

Jet Propulsion Laboratory California Institute of Technology Pasadena, California

## Technology Development for Exoplanet Direct Imaging Missions

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AIAA Space 2014 Session "Astronomy from Space 30 Years in the Future"

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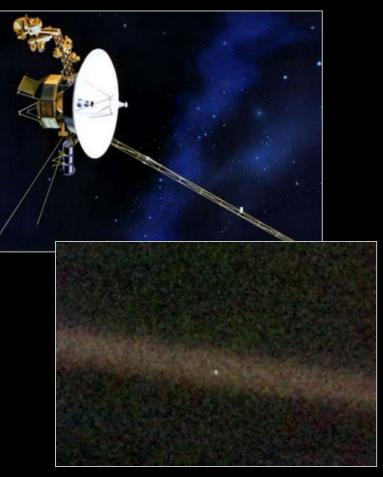
## Looking Back Nearly 30 years...to 1990



**ExoPlanet Exploration Program** 

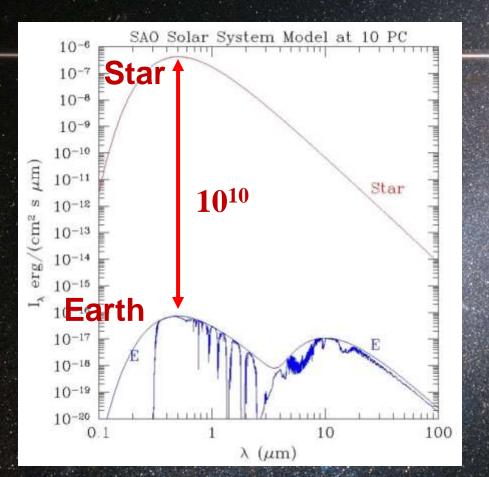






Are we Alone? The Search for Other Earths, The Search for Life in the Universe <sub>2</sub>

## The Challenge



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## Starlight Suppression for High-Contrast Imaging



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### http://exep.jpl.nasa.gov

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**External Occulter - Starshade** 







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No Mask

## WFIRST-AFTA

Wide-Field Infrared Survey Telescope (WFIRST) Astrophysics Focused Telescope Assets (AFTA)



**ExoPlanet Exploration Program** 

Wide-Field Instrument

#### **Coronagraph Instrument**

- Imaging and spectra channels
- 0.4 1  $\mu$ m bandpass
- $\leq 10^{-9}$  detection contrast
- 100 mas inner working angle at 0.4  $\mu$ m
- R ~ 70

#### **Coronagraph Science**

- Imaging and spectroscopy of exoplanet atmospheres down to a few Earth masses
- Study populations of debris disks

2.4m HST-like telescope

Coronagraph Instrument With Mask

With Mask and Deformable Mirrors

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URS CL#14-5165 A's coronagraph will develop the technologies for a future exo-Earth mission

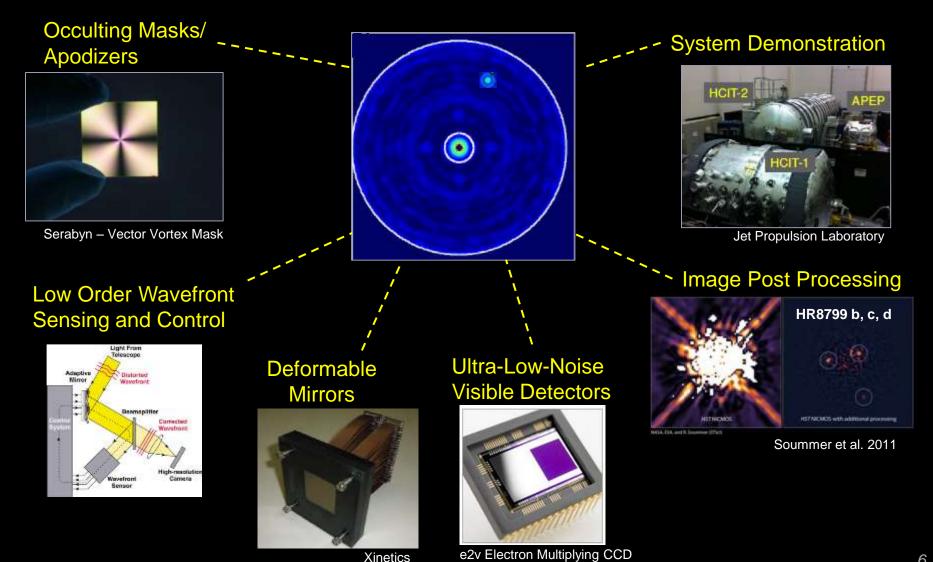


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## **Technology Development for Coronagraphs** (Internal Occulters)



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## The External Occulter – the Starshade



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The starshade could launch together with a telescope. Once in space, it would split off and move into position to block the starlight.



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## Technology Development for Starshades (External Occulters)



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#### Control of Scattered Light



# Validation of Optical Models



#### Starshade Deployment



#### NGAS, Princeton, JPL

#### Petal Prototype

Formation Flying



Princeton, JPL



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## Deployment Testing at Northrop Grumman (Astro-Aerospace)



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#### Demonstration of starshade development model

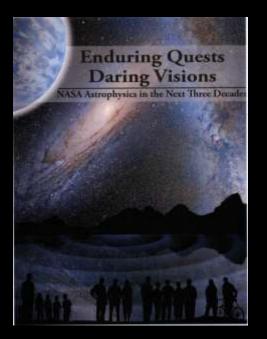


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# Formative Era: Large UV-Optical-IR Telescope



**ExoPlanet Exploration Program** 





	LUVOIR Surveyor
Formation flying	
Interferometry: precision metrology	
X-ray interferometry	
High-contrast imaging techniques	
Optics deployment and assembly	
Broadband coatings	
X-ray optics	
Large-format detector arrays	
New detector capabilities	
Cryogenics	



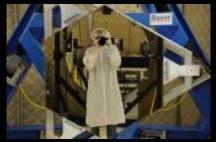
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## Formative Era: Large UV-Optical-IR Telescope (LUVOIR)

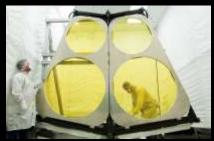


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#### Optics Deployment and Assy



SiC Active Hybrid Mirror, Xinetics



MOIRE, BATC



Lightweight ULE, ITT

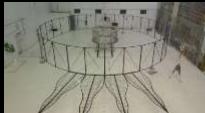
Starlight Suppression Systems



Visible Nuller, GSFC



Pupil Mapping, Univ. Arizona



Starshade NGAS, Princeton, JPL

#### Formation Flying

**Broadband Mirror Coatings** 

Telescope Mechanical Isolation Systems



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## **Technology Needs and Priorities**

- You are invited to read more about
  - Quantified technology gaps (needs, capabilities)
  - Past and current work conducted through SAT / ROSES / TDEM

http://exep.jpl.nasa.gov

• Next call: November 2014

Science Goal	Capability	Needed Technologies	Technology Gaps	Table /	A.4.Sper
Detection of life	Spectroscopy of light from direct exo-	starlight suppression (internal and	Coronagraph Technology Gap List	10 10 11	Title Contr Duate Sandy NaAd abard aptro
	planet imaging	external occulters)	Starshade Technology Gap List	85	literet Tegin

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ExoEarth Mapper

## Visionary Era: Exo Earth Mapper



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Exo-Earth Mapper					
	LUVOIR Surveyor	ExoEa Mapj			
Formation flying					
Interferometry: precision metrology					
X-ray interferometry					
High-contrast imaging techniques					
Optics deployment and assembly					

Broadband coatings

X-ray optics

Large-format detector

New detector capabilities

Cryogenics

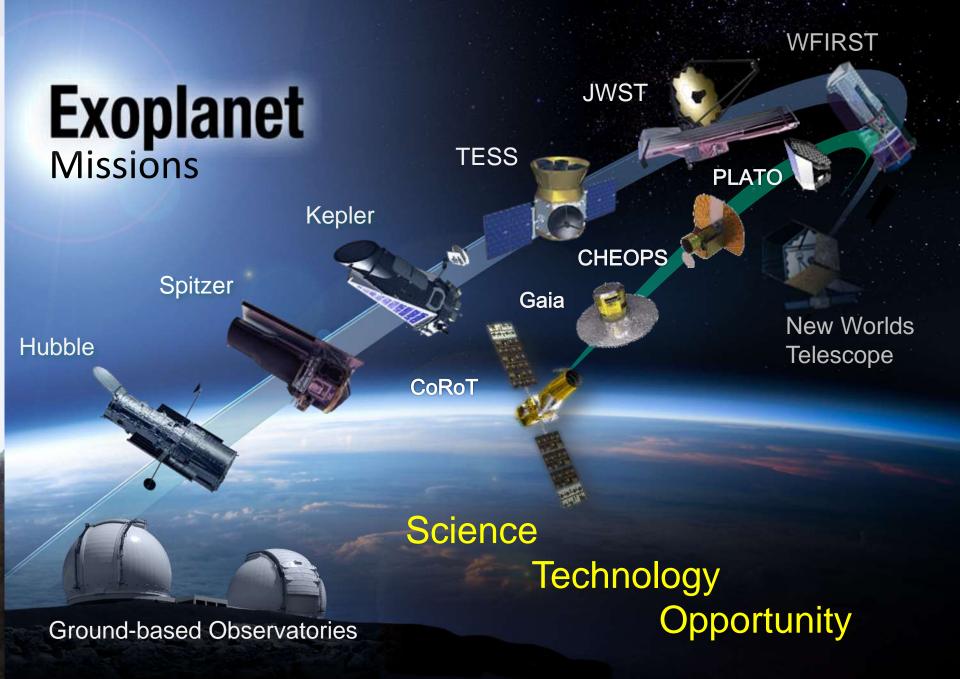
arrays

Formation-Flying Telescope Arrays

- 500 m^2 collecting area
- >370km baseline

#### **Interferometer Technologies**

- Precision Laser Metrology
- Beam combination,
- Aperture synthesis
- Formation Flying



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**ExoPlanet Exploration Program** 

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