Jet Propulsion Laboratory
California Institute of Technology

Technology Development towards Direct Imaging of Exo-Earths

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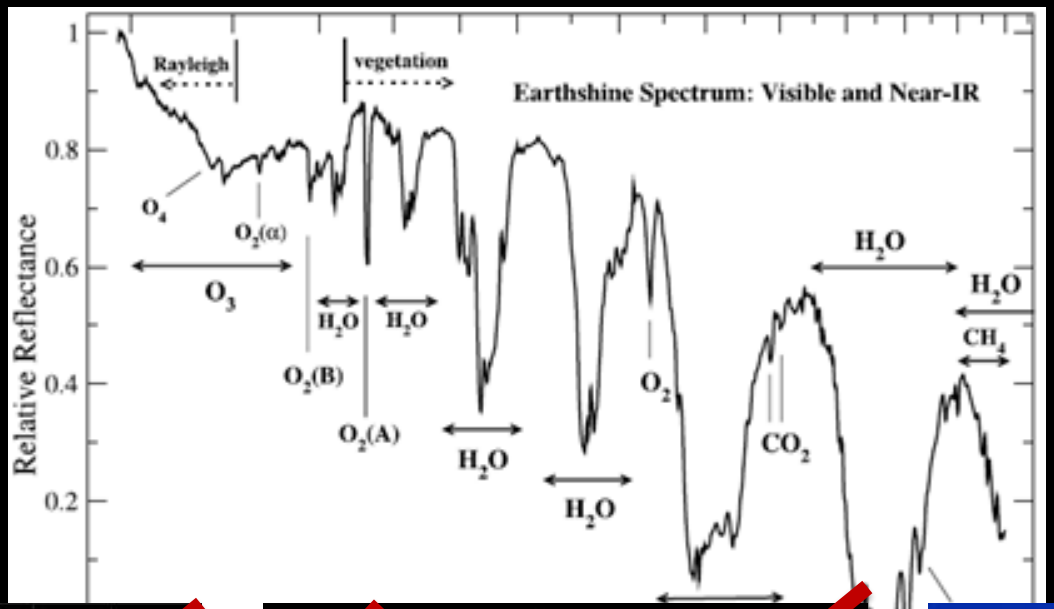
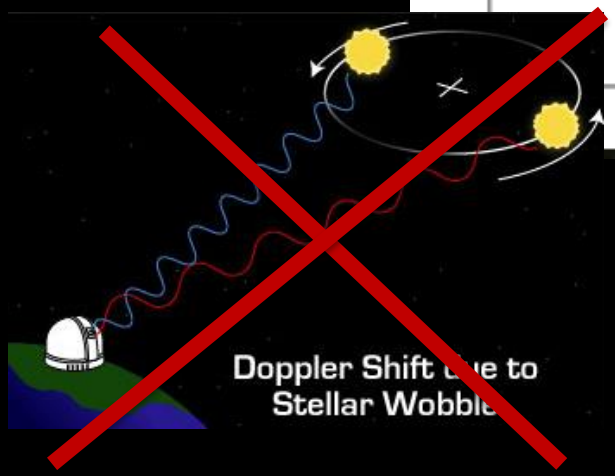
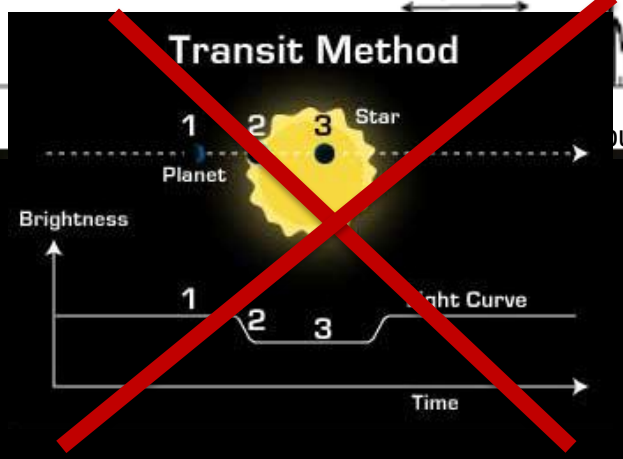
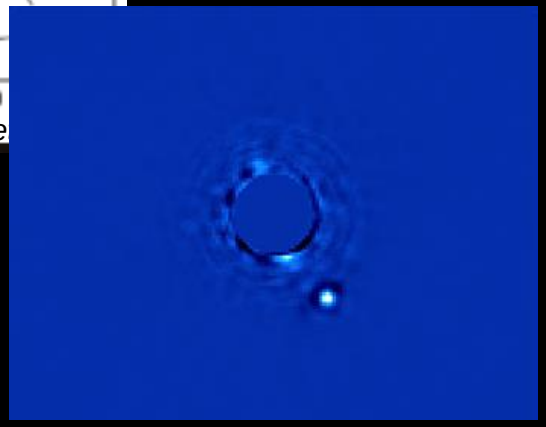
Starlight Suppression is <u>the</u> Key Technology in the Search for Life on Earth-Like Exoplanets



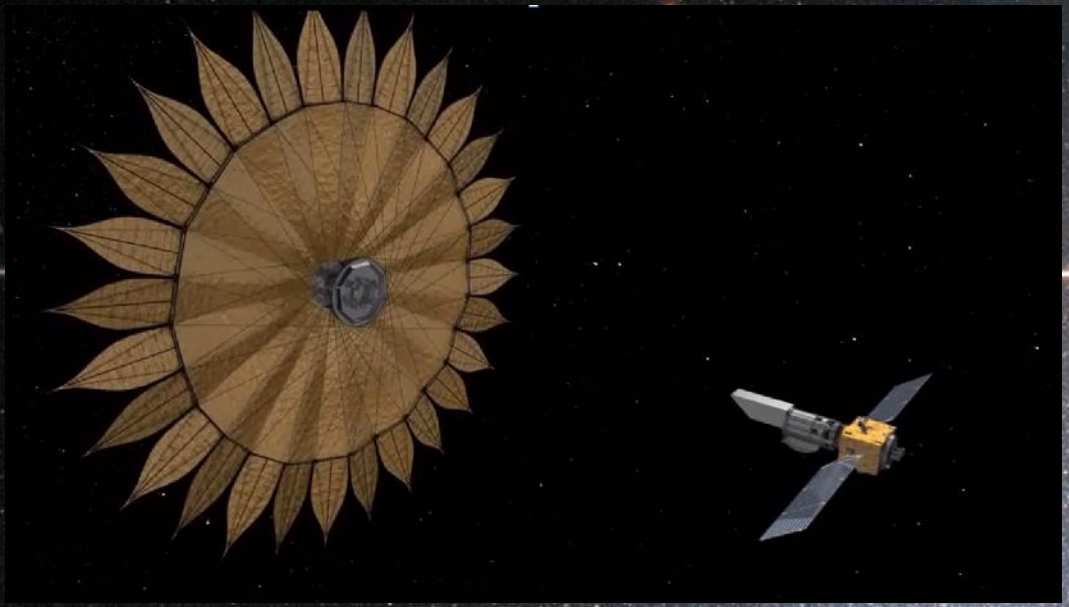


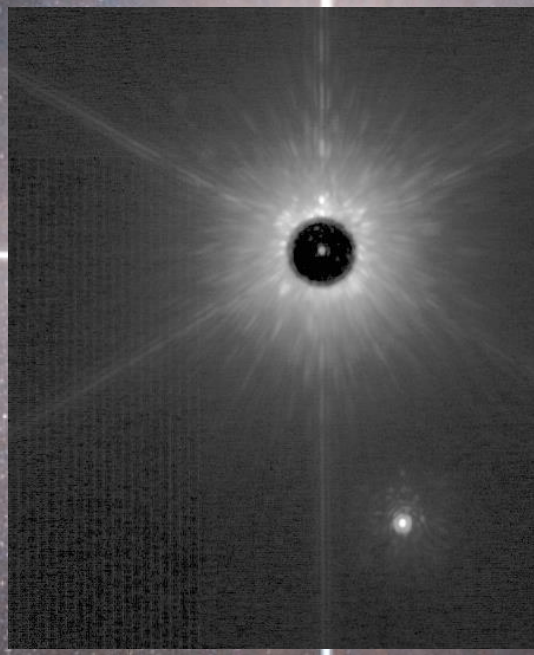




Two Enabling Starlight Suppression Technologies

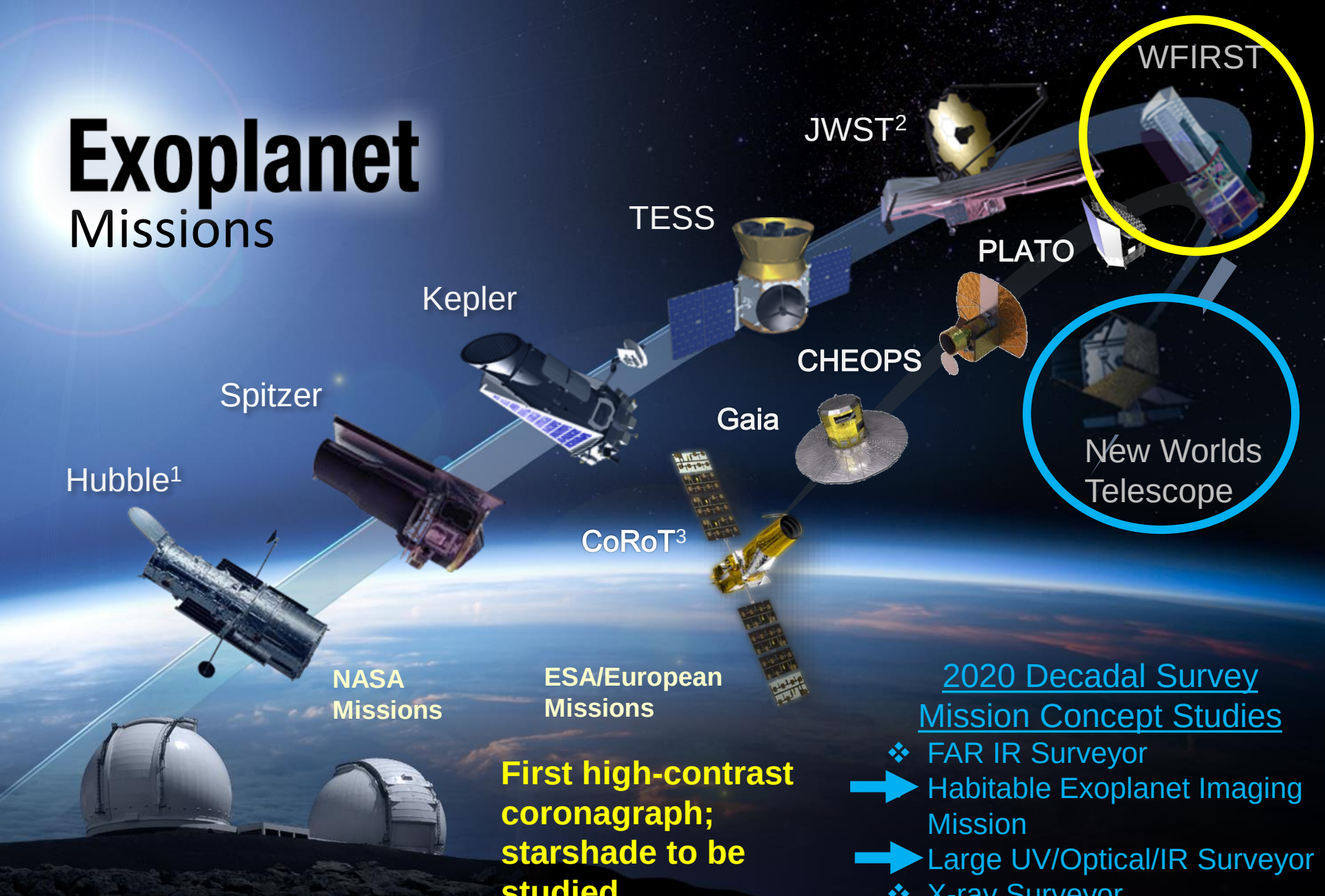
External Occulters (Starshades)





Internal Occulters (Coronagraphs)

Exoplanet Missions



First high-contrast coronagraph; starshade to be studied

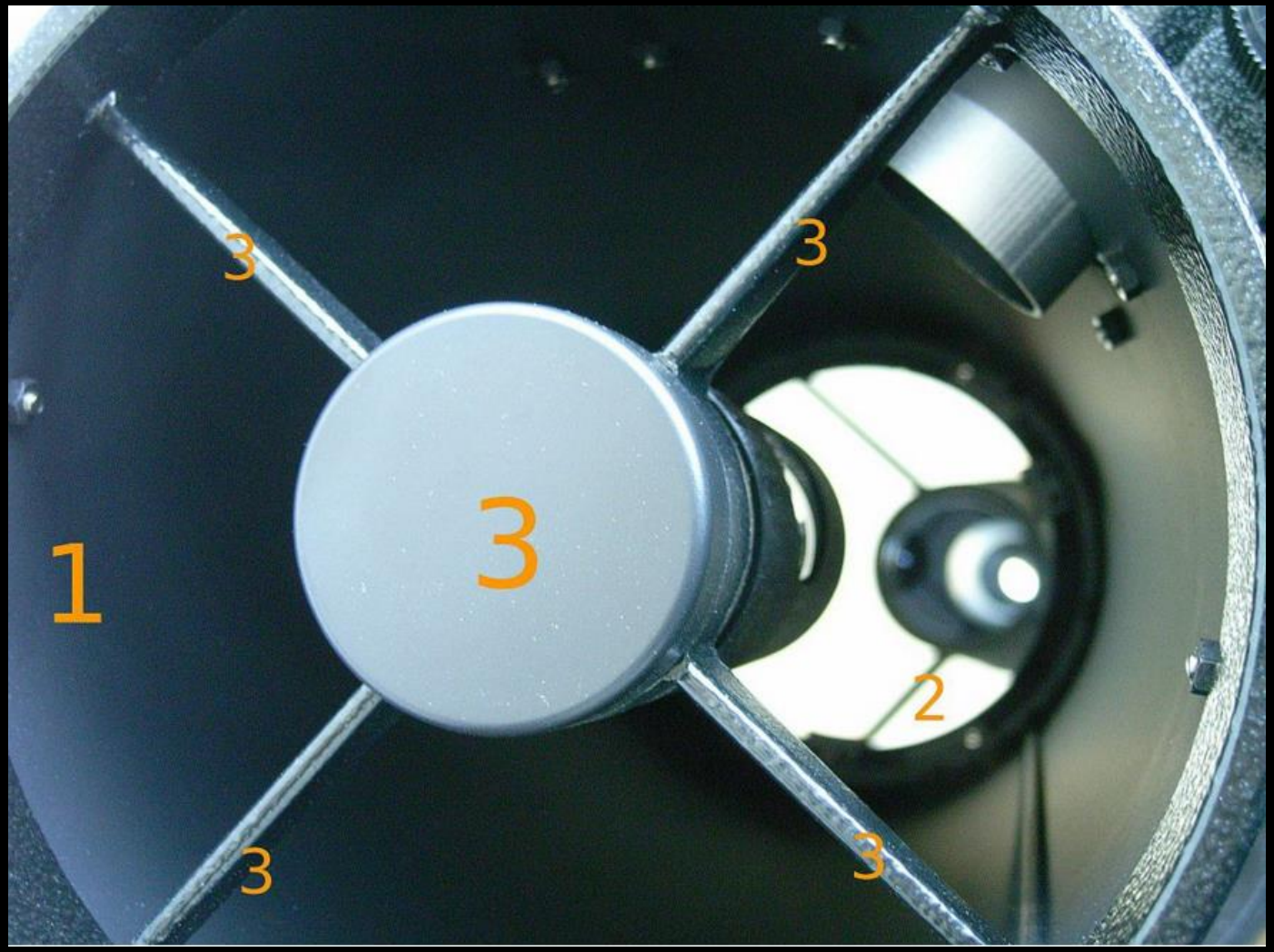
2020 Decadal Survey Mission Concept Studies

- FAR IR Surveyor
- → Habitable Exoplanet Imaging Mission
- → Large UV/Optical/IR Surveyor
- X-ray Surveyor

[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA Partnership

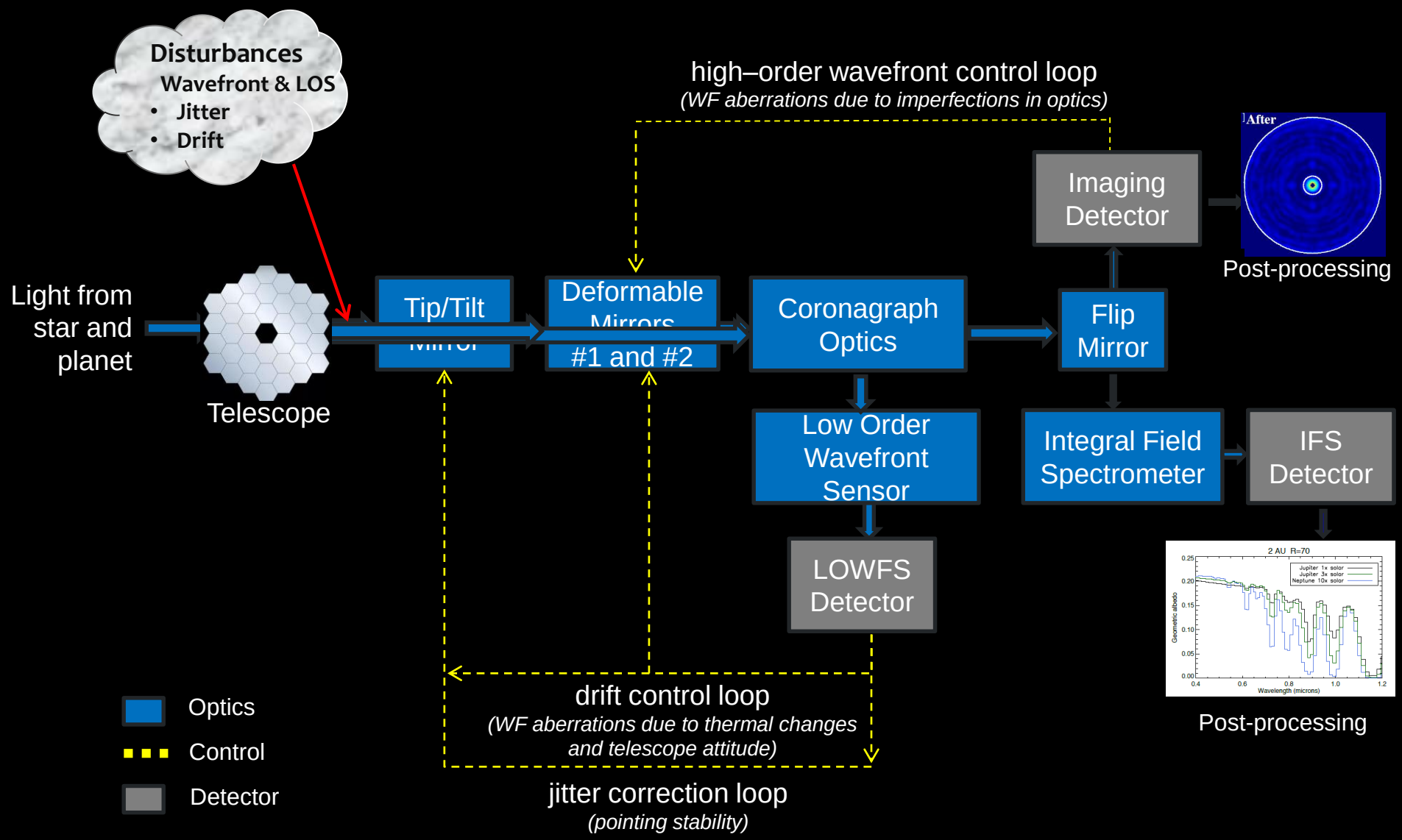
Coronagraph

Looking Down the Barrel of a Hubble-Like Telescope

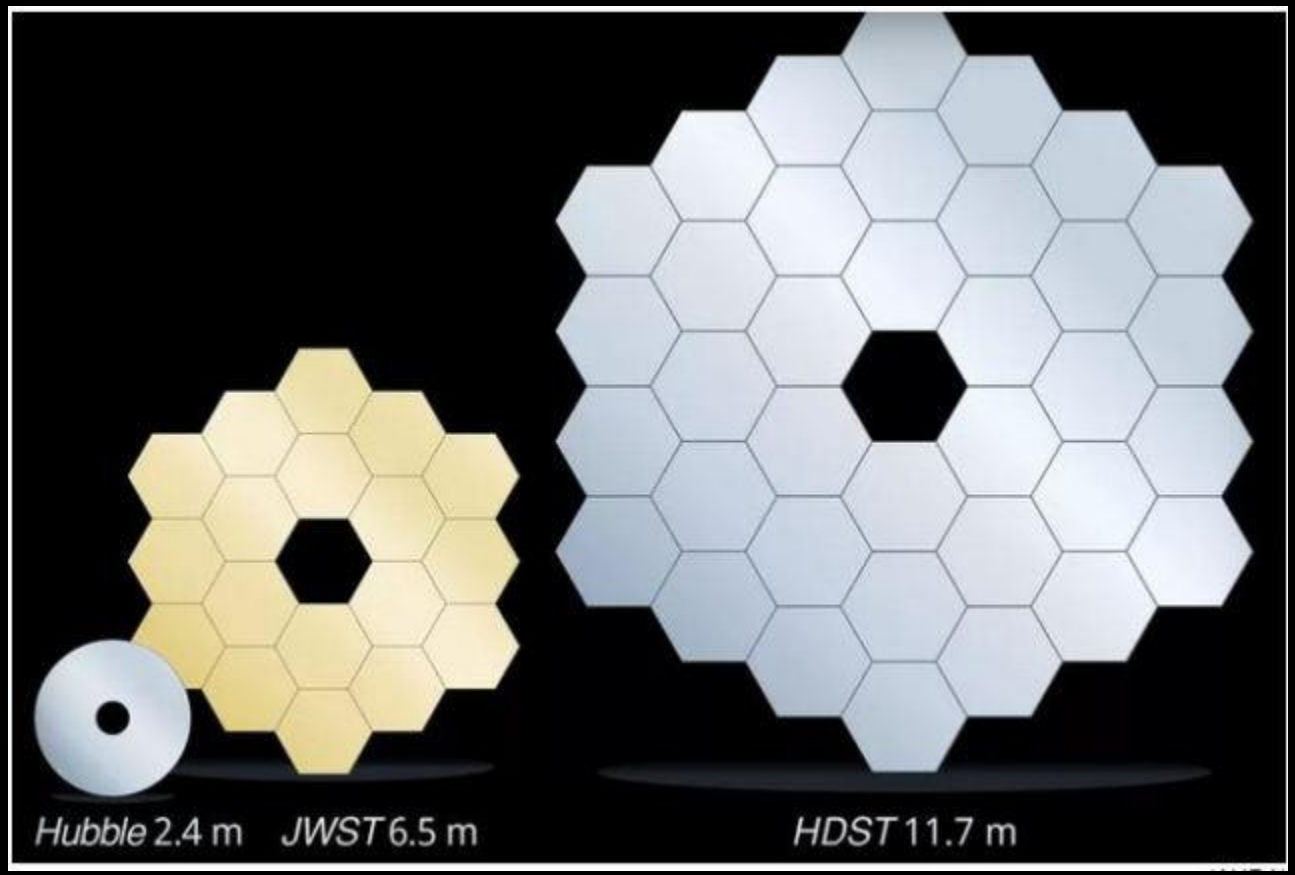


How a Coronagraph Works

Block Diagram of a Typical Lyot Coronagraph

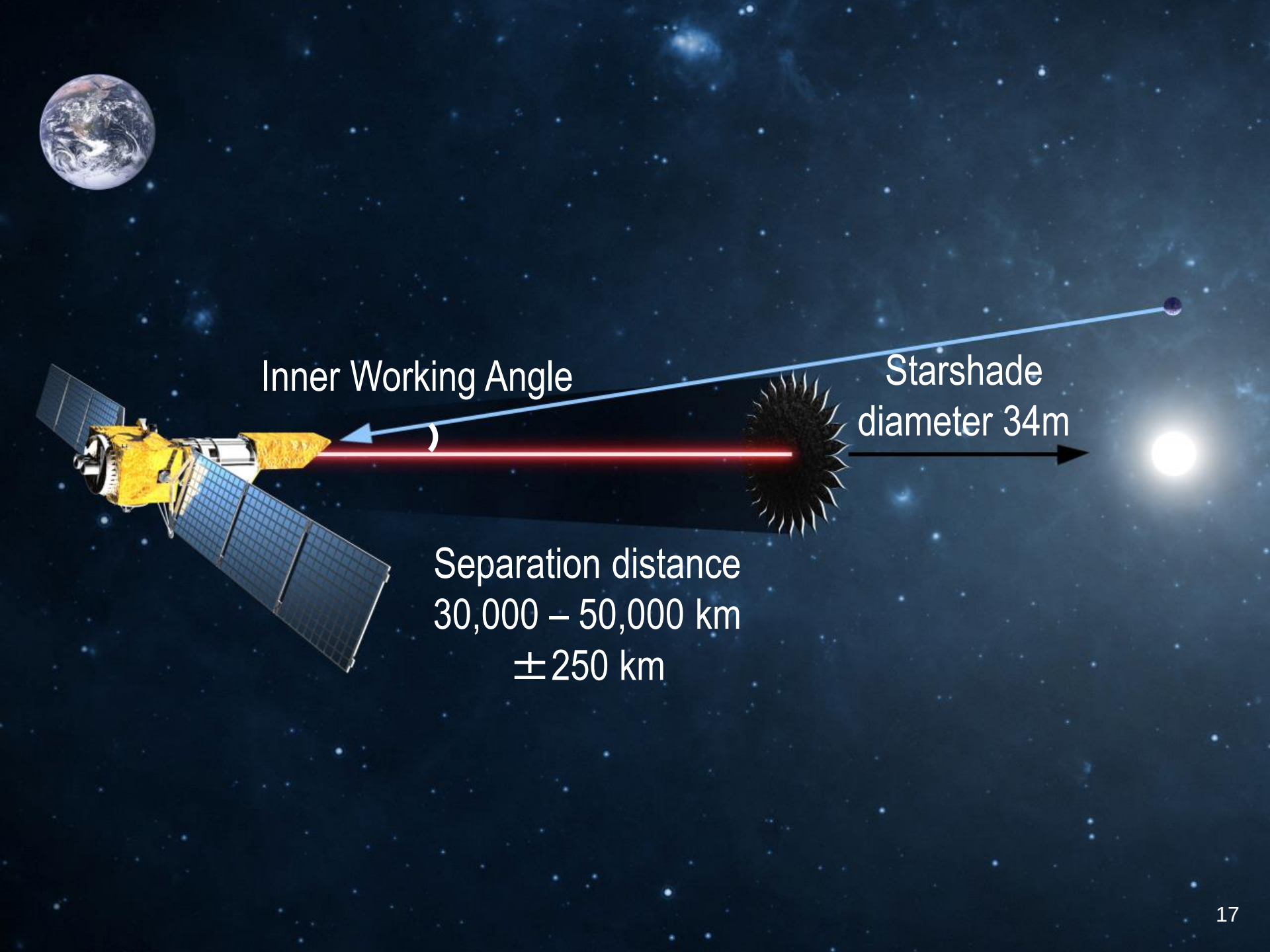


NASA's Future Telescope Primary Mirrors May Get Larger and More Segmented



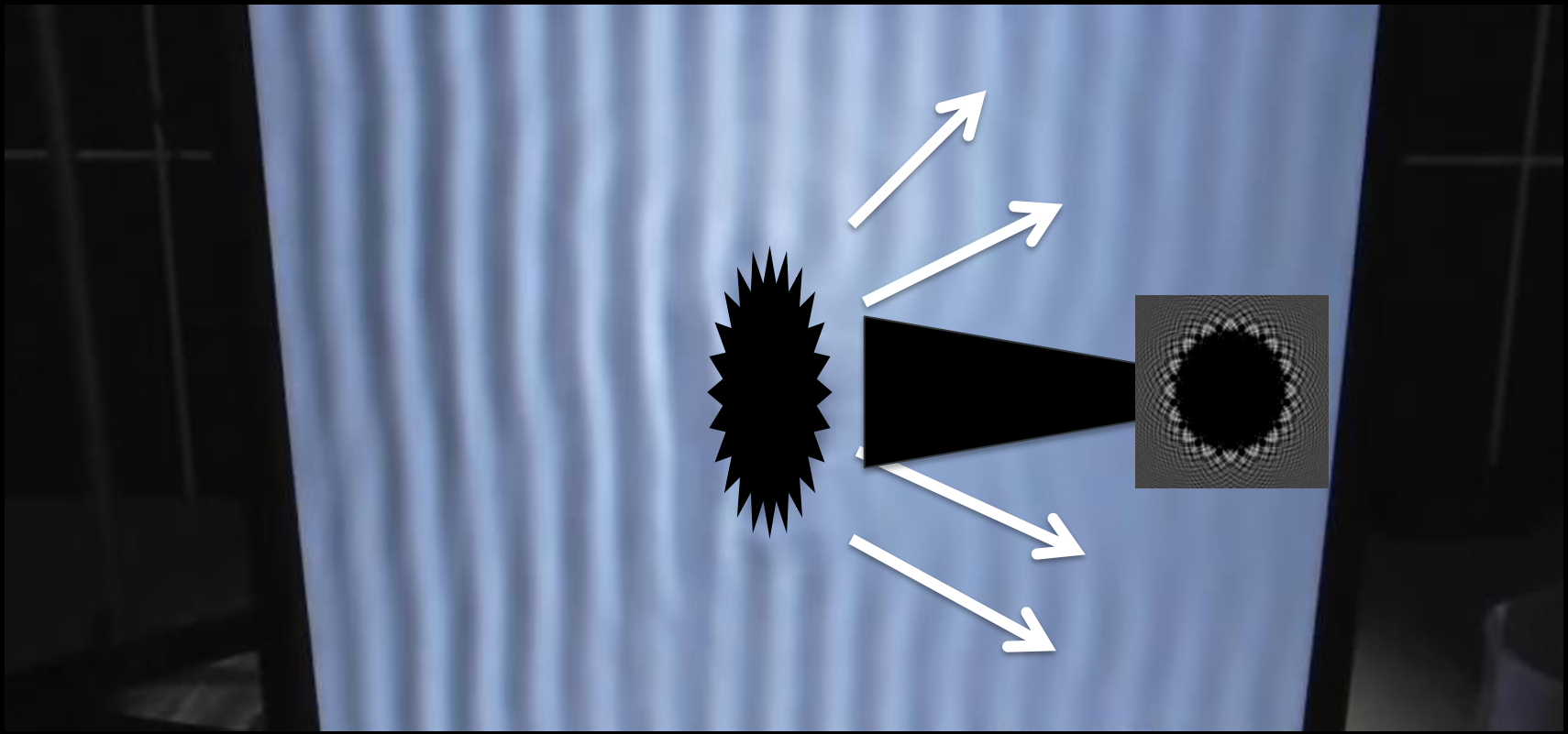
Starshade

35 years later


Inner Working Angle
Starshade
diameter 34m
Separation distance
30,000 – 50,000 km
±250 km

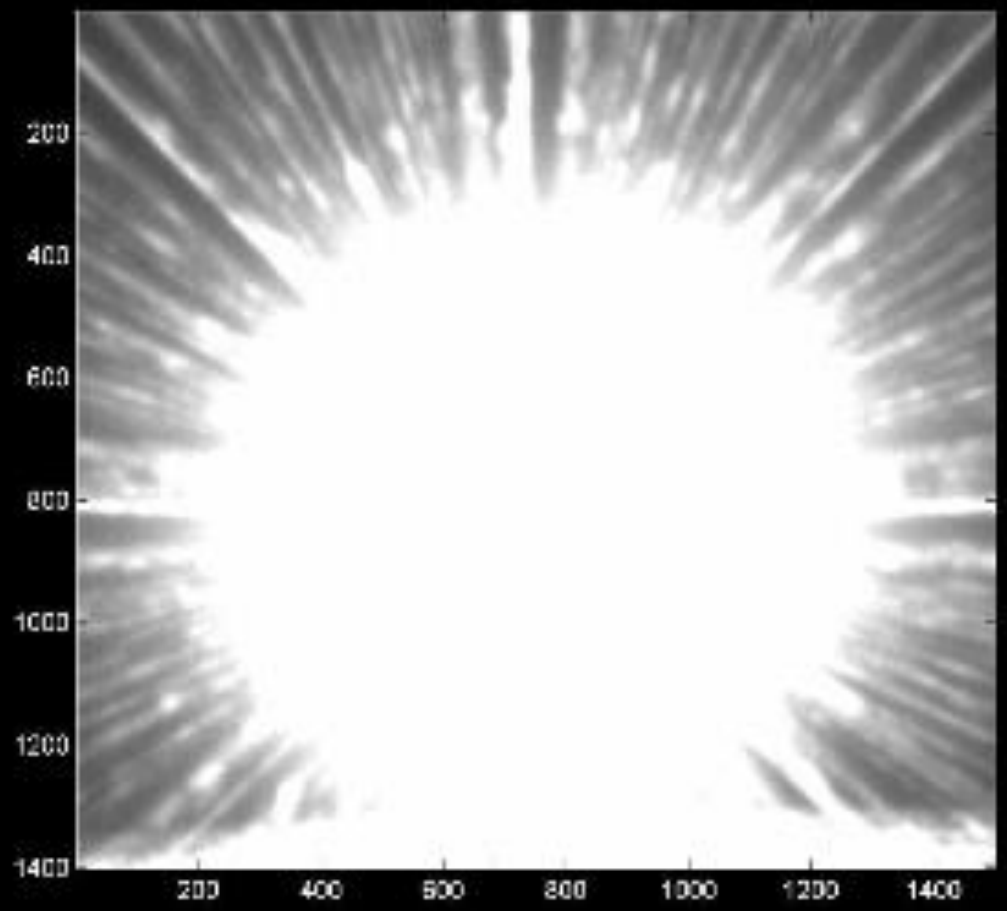
Welcome to the World of Diffraction

Welcome to the World of Diffraction

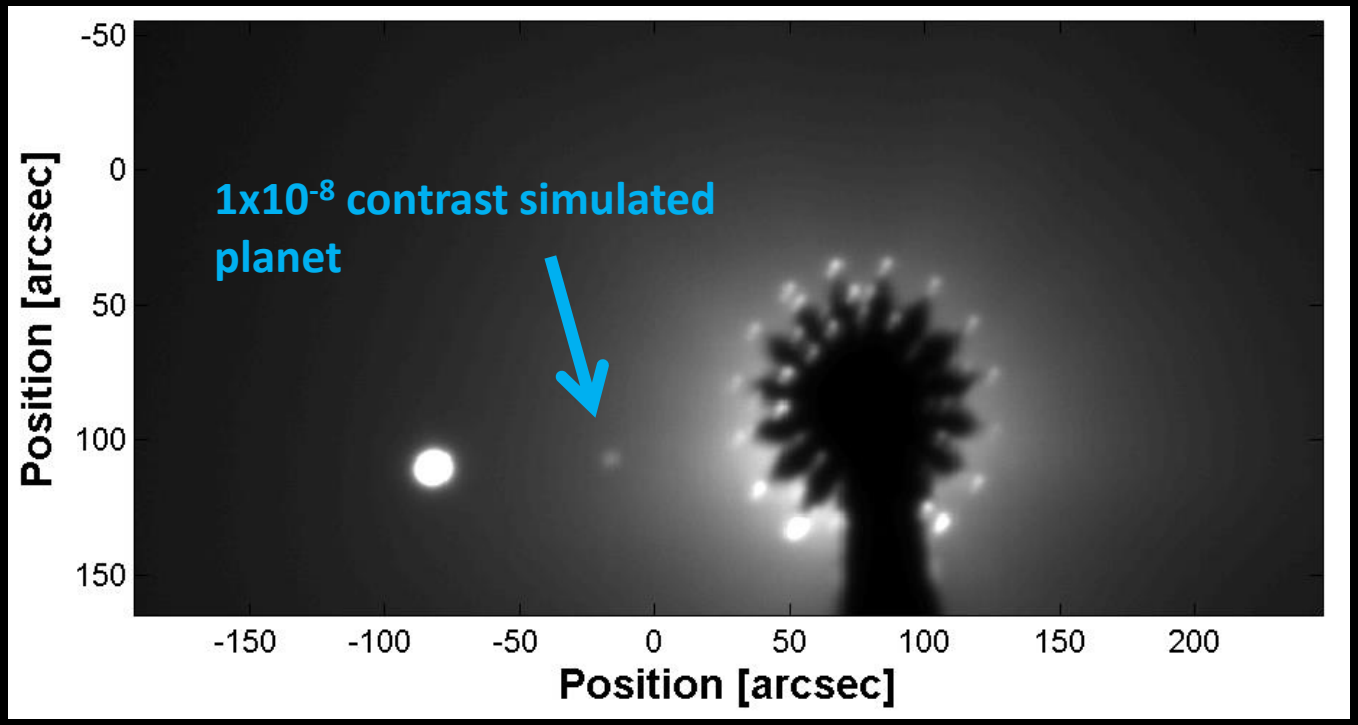


Early Inner Disk Deployment Trials at JPL

Credit: Northrop Grumman Aerospace Systems



Credit: Northrop Grumman Aerospace Systems



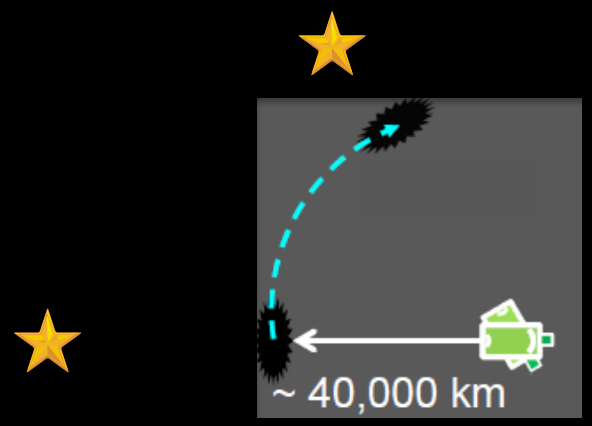
Credit: Northrop Grumman Aerospace Systems

Optical Shield Prototype Deployment Trial at JPL

Coronagraphs and Starshades: Strengths and Challenges

Key Challenges of the Starshade

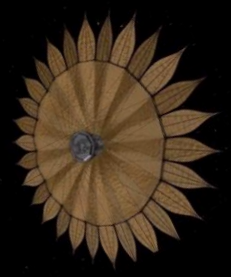
- Relatively long times between observations
  - Starshade slew time between targets may run ~ few days to two weeks



- Limited number of starshade movements
  - Due to limited propellant and time

- Full-scale end-to-end system optical testing on the ground not possible; same for formation flying
  - Must rely on ground sub-scale lab and field tests with validated high-fidelity models or
  - A space demo

Key Benefits of the Starshade



- The starshade can rendezvous with any starshade-ready telescope
  - *conventional on-axis or segmented telescopes are fine*
  - *diffraction by obscurations or segment gaps is a non-factor*

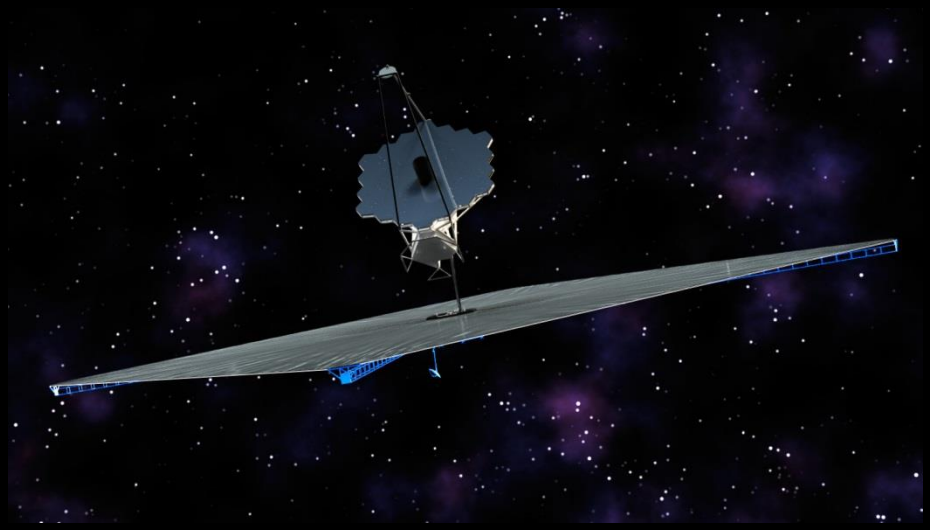
- The starshade does all the starlight suppression before it enters the telescope.
  - *does not require advanced telescope stability*
  - *wavefront sensing and correction is unnecessary*
  - *starshade will not drive the requirements of the telescope*

- High throughput
  - ~40-50%

- Inner working angle and starlight suppression is largely independent of the size of the telescope.
  - Rocky planets in the HZ can be imaged with smaller telescopes

We have a coronagraph, why do we need a starshade?

- Next generation coronagraphs may likely need to work with telescopes that are on-axis and segmented, with apertures > 8 m.

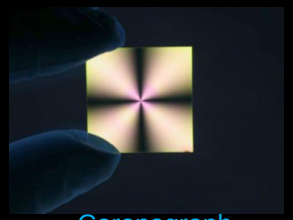


- Will require new solutions for:
  1. additional diffraction effects to reach 10^{-10} contrast – 10x better than WFIRST
  2. telescope jitter stability ~ 10x better than WFIRST
  3. wavefront sensing and control ~ 10x better than WFIRST

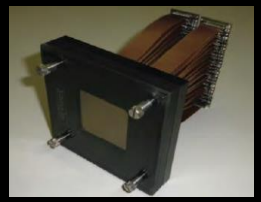
Backup Slides

Coronagraph Technology Gaps

Starlight Suppression



Coronagraph Architectures (CG-2)



Deformable mirrors (CG-3)

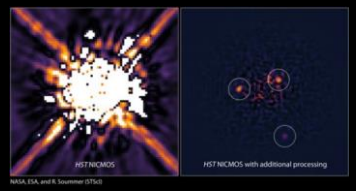
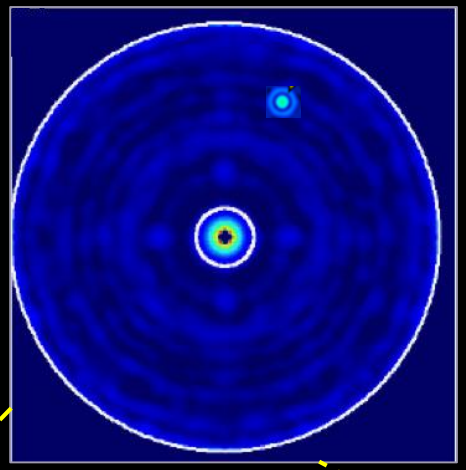
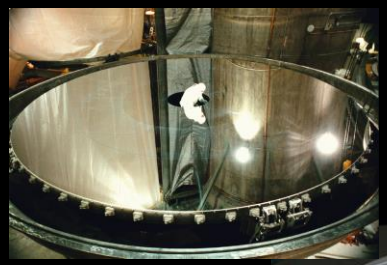


Image post-processing (CG-4)



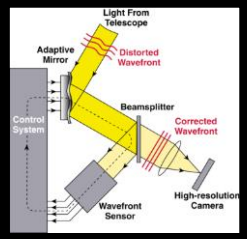
Mirrors



Large monolith (CG-1)

Segmented (CG-1)

WFE Stability

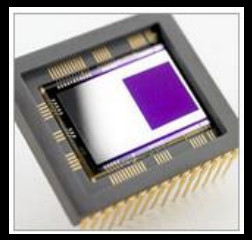


Wavefront sensing and control (CG-5)

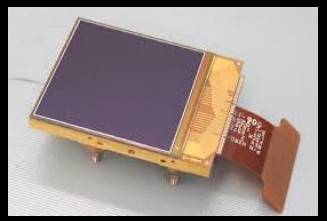
Segment phasing and rigid body sensing and control (CG-6)

Telescope vibration sensing and control (CG-7)

Detection Sensitivity



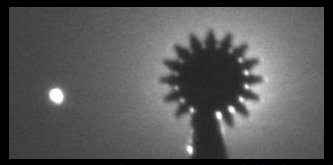
Ultra-low noise visible detectors (CG-8)



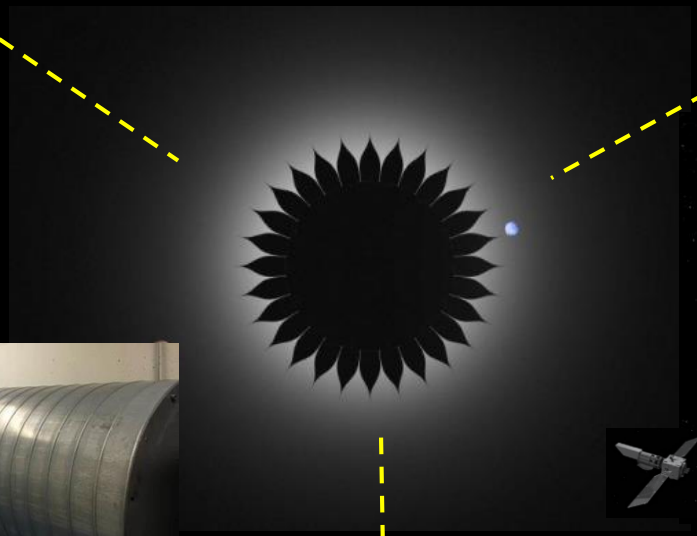
Ultra-low noise infrared detectors (CG-9)

The Three Key Technology Areas for a Starshade

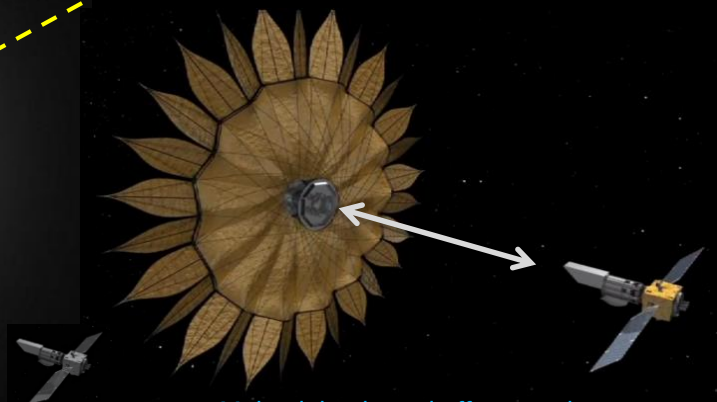
Starlight Suppression



Suppressing scatted light off petal edges from off-axis Sunlight (S-2)



Formation Sensing and Control



Maintaining lateral offset requirement between the spacecrafts (S-3)

Suppressing diffracted light from on-axis starlight (S-1)

Deployment Accuracy and Shape Stability

Fabricating the petal to high precision (S-4)

Positioning the petals to high precision, blocking on-axis starlight, maintaining overall shape on a highly stable structure (S-5)

S-# corresponds to ExEP Starshade Technology Gap number (http://exep.jpl.nasa.gov/technology/)