Jet Propulsion Laboratory
California Institute of Technology

Starshade Technology: Current Status at JPL

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NASA Exoplanet Exploration Program

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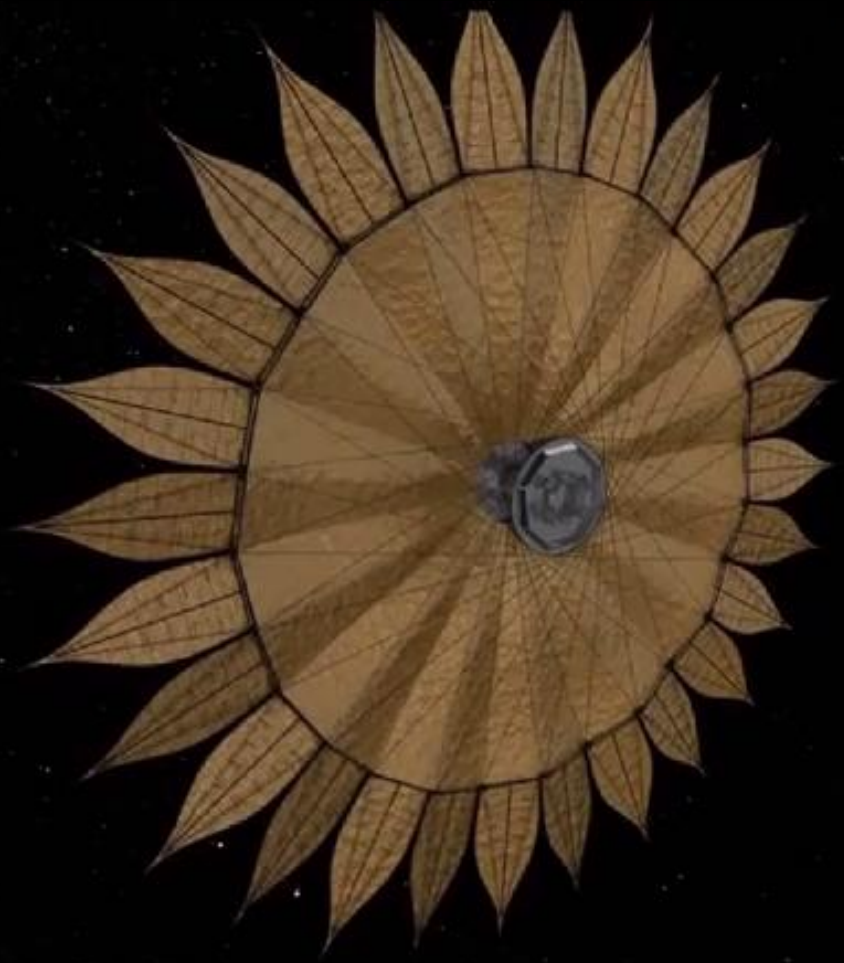
Starshade Technology Development Areas

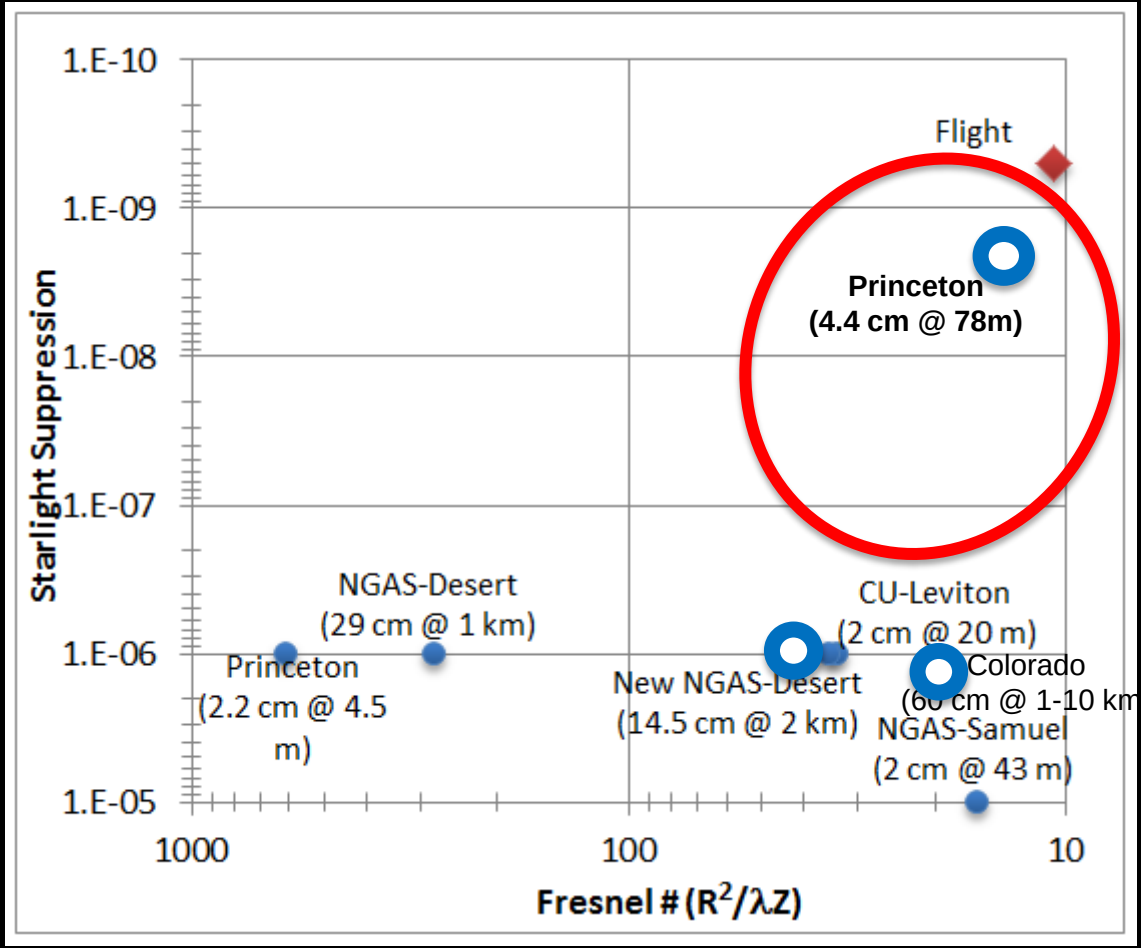


1. Contrast performance demonstrations and optical model validation
2. Controlling edge-scattered sunlight
3. Lateral formation-flying sensing accuracy
4. Flight-like petal fabrication
5. Inner disk deployment
6. Petal latching and unfurling

Fresnel Number

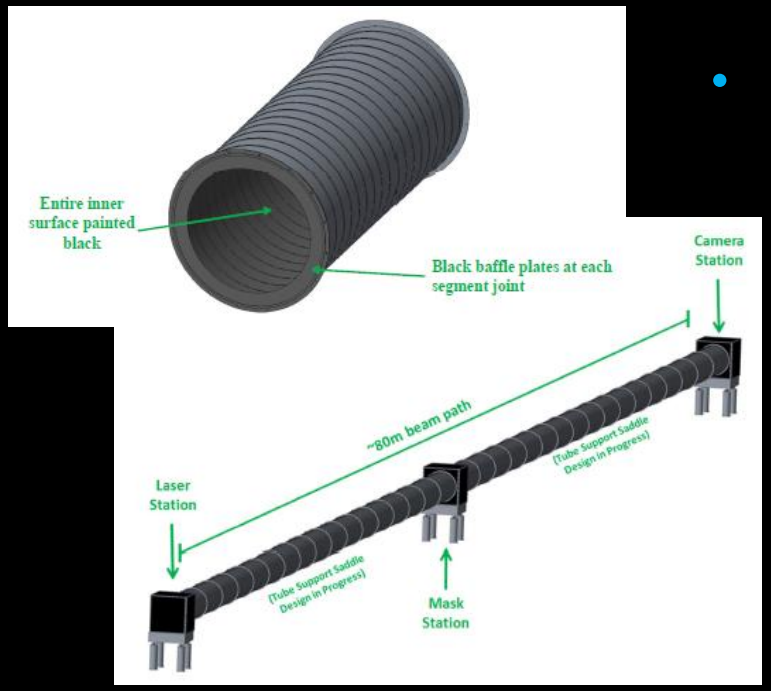
- F = radius^2 / Wavelength / Distance
- Flight: r=17 m, 34,000 km, 600 nm. F = 14
- Big F, e.g. F=100: Starshade close, highly resolved by telescope.
- Most experiments to date have been big F.
- Easy to get high contrast, because scatter is localized to defects.

Optical Performance Technology Gap

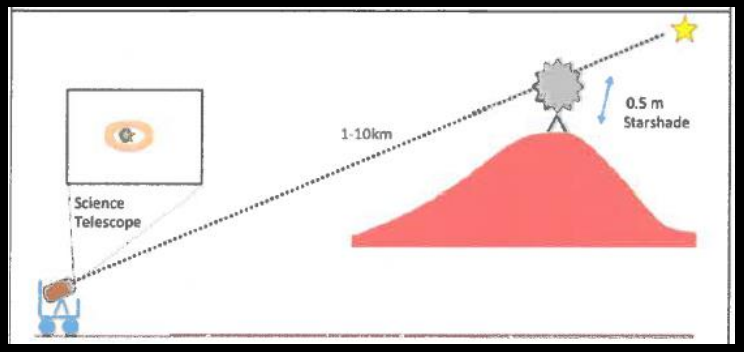


Scheduled demos Past demos Goal

Current Optical Performance Activities

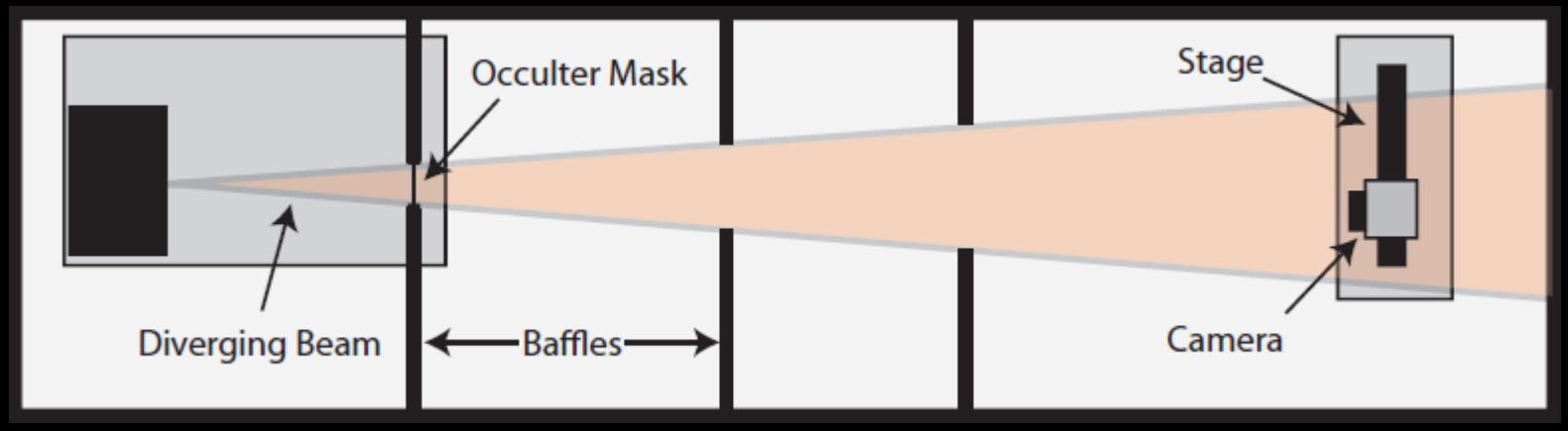


- Status
  - ❖ *~78m baseline with 44 mm mask (Princeton and JPL TDEM)*
    - ➢ *Testbed being constructed*
    - ➢ *Test plan approved by the ExEP TAC*
    - ➢ *44 mm starshade fabricated*
    - ➢ *Operational in Q1 CY16*

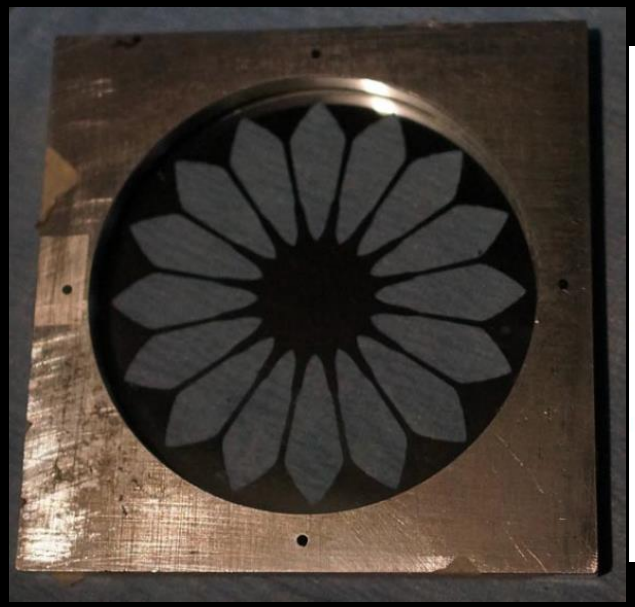


  - ❖ *Mountain ridge demonstration with longer baselines and larger starshades (JPL university IRAD funding UC Boulder)*
    - ➢ *Funding approved*
    - ➢ *Test plan being written*
    - ➢ *Completion end FY16*

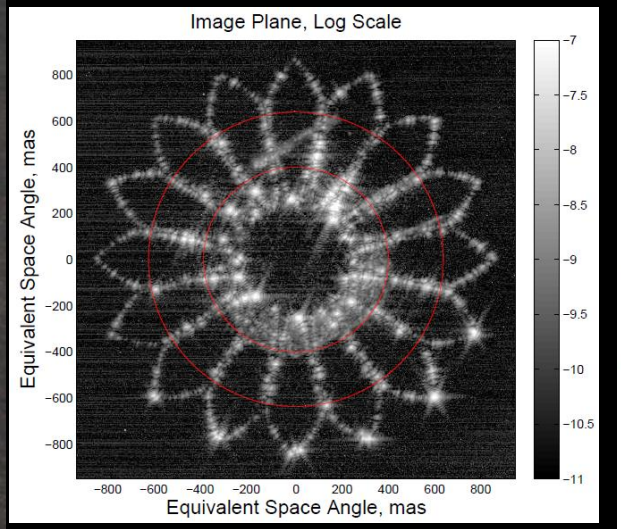
Princeton Starshade Testbed



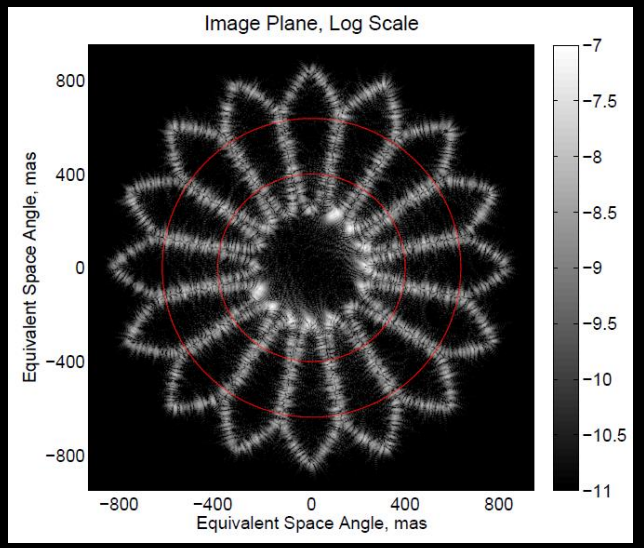
Mask



Measurement



Model



At Princeton: Jeremy Kasdin, Dan Sirbu, Robert Vanderbei

Northrop Grumman Desert Testing

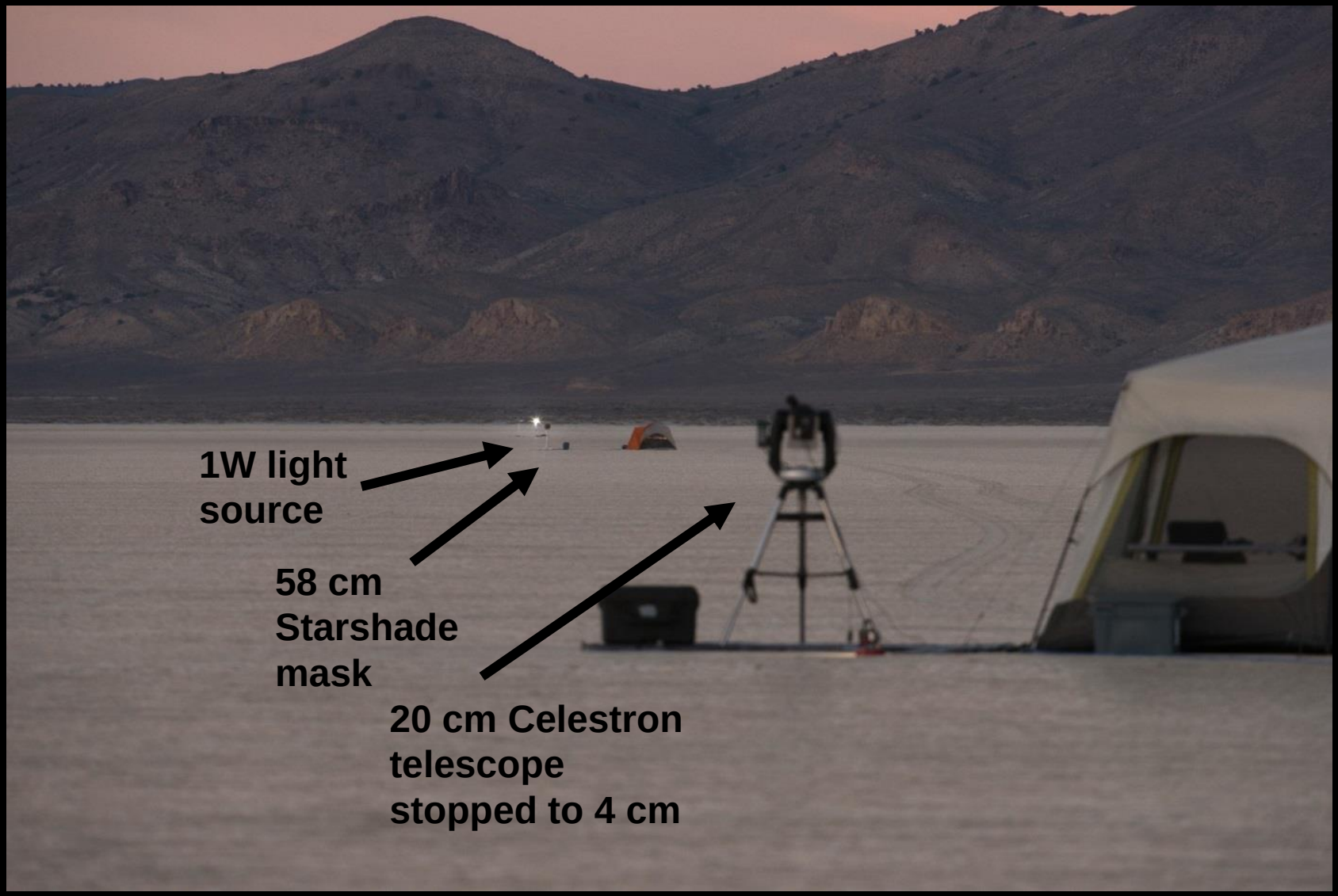
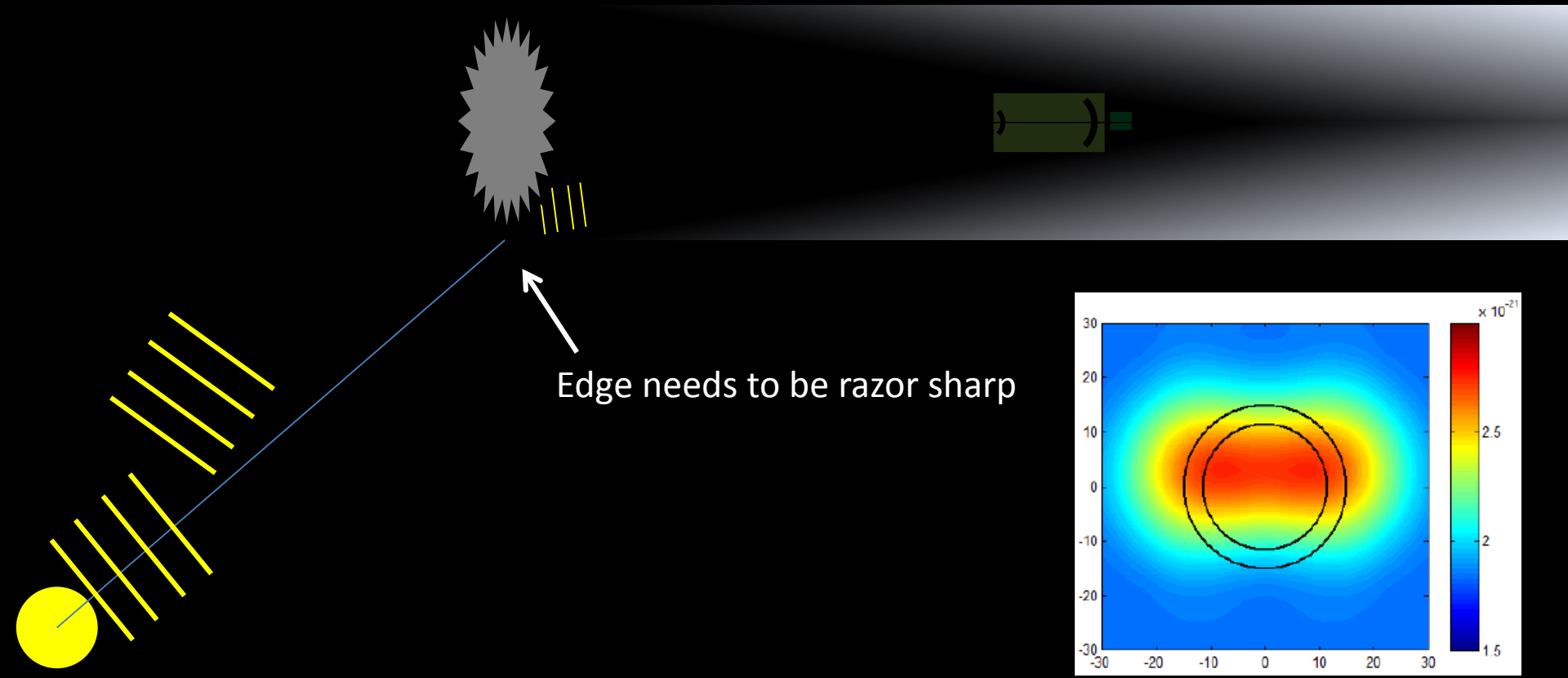


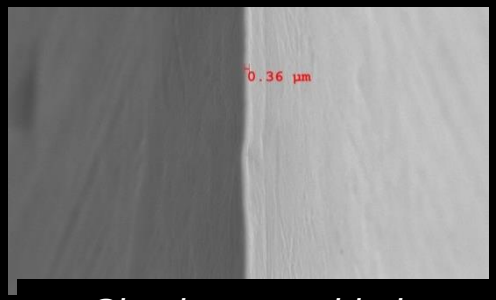
Photo credit NGAS

Solar Glint



Edge needs to be razor sharp

Optical Petal Edge Activities



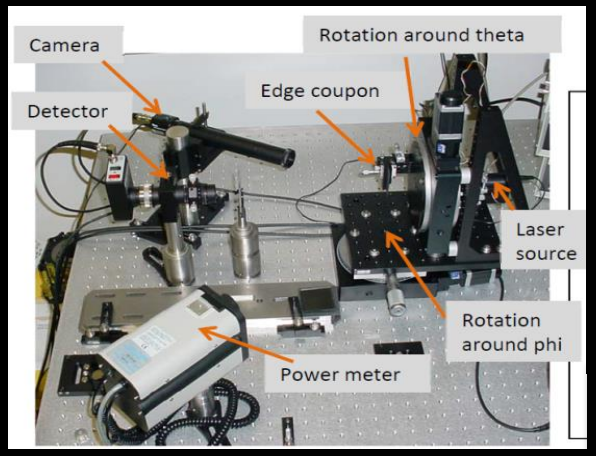
Shaving razor blade

Status

- Prototype optical edges using have been assembled and are being tested for mechanical properties.
  - ❖ *Etched amorphous metal edges recently showed some shape distortion due to residual stress relief at manufacture during etching.*
  - ❖ *Thin stainless steel edges are being pursued.*
  - ❖ *Can we make edges darker without making them much wider?*
  - ❖ *Diffraction is the limiting effect: how to reduce?*

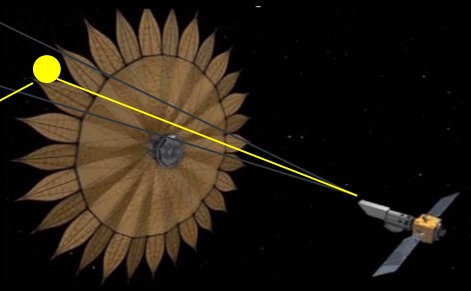
Planned

- Continue identifying candidate materials that meet both mechanical and optical requirements
- Produce additional full-size edges and assembled for testing.
- Down-select a material and integrate into the full-scale petal.



Scatterometer Testbed

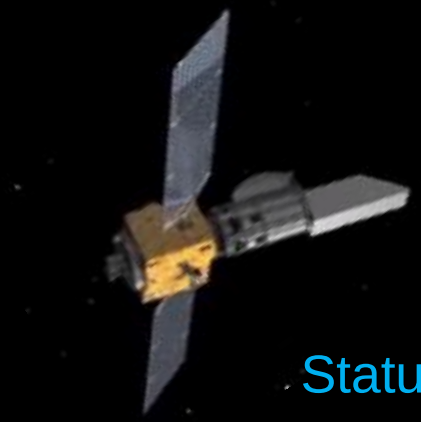
Keep the Edges Clean!

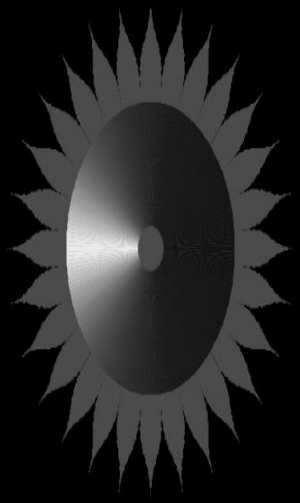


An Earth-size planet at 10 parsecs projects as a 1 mm diameter particle on the edge of the starshade.

Equivalent to 10,000 particles of dust 10 um in diameter, spread over about 40 m of the starhade edge.
Will it accumulate on the edges?

Reflection of Light from Earth and other Bodies on the Front Surface

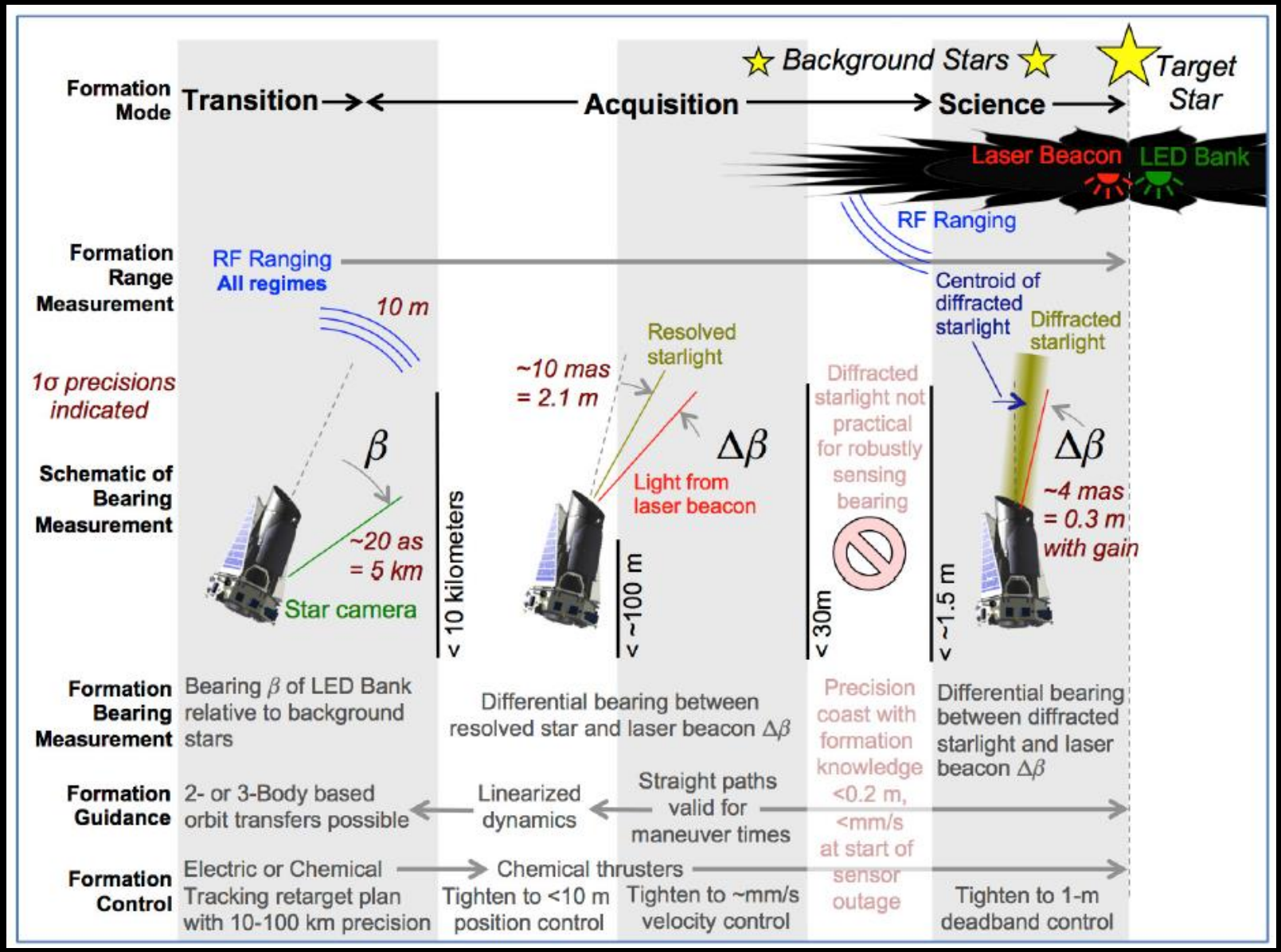




Status

- No sun allowed on telescope-facing surface
- Milky way, planets behind telescope is ok
- Still studying whether lambertian or specular is preferred.
- Black kapton is baseline material.

Formation Flying Modes



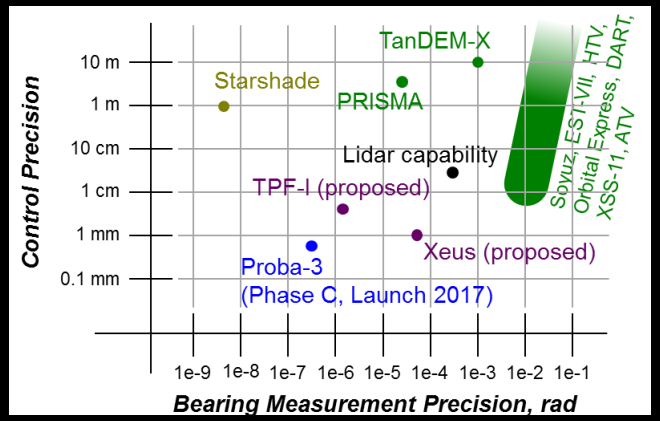
Formation Flying Sensing Accuracy Activities

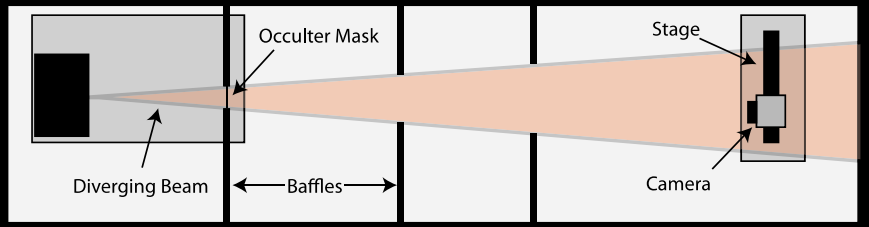
Status

- System engineering of sensor for scaled testbed in progress (Princeton/JPL TDEM-13)
- Demonstrated initial feasibility of estimator and dead-banding control for observations
- Testbed enclosure being constructed (same as optical demonstration at Princeton)

Planned

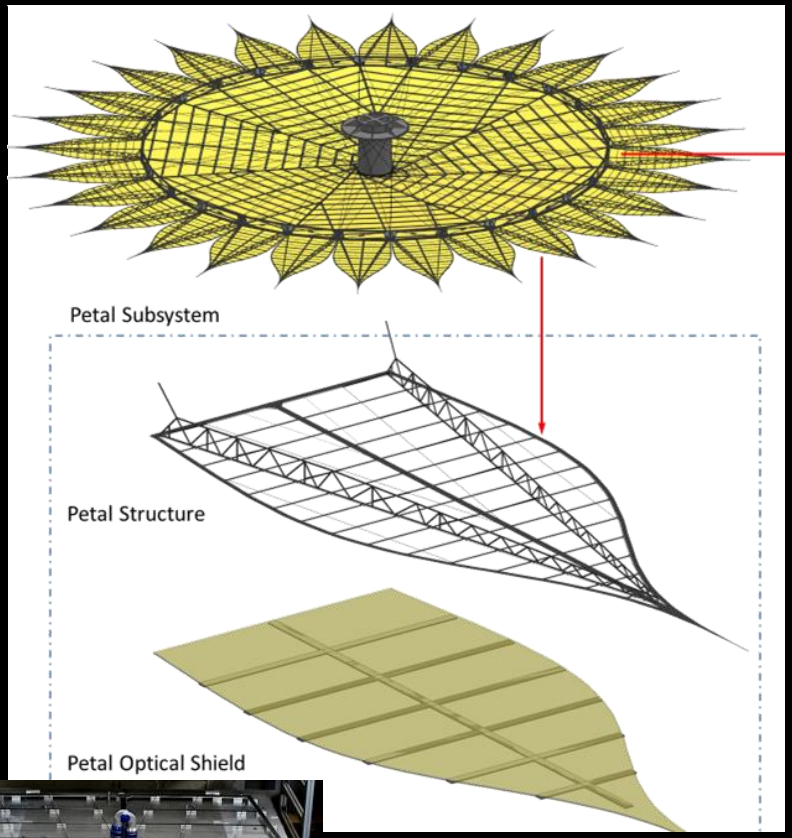
- Demonstrate feedback control with milli-arcsecond bearing precision in scaled testbed with sensor and GNC
- Demonstrate science-precision control using sensor model verified in testbed

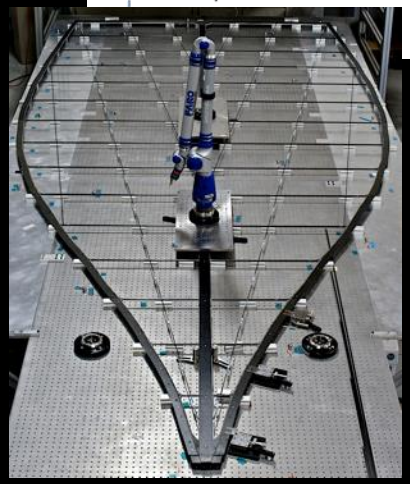




Modify optical testbed and demonstrate formation flying sensor performance across flight equivalent shadow

Petal Fabrication Activities





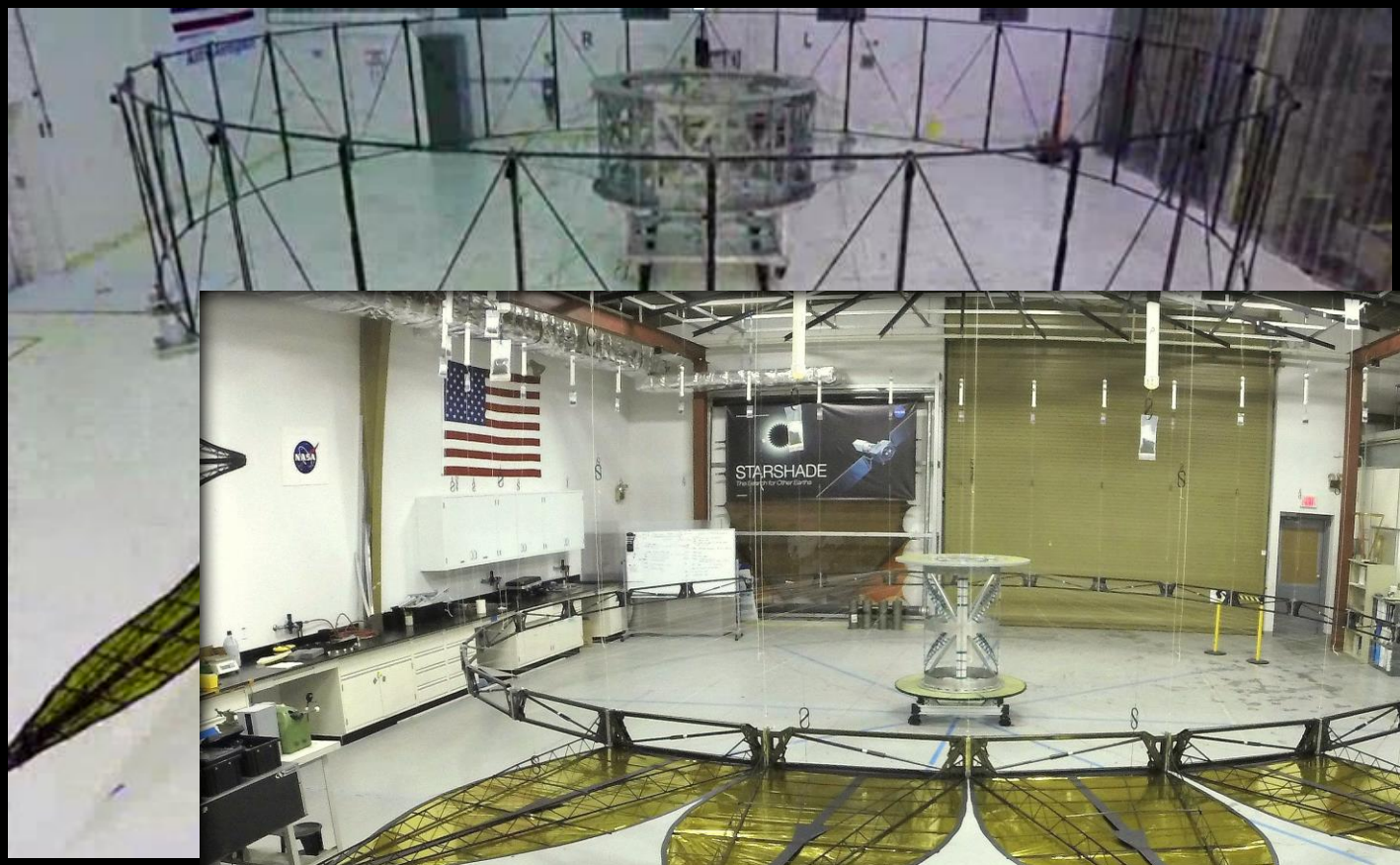
Status

- Design of 7m petal with flight-like materials underway *(Princeton and JPL TDEM-12)*
- Designing flight-like interfaces to integrate petal to overall structure
  - Base hinges
  - Launch tie downs
  - Petal unfurling mechanism
  - Optical edge and tip interfaces

Planned

- Fabricate a full-scale petal with optical edges and optical shield *(Princeton and JPL TDEM-12)*
- Demonstrate stowing and unfurling the full-scale petal to verify shape tolerance requirements *(Princeton and JPL TDEM-12)*

Thuraya → Starshade



Inner Disk Deployment Activities

Status

- Completed rebuilding half-scale (10m) perimeter truss testbed with upgraded design and more flight-like parts
- New petal interface integrated

Planned

- Build flight-like spokes
- Verify inner disk deployment tolerances
- Integrate optical shield *(JPL TDEM with NGAS support)*

Optical Shield Activities

Status

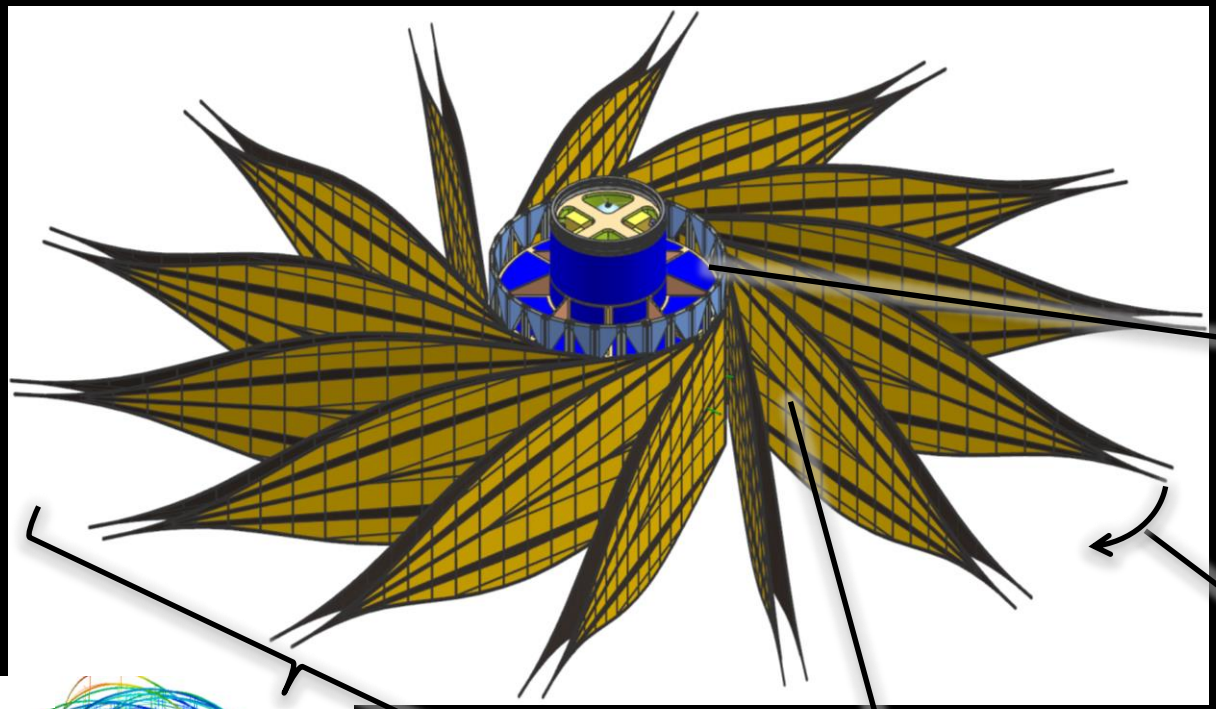
- Operational 1/10-scale (2m) testbed completed for demonstrating origami shield designs
- Working on designs for shield/truss interfaces

Planned

- ¼-scale testbed (5m)
- Integrate ½-scale optical shield into existing ½-scale testbed *(JPL TDEM with NGAS support)*

SBIR Activities

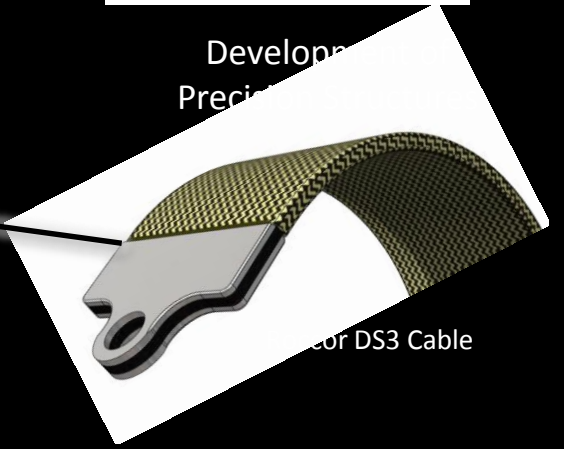
JPL Starshade Development via the Roccor & Tendeg SBIR Efforts



ROCCOR

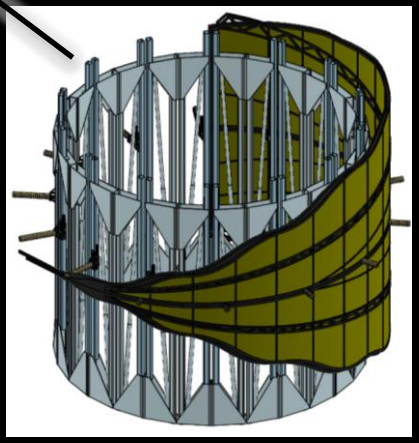
TENDEG

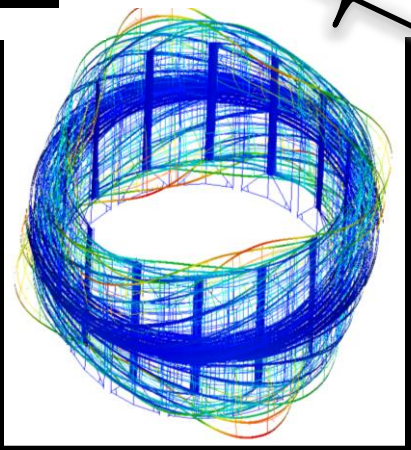
Develop… Precis…



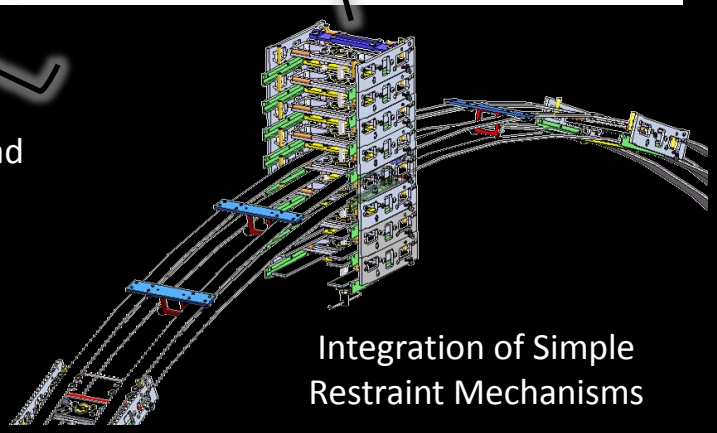
…cor DS3 Cable

Petal Furling and Controlled Release





Launch Load Analysis



Integration of Simple Restraint Mechanisms