 m	0.9 m
Wire diameter	N/A	N/A	0.029"	0.029"	0.029"
Release	Manual	Manual	Manual	Slipstring	Slipstring
Stow method	Wrapper	Wrapper	Wrapper	Drawstring	Spring Frame
Env. Test?	No	No	Therm cycles -50C to +90C in atmosphere	Vibe: GEVS T-VAC: -50C to +90C	No
Deployment	Strong	Moderate	Moderate	Very Strong	Weak

### Future Funding & Applications

- We intend to submit an H-Fort proposal in FY24
- The deployable sunshade would be needed for any smaller precursor mission prior to development of the Coronal Microscale Observer (CMO) mission.