

The background of the slide is a composite image. On the right side, there is a large, detailed view of the Earth from space, showing the Western Hemisphere with the Americas and the Atlantic Ocean. The Earth is illuminated from the left, creating a bright horizon. On the left side, there is a view of a galaxy, likely the Milky Way, showing its spiral arms and a central bulge. The galaxy is rendered in a color palette of blues, reds, and oranges, set against a dark, star-filled background.

# THE LUVOIR SURVEYOR: DESIGN UPDATE & TECHNOLOGY NEEDS

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**NASA GSFC**

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# What is LUVOIR ?

Crab Nebula with HST ACS/WFC  
Credit: NASA / ESA

## Large UV / Optical / Infrared Surveyor (LUVOIR)

- ◎ A space telescope concept in tradition of Hubble
  - Broad science capabilities
  - Far-UV to Near-IR bandpass
  - ~ 8 – 16 m aperture diameter
  - Suite of imagers and spectrographs
  - Serviceable and upgradable
  - Hubble-like guest observer program

“Space Observatory for the 21<sup>st</sup> Century”

Ability to answer questions we have not yet conceived

# We are studying two architectures in depth...

## ◎ Architecture A

- 15-m diameter aperture
- Four instrument bays:
  - Extreme Coronagraph for Living Planetary Systems (“ECLIPS”)
  - UV Multi-object Spectrograph (“LUMOS”)
  - High-definition Imager (“HDI”)
  - High-res UV Spectropolarimeter (“Pollux”, *CNES Contributed*)

## ◎ Architecture B

- ~9-m diameter aperture
- Three instruments to be studied:
  - ECLIPS-B
  - LUMOS-B
  - HDI-B

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## ◎ Architecture A

- 15-m diameter aperture
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**Subject of this talk**

## ◎ Architecture B

- ~9-m diameter aperture
- Three instruments to be studied:
  - ECLIPS-B
  - LUMOS-B
  - HDI-B

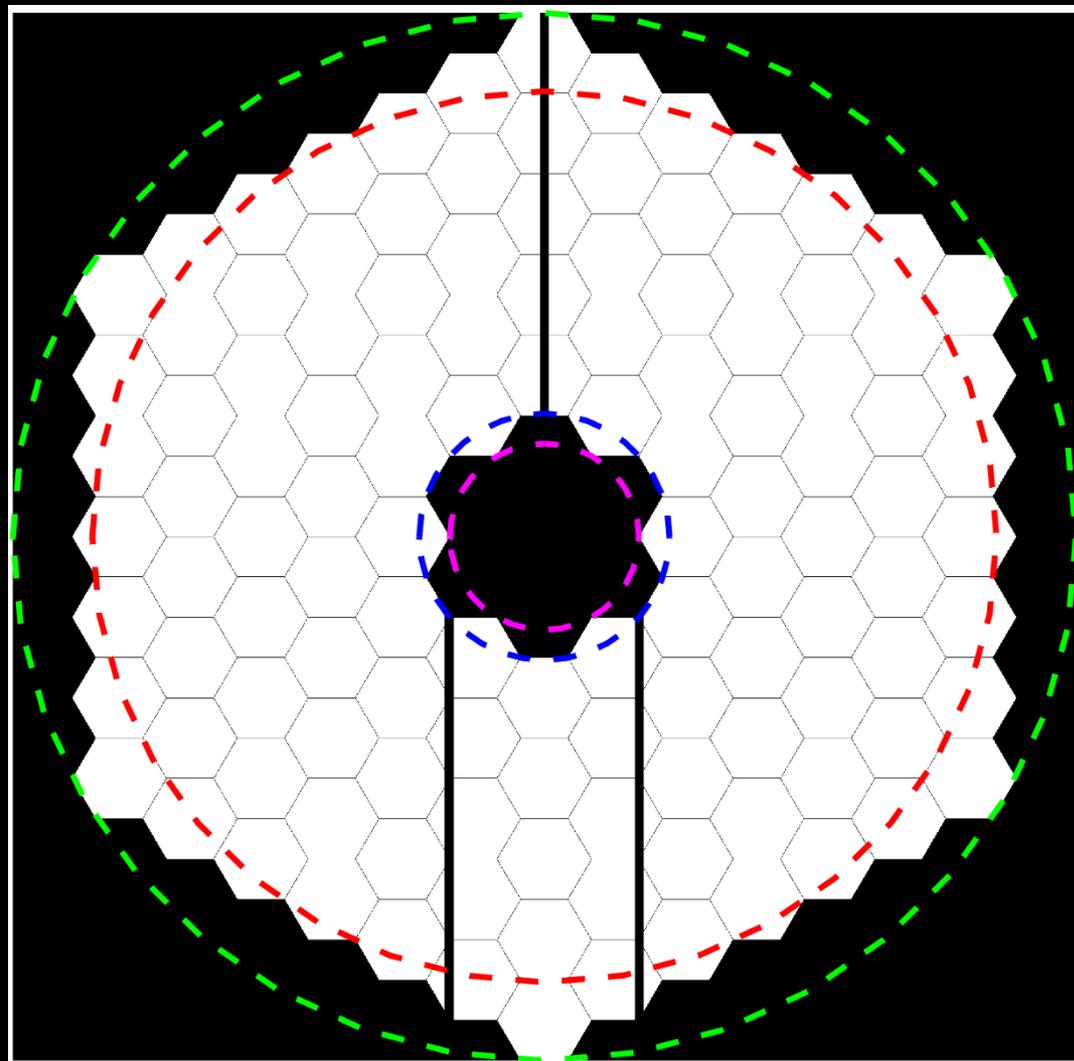
Note: In this representation,  
spacecraft & sunshield are  
notional.



LUVOIR Architecture A (15-m)

Credit: A. Jones (GSFC)

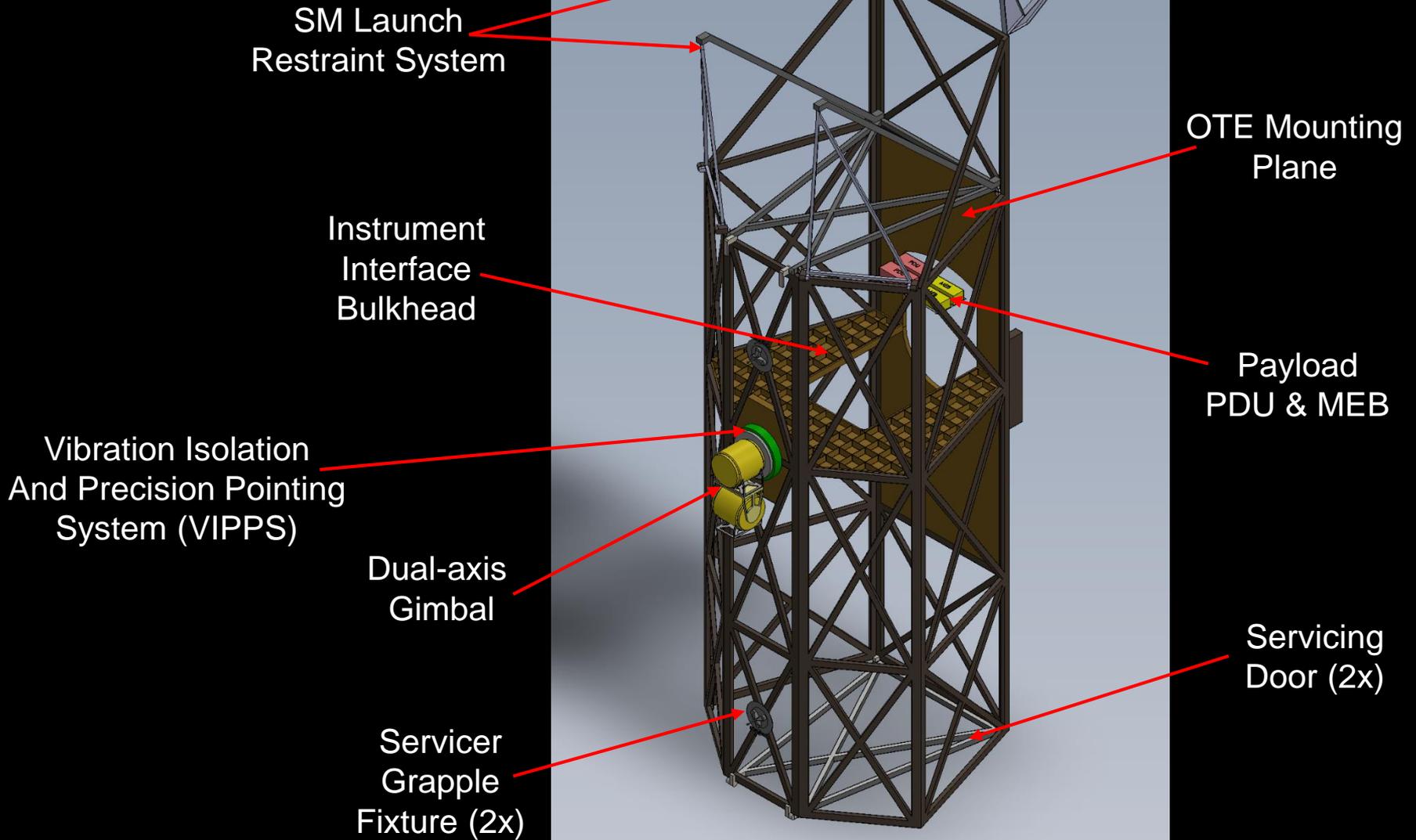
# LUVOIR "A" OTE: Aperture



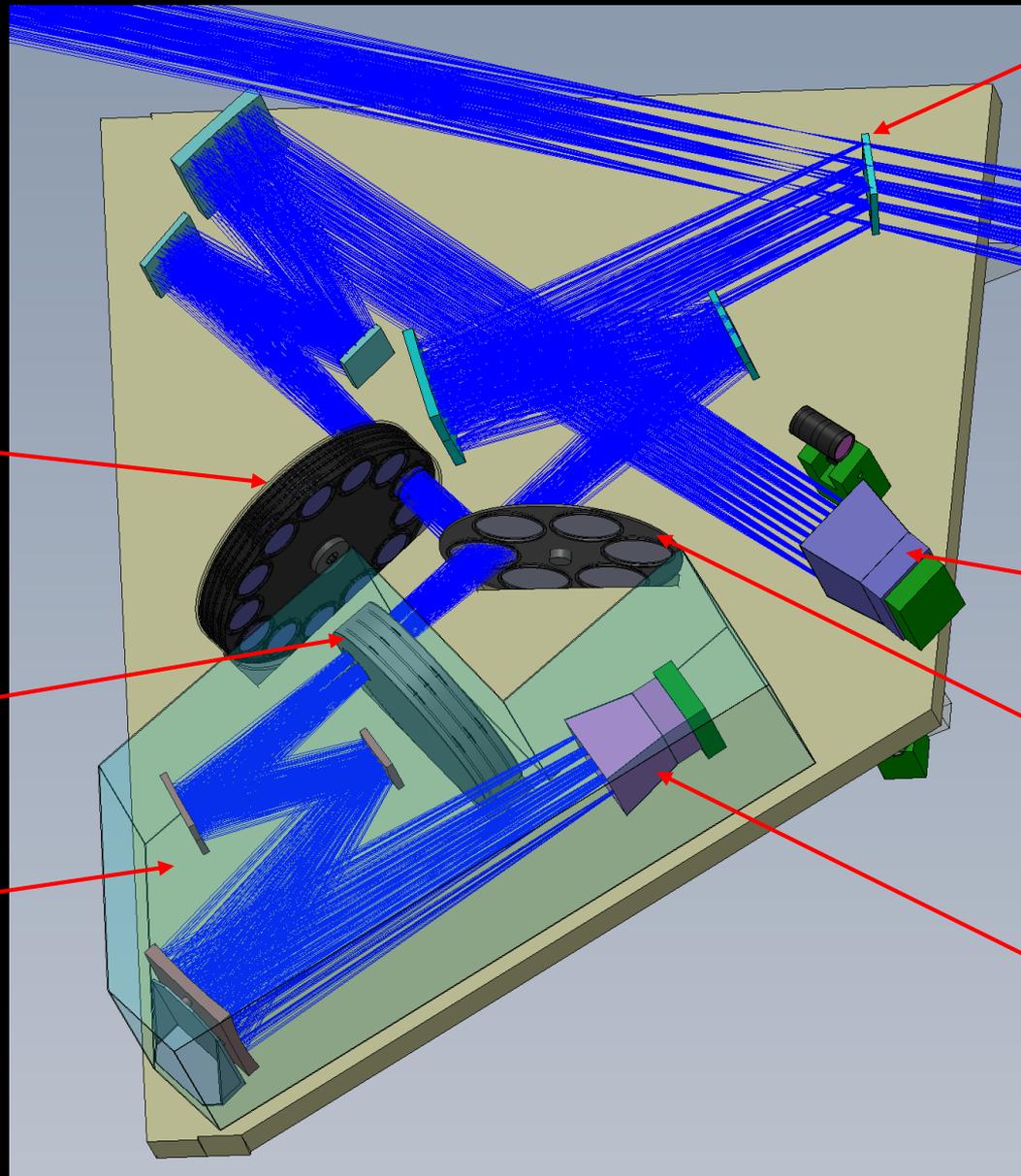
- 15.0 m
- 12.8 m
- 3.5 m
- 2.7 m

- ⦿ 1.15-m flat-to-flat segments
  - 120x segments
  - 20 different surface prescriptions
  - Baseline Corning ULE™ substrates for all mirrors
  - 6 mm gaps
- ⦿ Central ring removed to accommodate aft-optics & secondary mirror obscuration
- ⦿ Collecting area is 135 m<sup>2</sup>

# Backplane Support Frame



# High-Definition Imager (HDI)



Pick-off Mirror  
(piston, tip,  
tilt control)

UVIS Filter  
Wheel Assy.

UVIS Focal  
Plane Array

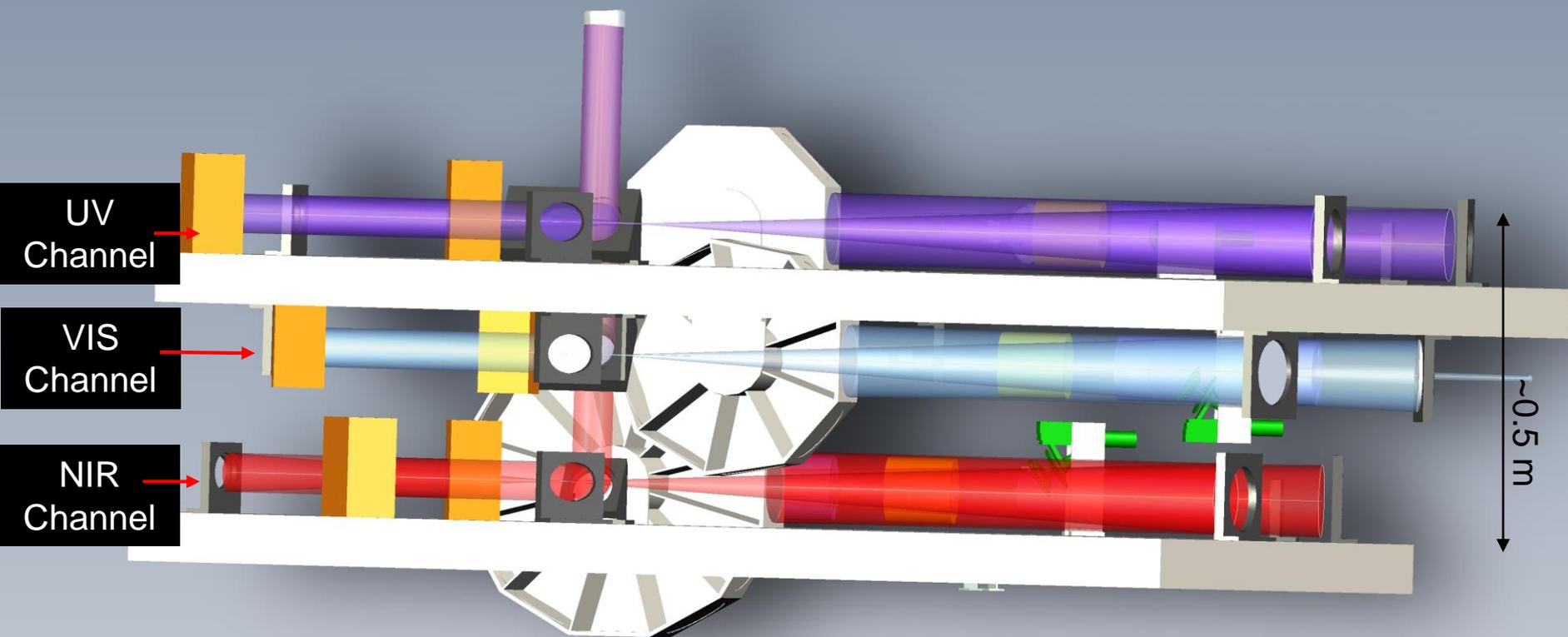
NIR Filter  
Wheel Assy.

Channel Select  
Mechanism

NIR Channel  
Shroud

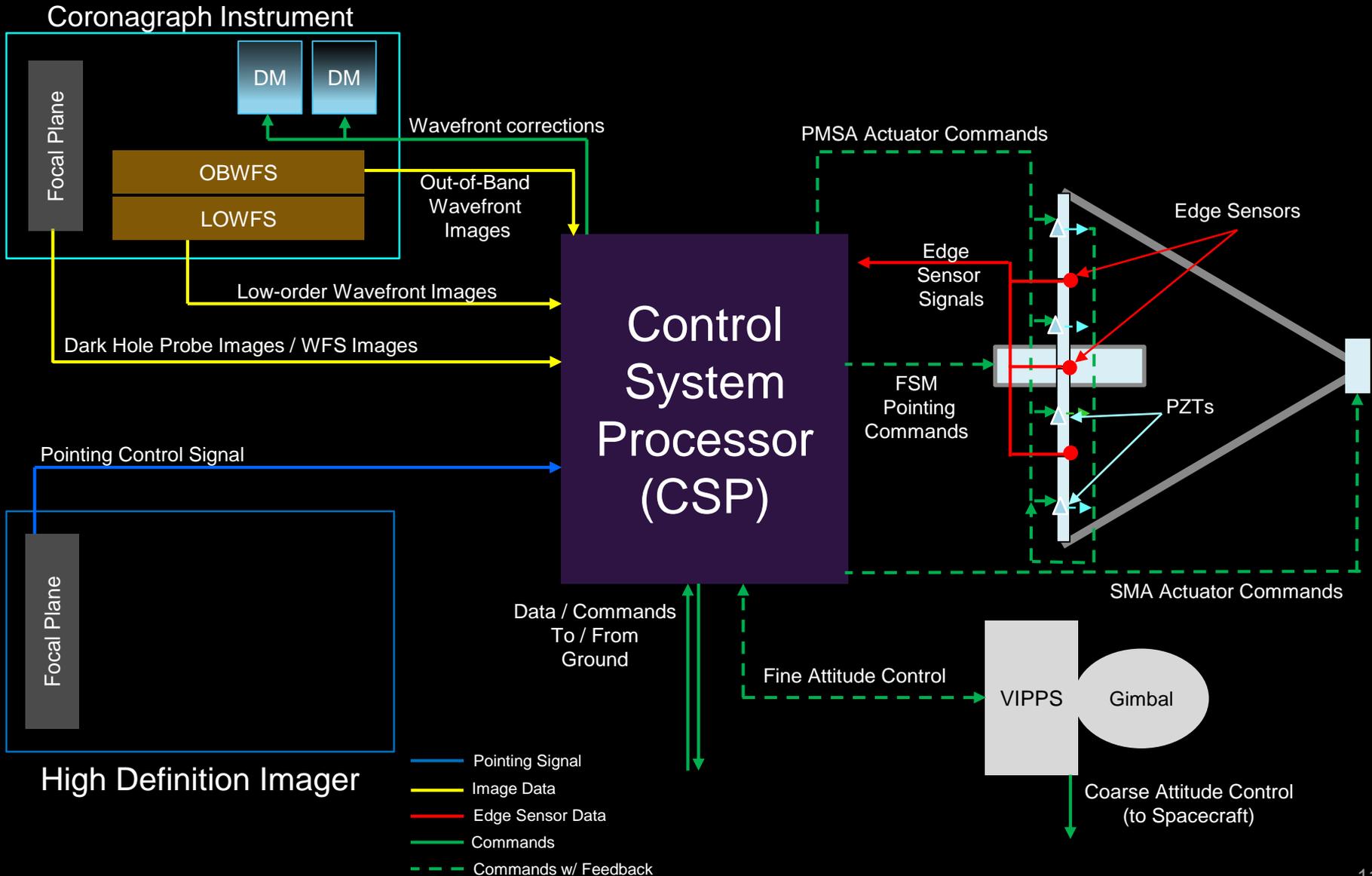
NIR Focal  
Plane Array

# Extreme Coronagraph for Living Planetary Systems (ECLIPS)





# Control System Processor (CSP)



# LUVOIR UV Multi-object Spectrograph (LUMOS)

Microshutter Array

MOS Pick-off Mirror

MOS Gratings

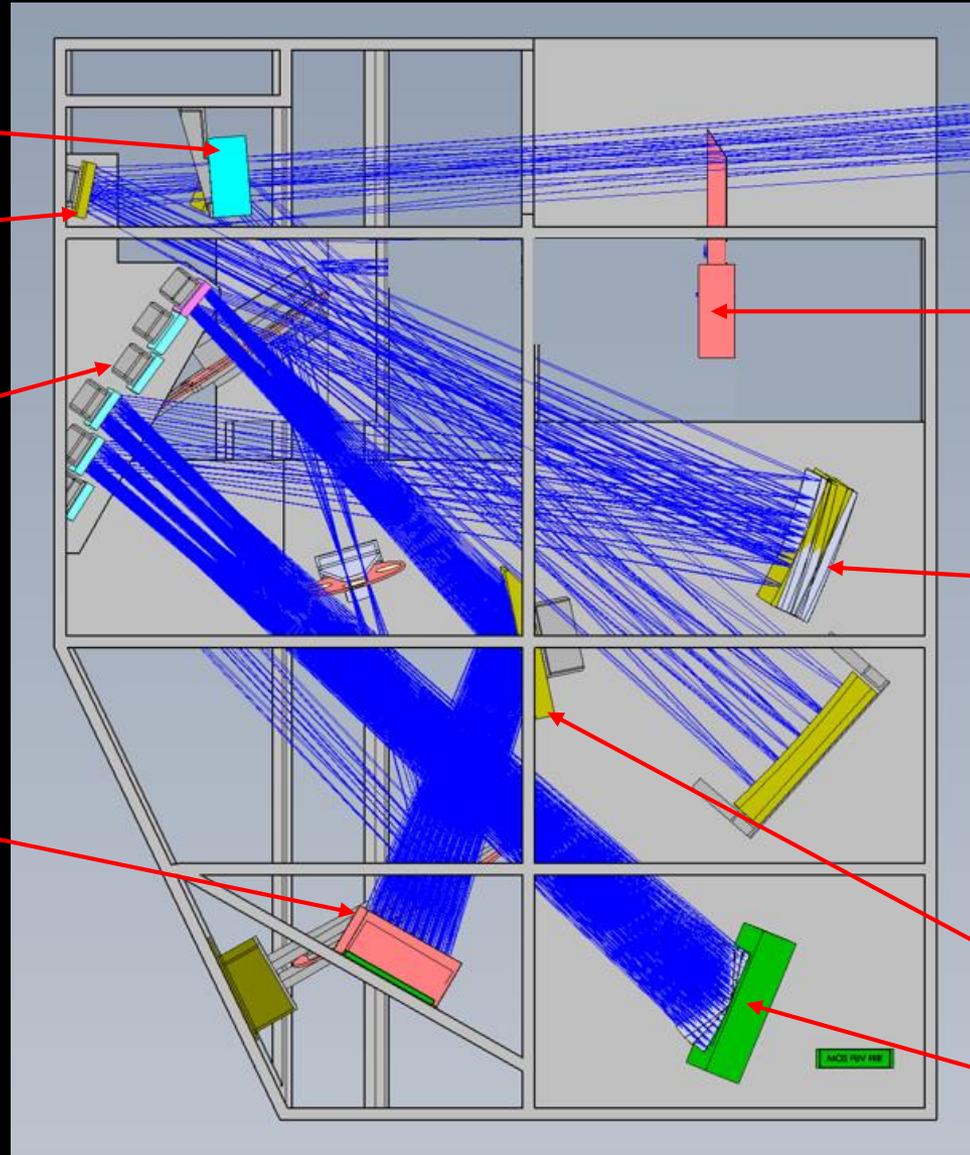
MOS NUV Detector

MOS Calibration System

MOS Grating Select Mirror

MOS NUV Fold Mirror

MOS FUV Detector



# Technology Drivers

## ◎ Direct imaging & spectral characterization of habitable exoplanets

- **Requires:**

- Large, segmented aperture for high yields
- High-contrast coronagraph, compatible with segmented aperture
- Ultra-stable wavefront error
- Near-zero read noise detectors

## ◎ High-throughput general astrophysics, emphasizing Far-UV Spectroscopy

- **Requires:**

- Large, segmented aperture for sensitivity and resolution
- High reflectivity UV coatings
- High sensitivity, large format detectors
- Large format microshutter arrays for multi-object capability

# LUVOIR Technology Prioritization

Priority	Technology Gap Name	TRL
1	<b>Ultra-stable Opto-mechanical Systems</b>	2
1a	Segment Phase & Control	3
1b	Dynamic Isolation Systems	4
1c	Mirror Segments	5
2	<b>High-contrast Segmented Aperture Coronagraphy</b>	3
2a	Segmented-aperture Coronagraph Architecture	3
2b	Deformable Mirrors	4
2c	Wavefront Sensing & Control	4
2d	High-contrast Imaging Post-processing	4
3	<b>High Performance UV/Vis/NIR Detectors</b>	
3a	Large-format High-dynamic Range UV Detectors	4
3b	Ultra-low Noise Detectors for Visible Exoplanet Science	5
3c	Ultra-low Noise Detectors for NIR Exoplanet Science	5
4	<b>Next Generation Microshutter Arrays</b>	4
5	<b>High Reflectivity Broadband FUV-to-NIR Mirror Coatings</b>	3

Stability for high-contrast is #1 challenge

*“~ 10 pm RMS per ~10 minutes”*

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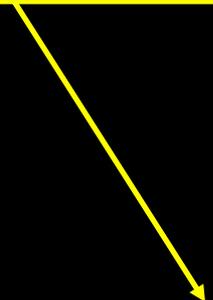
Set by coronagraph's  
sensitivity to  
wavefront error.

# Stability for high-contrast is #1 challenge

“~10 pm RMS per ~10 minutes”



Set by coronagraph's sensitivity to wavefront error.



Set by how fast the wavefront control loop can be closed.

# Stability for high-contrast is #1 challenge

*“~ 10 pm RMS per ~10 minutes”*

- ⊙ High-contrast imaging through wavefront **stability**
  - Stiff, thermally-stable materials and structures
  - Active and passive dynamic isolation
  - Thermal sensing & control at the milli-Kelvin level
  - Metrology to verify performance at the picometer level

# Stability for high-contrast is #1 challenge

“~ 10 pm RMS per ~10 minutes”

- ⊙ High-contrast imaging through wavefront **stability**
- ⊙ High-contrast imaging through wavefront **control**
  - Slow, low-order wavefront control from stellar photons
  - Fast, higher-order wavefront control from metrology
    - Edge sensors, laser truss, artificial guide star, etc.
  - Go from 10 minutes to seconds or less

# Stability for high-contrast is #1 challenge

“~10 pm RMS per ~10 minutes”

- ⊙ High-contrast imaging through wavefront **stability**
- ⊙ High-contrast imaging through wavefront **control**
- ⊙ High-contrast imaging through wavefront **tolerance**
  - Design coronagraphs that can tolerate >10 pm of WFE
  - New optimization techniques open up the design space
    - Vector vortex, aperture masks, nulling interferometry, etc.
  - Tolerate 100s of pm or even nanometers of WFE

# Stability for high-contrast is #1 challenge

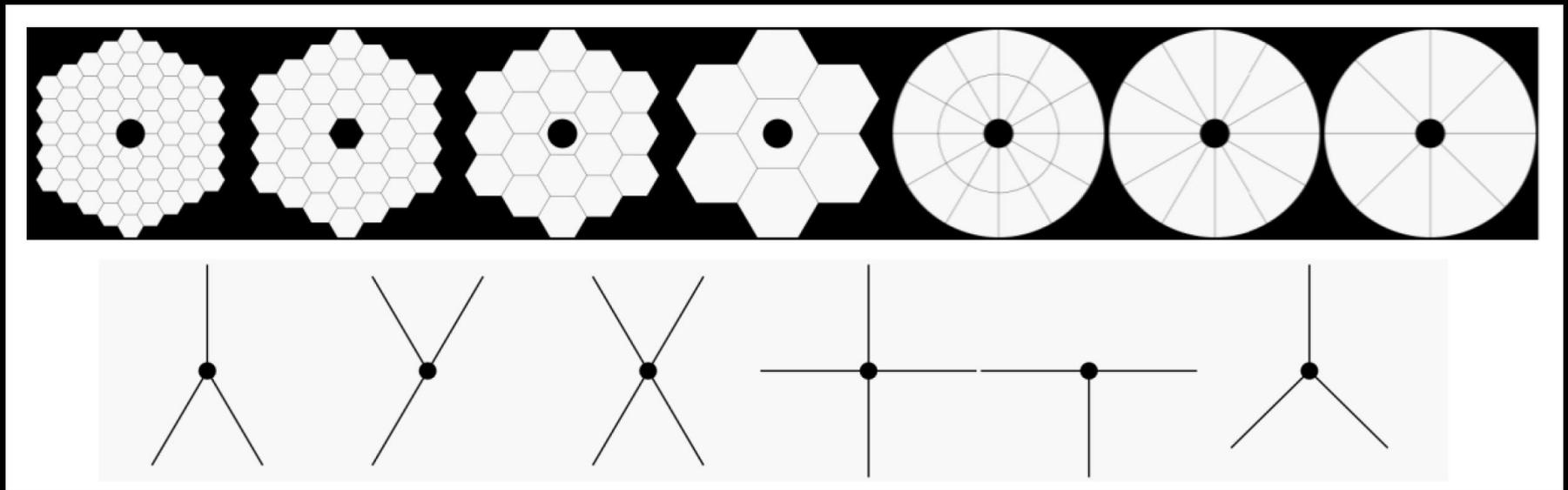
“~ 10 pm RMS per ~10 minutes”

- ⊙ High-contrast imaging through wavefront **stability**
- ⊙ High-contrast imaging through wavefront **control**
- ⊙ High-contrast imaging through wavefront **tolerance**
- ⊙ Solution consists of a combination of all three

# High-Contrast Segmented-Aperture Coronagraphy

# Coronagraph Architecture

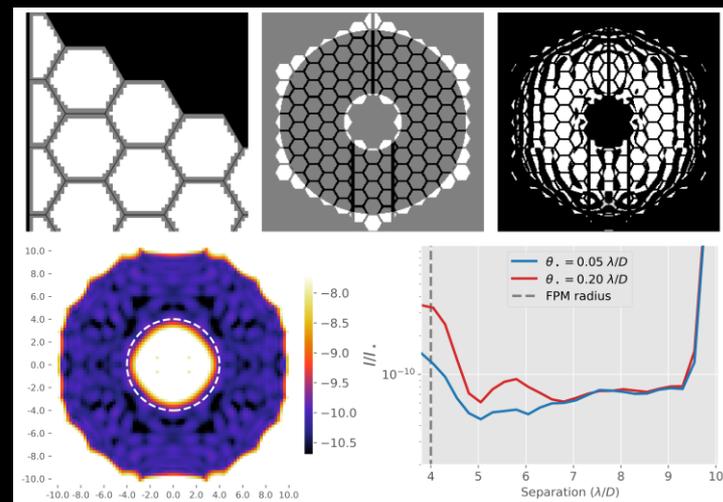
- ◎ Segmented Coronagraph Design & Analysis (SCDA) Study
  - Develop coronagraph designs with high-contrast, high-throughput, small inner working angle, and broad bandwidth



Credit: S. Shaklan / JPL

# Coronagraph Architecture

- ◎ Segmented Coronagraph Design & Analysis (SCDA) Study
  - Develop coronagraph designs with high-contrast, high-throughput, small inner working angle, and broad bandwidth
- ◎ Coronagraphs being studied:
  - Apodized Pupil Lyot Coronagraph (APLC)
  - Phase-Induced Amplitude Apodization (PIAA)
  - Vector Vortex Coronagraph (VVC)
  - Visible Nulling Coronagraph (VNC)



Credit: N. Zimmerman/GSFC

# Design for Wavefront Tolerance

- ◎ Studying techniques to relax coronagraph sensitivity to wavefront error, segmentation, and stellar diameter:
  - Mitigation of segmentation with DMs
  - Dark hole optimization with IFS images
  - High-contrast, high-resolution fiber fed spectroscopy
  - Micro-lens pinhole contrast enhancement
  - Artificial laser guide star for high-speed wavefront sensing

# UV / VIS / NIR Detectors

# LUVOIR Baseline Detectors:

## ◎ *HDI*

- 40 8k x 8k CMOS detectors for UVIS channel
- 20 4k x 4k H4RG detectors for NIR channel

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- 40 8k x 8k CMOS detectors for UVIS channel
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## ◎ *Coronagraph*

- $\delta$ -doped EMCCD detector for UV channel
- EMCCD detector for Vis channel
- H4RG detector for NIR channel

# LUVOIR Baseline Detectors:

## ◎ **HDI**

- 40 8k x 8k CMOS detectors for UVIS channel
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## ◎ **Coronagraph**

- $\delta$ -doped EMCCD detector for UV channel
- EMCCD detector for Vis channel
- H4RG detector for NIR channel

## ◎ **LUMOS**

- CsI and bialkali Microchannel Plate for FUV multi-object spectrograph and imager
- 21 8k x 8k  $\delta$ -doped CMOS detectors for NUV multi-object spectrograph

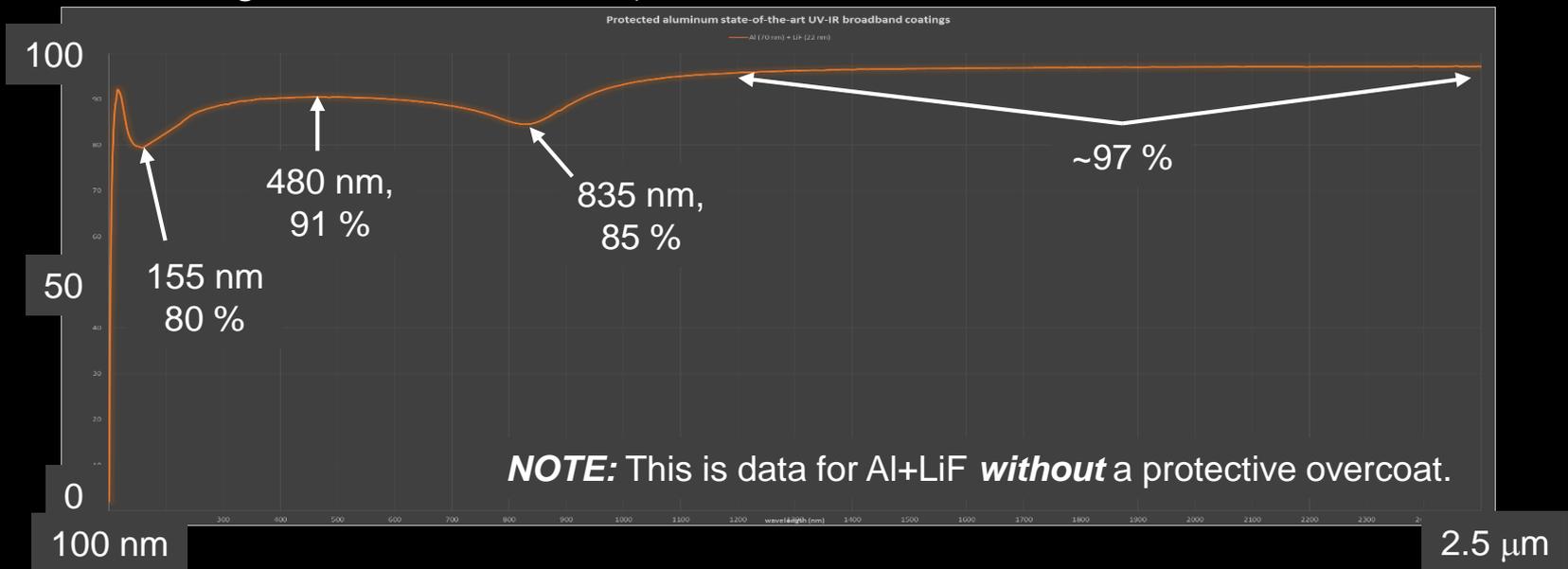
## Additional Detector Technologies Being Considered

- ◎ Hole-multiplying CCDs
  - p-channel version of EMCCD
  - Inherently radiation hard
  
- ◎ Avalanching photodiode arrays for photon-counting NIR detector
  - Would provide better noise performance for NIR exoplanet science

# High Reflectivity Far-UV to Near-IR Mirror Coatings

# LUVOIR “A” OTE: Coating

- Baseline: Al + LiF + thin protective overcoat of MgF<sub>2</sub> or AlF<sub>3</sub>
  - Al + LiF is high TRL and well understood
    - Additional “capping” layer to address hygroscopicity requires additional demonstration (underway)
  - Approximate Reflectivities:
    - 65% @ 105 nm
    - 91% @ 115 nm
    - Average 85% 115 nm – 200 nm
    - Average 88% 200 nm – 850 nm
    - Average 96% 850 nm – 2.5 μm



# Get involved with LUVOIR

<http://asd.gsfc.nasa.gov/luvoir/>

Large UV/Optical/Infrared Surveyor (LUVOIR)

 National Aeronautics and Space Administration  
Goddard Space Flight Center

Astrophysics Science Division • Sciences and Exploration

# LUVOIR

## Large UV/Optical/Infrared Surveyor



- Home
- Science
- LUVOIR Flyer
- Technology
- Seminars
- Events
- Meet the Team
- Working Groups
- Documents
- Images & Videos
- Simulation Tools

## Large UV/Optical/Infrared Surveyor

The Large UV/Optical/IR Surveyor (LUVOIR) is a concept for a highly capable, multi-wavelength space observatory with ambitious science goals. This mission would enable great leaps forward in a broad range of science, from the epoch of reionization, through galaxy formation and evolution, star and planet formation, to solar system remote sensing. LUVOIR also has the major goal of characterizing a wide range of exoplanets, including those that might be habitable - or even inhabited.

LUVOIR is one of four Decadal Survey Mission Concept Studies initiated in Jan 2016. The study will extend over three years and will be executed by the Goddard Space Flight Center, under the leadership of a Science and Technology Definition Team (STDT) drawn from the community.

A brief description of LUVOIR science goals and capabilities are available in this [flyer](#).

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## News

### Fourth LUVOIR STDT Meeting

The fourth face-to-face team meeting took place at JPL in Pasadena CA on April 17 & 18, 2017. Meeting info can be found on the [Events](#) page.



- [For Science](#)