



**Jet Propulsion Laboratory**  
California Institute of Technology

# Exoplanet Exploration Technology

Gary Blackwood  
NASA Exoplanet Exploration Program

April 14, 2016

2016 National Space Symposium

# NASA Exoplanet Exploration Program



## Purpose:

1. Discover planets around other stars
2. Characterize their properties
3. Identify candidates that could harbor life

The Search for Exoplanets ...is the Search for Life in our Galaxy

# Exoplanet Missions



W. M. Keck Observatory



Large Binocular  
Telescope Interferometer



NN-EXPLORE

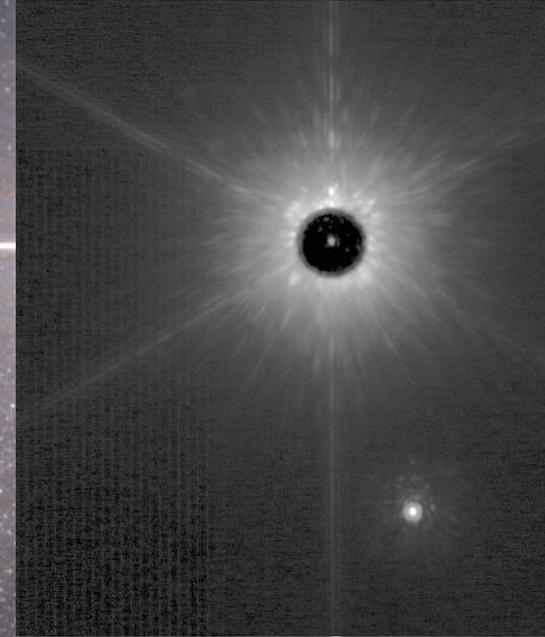
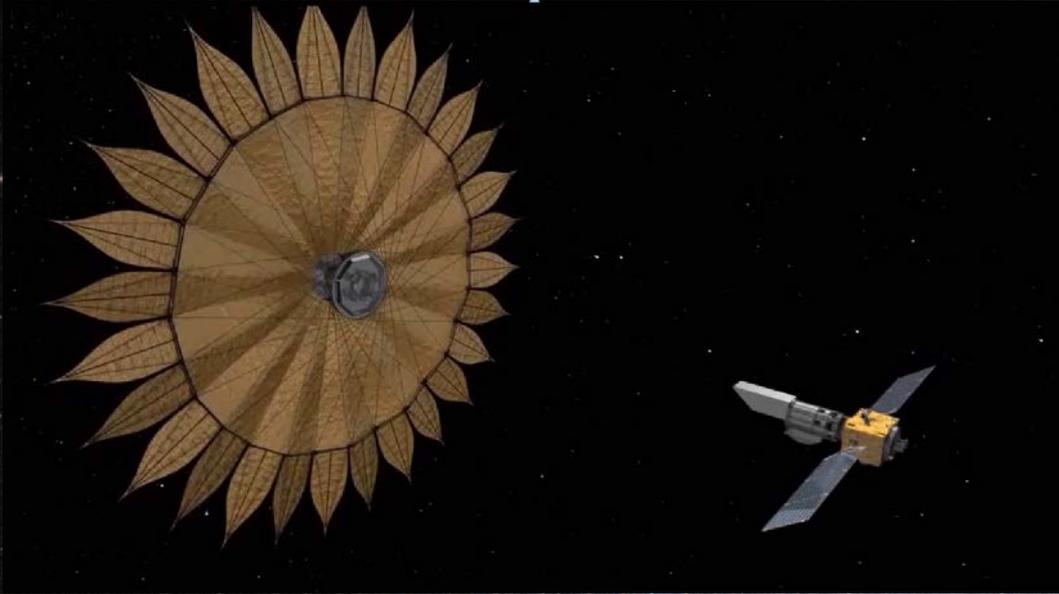
## Ground Telescopes with NASA participation

<sup>1</sup> NASA/ESA Partnership

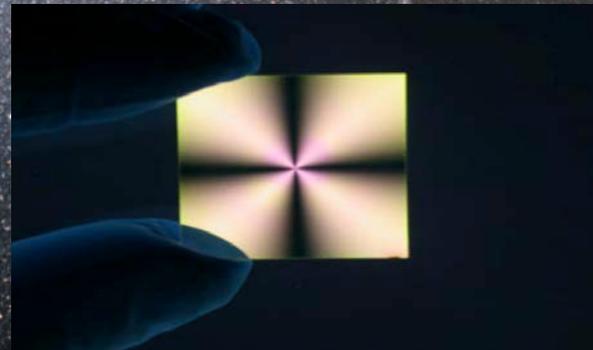
<sup>2</sup> NASA/ESA/CSA Partnership

<sup>3</sup> CNES/ESA

## External Occulters (Starshades)



## Internal Occulters (Coronagraphs)



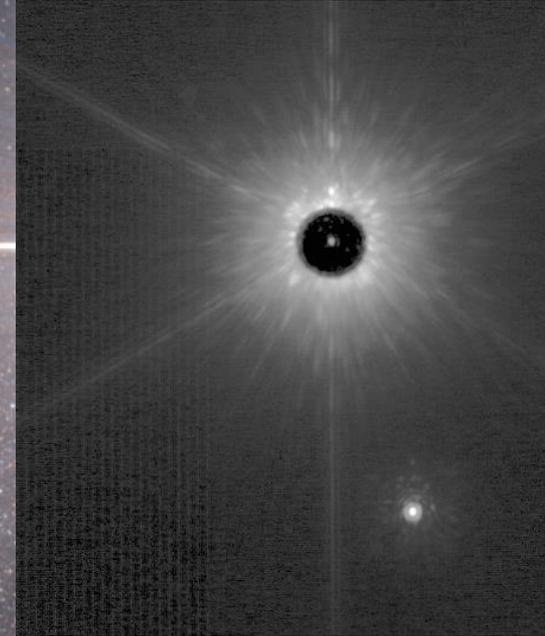
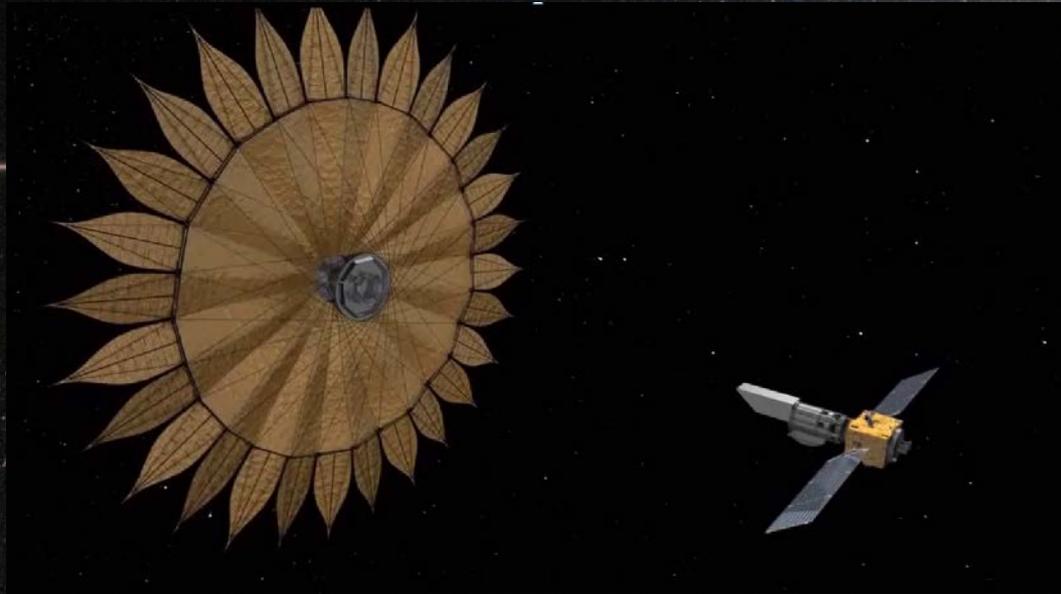
# WFIRST Science

The Fate of the Universe, and our Place in it

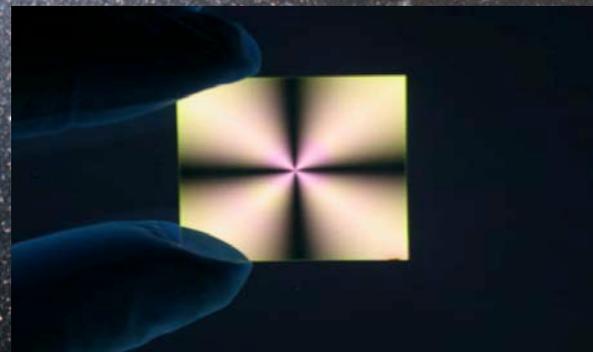


# StarLight Suppression

## External Occulters (Starshades)

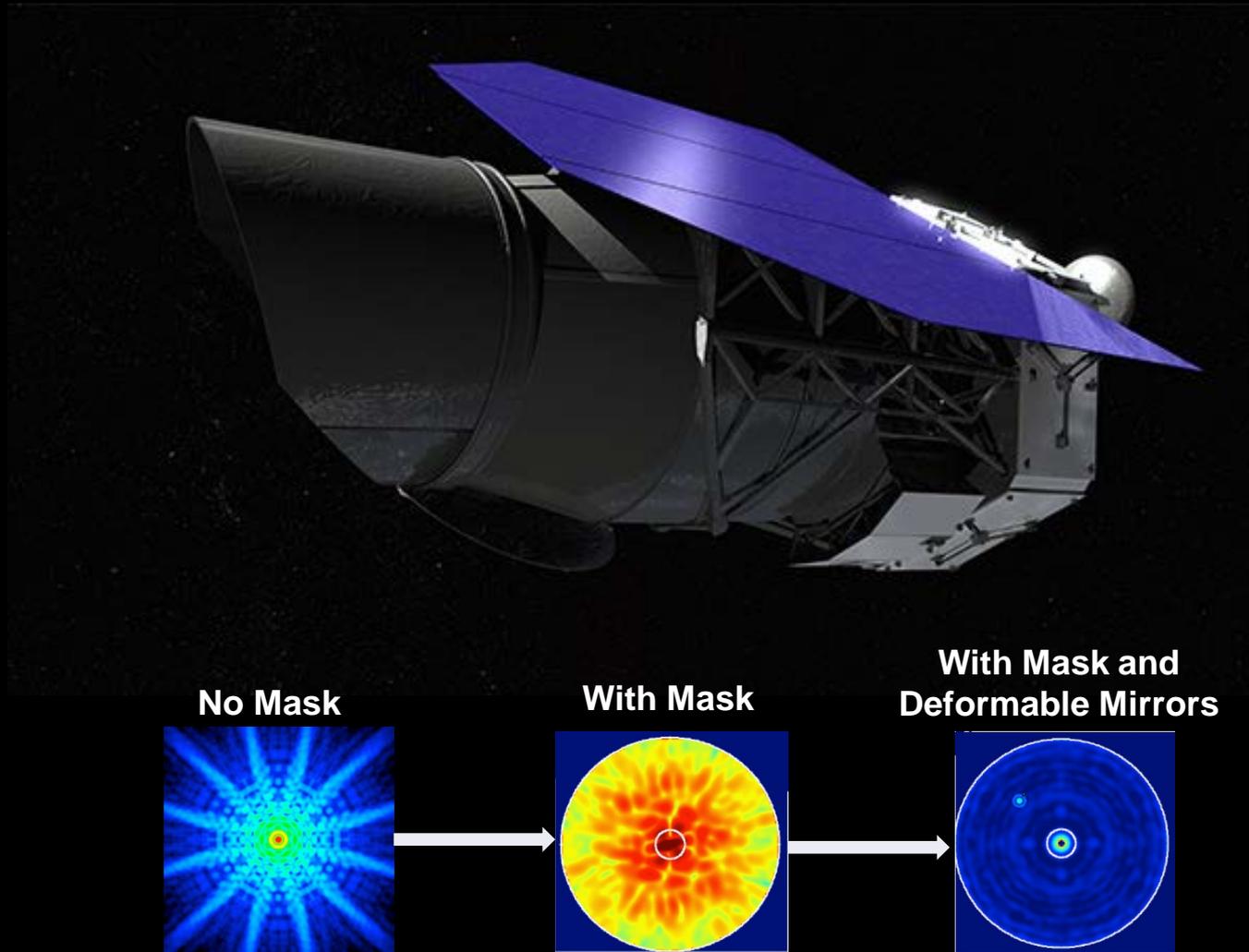


## Internal Occulters (Coronagraphs)



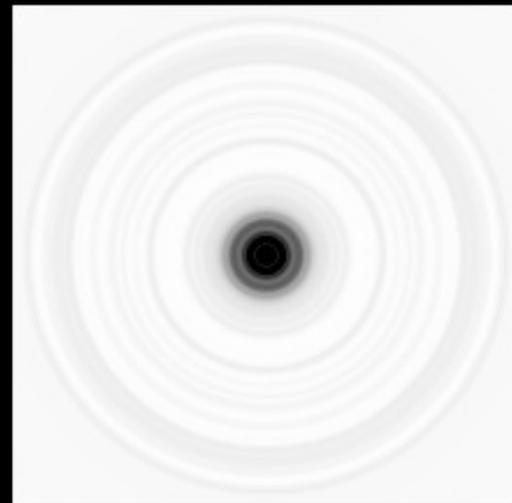
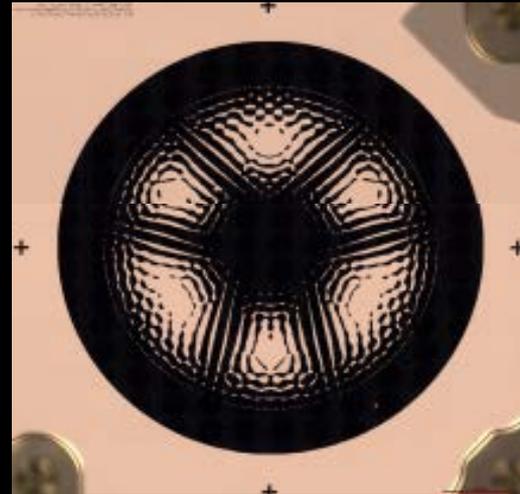
# WFIRST Coronagraph

Direct Imaging of our Nearest Neighbors



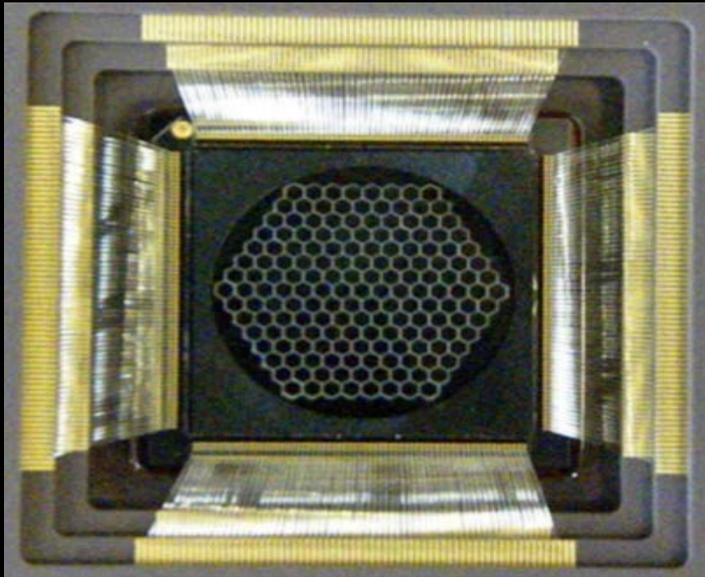
Technology Demonstration for exoEarth-Characterization Missions

# Coronagraph Technology Development



# Large Format Deformable Mirrors

For Active Wavefront Correction



167-Segment  
Piston-Tip-Tilt  
Deformable Mirror  
(*Iris AO*)



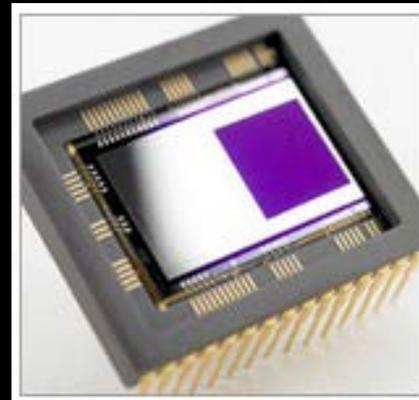
48x48 Continuous  
Face-Sheet  
Deformable Mirror  
(*AOA/Xinetics*)

# High Performance Detectors

Ultra-Low Noise for Exoplanet Detection and Spectroscopy

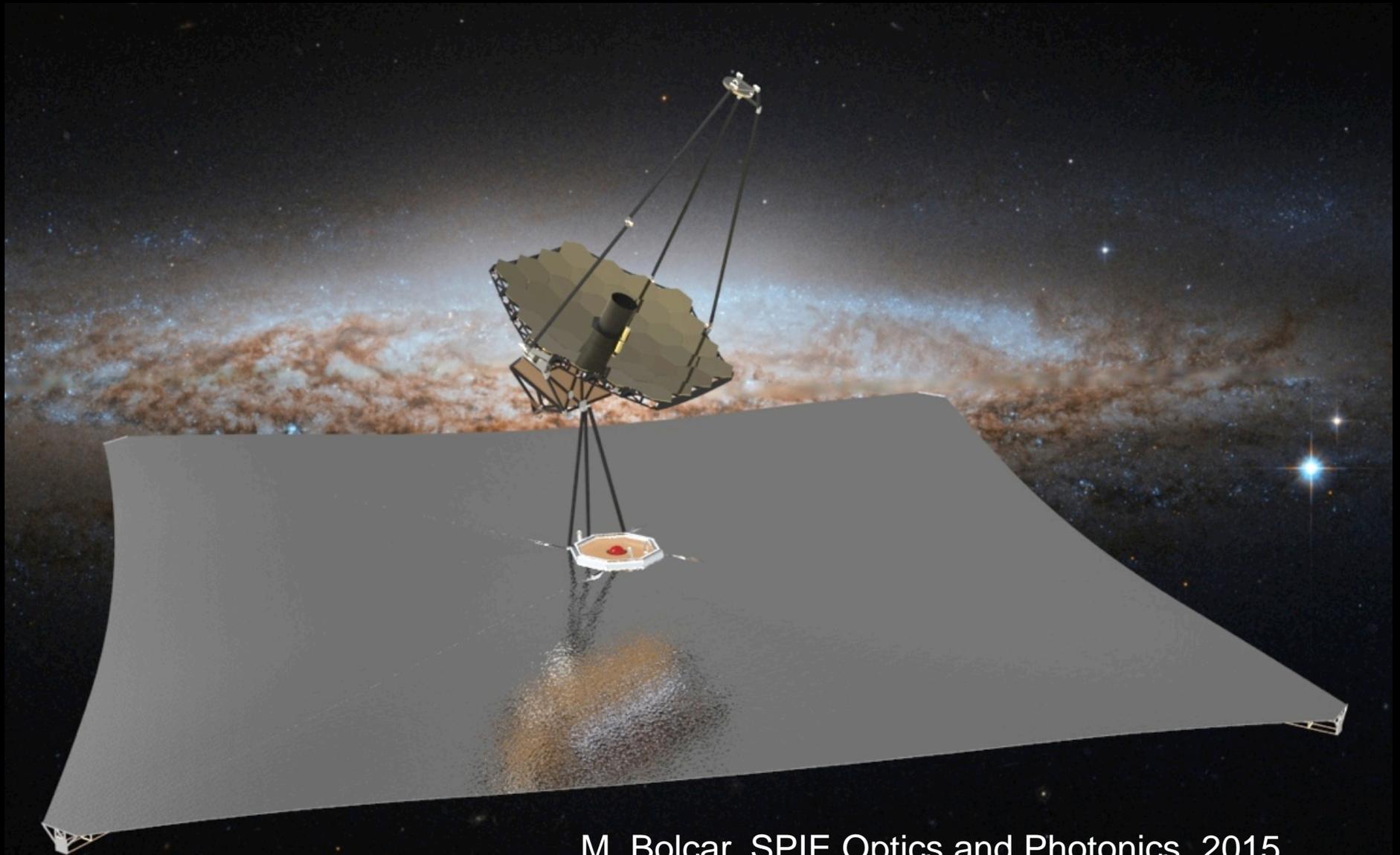


H4-RG Infrared Detector  
(*Teledyne*)



Electron Multiplying CCD  
(*e2v*)

# ATLAST Concept



M. Bolcar, SPIE Optics and Photonics, 2015

# Large Mirror Technology

For Faint Exoplanets at Small Inner Working Angles



Multi-Mirror System Demonstration (MMSD) Lightweight ULE Segment Substrate (*Harris*)



Active Hybrid Mirror (AHM) SiC-based Mirror Segment (AOA/Xinetics/JPL)

# A Starshade Mission Concept



# Key Technology Areas for a Starshade

## Starlight Suppression

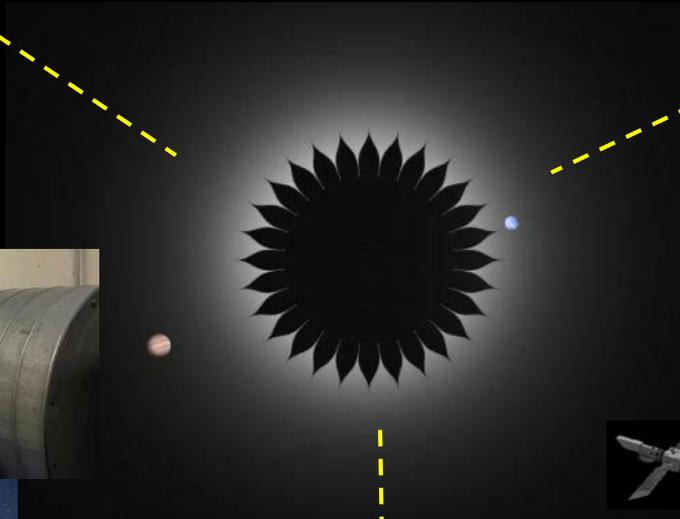


Controlling Sunlight scattering off petal edges (S-2)



Suppressing starlight and validating optical model (S-1)

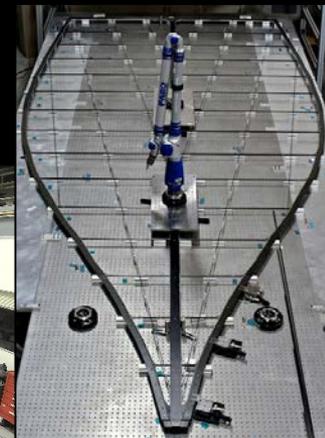
## Formation Sensing and Control



## Deployment Accuracy and Shape Stability



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

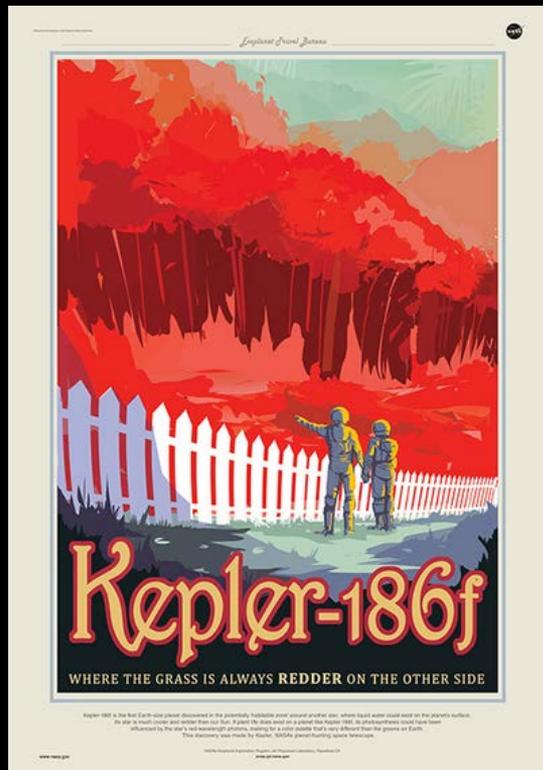


Fabricating the petal to high precision (S-4)

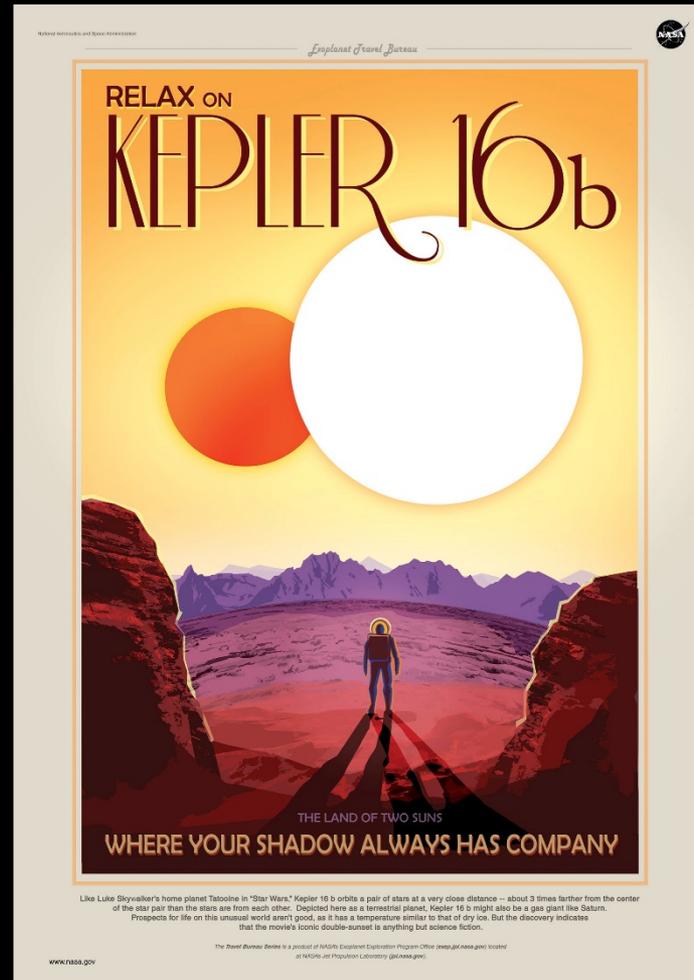
# 5 m Origami Optical Shield Deployment Trial at JPL



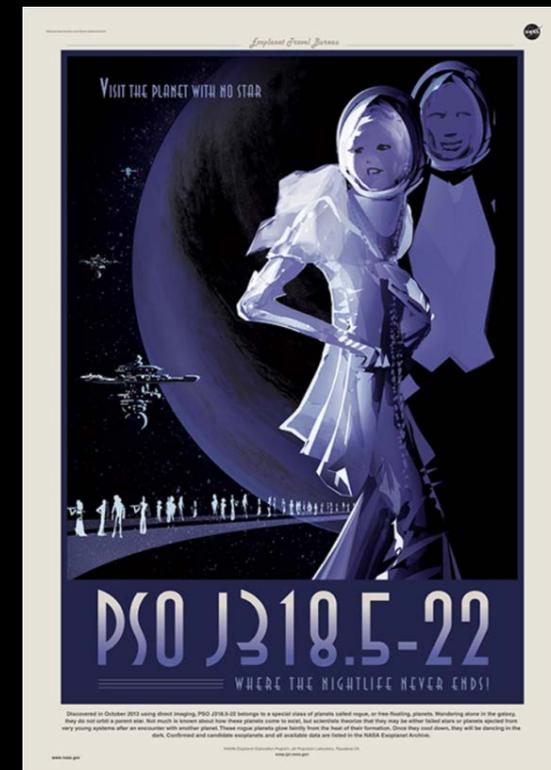
# Exoplanet Exploration – a Compelling Future



Bold Science



Achievable with Technology



Next Steps Worth Taking



National Aeronautics and  
Space Administration

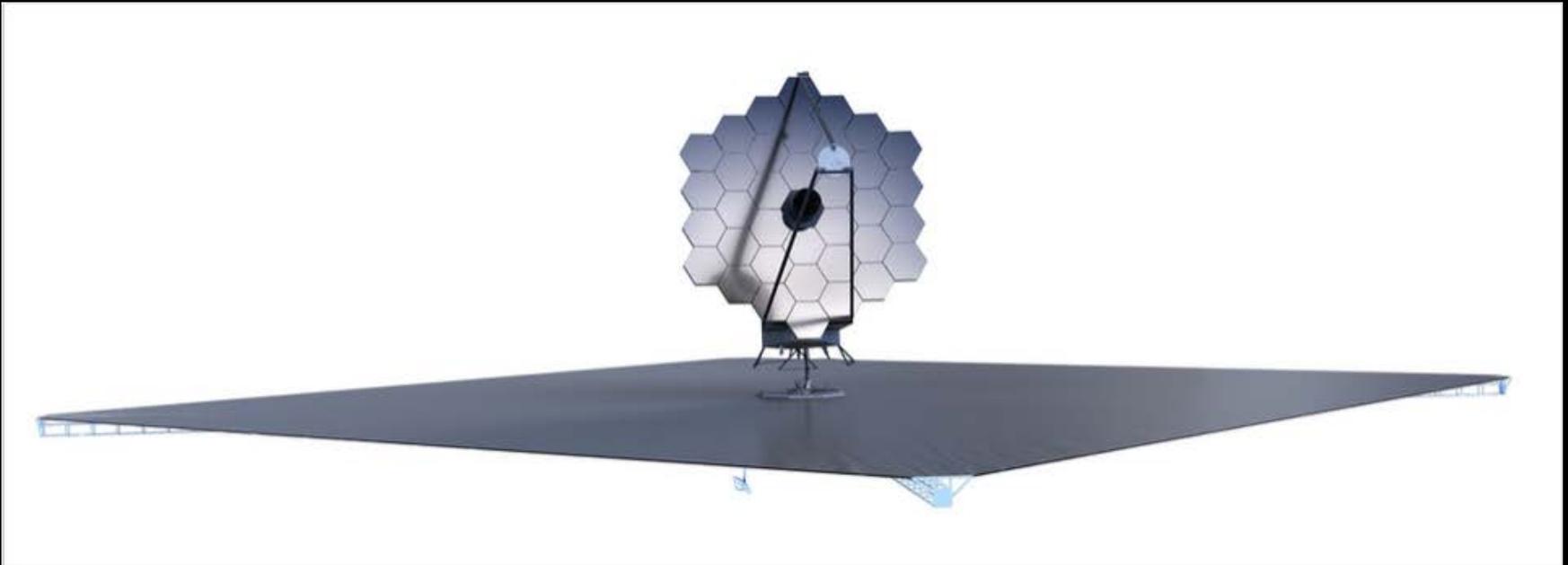
Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California

# Acknowledgements

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Government sponsorship acknowledged

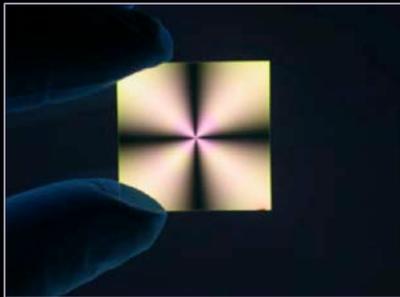
Backup



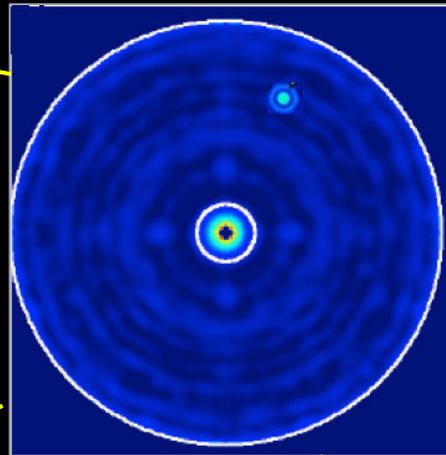
This is a past concept of ATLAST or HDST, and what LUVOIR looks like will be determined by the STDT

# Technology Development for Coronagraphs

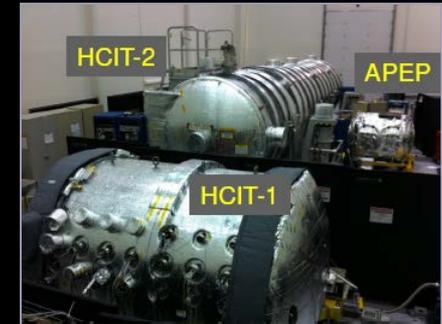
## Occulting Masks/ Apodizers



Serabyn – Vector Vortex Mask

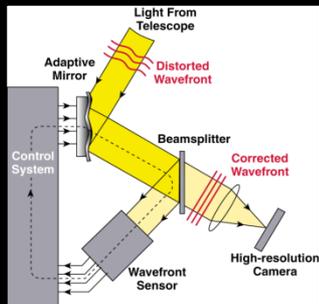


## System Demonstration

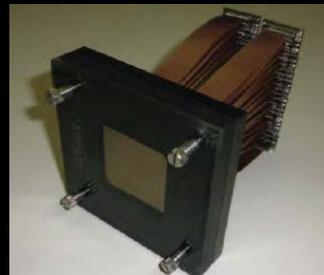


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## Low Order Wavefront Sensing and Control

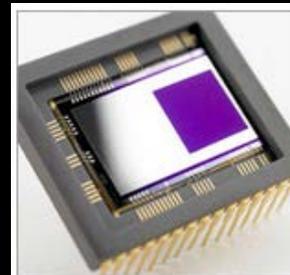


## Deformable Mirrors



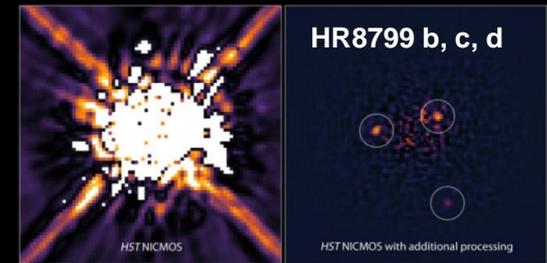
Xinetics

## Ultra-Low-Noise Visible Detectors



e2v Electron Multiplying CCD

## Image Post Processing



NASA, ESA, and R. Soummer (STScI)

Soummer et al. 2011