# Using a Starshade with WFIRST

Doug Lisman
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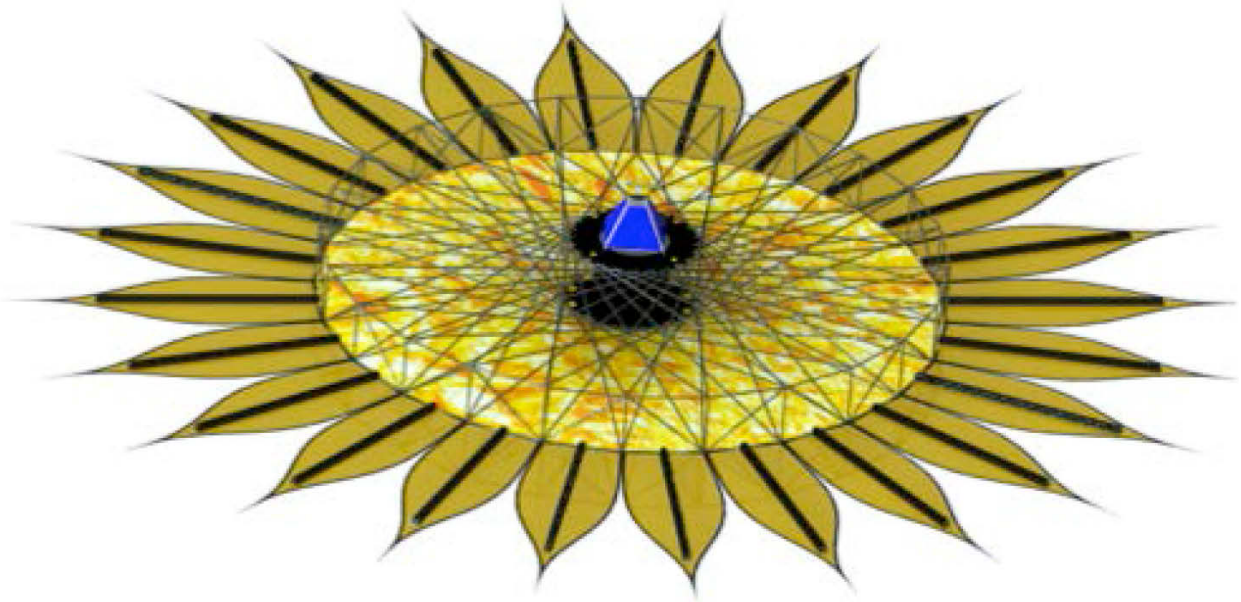
Jet Propulsion Laboratory, California Institute of Technology

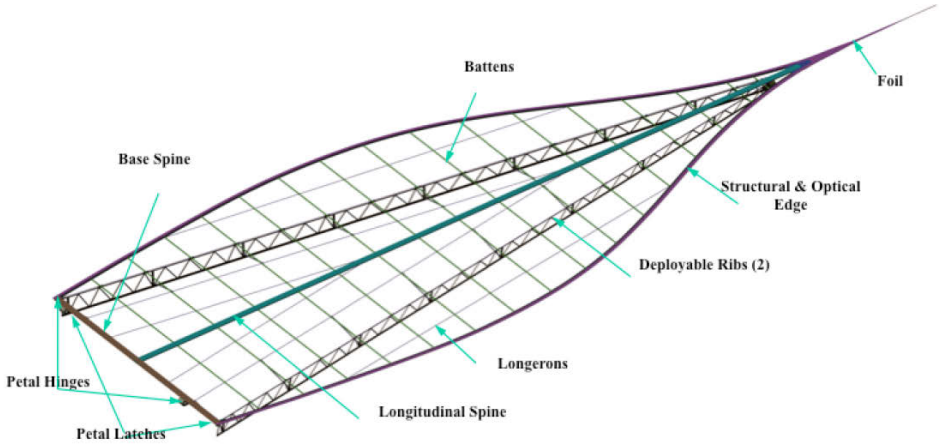
# Summary

- A starshade operating with WFIRST at Earth-Sun L2 can characterize Earthlike exoplanets
- A starshade can launch together with WFIRST via EELV with standard 5m launch fairings
- A starshade experiment requires no telescope modification and limited instrumentation
- Implementation requirements are all realistically achievable
- Key performance parameters are being verified via NASA TDEMs (ROSES NRA)

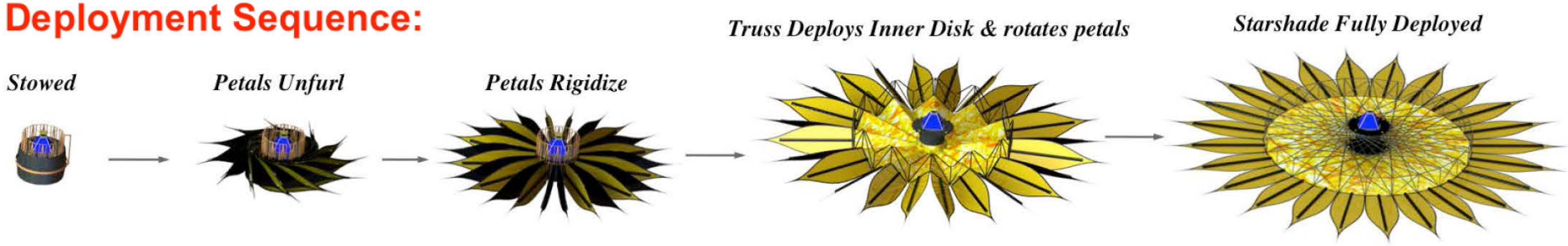


# Design

- Starshade diameter is 32m and consists of 20m inner disk and 30 6m petals
- Inner disk is formed by perimeter truss with heritage from deployable antennas
- Petals optimized for stability – width controlled by near-zero CTE carbon pultruded rods
- Flexible petals stow (wrap) around central hub and rigidize with passive pop-up ribs
- Covered with Opaque multi-layer blanket with spaced layers to mitigate micrometeorites

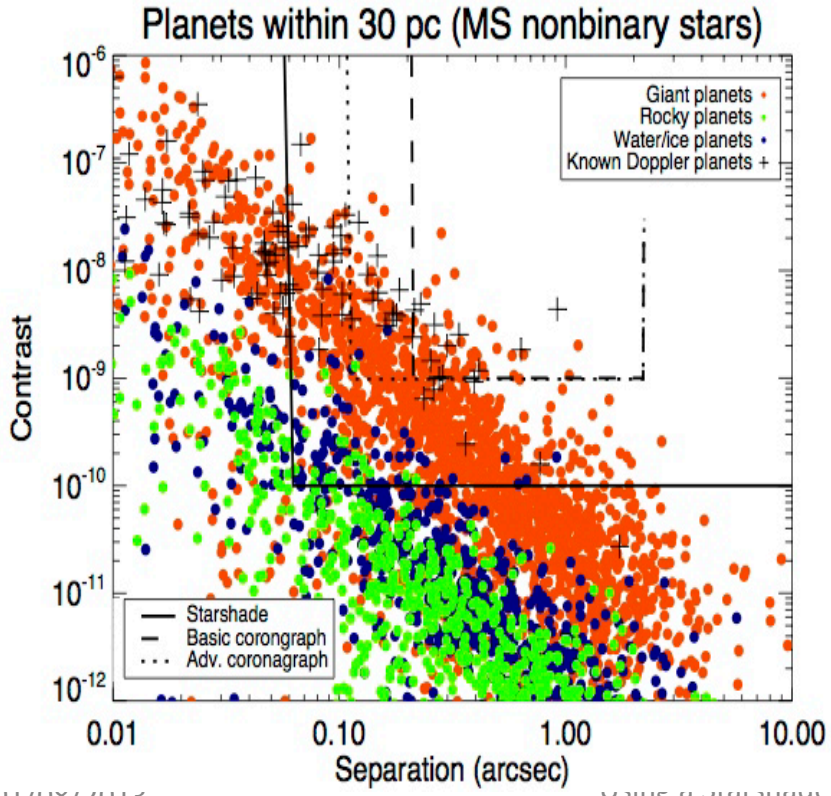


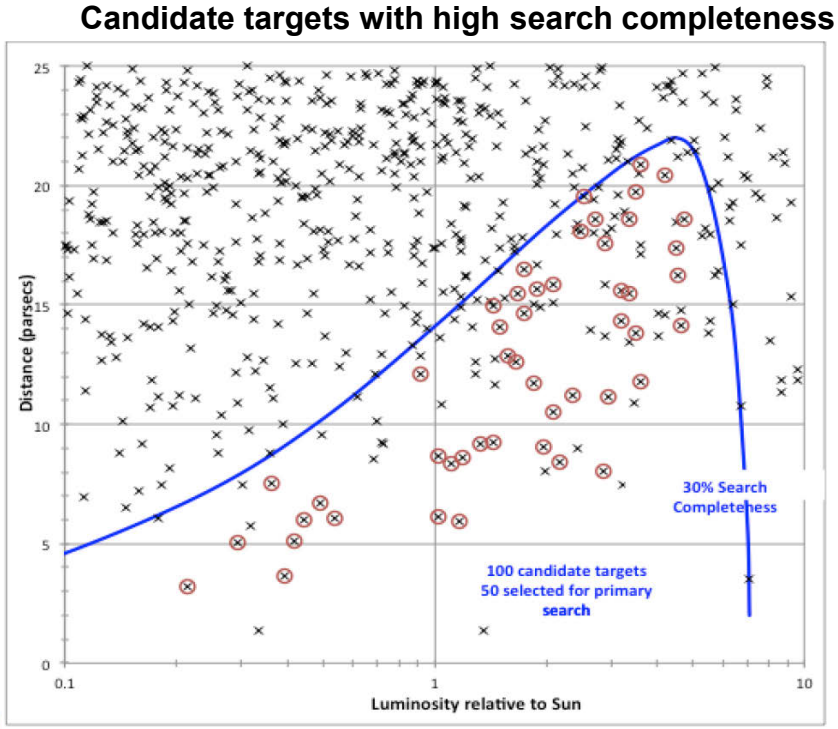

## Deployment Sequence:



# Performance

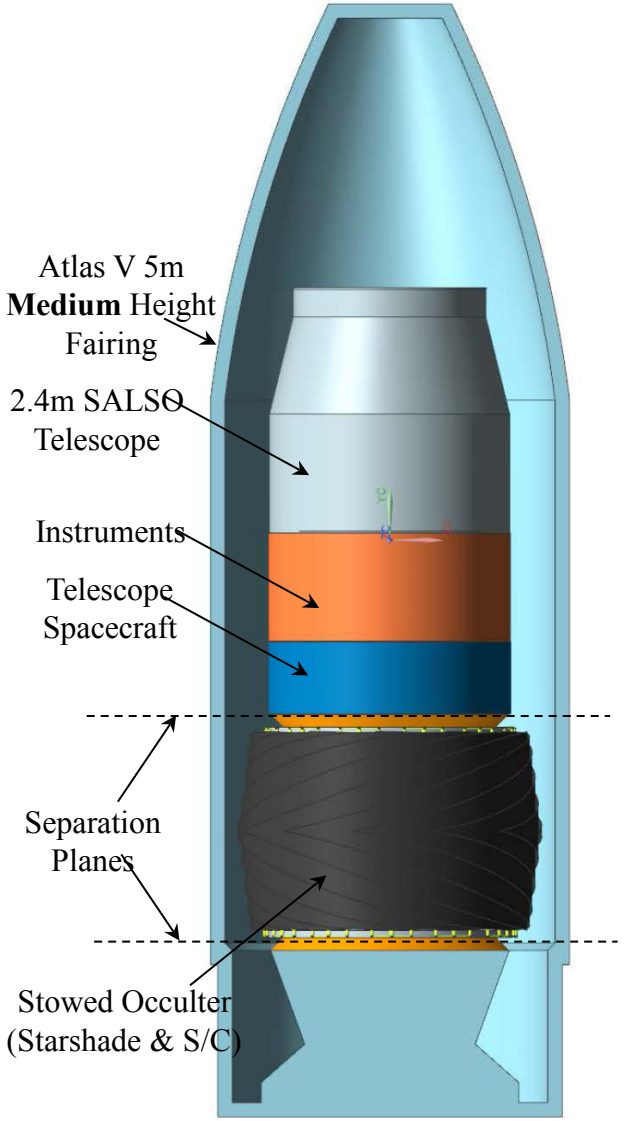
- Starshade performance is largely independent of telescope size or stability
- Starlight suppression for Earthlike exoplanets ($10^{-10}$) is achievable with realistic tolerances – greatly relaxed by spinning the occulter (1 rev./5 min)
- Inner working angle is 60 mas (50% power point) - yields 100 candidate targets (F, G, or K stars) with high search completeness (≥ 30%, average is 50%)
  - Primary search phase might focus on 50 select targets per location and propulsion efficiency



# Launch Vehicle Accommodation

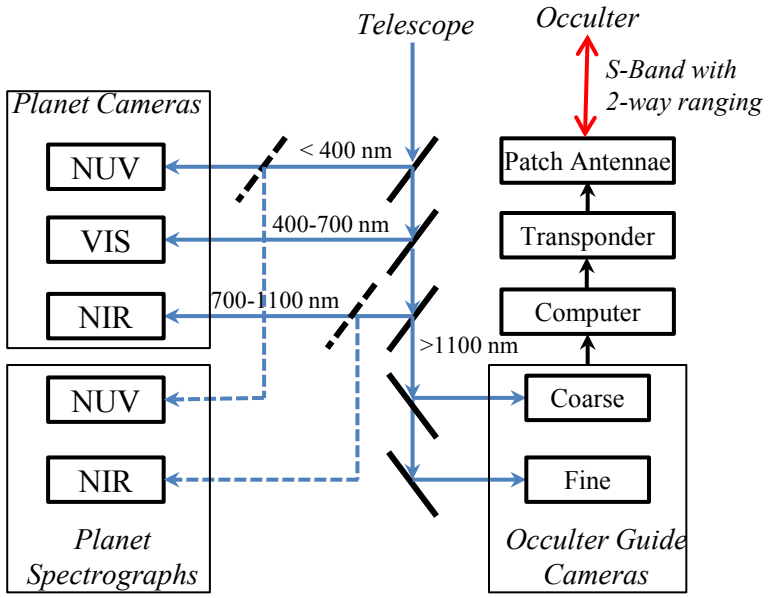
- Starshade stows compactly and can be stacked with the telescope in standard 5 m fairings
  - Medium height Atlas-V fairing shown to right
  - Desired hub diameter matches nicely with telescope and a truss style launch adapter
- Occulter launch mass is ≤ 2,000 kg, Atlas-551 capacity is 6,400 kg to L2, so 4,400 kg remains for all other flight systems
- Also fits in Falcon-9 5 m fairings, but launch mass capacity is not sufficient to E-S L2



# Instrument Accommodations

- Instrumentation with telescope consists of:
  - planet cameras,
  - spectrographs,
  - guide cameras,
  - radio system to measure range and send guide camera derived occulter positions
- Total instrument mass ≤ 250 kg
- Total instrument volume is a small fraction of available volume behind telescope
- Search Phase observation time ≤ 2 days (mostly acquisition) every 10 days, on average
  - Can search 50 targets in 500 days
- Characterization Phase observation time ≤ 25%
  - Focuses on select set of candidate earths
  - Visit each candidate ≥ 5 times for ≥ 3 detections to place orbit in HZ with high confidence

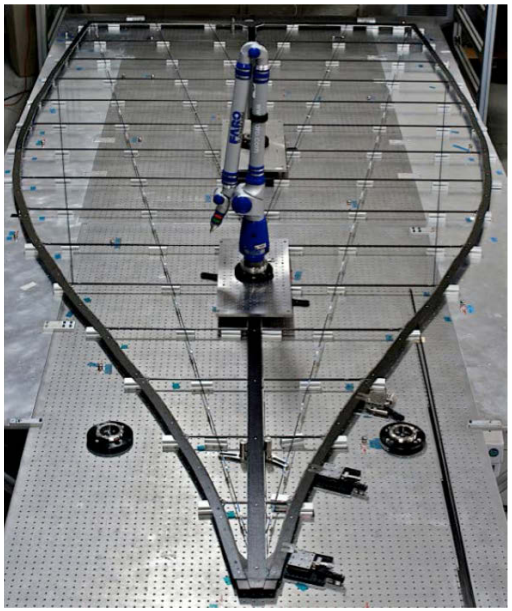
**Instrumentation Concept**



# Technology Status

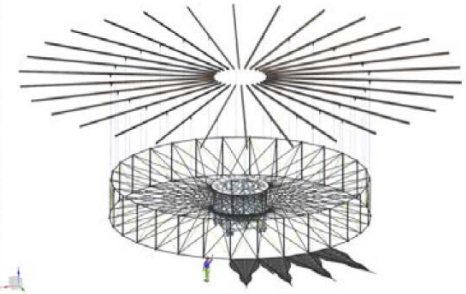
- TDEM-1 has demonstrated petal manufacturing tolerances to flight levels
- TDEM-2 is in progress to demonstrate deployed petal position tolerances
- Structural and thermal deformation tolerances are verified by analyses with large margins
- Currently developing manufacturing plan for sharp optical edges to limit scattered sun light
- Significant engineering challenges remain – launch restraint & deployment control systems

*TDEM-1 Petal*



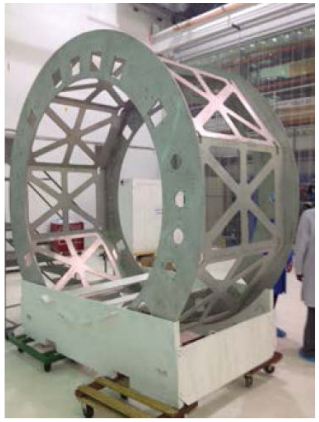
*TDEM-2 Petals, assembled by summer students*

*TDEM-2 system with gravity off-loader*



*Existing 12m truss adapted for TDEM-2*

*TDEM-2 hub structure*



# Optical Performance Verification

- Laboratory experiments with very small starshades (few cm dia.) have already demonstrated starlight suppression to within a few times flight levels
- Several independently generated optical models generate contrast predictions with excellent agreement, to within $10^{-12}$, giving high confidence that the starshade will perform on-orbit, as predicted