THE LUVOIR SURVEYOR: DESIGN UPDATE & TECHNOLOGY NEEDS

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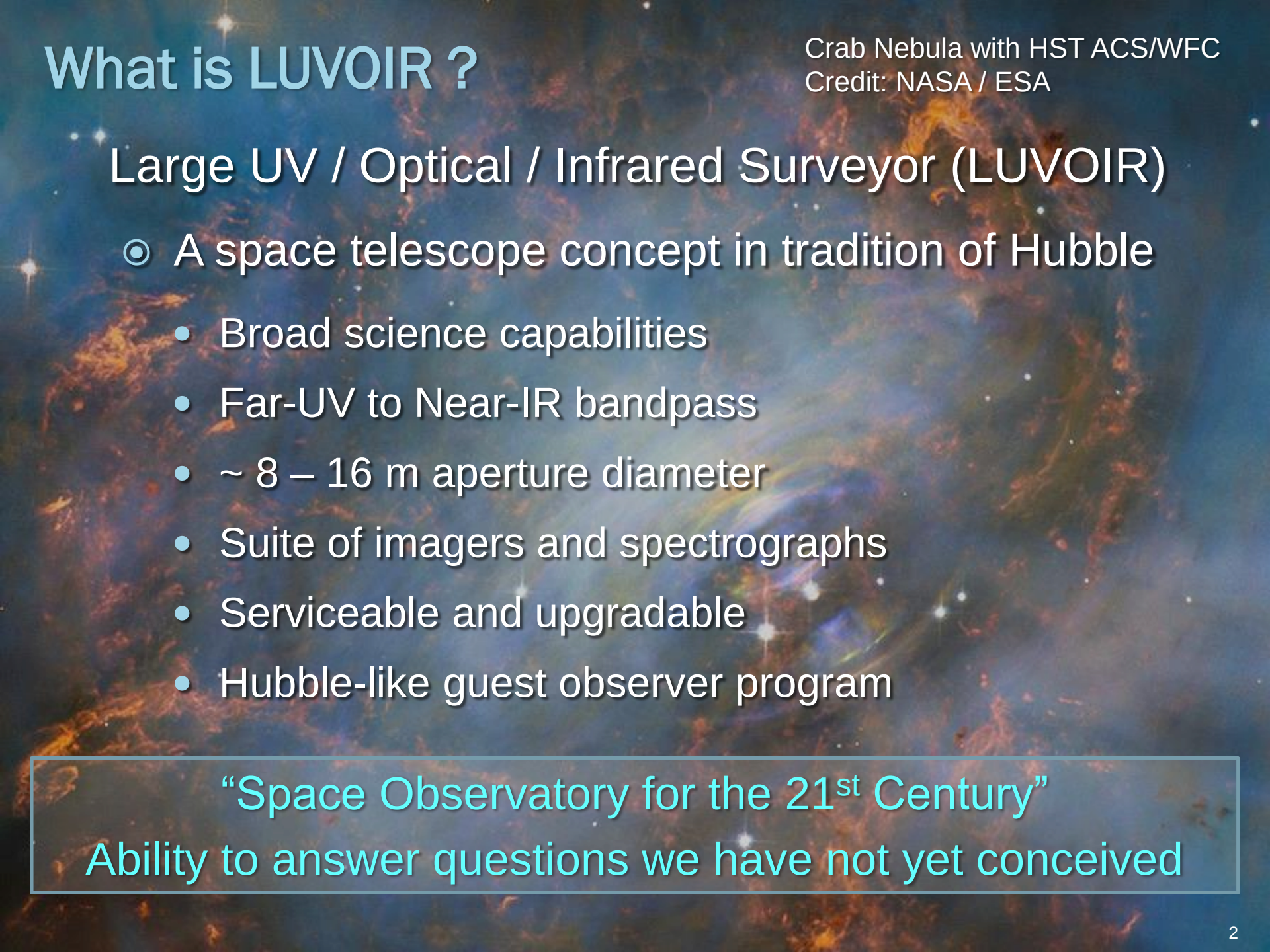
NASA GSFC

14 November 2017

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 21st 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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Subject of this talk

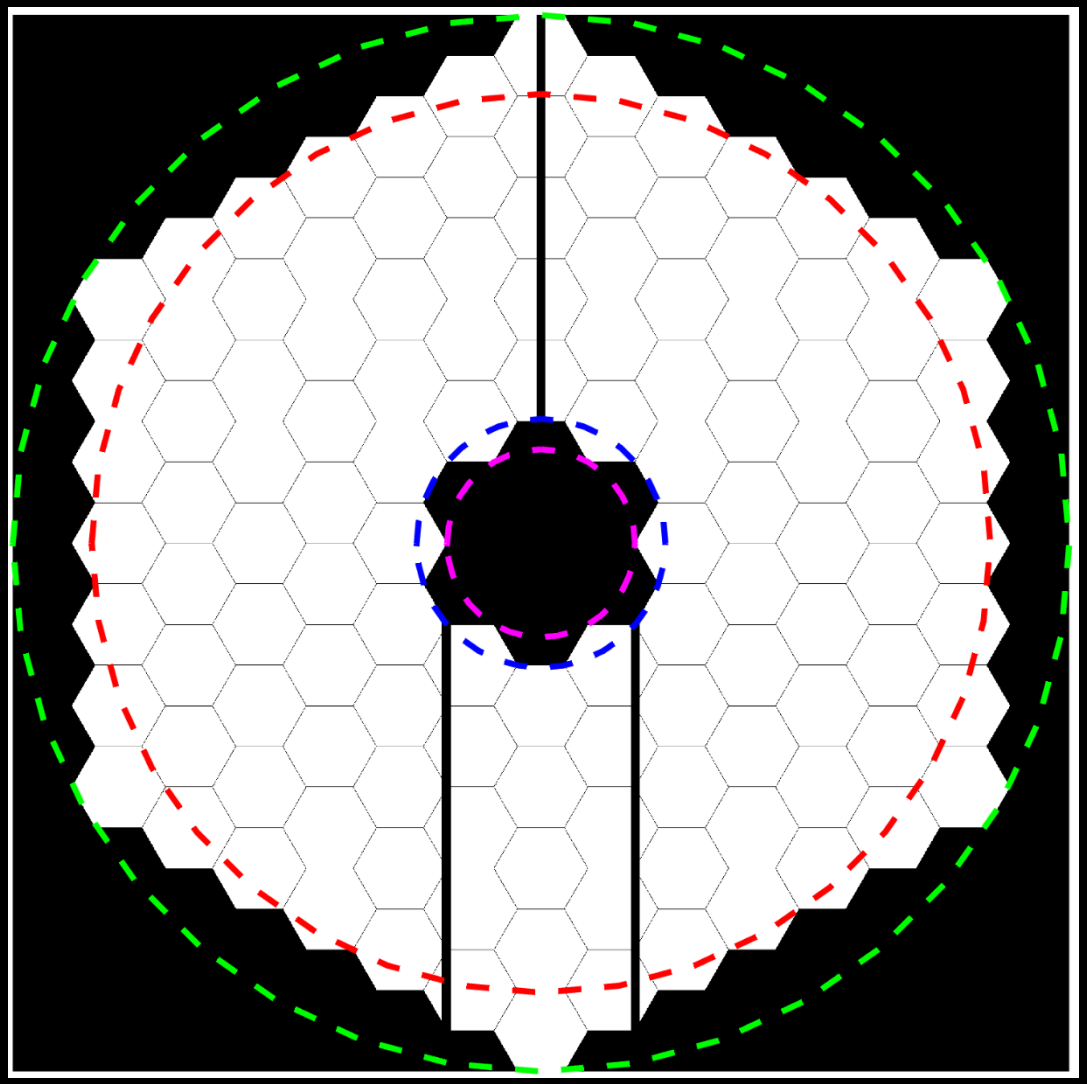
- Architecture B
  - ~9-m diameter aperture
  - Three instruments to be studied:
    - ECLIPS-B
    - LUMOS-B
    - HDI-B

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

LUVOIR Architecture A (15-m)

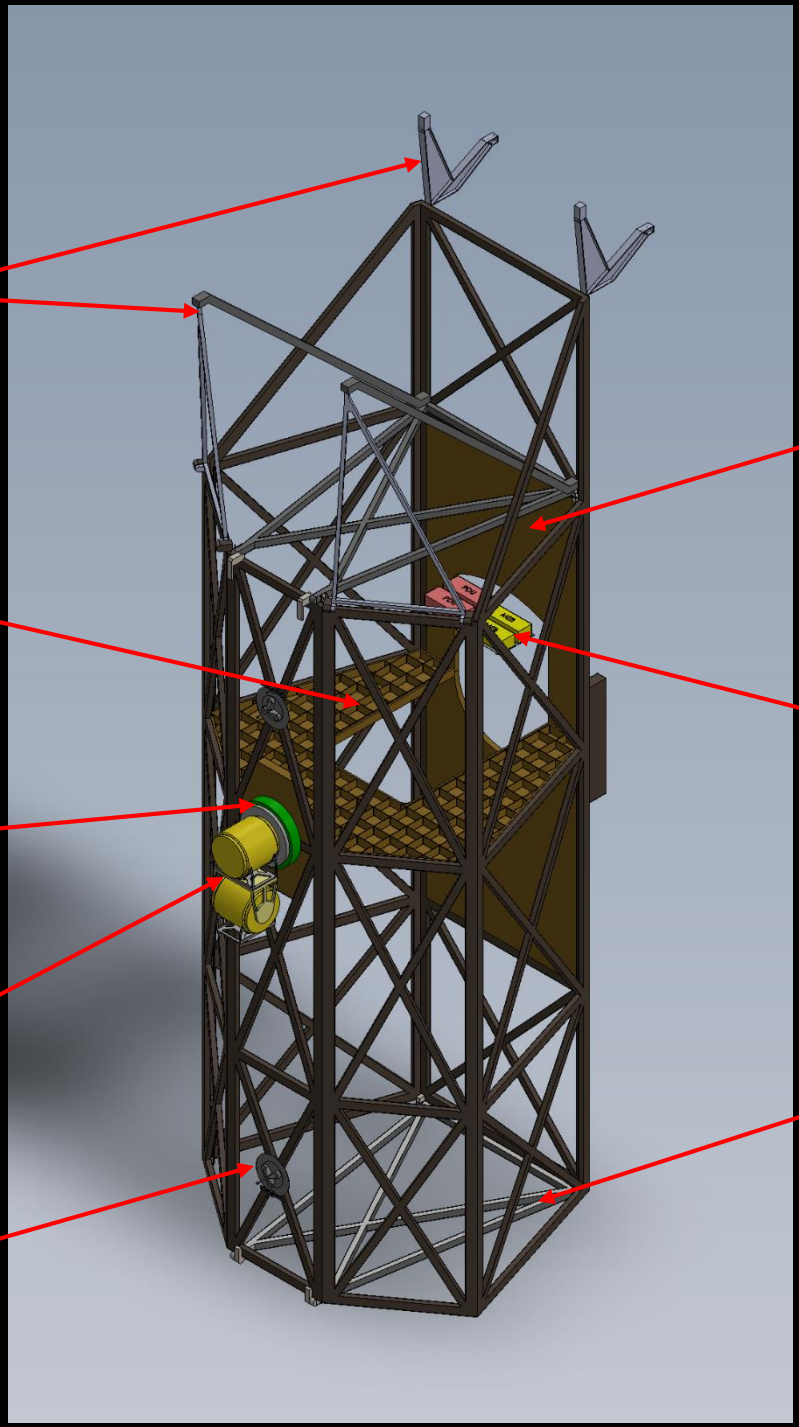
Credit: A. Jones (GSFC)

LUVOIR “A” OTE: Aperture

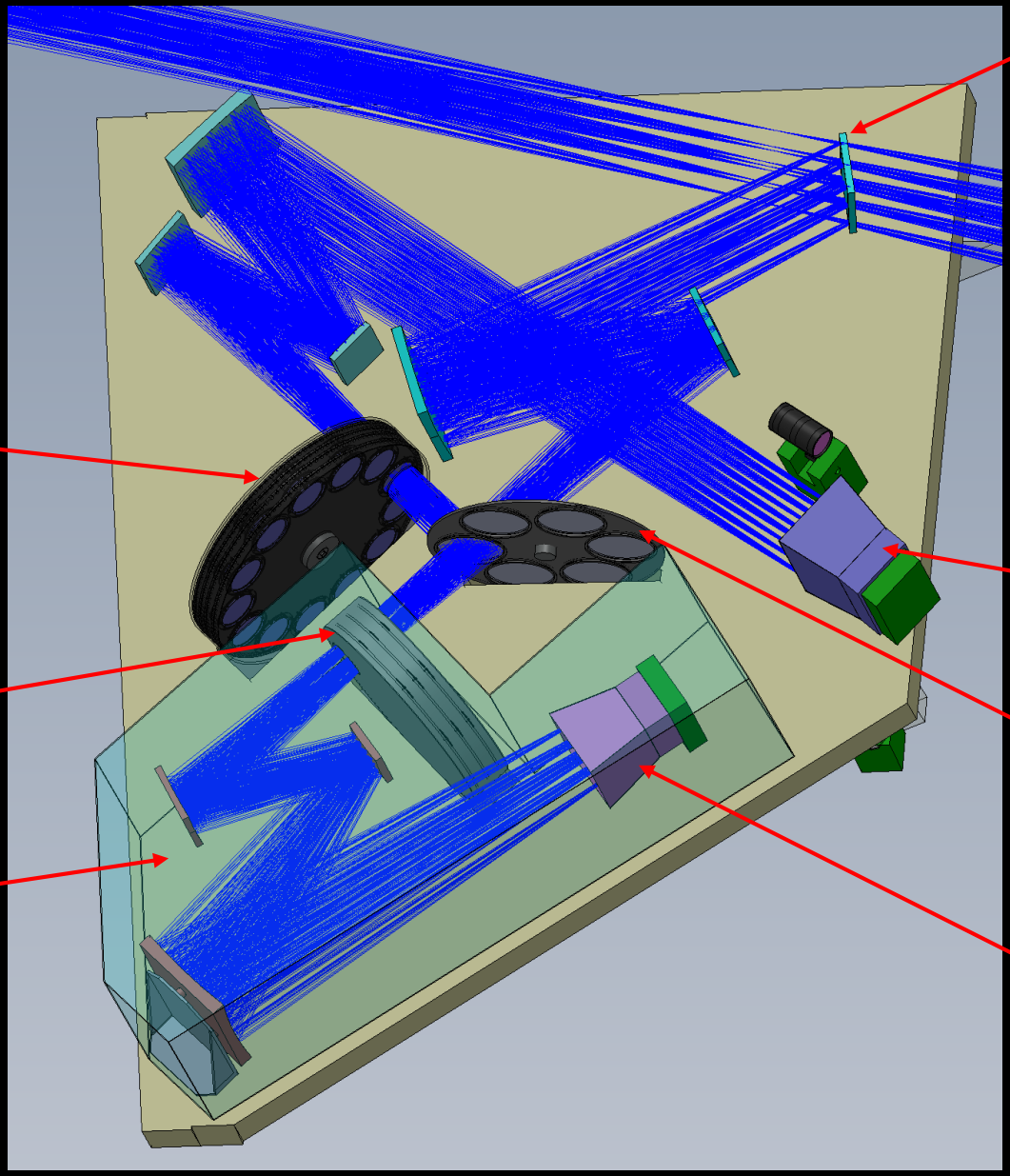


- 1.15-m flat-to-flat segments
  - 120x segments
  - 20 different surface prescriptions
  - Baseline Corning ULE™ substrates for all mirrors
  - 6 mm gaps
- Central ring removed to accommodate aft-optics & secondary mirror obscuration
- Collecting area is 135 m^2

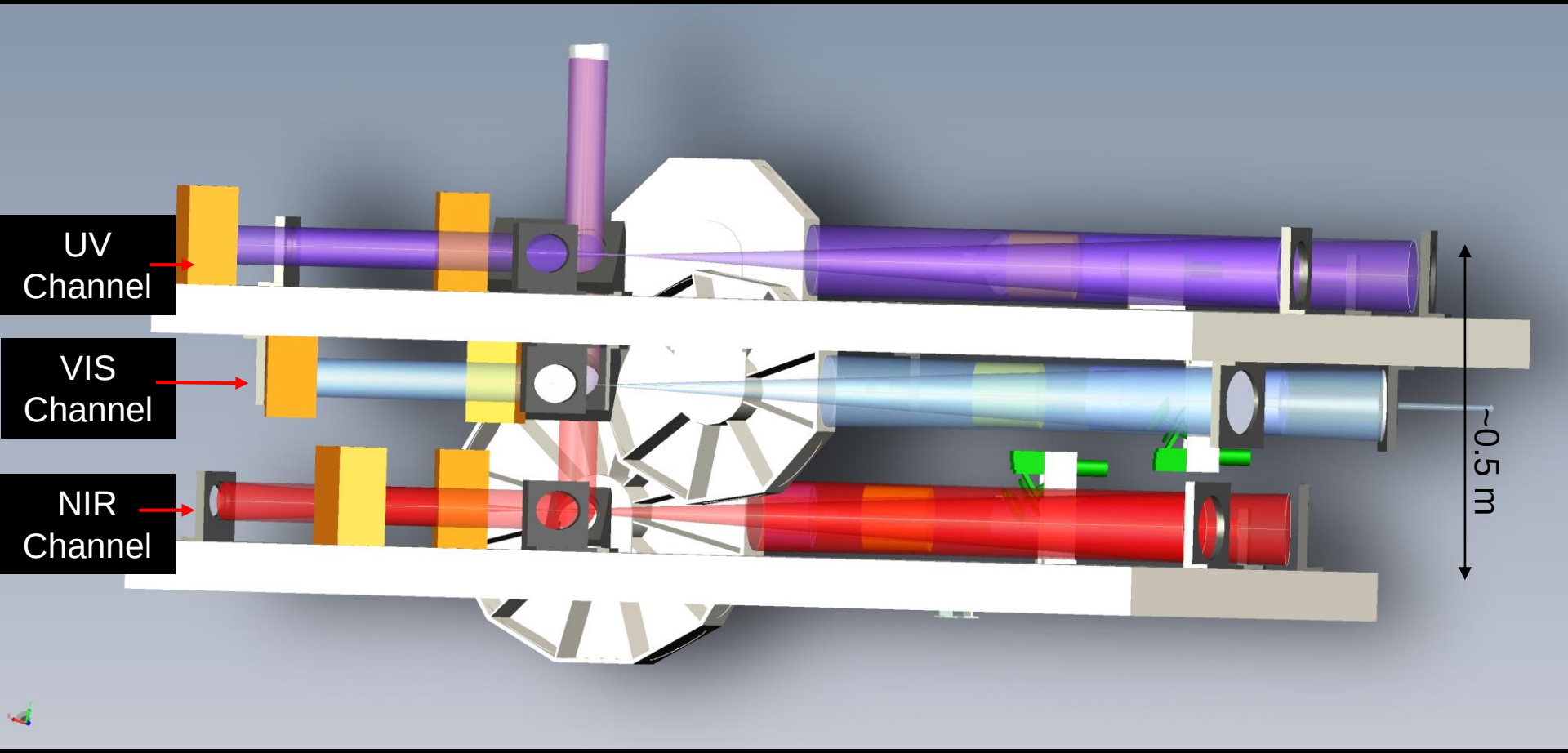
Backplane Support Frame



High-Definition Imager (HDI)



Extreme Coronagraph for Living Planetary Systems (ECLIPS)



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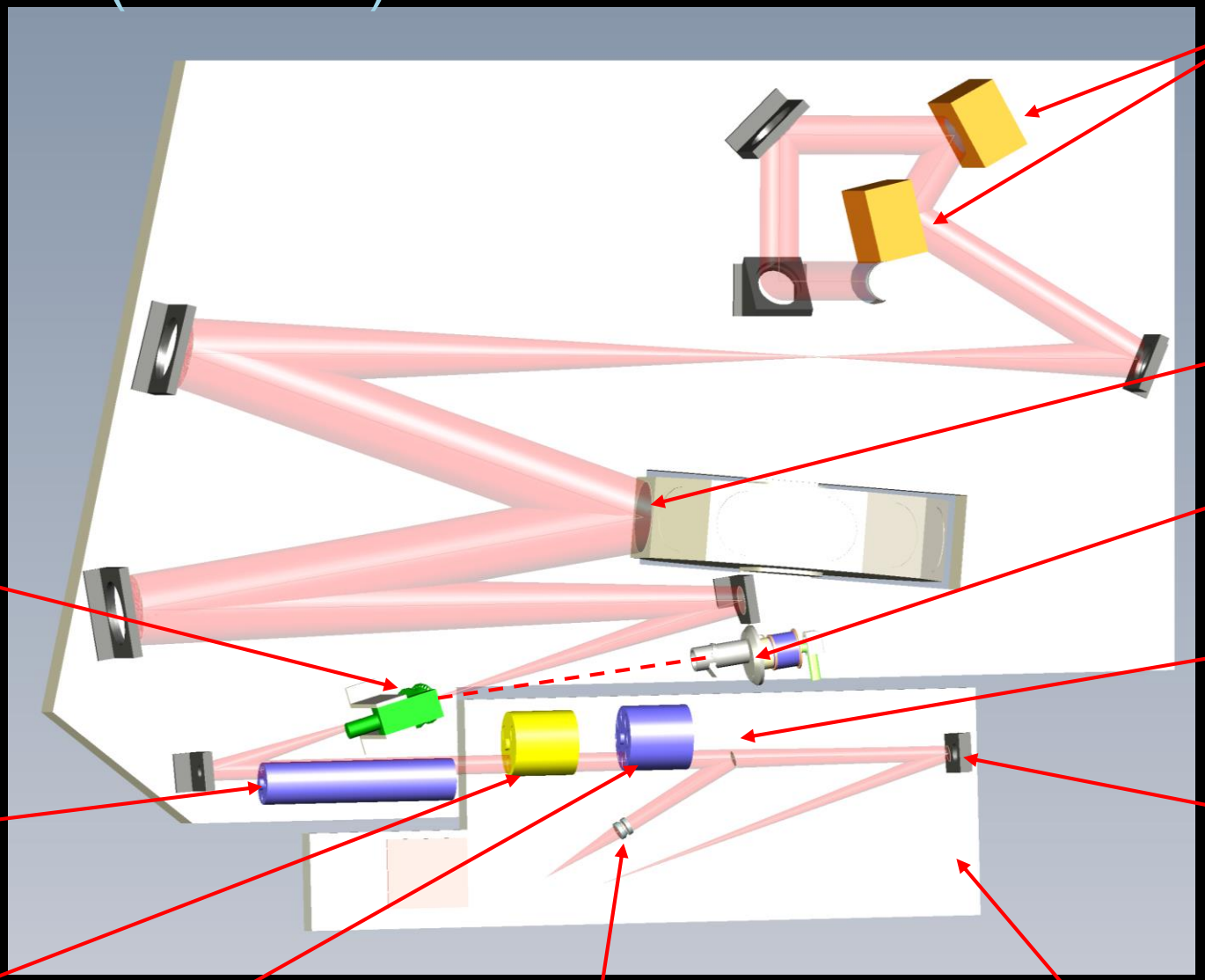
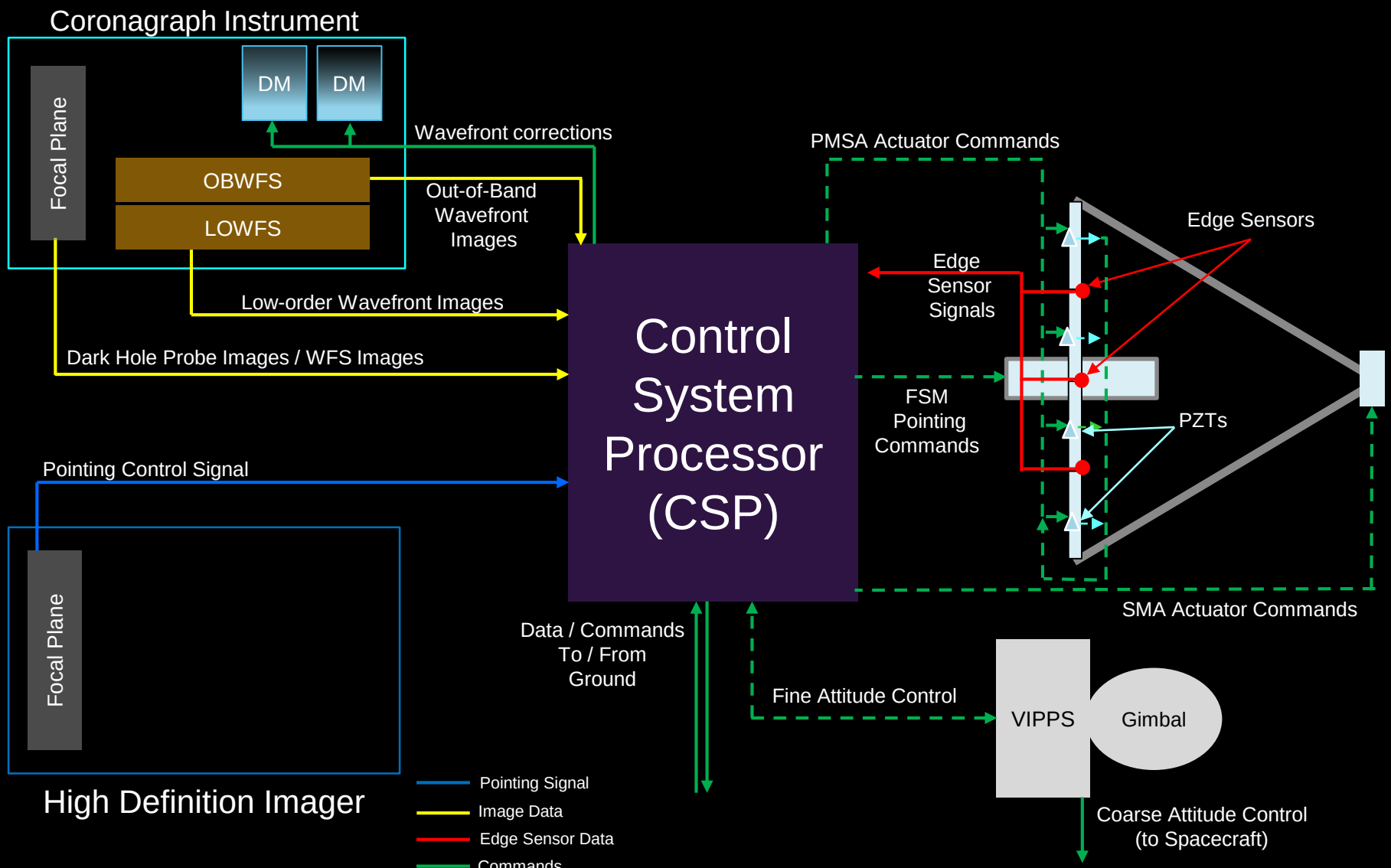
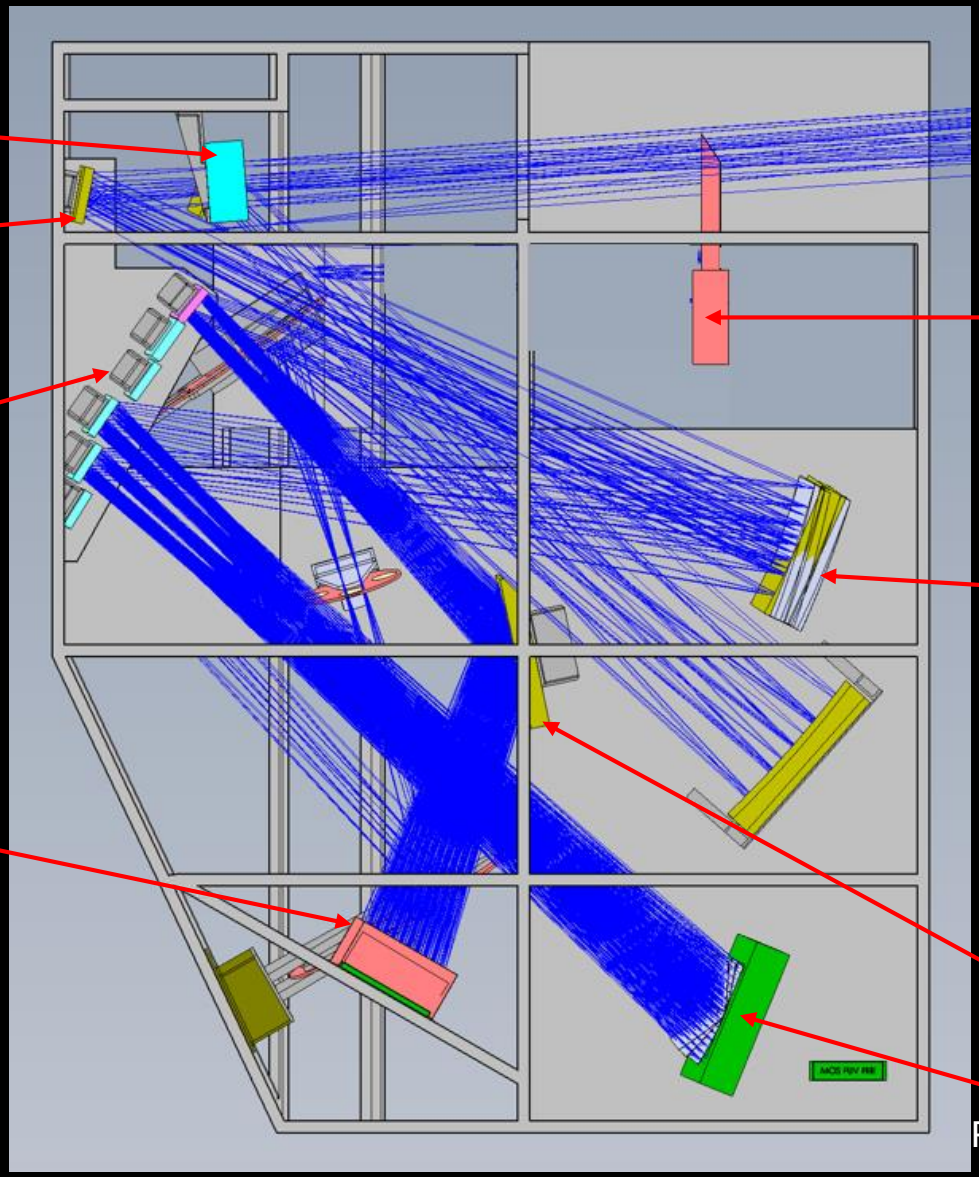


Control System Processor (CSP)



LUVOIR UV Multi-object Spectrograph (LUMOS)



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	**Ultra-stable Opto-mechanical Systems**	**2**
1a	Segment Phase & Control	**3**
1b	Dynamic Isolation Systems	**4**
1c	Mirror Segments	**5**
2	**High-contrast Segmented Aperture Coronagraphy**	**3**
2a	Segmented-aperture Coronagraph Architecture	**3**
2b	Deformable Mirrors	**4**
2c	Wavefront Sensing & Control	**4**
2d	High-contrast Imaging Post-processing	**4**
3	**High Performance UV/Vis/NIR Detectors**	
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	**Next Generation Microshutter Arrays**	**4**
5	**High Reflectivity Broadband FUV-to-NIR Mirror Coatings**	**3**

Stability for high-contrast is #1 challenge

"*~10 pm RMS per ~10 minutes*"

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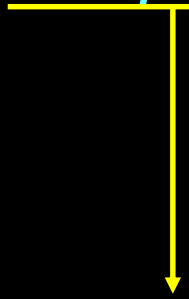


Set by coronagraph's sensitivity to wavefront error.

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

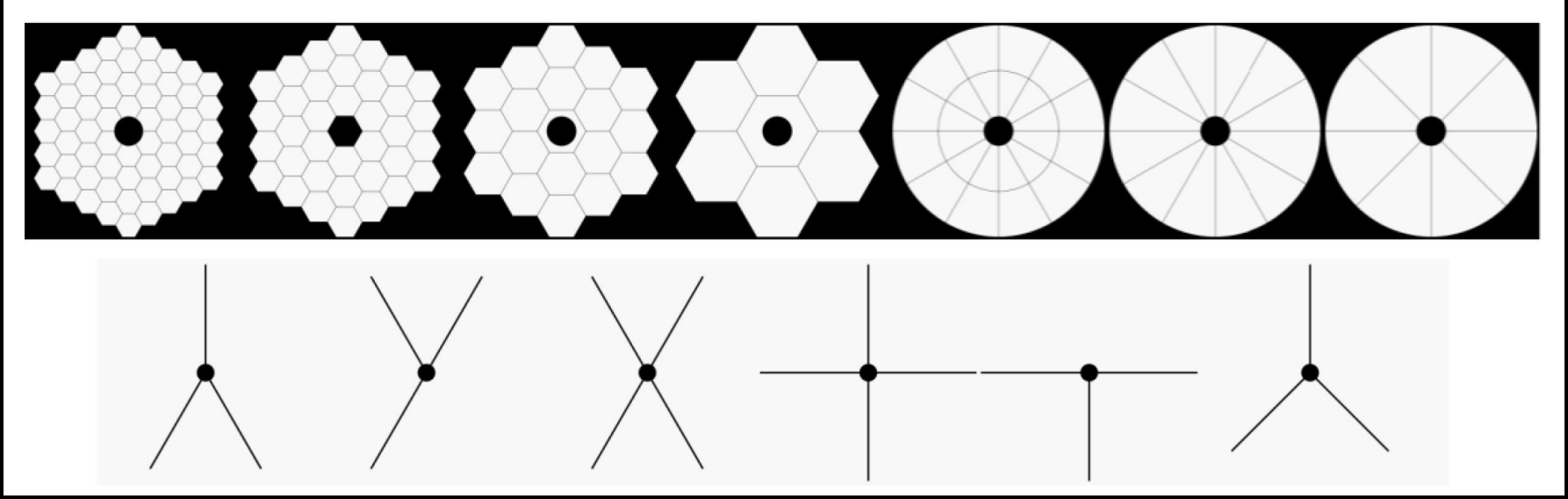
"*~10 pm RMS per ~10 minutes*"

- 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

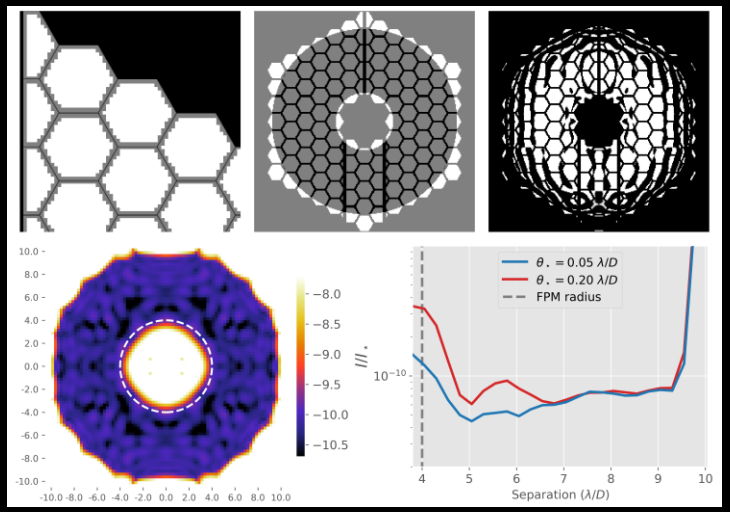


Credit: S. Shaklan / JPL

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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- ***HDI***
  - 40 8k x 8k CMOS detectors for UVIS channel
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- ***Coronagraph***
  - δ-doped EMCCD detector for UV channel
  - EMCCD detector for Vis channel
  - H4RG detector for NIR channel

LUVOIR Baseline Detectors:

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  - 40 8k x 8k CMOS detectors for UVIS channel
  - 20 4k x 4k H4RG detectors for NIR channel
- ***Coronagraph***
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  - 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 δ-doped CMOS detectors for NUV multi-object spectrograph

Additional Detector Technologies Being Considered

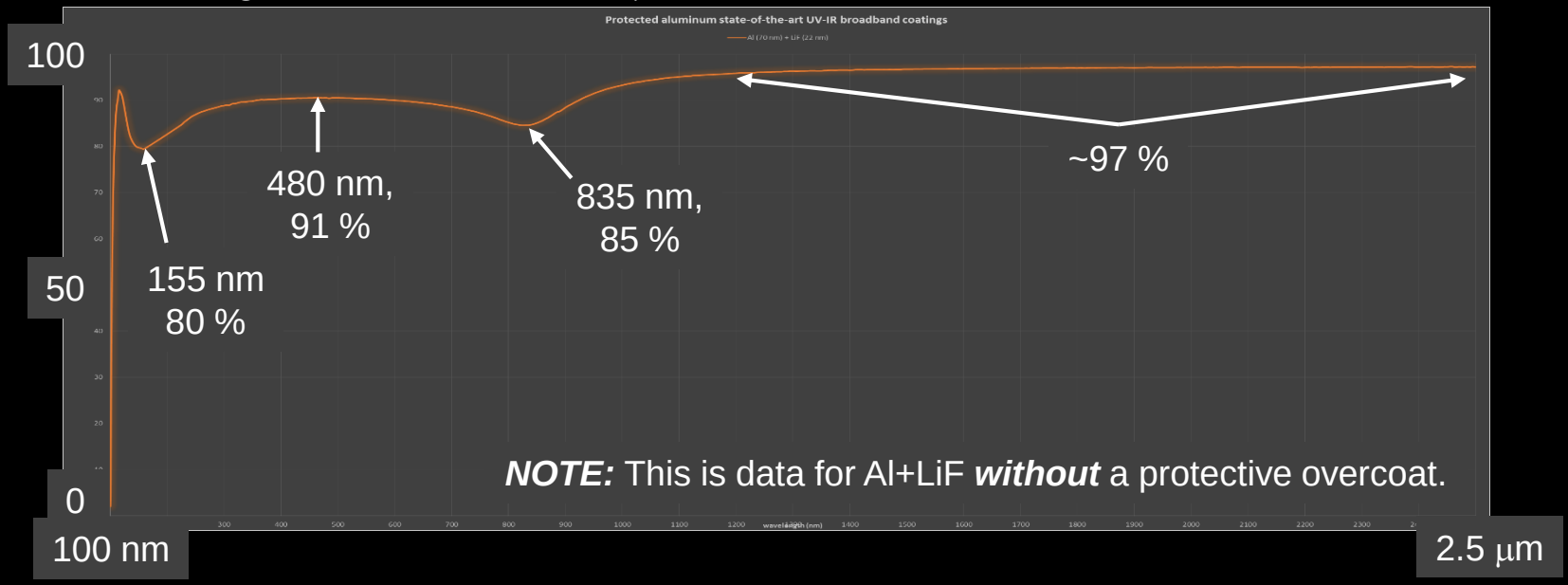
- Hole-multiplying CCDs
  - p-channel version of EMCCD
  - Inherently radiation hard

- 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_2 or AlF_3
  - 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/