Probe Class Starshade Mission STDT Progress Report

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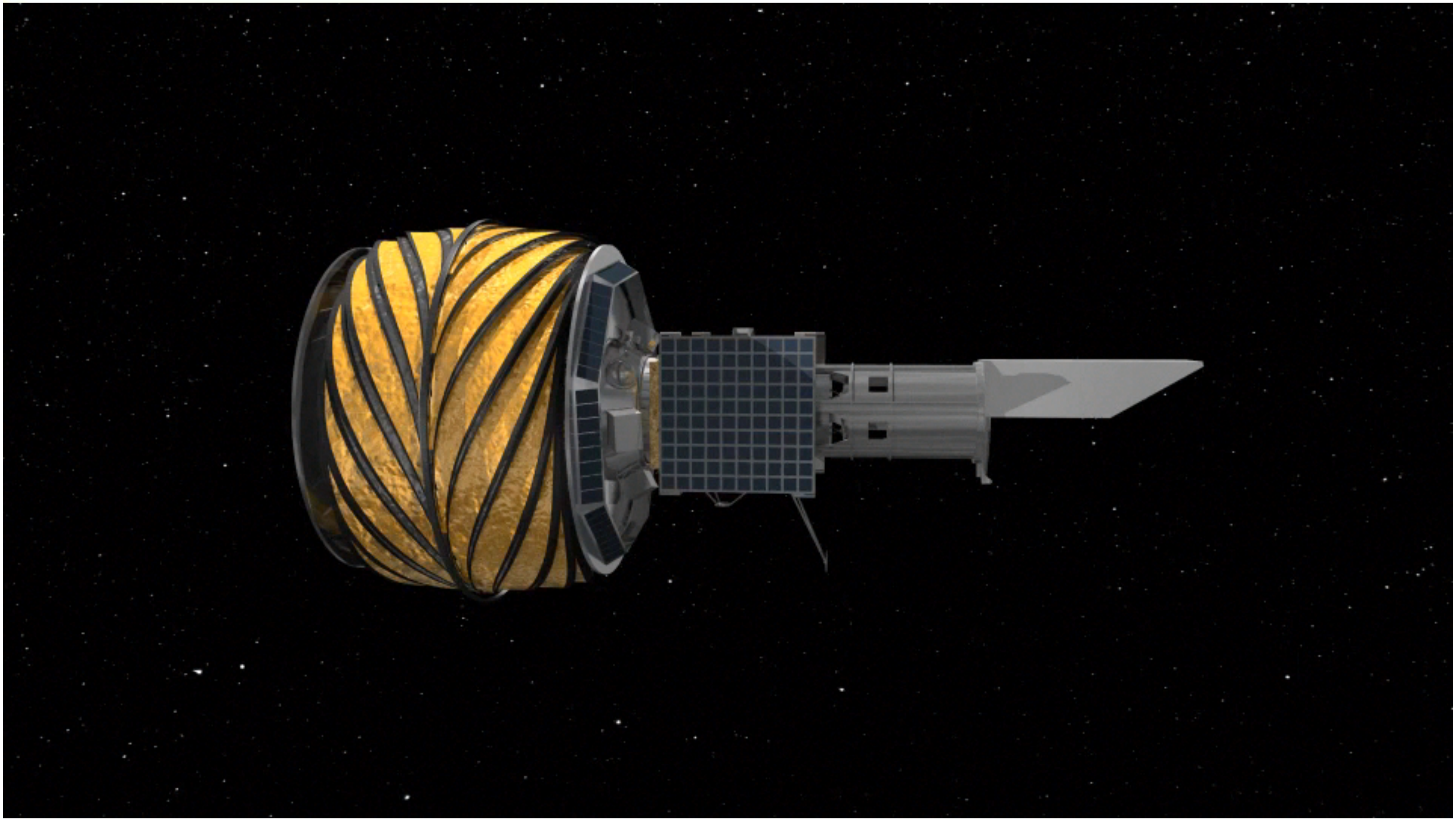
"Can we find another planet like Earth orbiting a nearby star? To find such a planet would complete the revolution, started by Copernicus nearly 500 years ago, that displaced Earth as the center of the universe. . . The observational challenge is great, but armed with new technologies. . . astronomers are poised to rise to it."

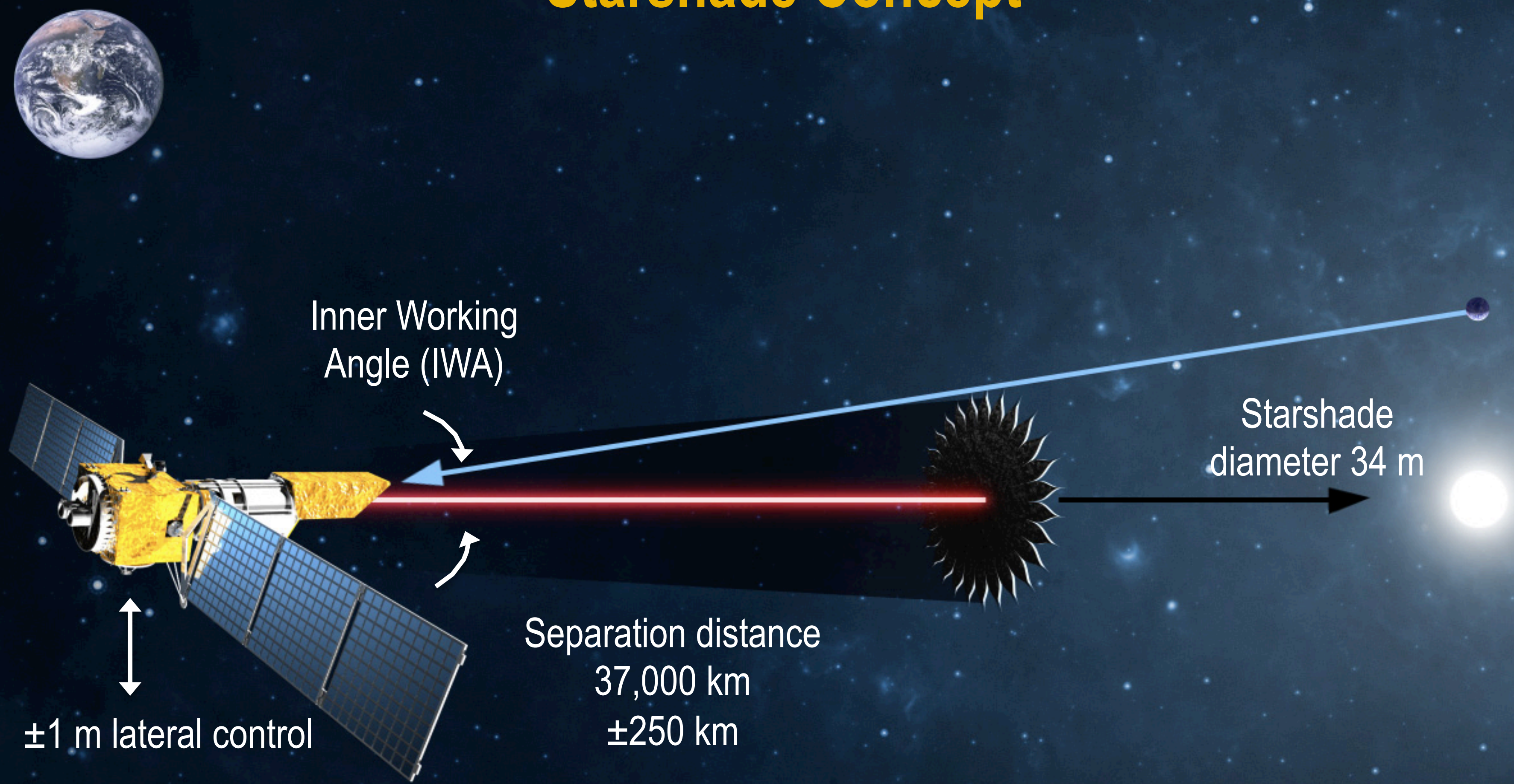
–New Worlds, New Horizons, 2010

Starshade Concept

ExoPlanet Exploration Program



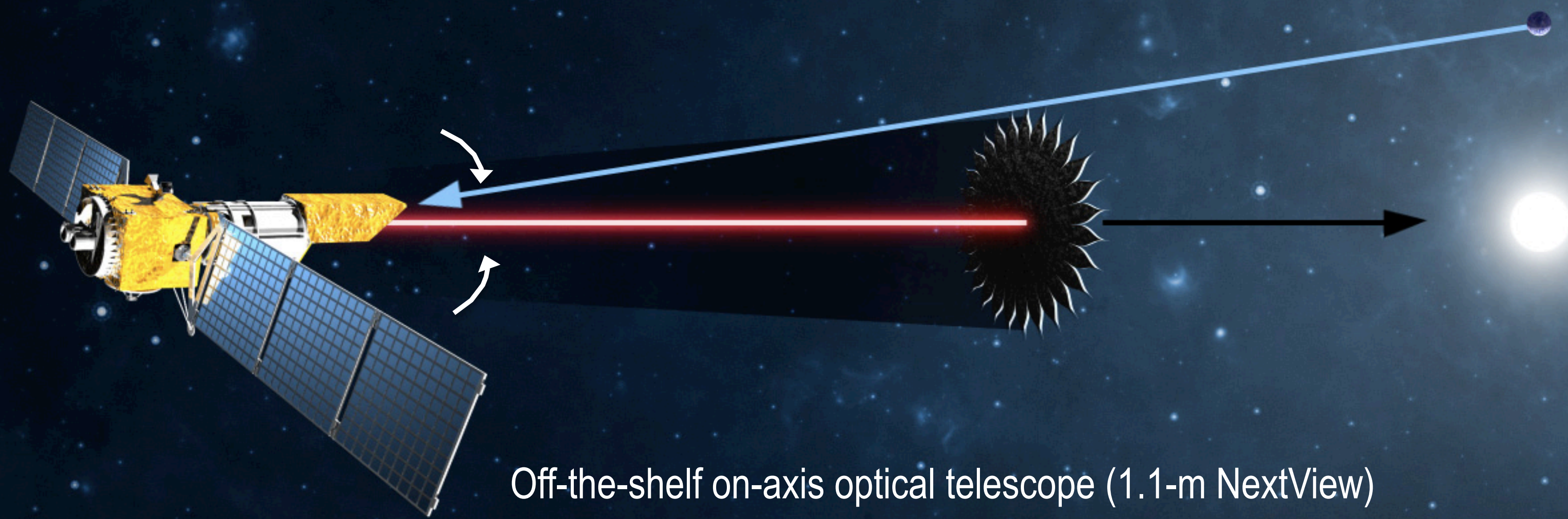
Starshade Concept



- Contrast and inner working angle are decoupled from the telescope aperture size
  - A simple space telescope can be used
  - No wavefront correction is needed
- No outer working angle

Exo-S Baseline Design Overview

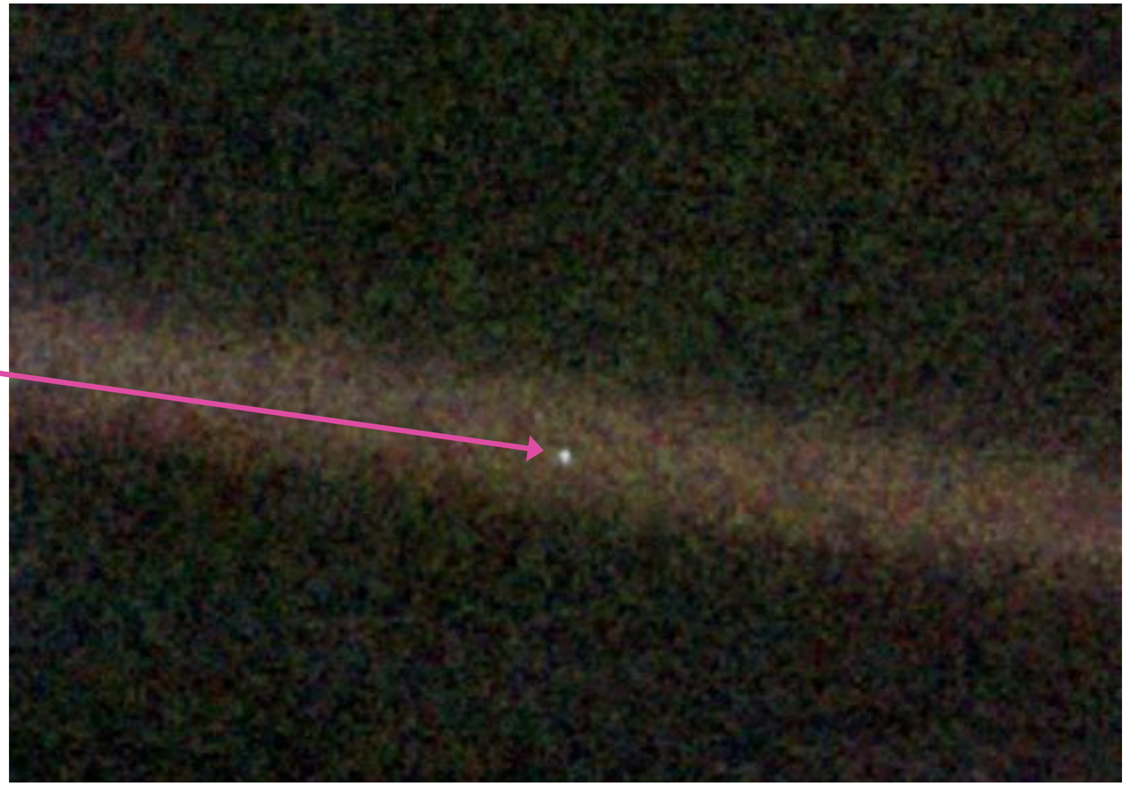
Band	Blue	Green	Red
Wavelengths (nm)	400–630	510–825	600–1,000
IWA (mas)	75	95	115
Separation (Mm)	47	37	30



- Off-the-shelf on-axis optical telescope (1.1-m NextView)
- Heliocentric, Earth-drift away orbit (Earth-Sun L2 is also a possibility)
- Move telescope, not starshade for retargeting
- Instrumentation: imager and low-resolution spectrograph
- Single launch vehicle

Science Goal #1:
Photometric Search for New Exoplanets

ExoPlanet Exploration Program

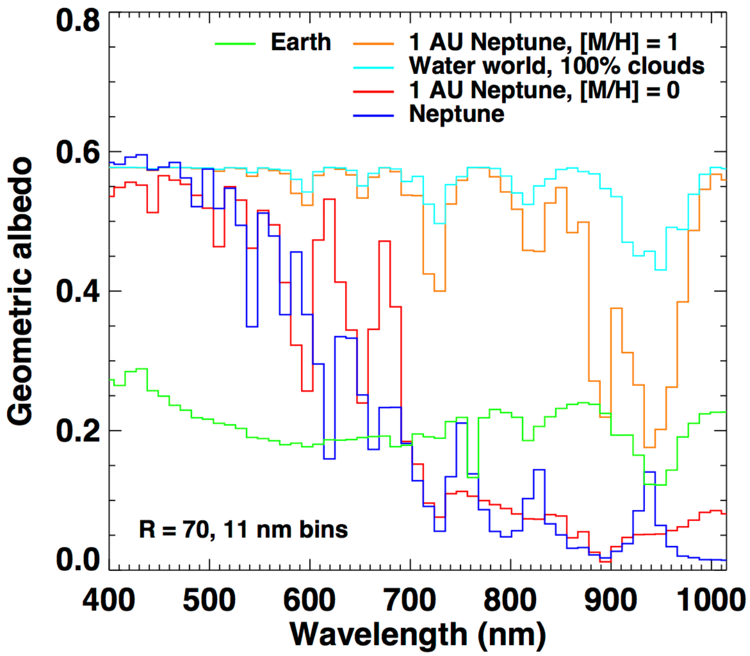


Earth as seen from Voyager I from 4 billion miles

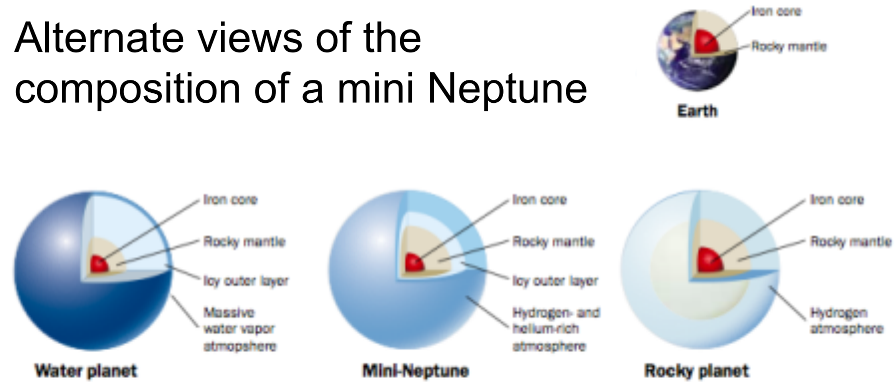
- Discover planets from Jupiter-like planets down to rocky planets orbiting nearby Sun-like stars
- Image rocky planets in a Sun-like star's habitable zone
- Discover multiple planets and circumstellar dust, around target stars

Science Goal #2:
Spectral Characterization of New Exoplanets

ExoPlanet Exploration Program



Alternate views of the composition of a mini Neptune

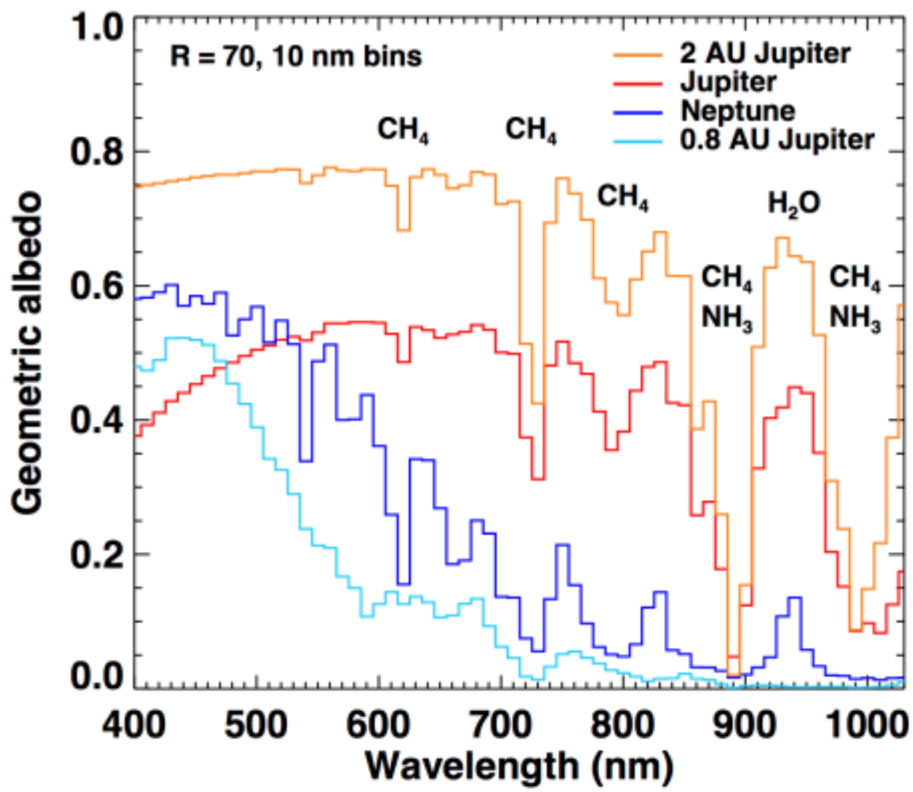


Credit: Science News 2010

- Spectra of newly discovered planets from 400–1000 nm, with a spectral resolution *R* = 70
- Spectra of mini Neptunes to ascertain the very nature of the low-density, extremely common, yet mysterious planets
- Potential for rocky planet spectra, for a handful of favorable target stars

Science Goal #3: *Spectroscopy of Known Jupiters*

ExoPlanet Exploration Program

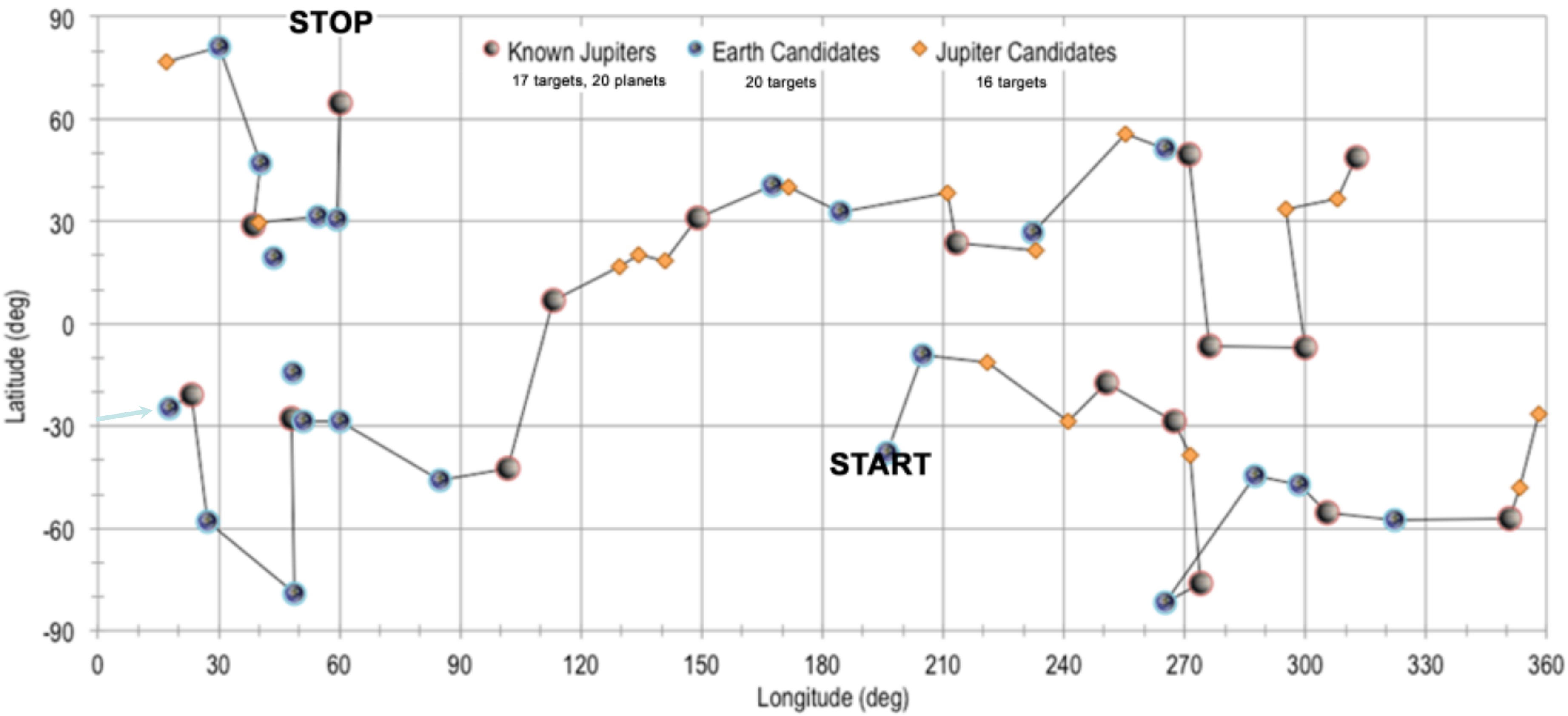


- Spectra of 17 known Jupiter-mass exoplanets
- Spectral characterization from 400–1000 nm, with a spectral resolution R = 70
- Molecular composition and presence of clouds or haze will inform us of the diversity of giant planet atmospheres
- Comparative planetology with a variety of Jupiter-type exoplanets

The known Jupiters are detectable by virtue of extrapolated position in 2024 timeframe

Preliminary Observing Strategy

ExoPlanet Exploration Program

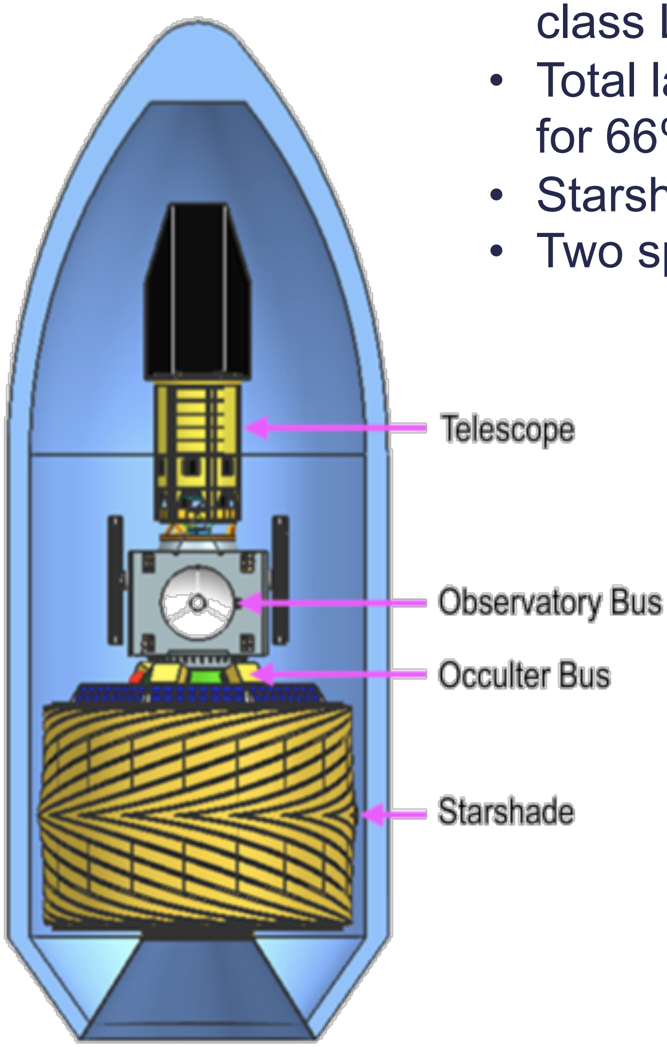


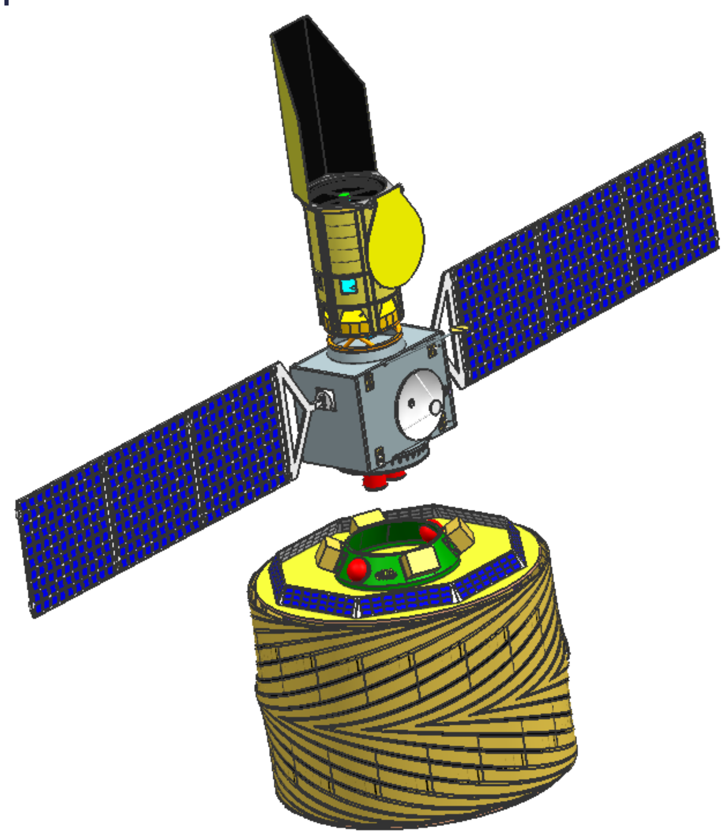
- The prime mission is 3 years; a 22 month example observing schedule is shown with targets sequential in longitude; an additional year is available for revisits and spectroscopy
- Observation times are approximately 1 to 5 days and retargeting times are about one week
- Observations include multi-color imaging to identify planet candidates and spectroscopy for known Jupiters and newly discovered planets
- Disk science and search for Jupiter analogs around all stars
- The observing schedule is adaptable to real-time discoveries

Launch Configuration

ExoPlanet Exploration Program

- Telescope and starshade fit in the low cost intermediate-class L/V 5-m fairing
- Total launch mass is 2,140 kg vs. 3,550-kg launch capacity for 66% launch margin
- Starshade carries loads through existing central cylinder
- Two spacecraft separate on-orbit





Summary of Critical Technologies

Optical Model Validation

- Experimentally demonstrate that models predict performance to 10^{-11} contrast

Precision Deployment and Shape Control

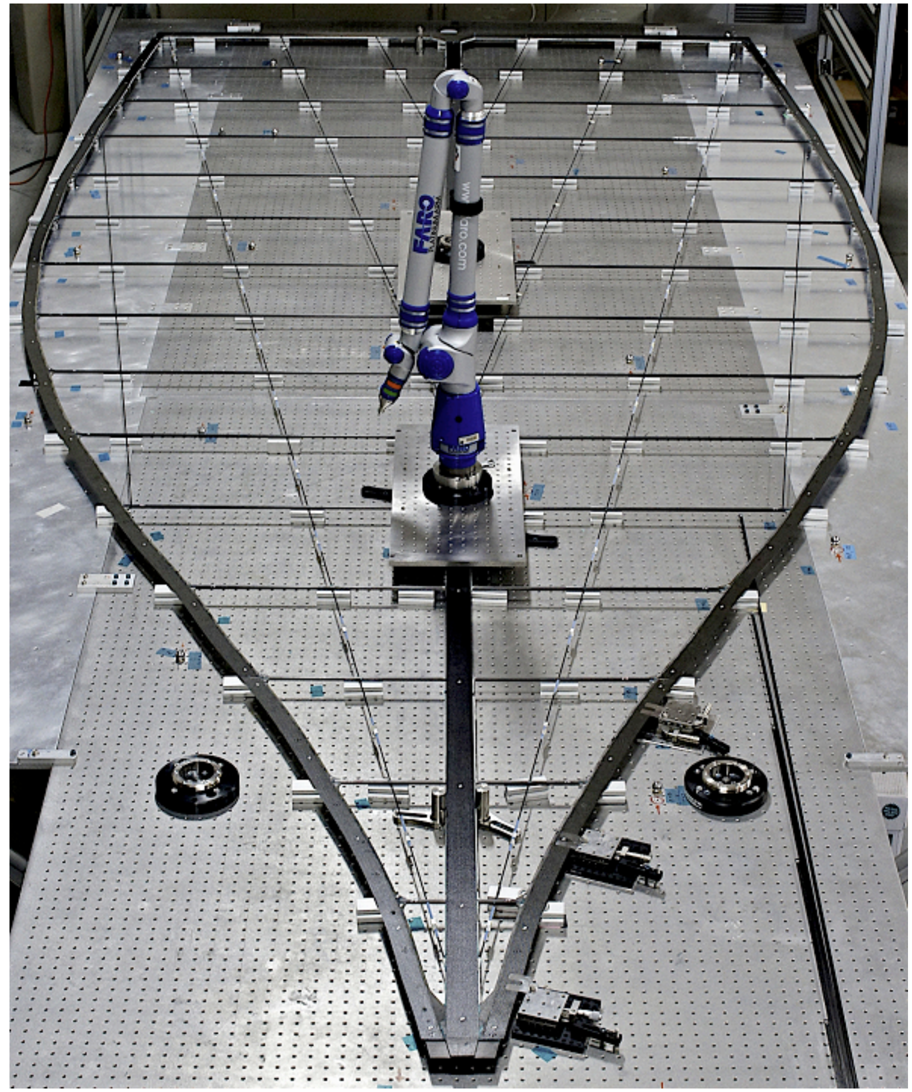
- Build structure that meets shape requirements
- Deploy accurately and with high reliability
- Maintain shape during on-orbit disturbances such as jitter and thermal gradients

Long Distance Formation Flying

- Sense cross-track alignment errors between starshade and telescope
- Control relative position of starshade and telescope line of sight

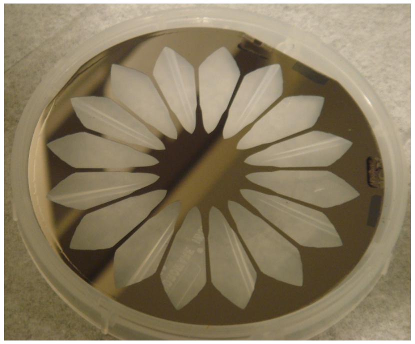
Stray Light Control

- Mitigate scattering of sunlight off edge of starshade petals
- Control transmission of sunlight and starlight through membrane

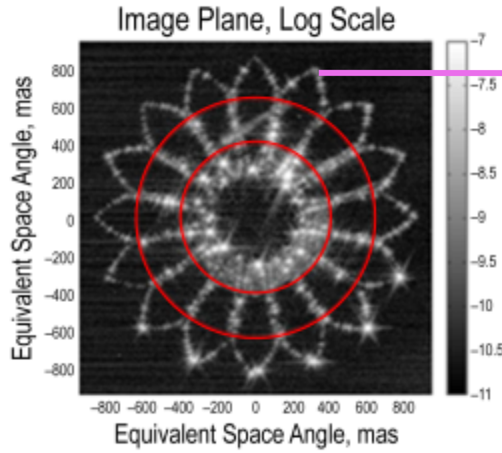


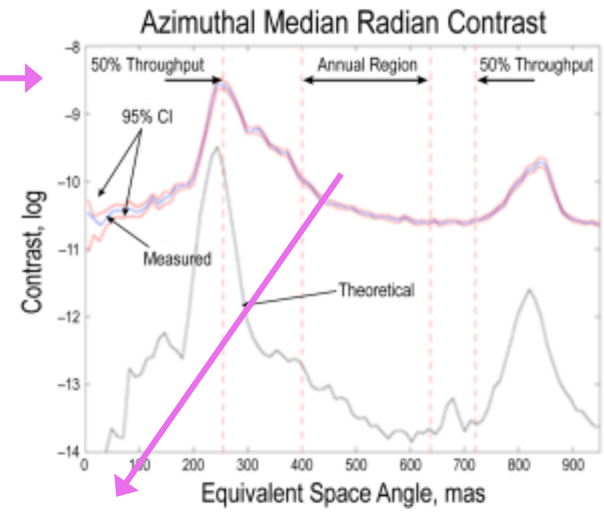
Optical Model Validation

ExoPlanet Exploration Program

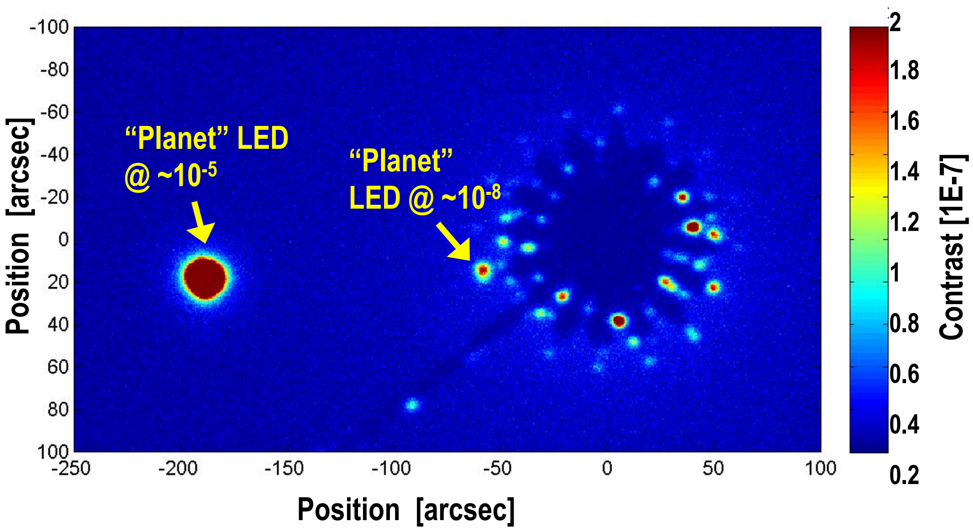


Lab experiments at Princeton and NGST have demonstrated contrasts close to flight levels for large flight versions





< 10^{-10} contrast at 400 mas equivalent



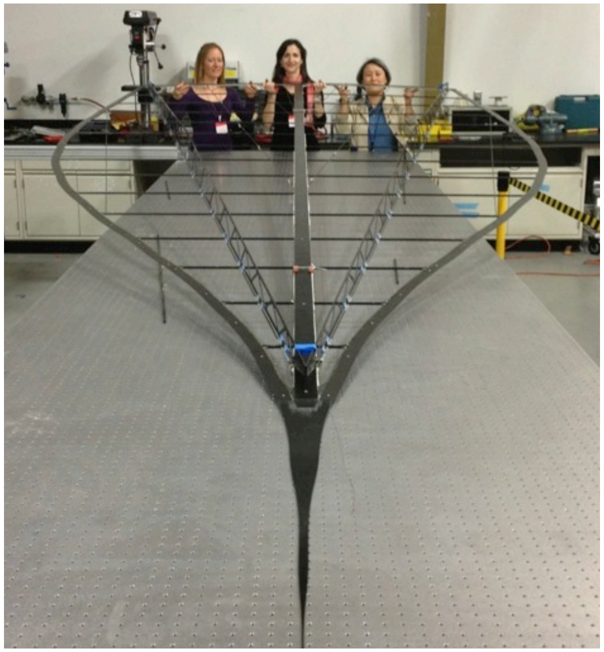
Desert field testing at 1% scale has demonstrated contrasts at 10^{-7}; Glassman et al. 2013

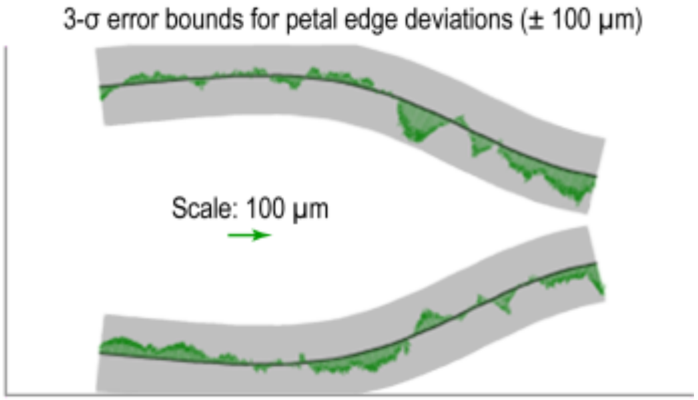
NASA funded effort is directed at larger-scale experiments closer to flight geometry and in broadband light to completely verify the propagation models.

Petal Prototype and Deployment

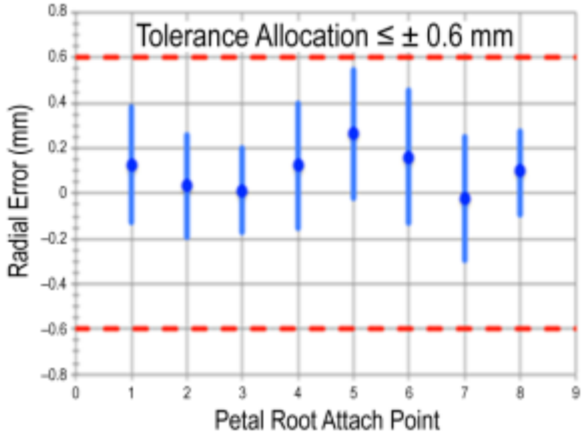
ExoPlanet Exploration Program

Full-scale petal prototype with the petal width profile manufactured to required tolerances. JPL facility.



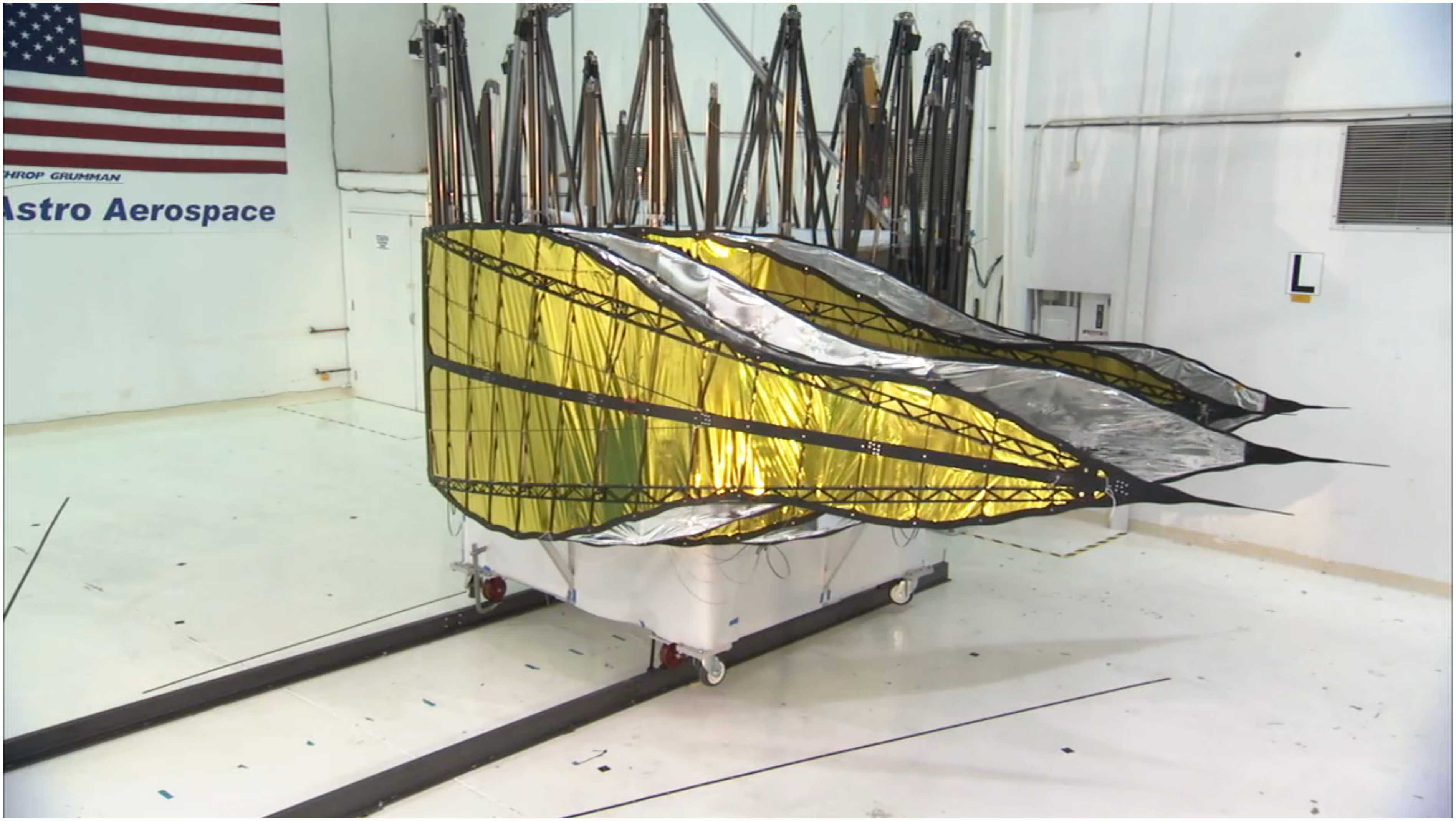


Subscale (2/3) partial starshade prototype. 25 deployment cycles demonstrated deployed positions to within required tolerances. NGC facility.



Starshade Stowage and Deployment

ExoPlanet Exploration Program



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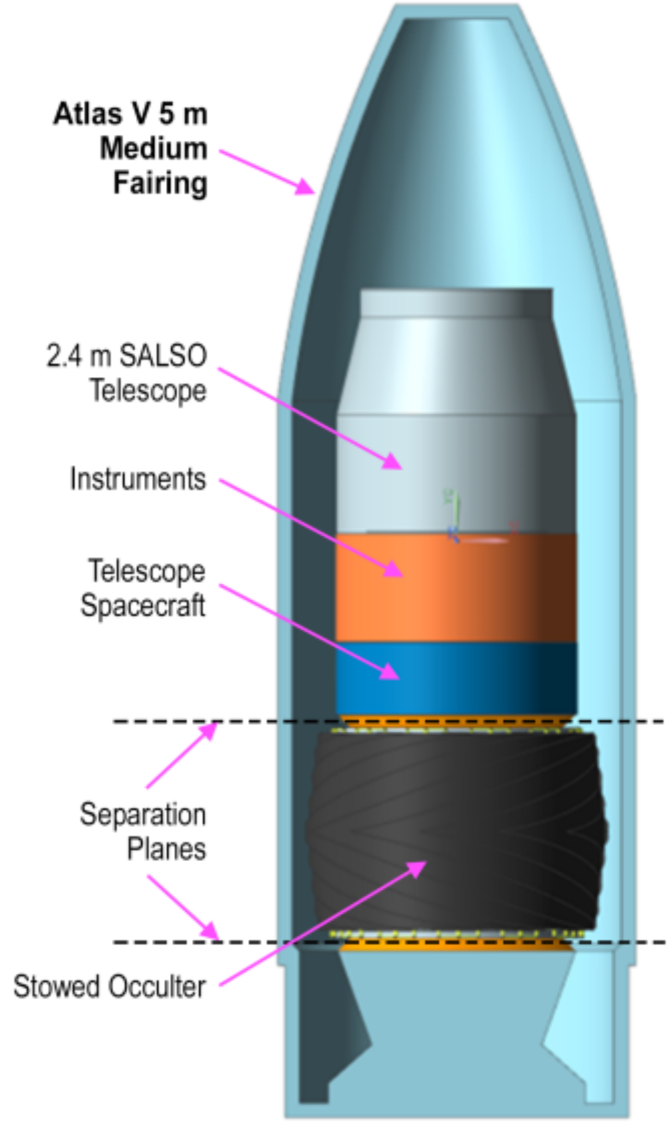
STDT Next Steps

ExoPlanet Exploration Program

Baseline Probe Design
- Refine Design Reference Mission and science yield simulations
- Complete trades for the baseline design of starshade + telescope system

"Starshade Ready" Design
- Starshade design for a future or existing telescope (e.g., NRO)
- Starshade readiness of telescope

Technology Development
- Priorities recommended by STDT
- Where technology development will continue by the community through competed NASA technology programs; some STDT members participating



Occulter with 2.4-m NRO telescope stacked on top

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Starshade Summary

ExoPlanet Exploration Program