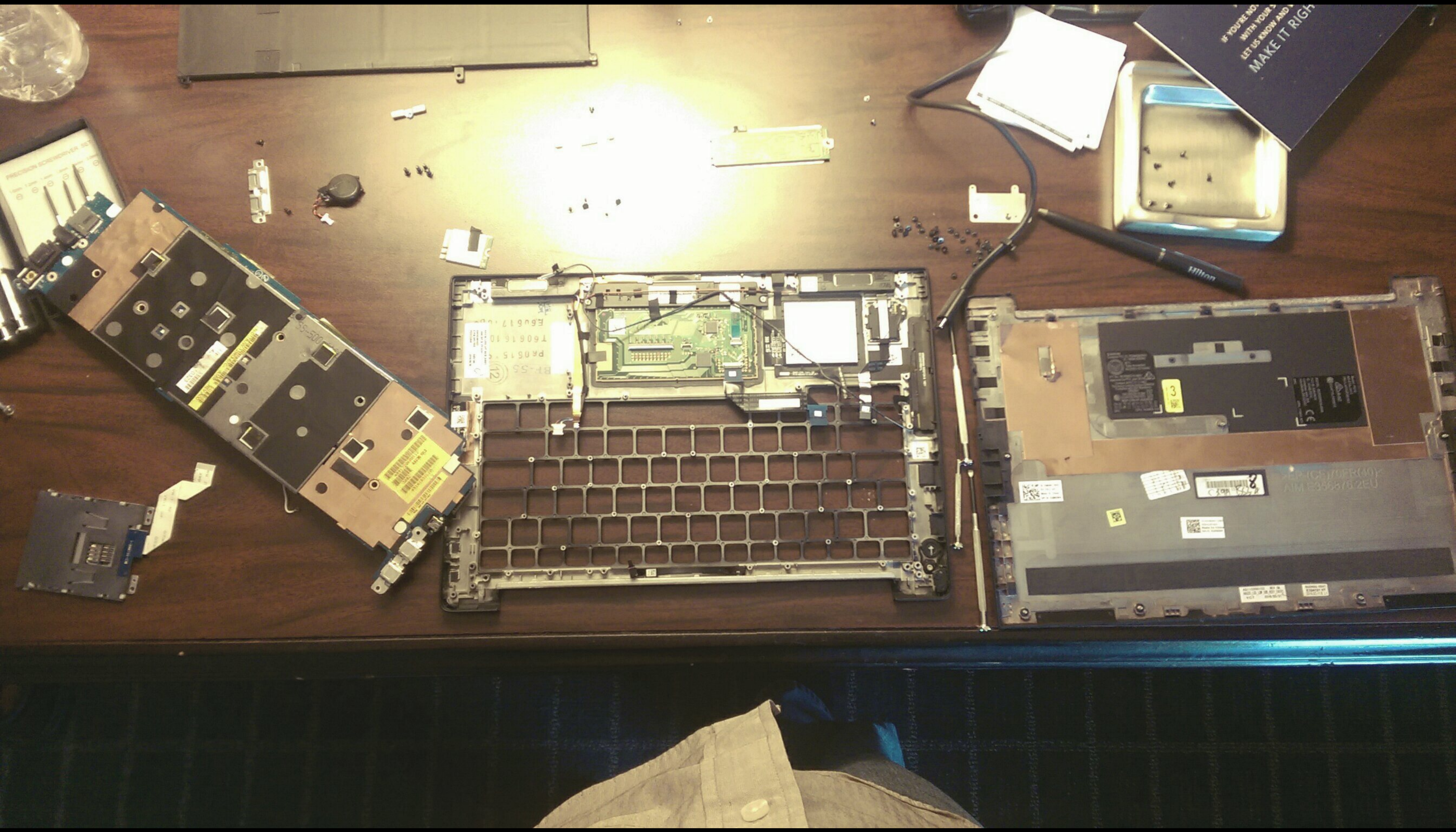
LUVOIR: UPDATE ON ARCHITECTURE "A" DESIGN PROGRESS

Presented to:
The LUVOIR STDT

Matthew R. Bolcar
April 17, 2017

Matt's Laptop at about 6pm yesterday



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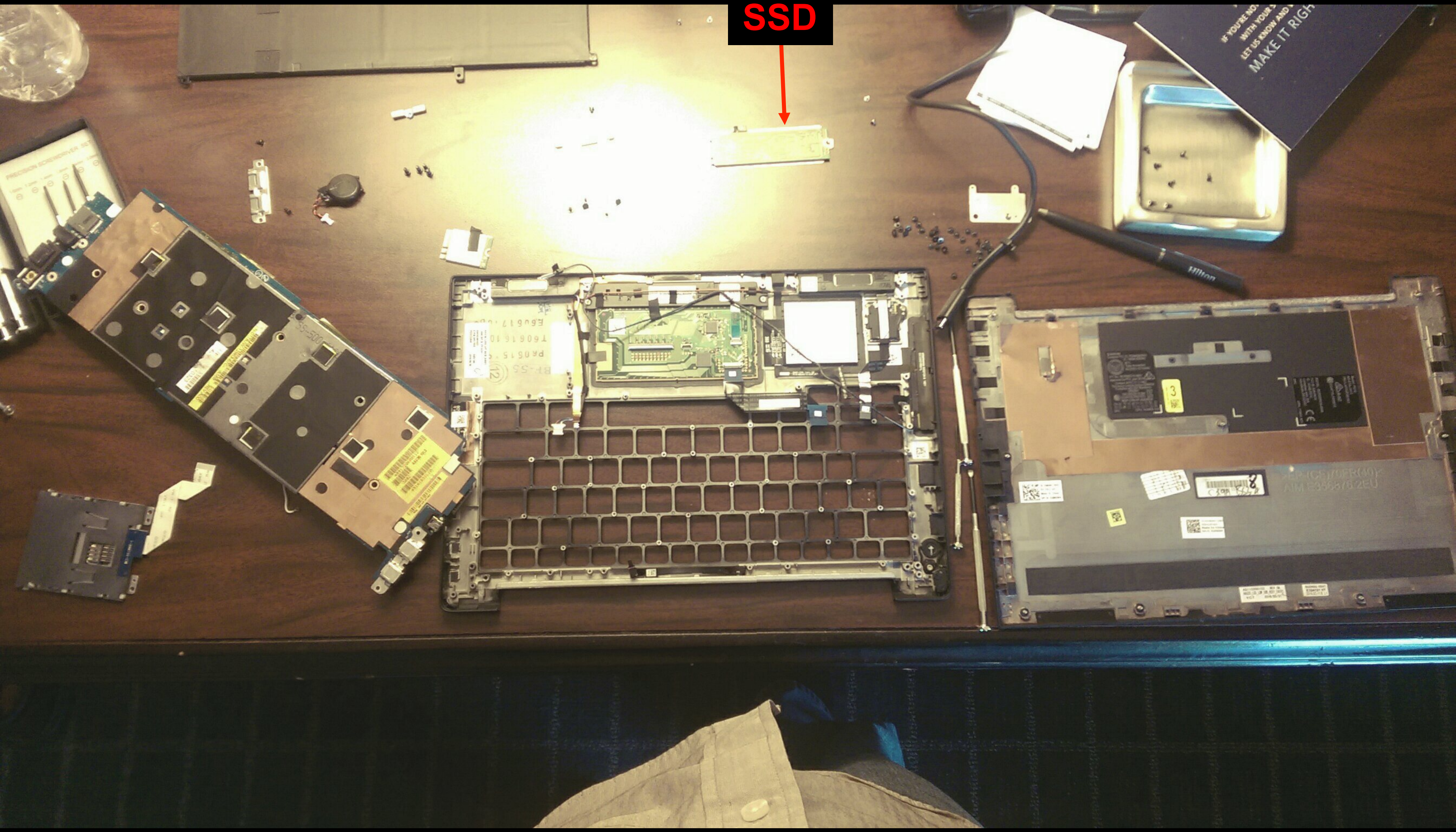


We will study two architectures in depth...

- Architecture A (first half of 2017)
  - 15-m diameter aperture
  - Four instrument bays:
    - Optical / NIR Coronagraph (A)
    - UV Multi-object Spectrograph ("LUMOS")
    - High-definition Imager (will also perform guiding / wavefront sensing)
    - *Pollux: UV Spectro-polarimeter and High-Resolution Spectrograph (CNES Contributed)*

- Architecture B (late 2017 into 2018)
  - ~9-m diameter aperture
  - Three instrument to be studied:
    - Optical / NIR Coronagraph (B)
    - UV Multi-object Spectrograph ("LUMOS")
    - Optical / NIR Multi-resolution Spectrograph

Three Teams Providing Engineering & Design Support

- Integrated Design Center (IDC):
  - Comprised of the Optical, Instrument, and Mission Design Labs (ODL, IDL, MDL)
  - Concurrent engineering environments for rapid development of a broad, baseline point design
- Study Office Engineering Team
  - Shadow IDC efforts and provide depth of analysis and additional design where IDC is unable to
  - This engineering team ultimately "owns" the final LUVOIR design
- Industry Team (via Cooperative Agreement Notice)
  - Lockheed Martin, Northrop Grumman, Ball Aerospace, Harris
  - Leverage expertise & specialized skills to address key elements of the design study
    - Deployments, I&T, Vibration Isolation, Error Budgeting, Straylight Analysis, etc.

IDC Study Schedule (2017):

- √ Jan. 17–24 – Telescope Instrument Design Lab (IDL)
  - Pre-work 1/10
- √ Feb. 6–10 – HDI IDL
  - Pre-work 1/31
- √ Mar. 20–24 – Coronagraph IDL
  - Pre-work 3/14
- ◉ May 15–19 – LUMOS IDL
  - Pre-work 5/9
- ◉ June 7–13 – Instrument Accommodation IDL
  - Pre-work 6/1
- ◉ July 10–14 – LUVOIR “A” Mission Design Lab (MDL)
  - Pre-work 7/5
- ◉ Sept. 11–15 – LUVOIR “B” Optical Telescope Element IDL
  - Pre-work 9/6
- ◉ Oct. 10–16 – LUVOIR “B” Instrument 1 IDL
  - Pre-work 10/3

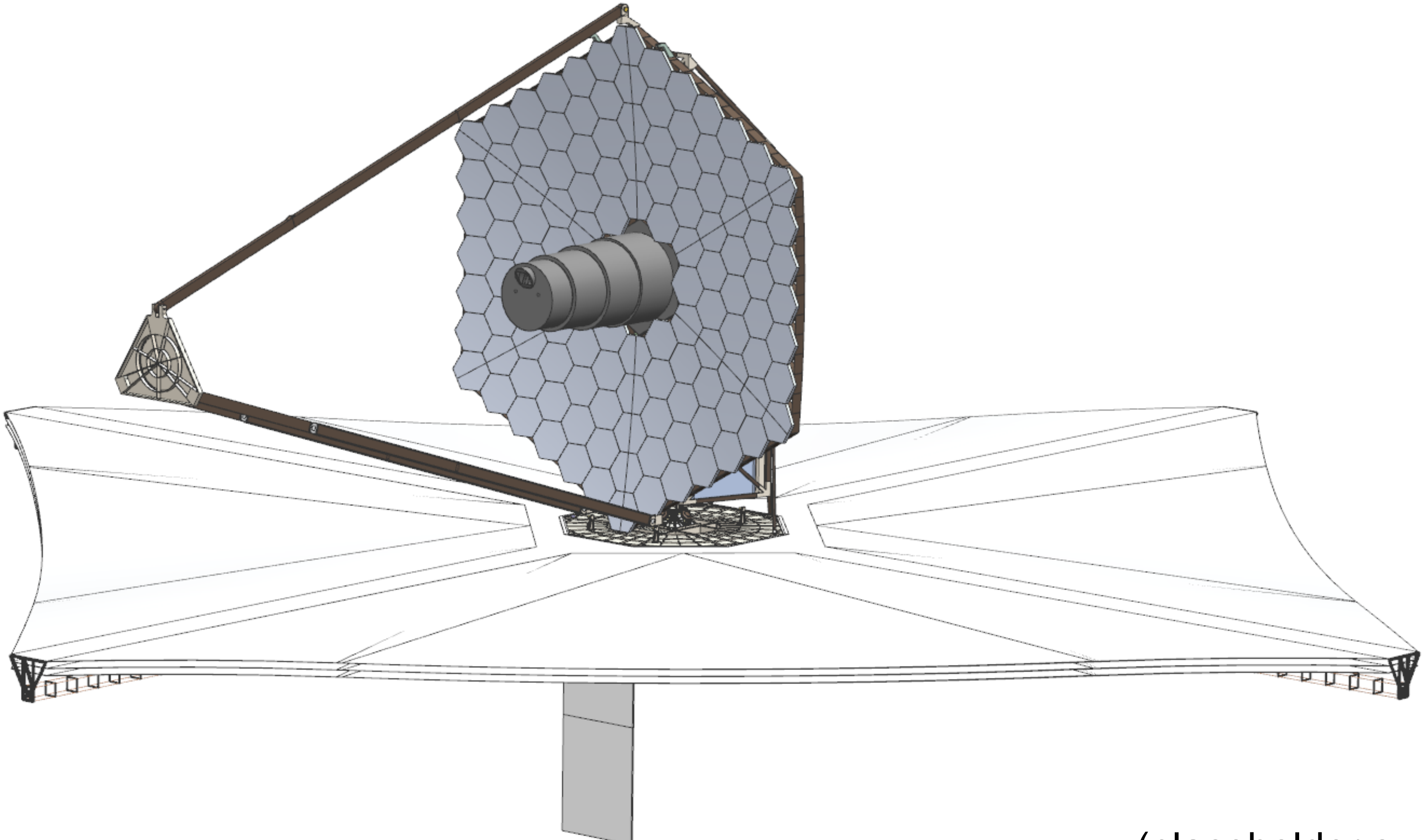
Study Schedule 2017

Design Cycle | *Reports Due* | x *Pre-work Meeting* | ⟷ *IDC Study Week*

Jan.	2 3 4 5 6	9 10(x) 11 12 13	16 17 18 19 20 “A” OTE IDL	23 24 25 26 27	
Feb.	30 31(x) 1 2 3	HDI IDL 6 7 8 9 10	13 14 15 16 17	20 21 22 23 24	
March	27 28 1 2 3	6 7 8 9 10	13 14(x) 15 16 17	Coronagraph IDL 20 21 22 23 24	27 28 29 30 31
April	3 4 5 6 7	10 11 12 13 14	17 18 19 20 21	24 25 26 27 28	
May	1 2 3 4 5	8 9(x) 10 11 12	LUMOS IDL 15 16 17 18 19	22 23 24 25 26	
June	29 30 31 1(x) 2	5 6 7 8 9 Integrated Payload IDL	12 13 14 15 16	19 20 21 22 23	26 27 28 29 30
July	3 4 5 6 7	Architecture “A” MDL 10 11 12 13 14	17 18 19 20 21	24 25 26 27 28	
Aug.	31 1 2 3 4	7 8 9 10 11	14 15 16 17 18	21 22 23 24 25	28 29 30 31 1
Sept.	4 5 6(x) 7 8	“B” OTE IDL 11 12 13 14 15	18 19 20 21 22	25 26 27 28 29	
Oct.	2 3(x) 4 5 6	9 10 11 12 13 B Instr. 1	16 17 18 19 20	23 24 25 26 27	
Nov.	30 31 1 2 3	6 7 8 9 10	13 14 15 16 17	20 21 22 23 24	27 28 29 30 1
Dec.	4 5 6 7 8	11 12 13 14 15	18 19 20 21 22	25 26 27 28 29	

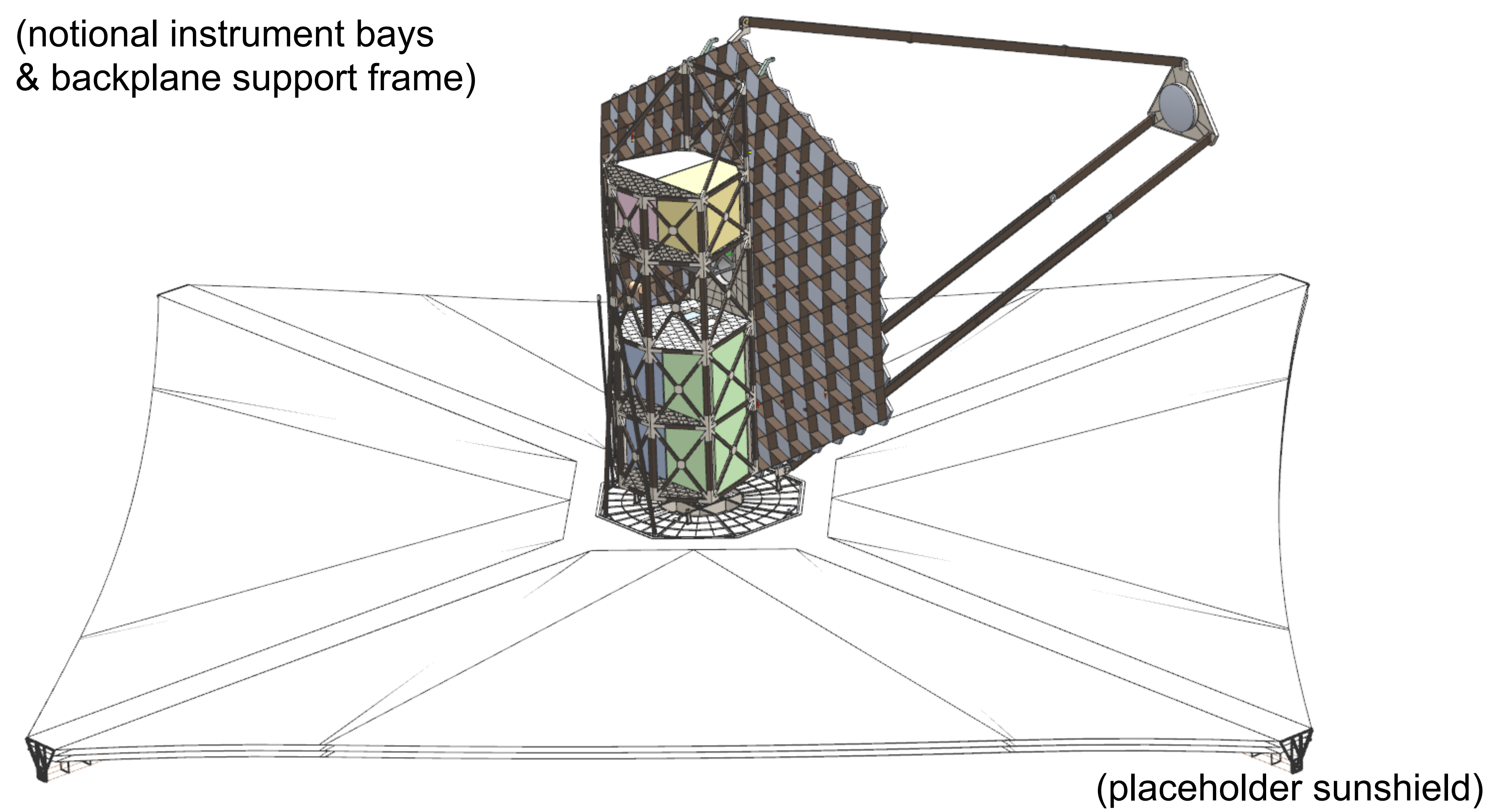
Design Overview: Observatory Level

Mechanical Views

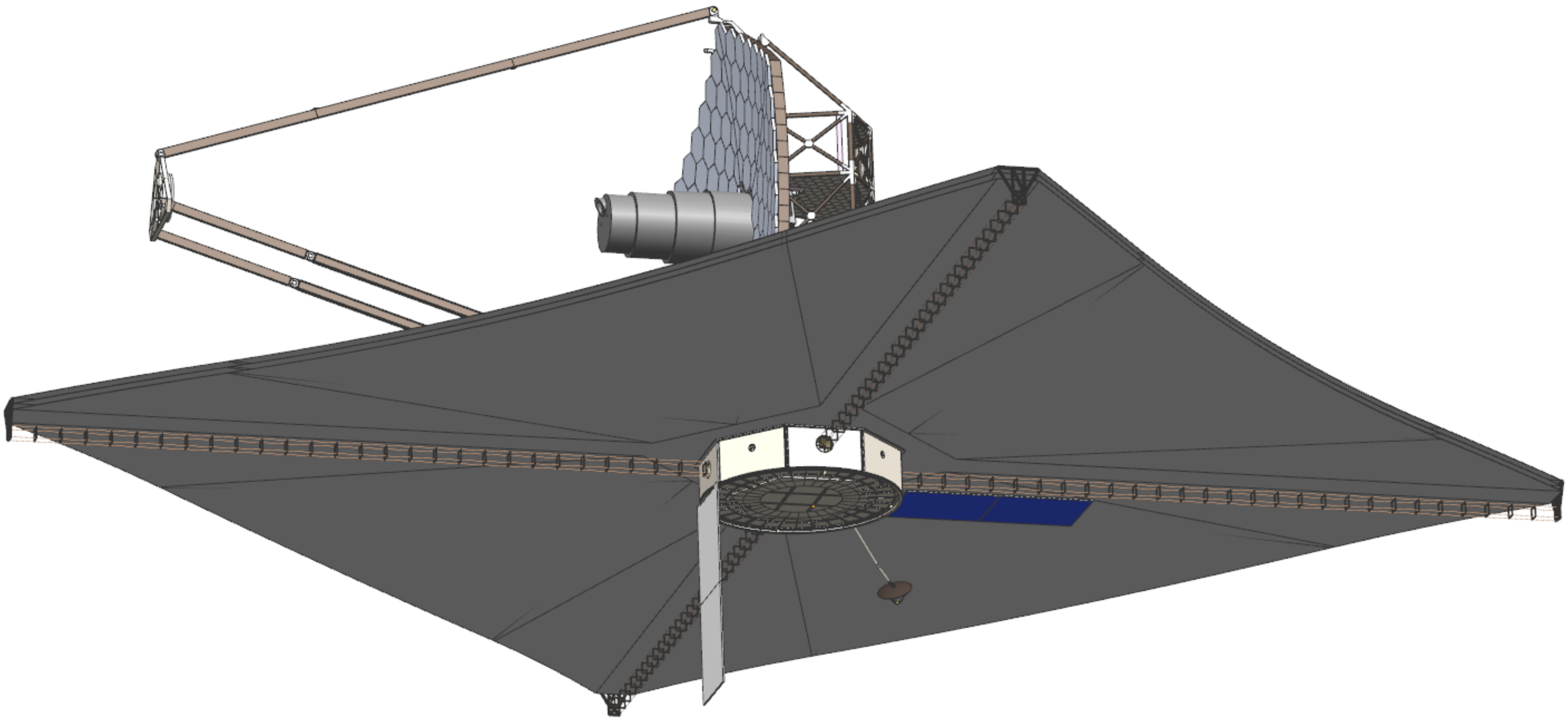


(placeholder sunshield)

Mechanical Views

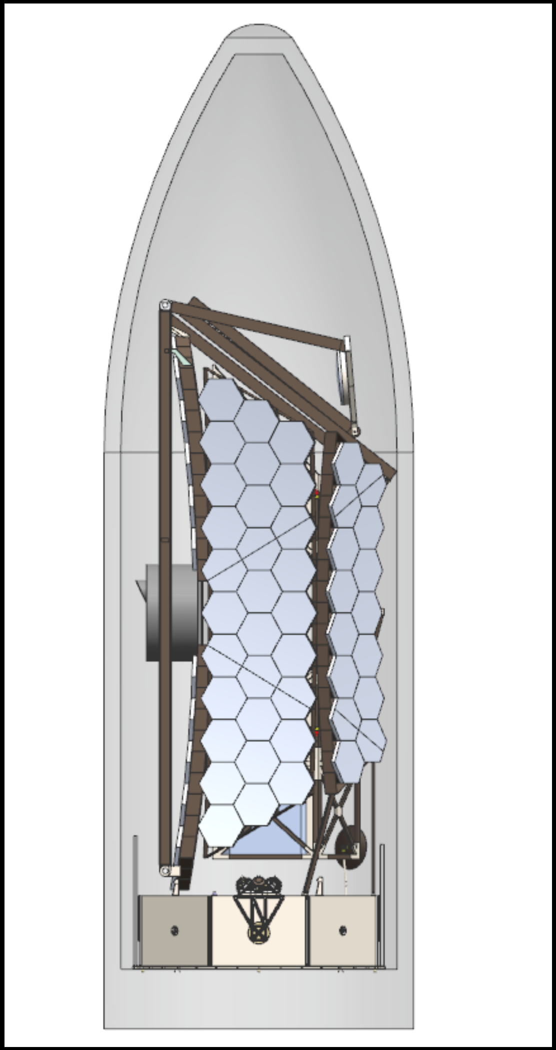


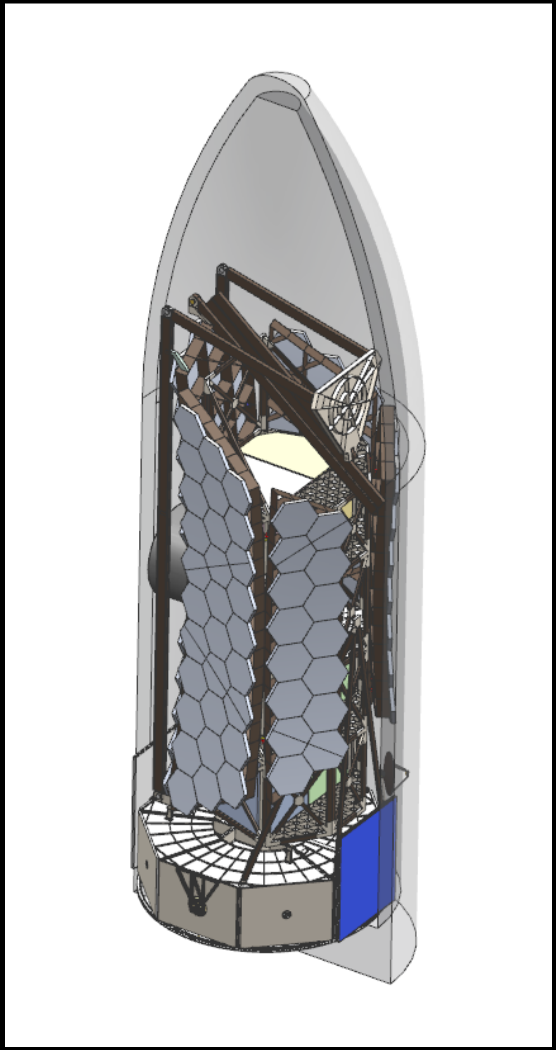
Mechanical Views



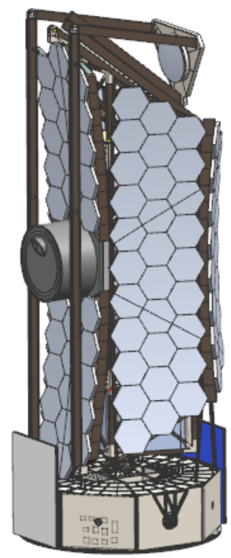
(placeholder sunshield and spacecraft)

Mechanical Views





Mechanical Views (Deployment)



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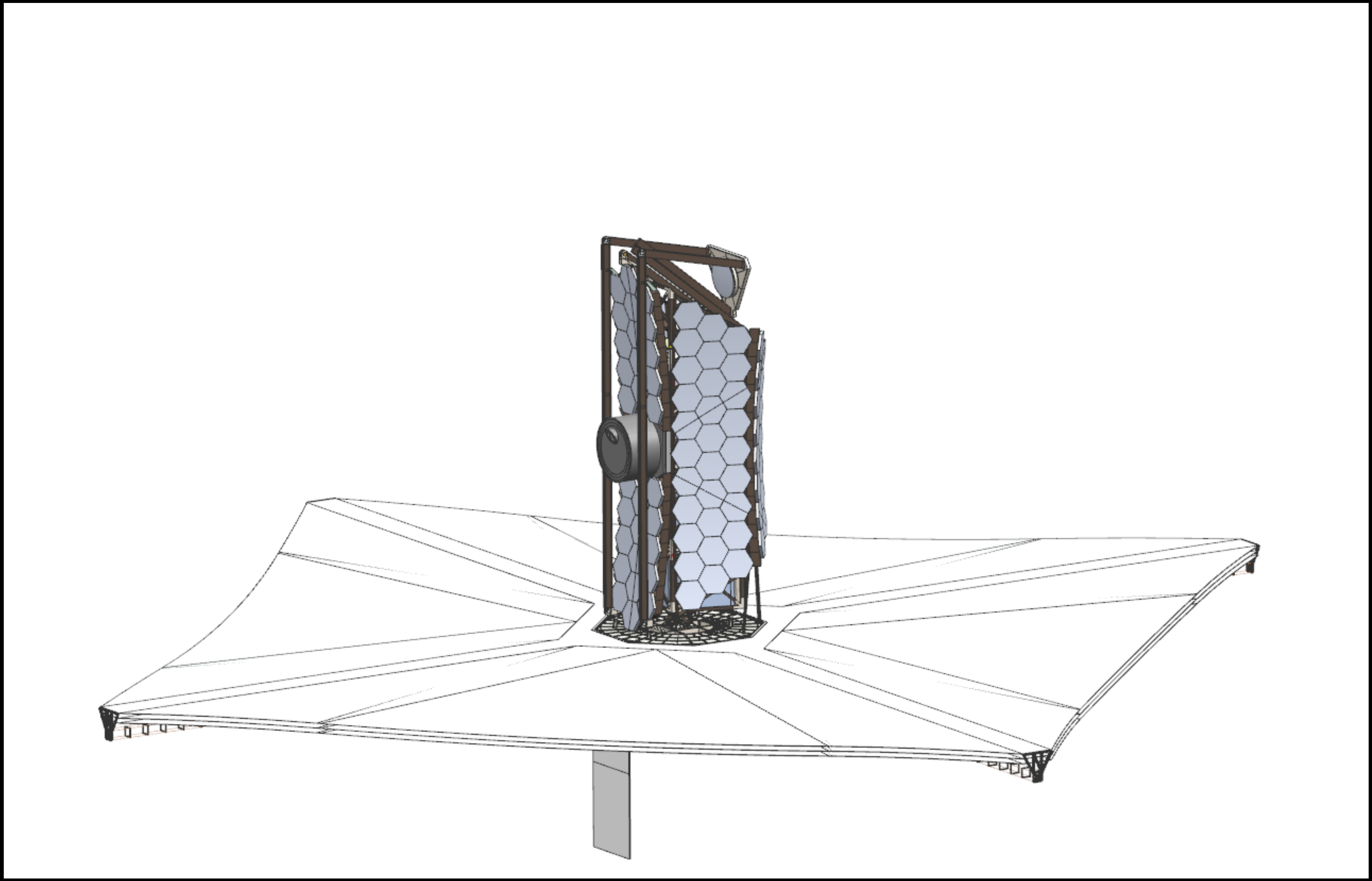

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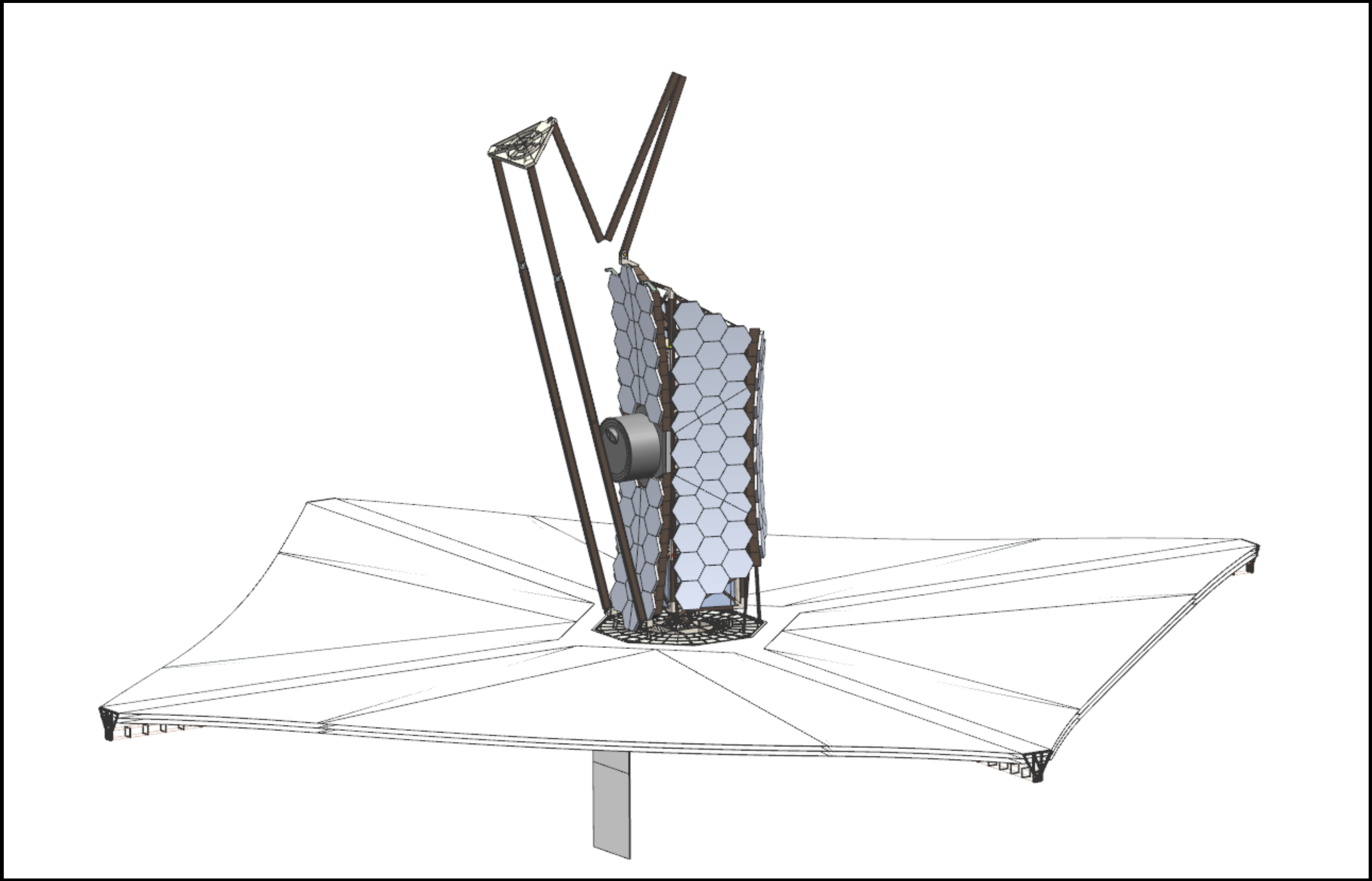

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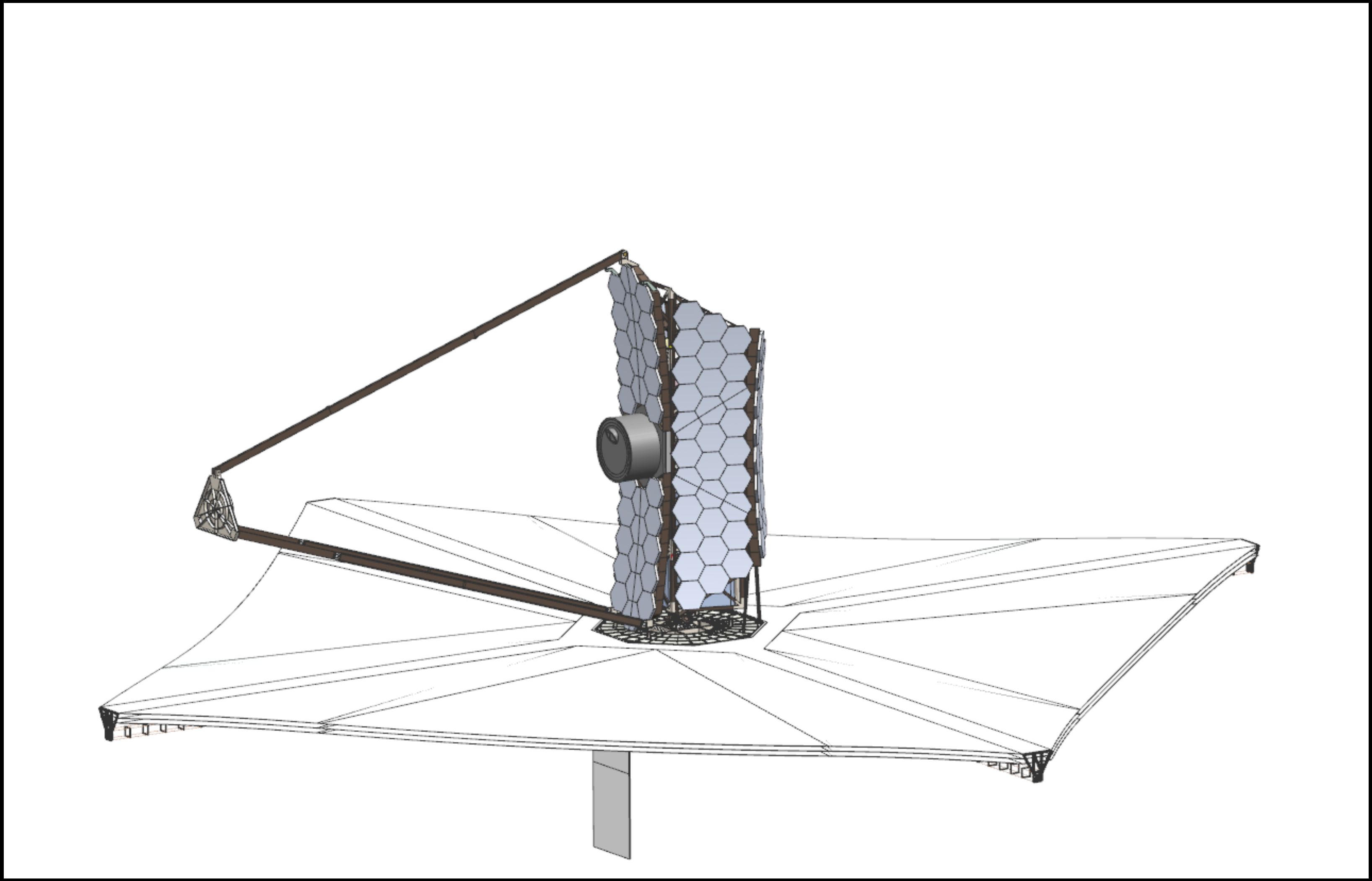

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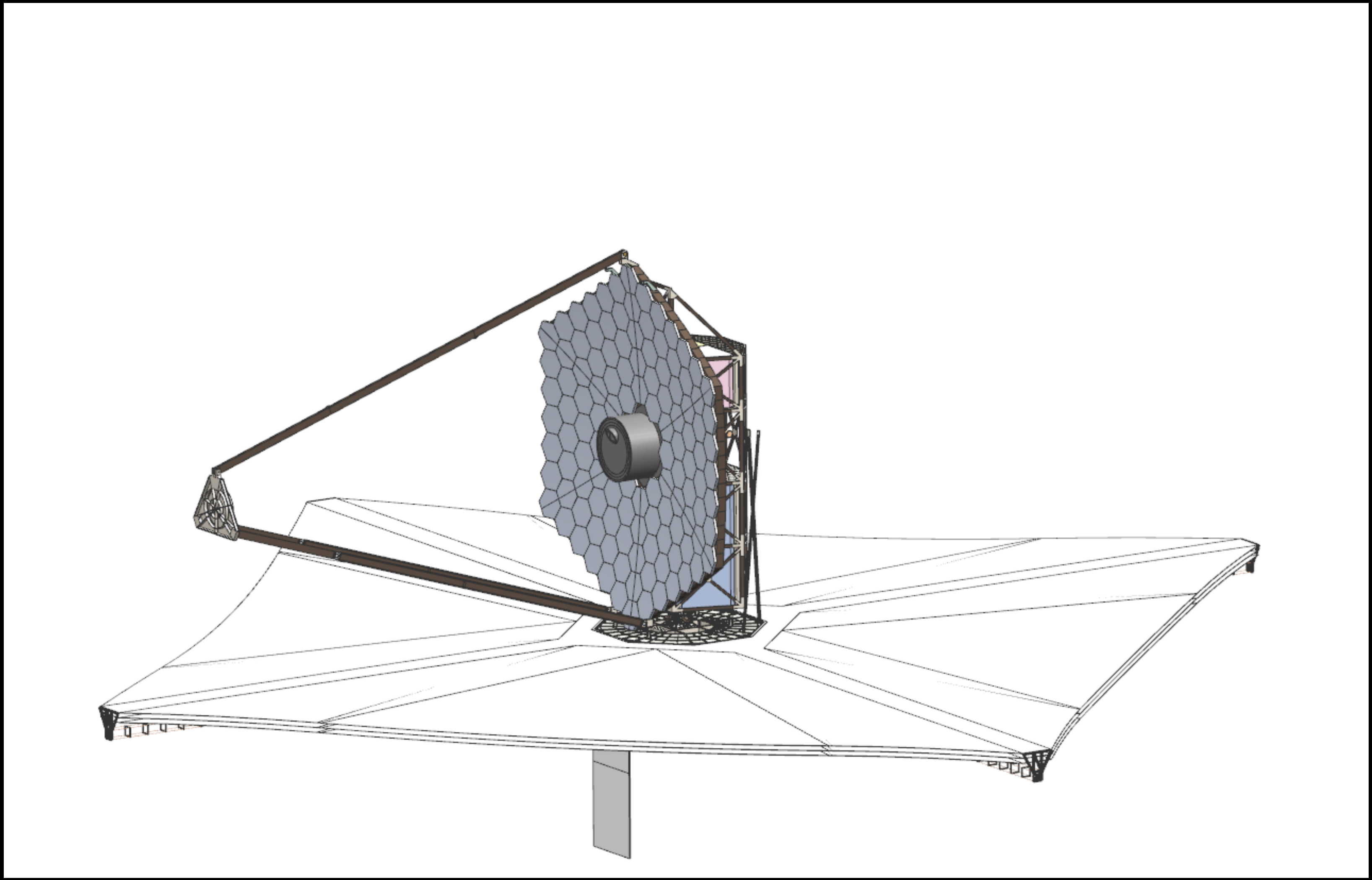

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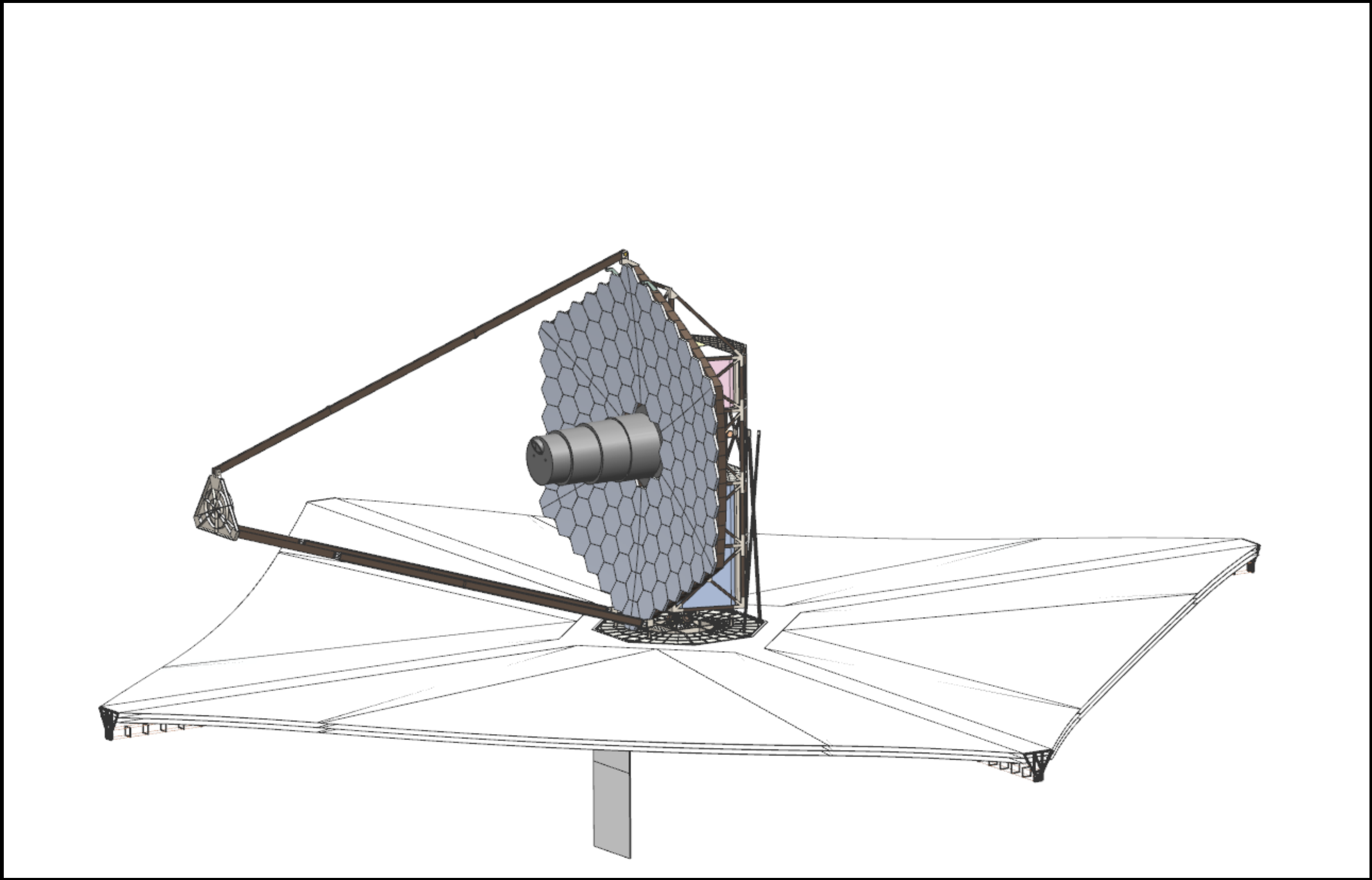
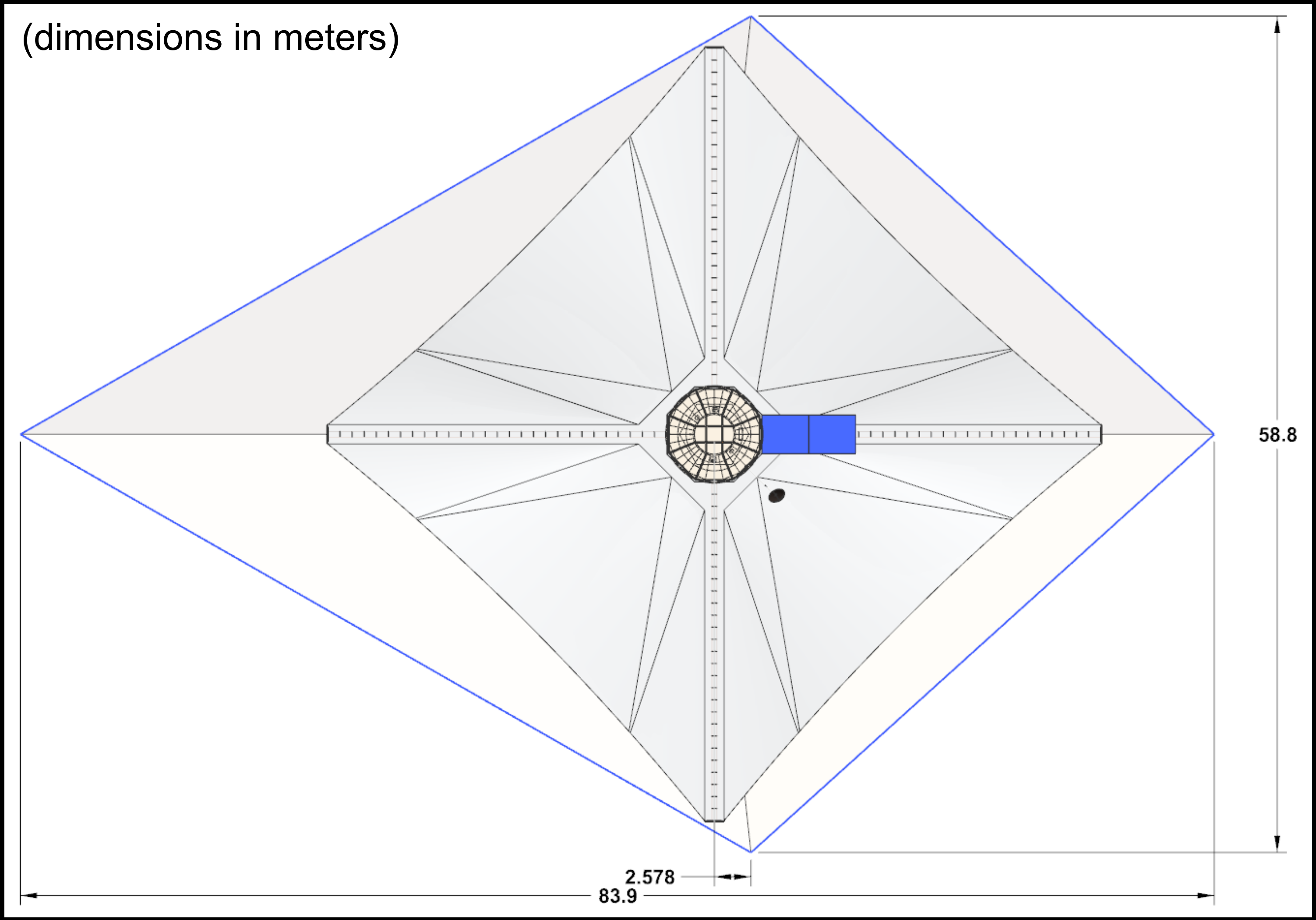


Sunshield Sizing



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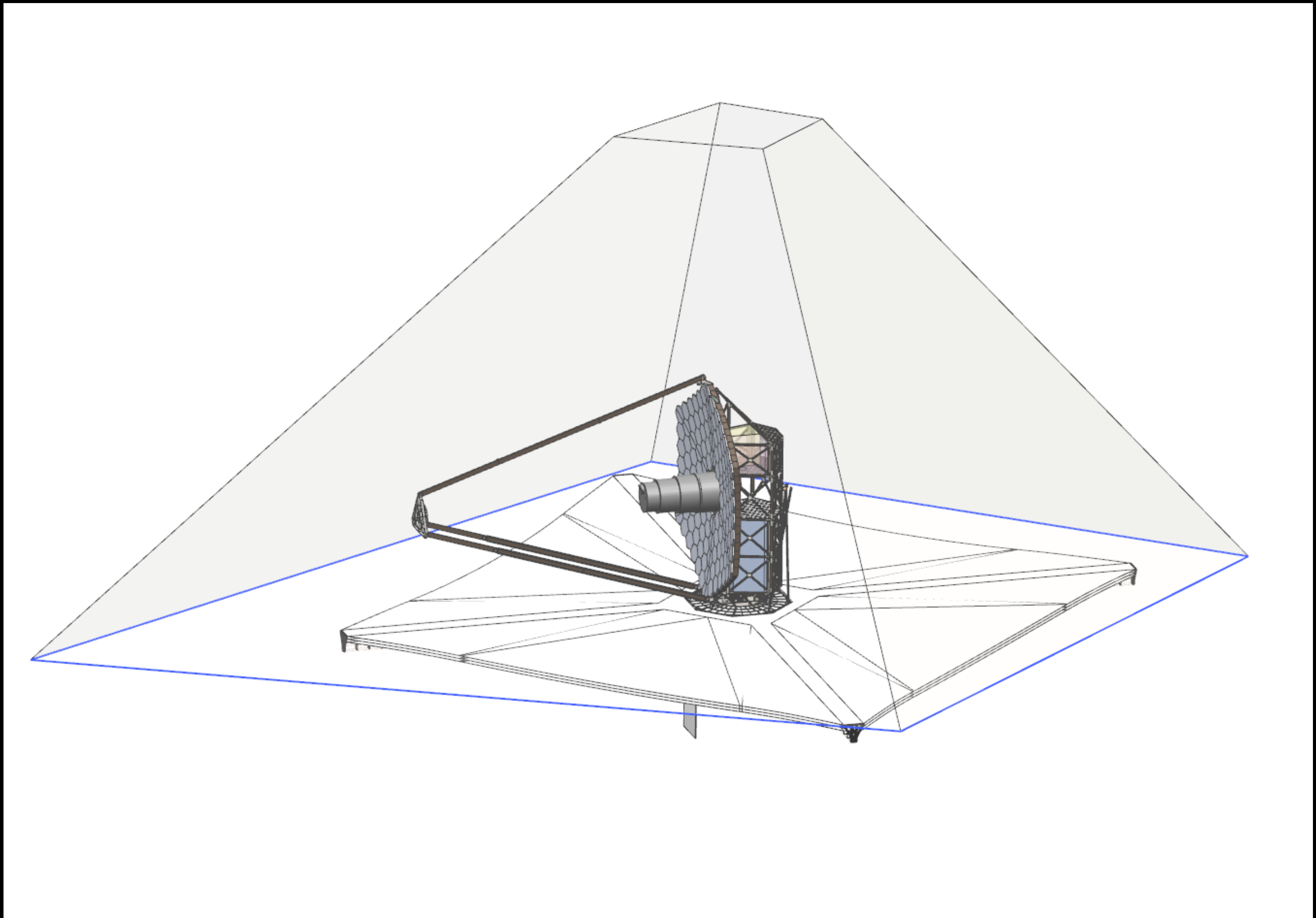

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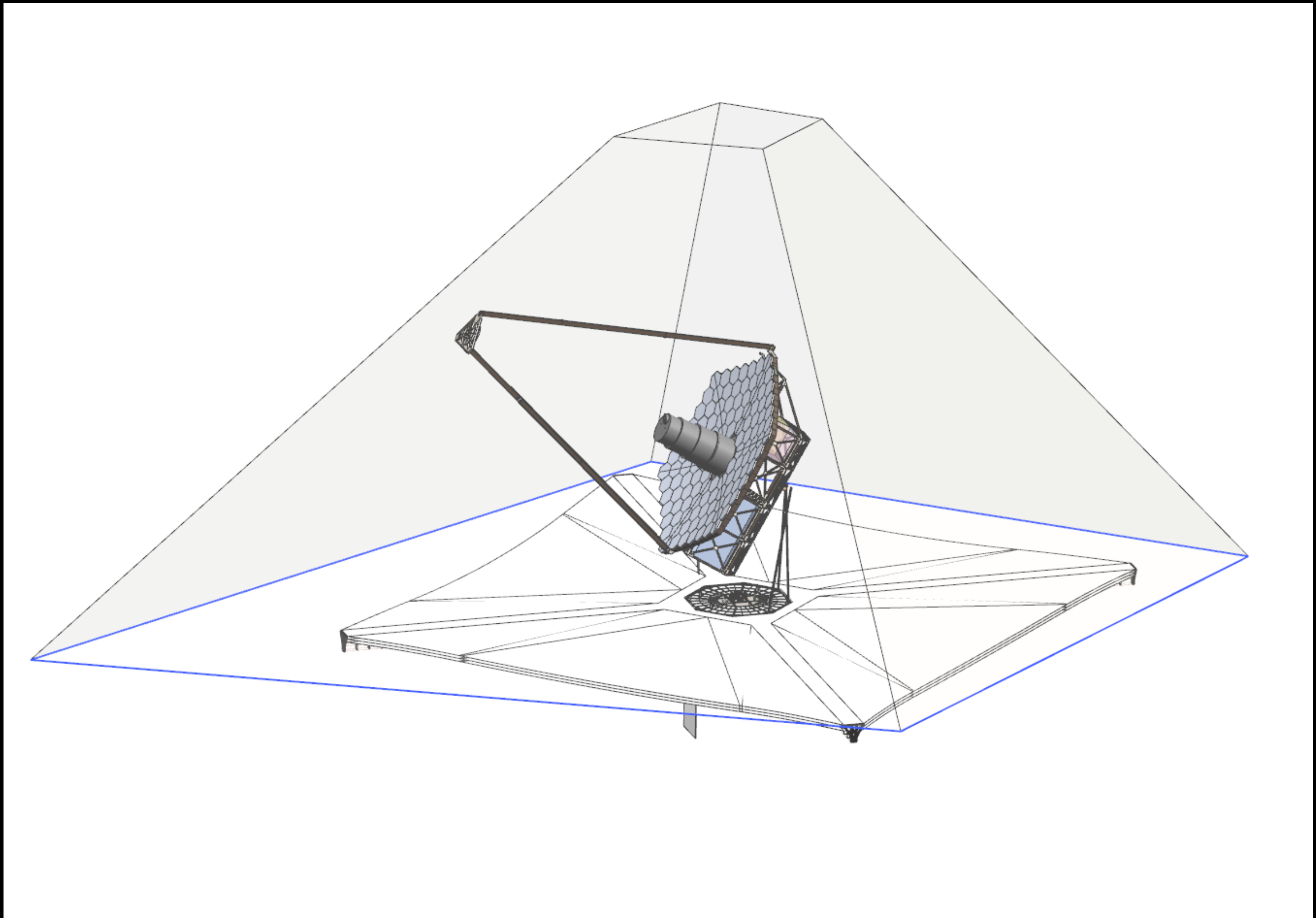

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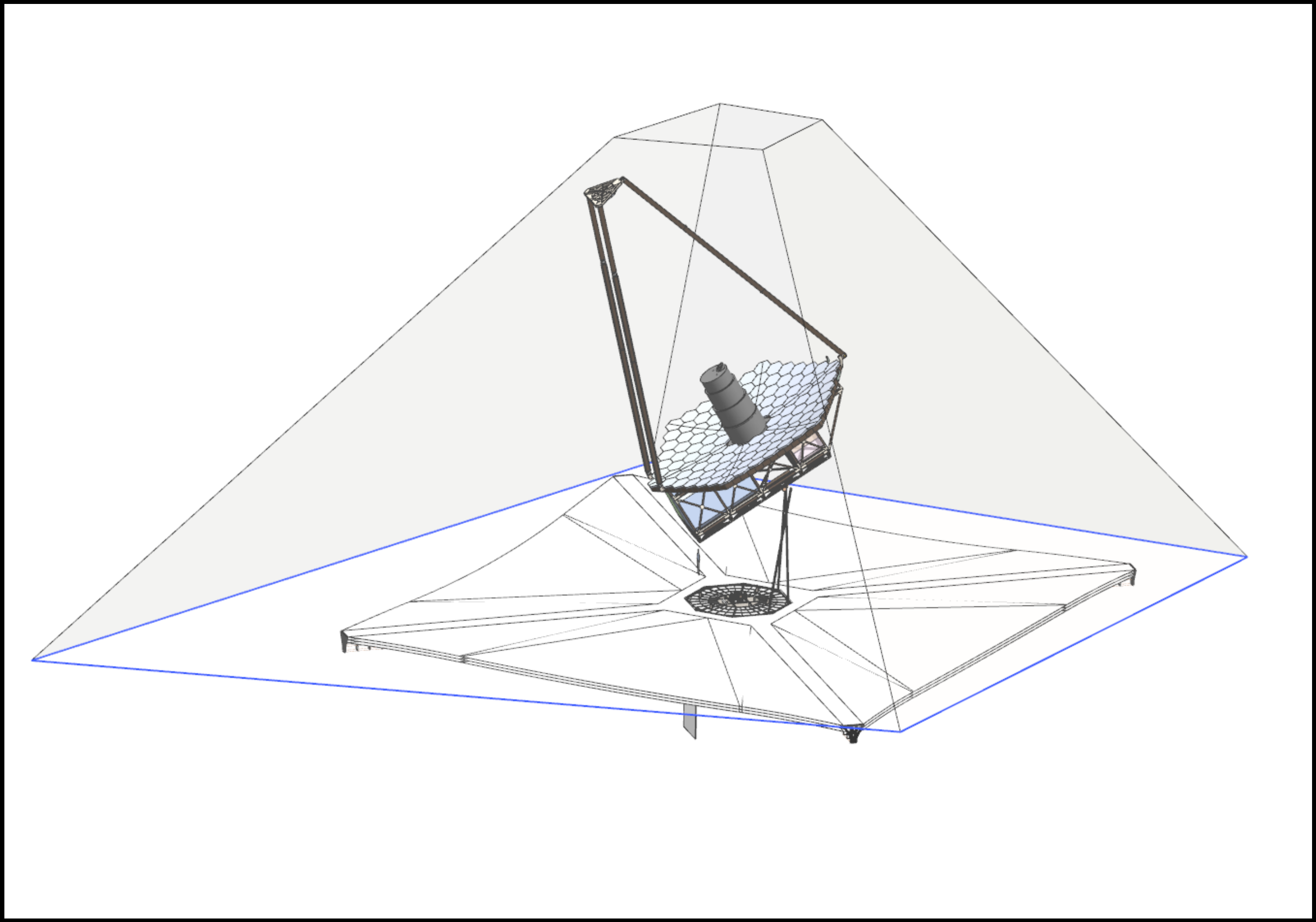

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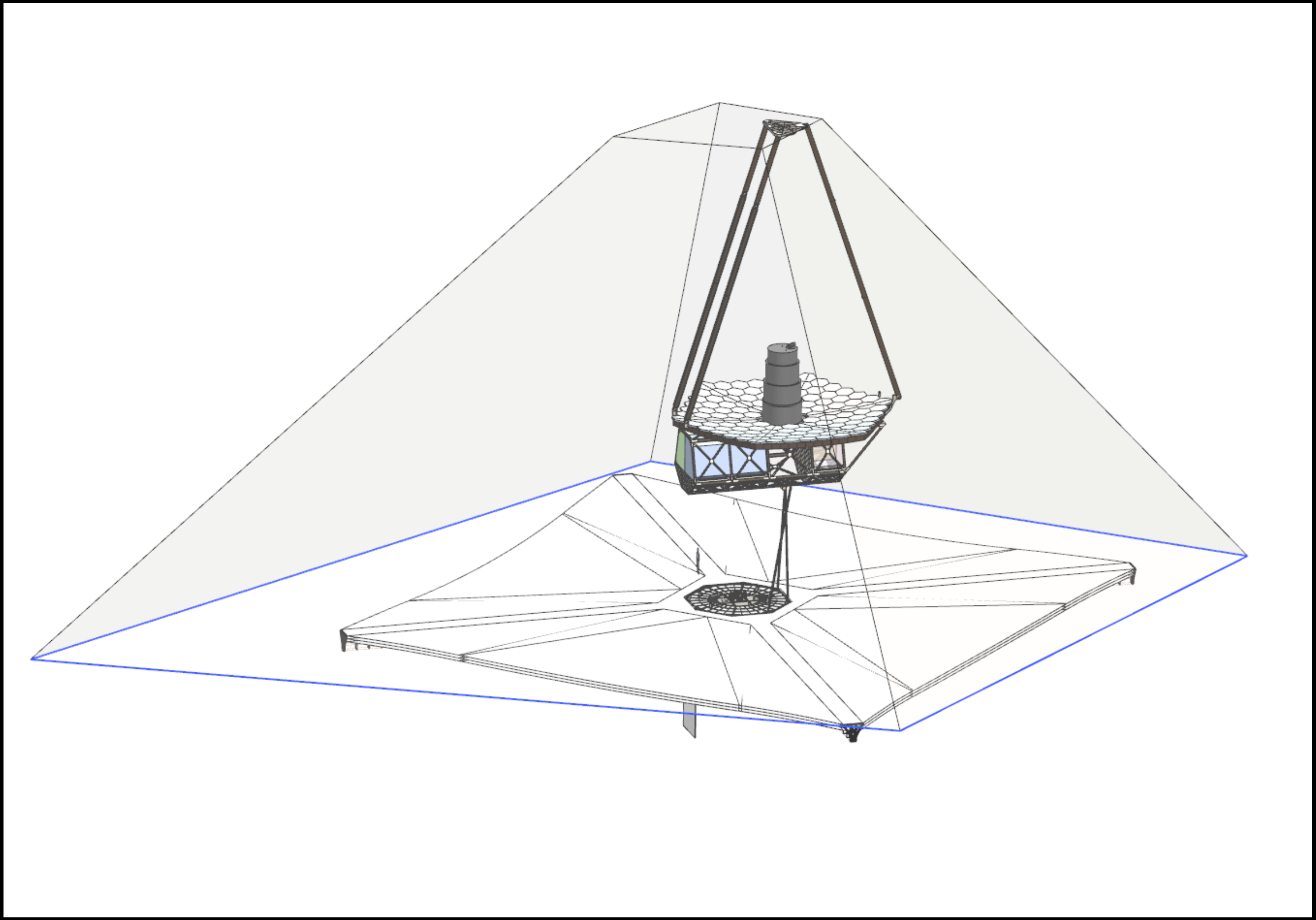
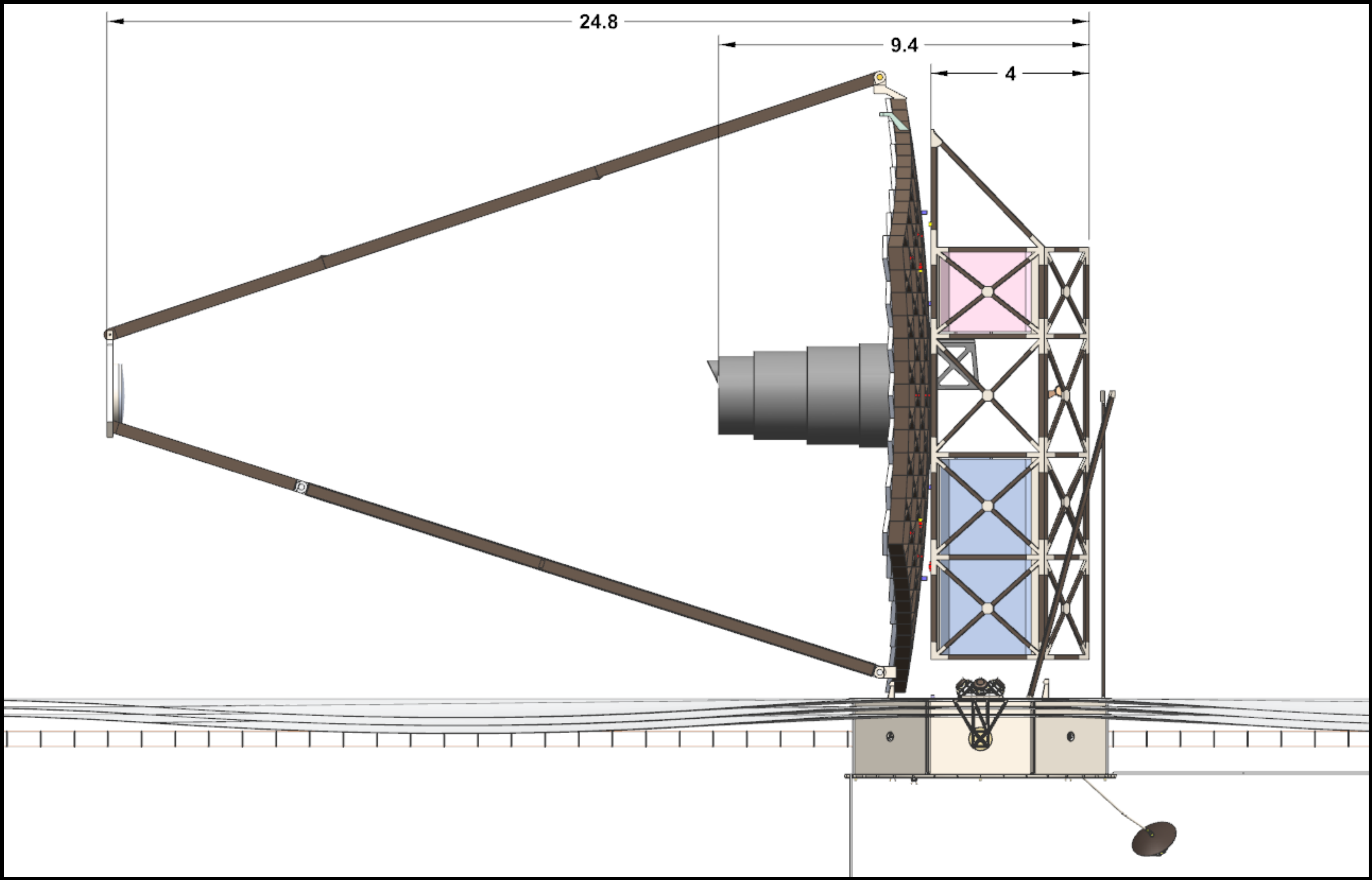


Basic Dimensions (meters)



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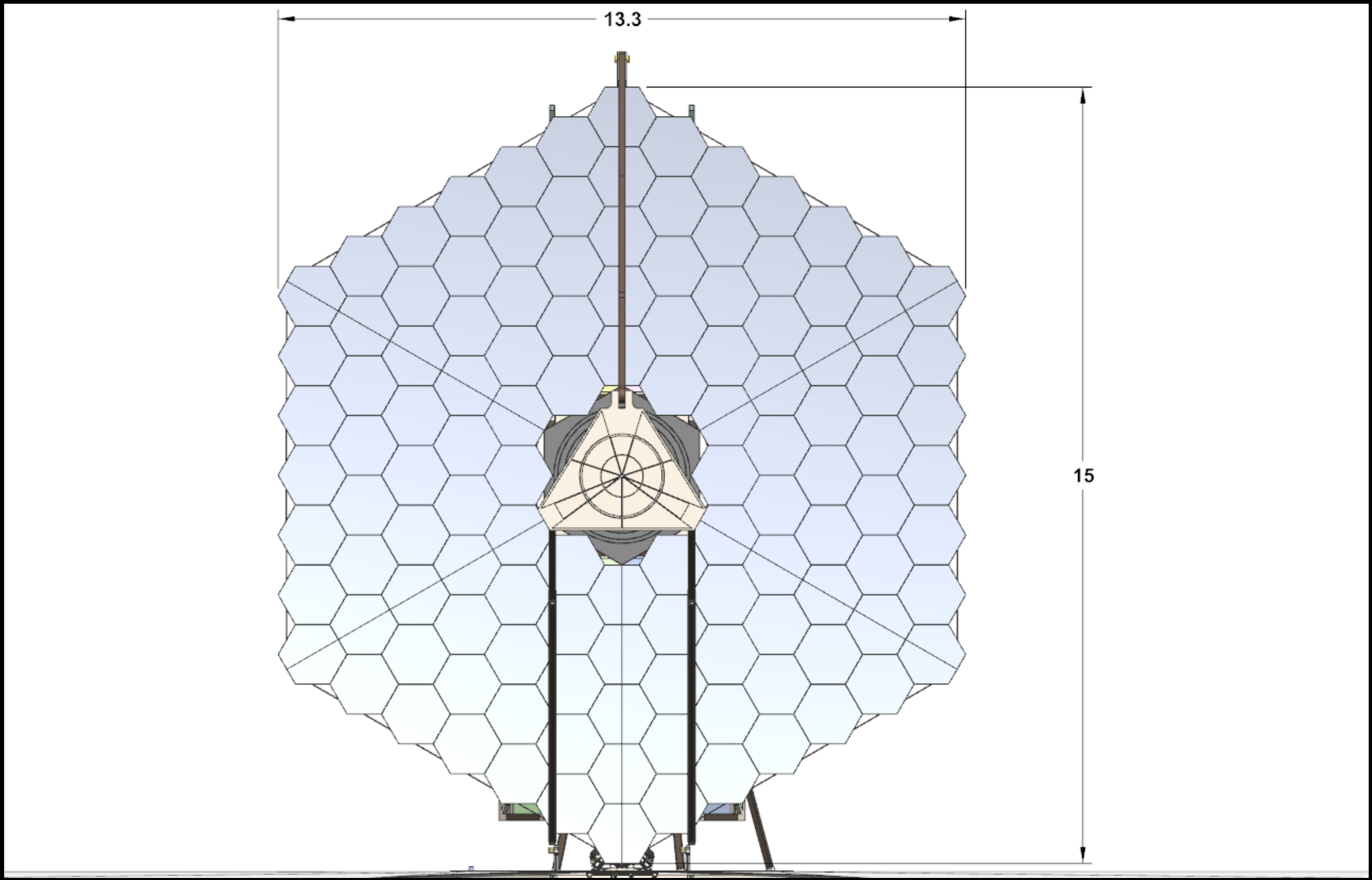
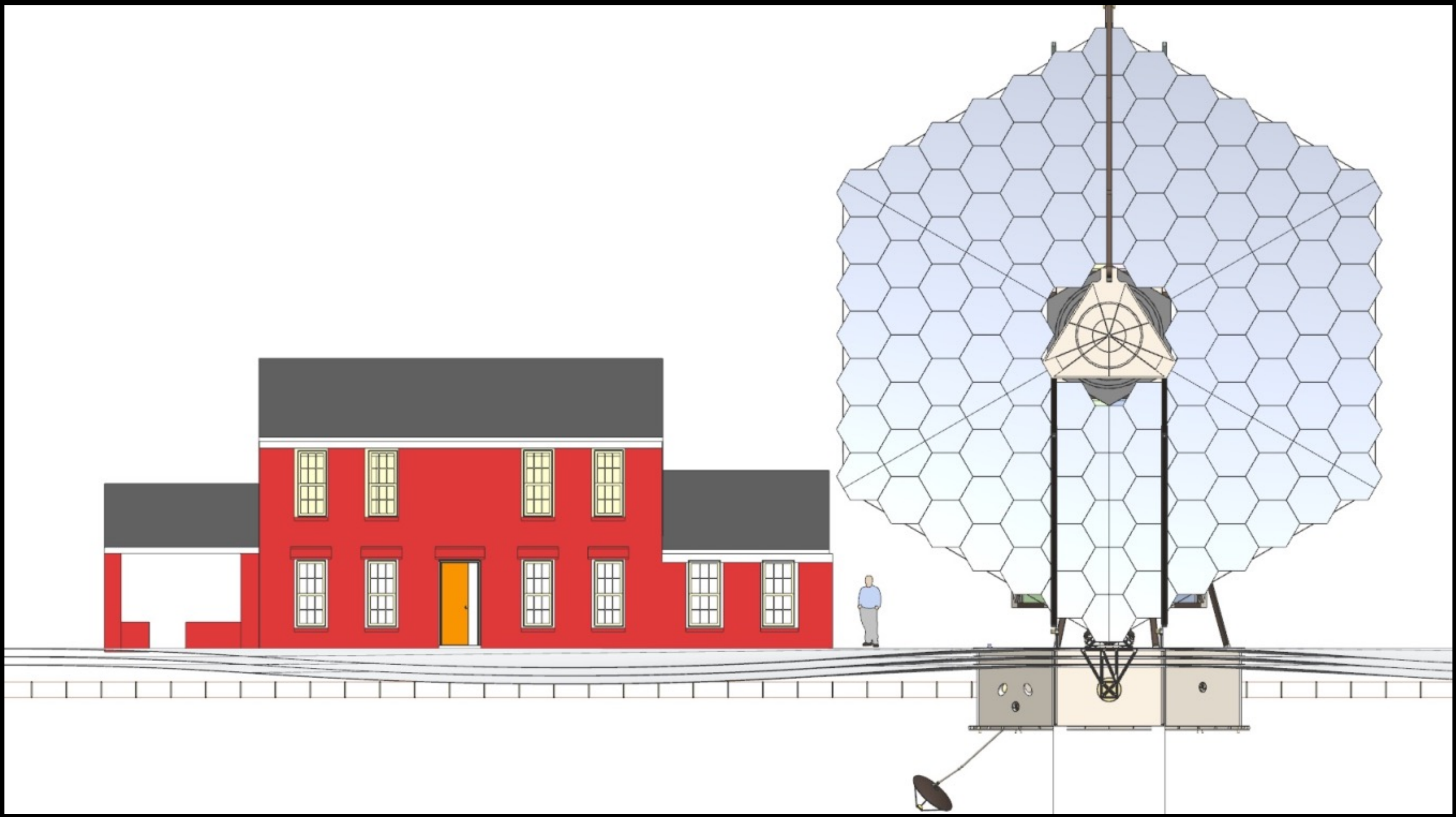


“Yep, it’s big.”

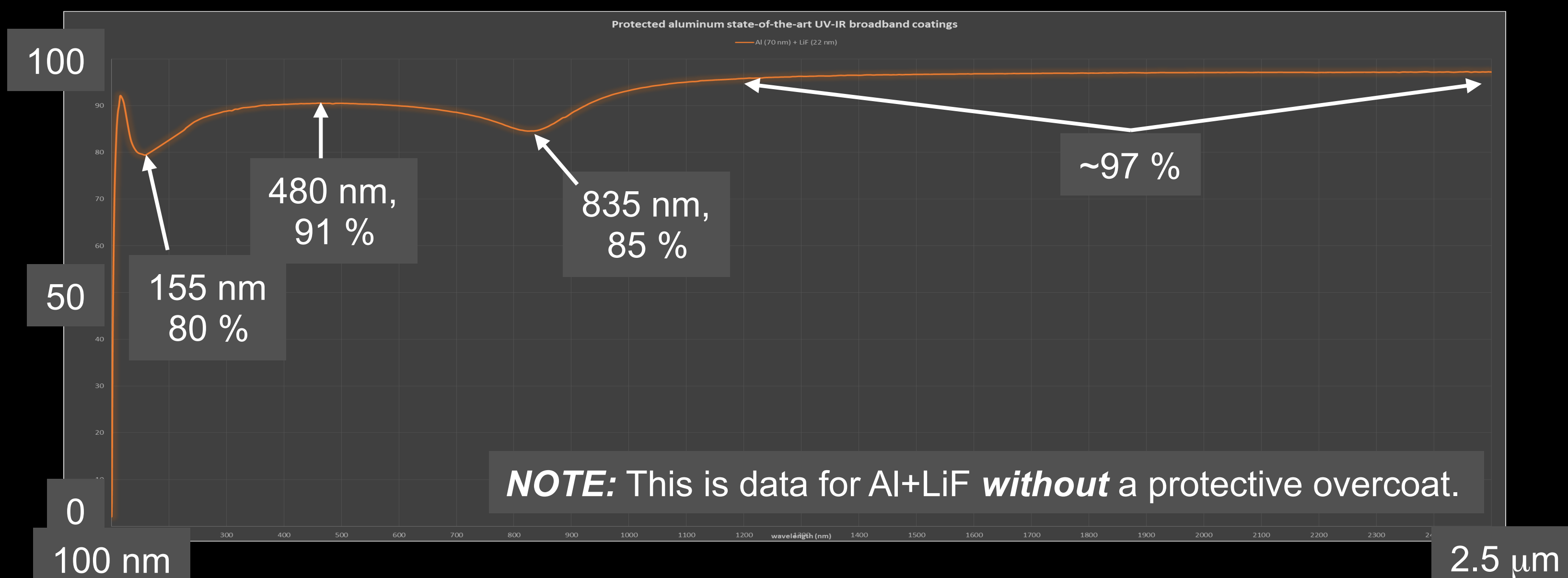


Credit: Drew Jones

Design Overview:
Optical Telescope Element (OTE)

LUVOIR “A” OTE Specifications

- Instantaneous Field-of-View: 10 arcmin x 8 arcmin
- Instantaneous Field-of-Regard: 2π sr, anti-sun
- Mirror Coating: Al + LiF + thin protective overcoat of MgF_2 or AlF_3
  - Approx. 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



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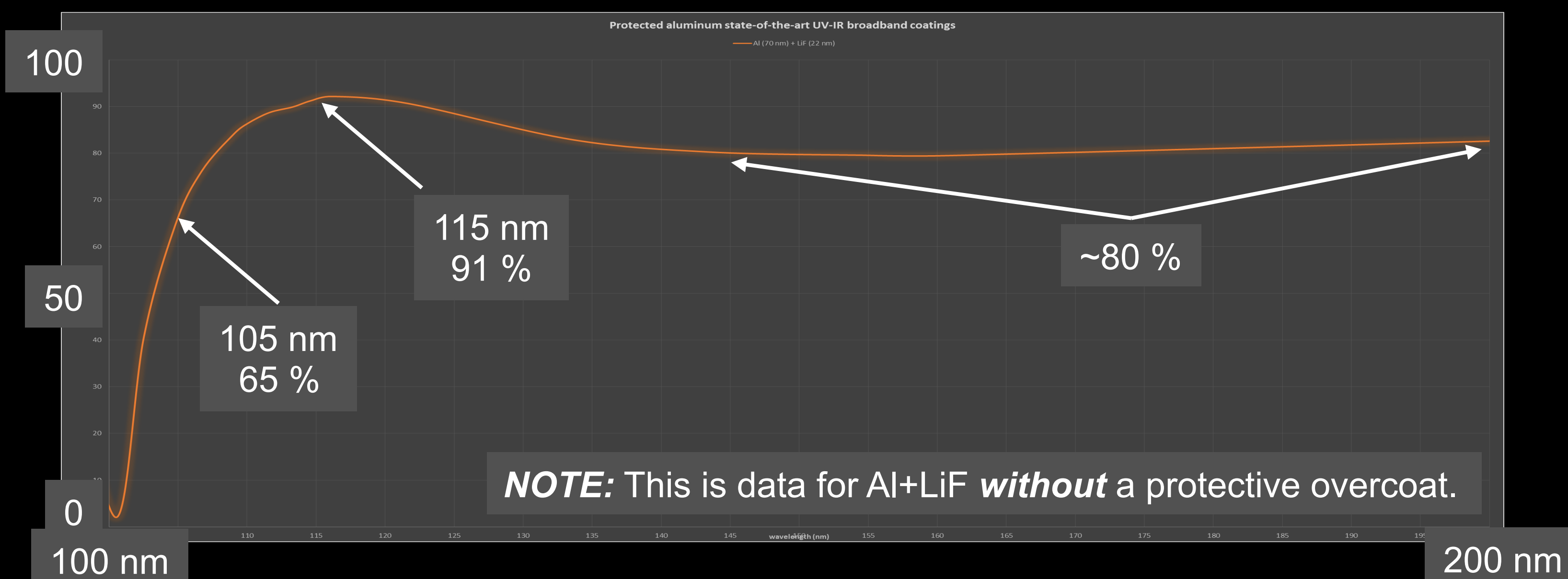
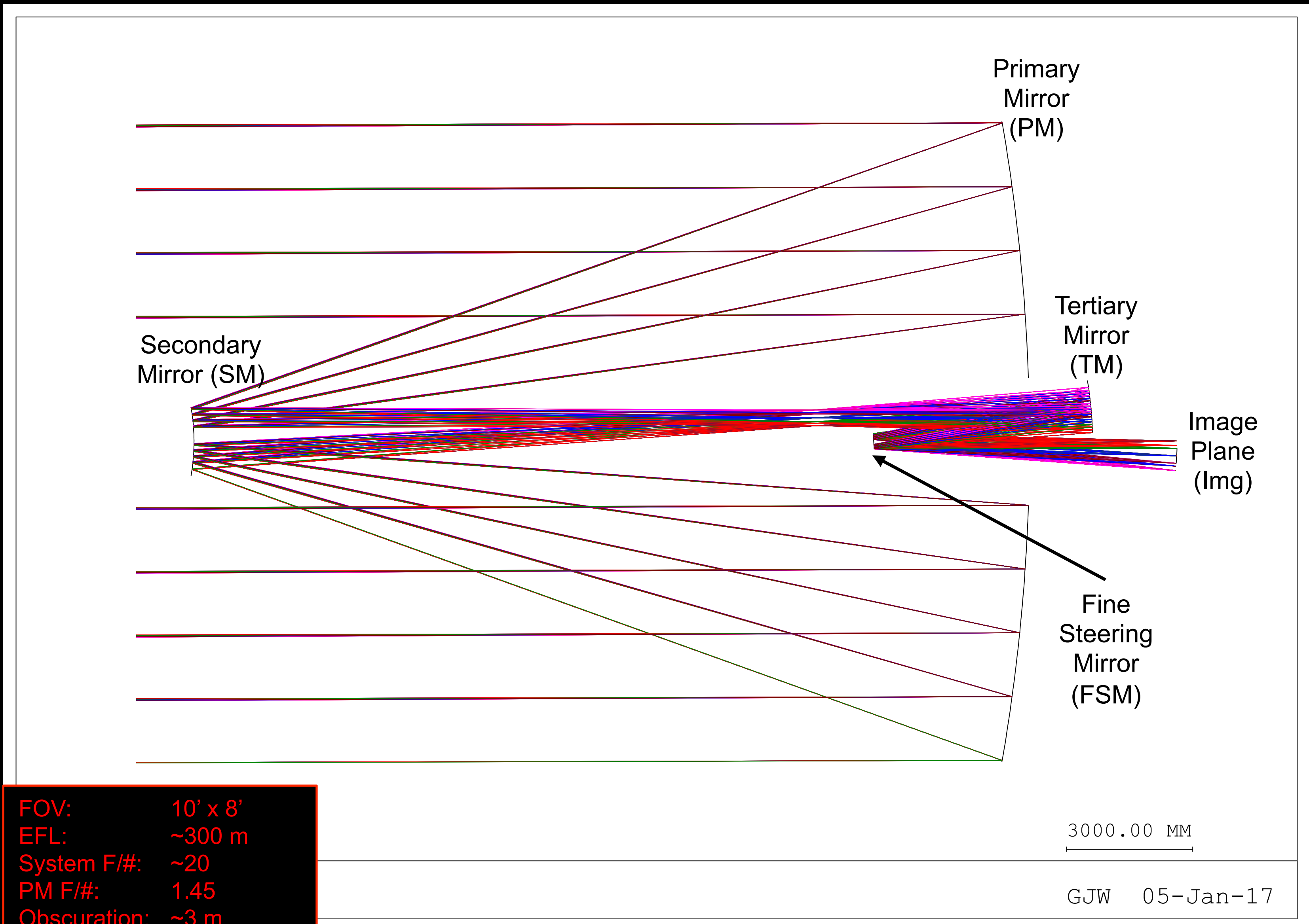


LUVOIR "A" OTE Specifications

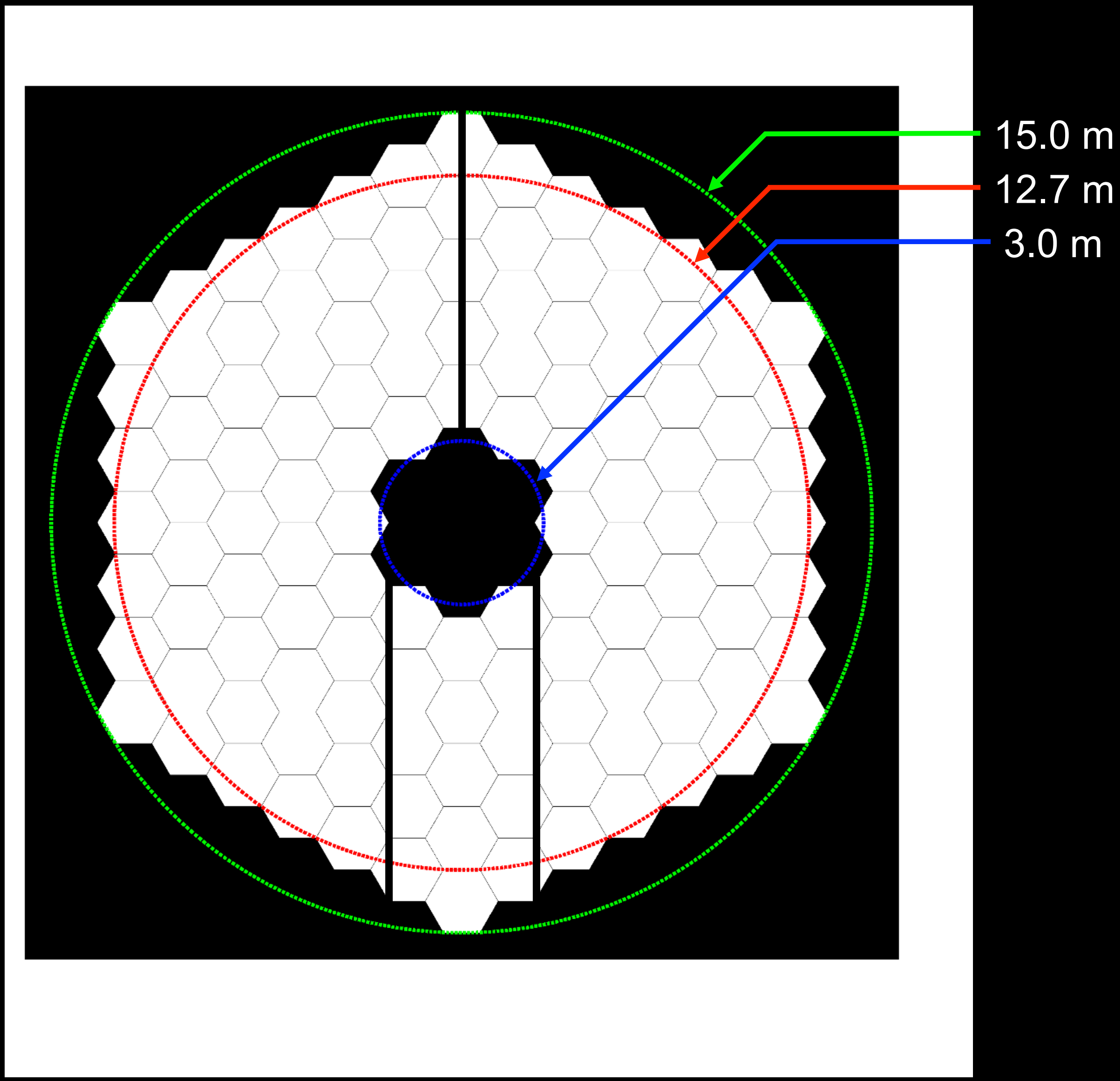
- Pointing stability provided by Fine Steering Mirror and Vibration Isolation and Precision Pointing System (VIPPS):
  - Repeatability / Step Size: 1 mas
  - Stability: +/- 0.33 mas during an observation
- Tracking capability provided by VIPPS:
  - 60 mas / s
  - JWST is 30 mas / s
- Slew capability provided by spacecraft and gimbal system
  - Work in progress
  - Targeting a 90° / 45 min. with a goal of 90° / 30 min.
  - JWST is 90° / 60 min.

LUVOIR “A” Telescope Optical Design



FOV:	10’ x 8’
EFL:	~300 m
System F/#:	~20
PM F/#:	1.45
Obscuration:	~3 m

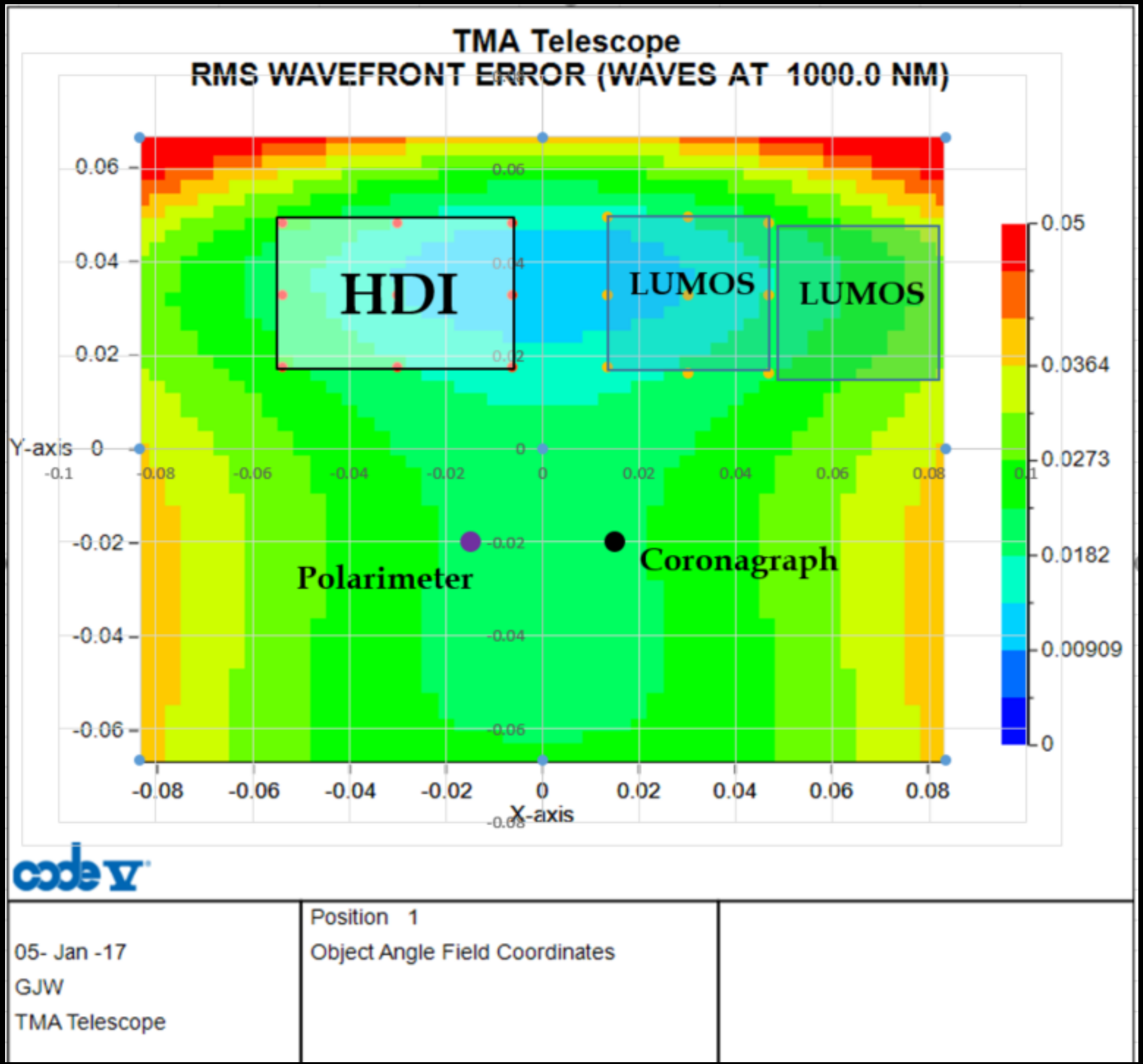
LUVOIR "A" Telescope Aperture



- 1.15-m flat-to-flat segments (120x)
- Central ring of array removed to accommodate Aft-optics & Secondary Mirror Obscuration
- Effective area is 135 m^2
- Assumes 6 mm gaps

OTE Focal Plane Allocations

Field Coordinates on Sky (°)



Closed-loop Control of PM Segments

- Edge sensors:
  - Capacitive, inductive, or optical
  - Provides fast measurements of segment rigid body motions at picometer level
  - Baselined for ground-based systems (TMT, GMT, EELT, Keck)
  - Lab demos show sensitivity at the 10 pm level
- Piezoelectric (PZT) fine-stage in segment actuators
  - Respond to edge sensor data to move mirror segments
  - Range of PZT motion is hundreds of picometers; mechanical linkage reduces that motion to single digit picometers
- Closed-loop system creates a “virtual monolith”
- Technology challenges for LUVOIR
  - Read-out electronics for high-speed, single digit accuracy
  - Verify motion reduction with mechanical linkage

High Definition Imager Design

HDI Technical Overview (1/2)

- Two-channel Imaging Instrument:
  - UV/Vis Imaging (200 nm - ~1.0 μm)
    - Diffraction-limited performance at 500 nm
    - Nyquist sampled at 400 nm
  - NIR Imaging (~1.0 μm – 2.5 μm)
    - Diffraction-limited performance at 1.2 μm
    - Nyquist sampled at 1.2 μm

- Each channel will contain a suite of spectral filters:

- Field-of-view: 2 x 3 arcmin
  - Channel Select Mechanism (CSM) allows:
    - Non-simultaneous observation over each channel's full band
    - Simultaneous observation in each channel over limited bandpasses or with limited throughputs

HDI Technical Overview (2/2)

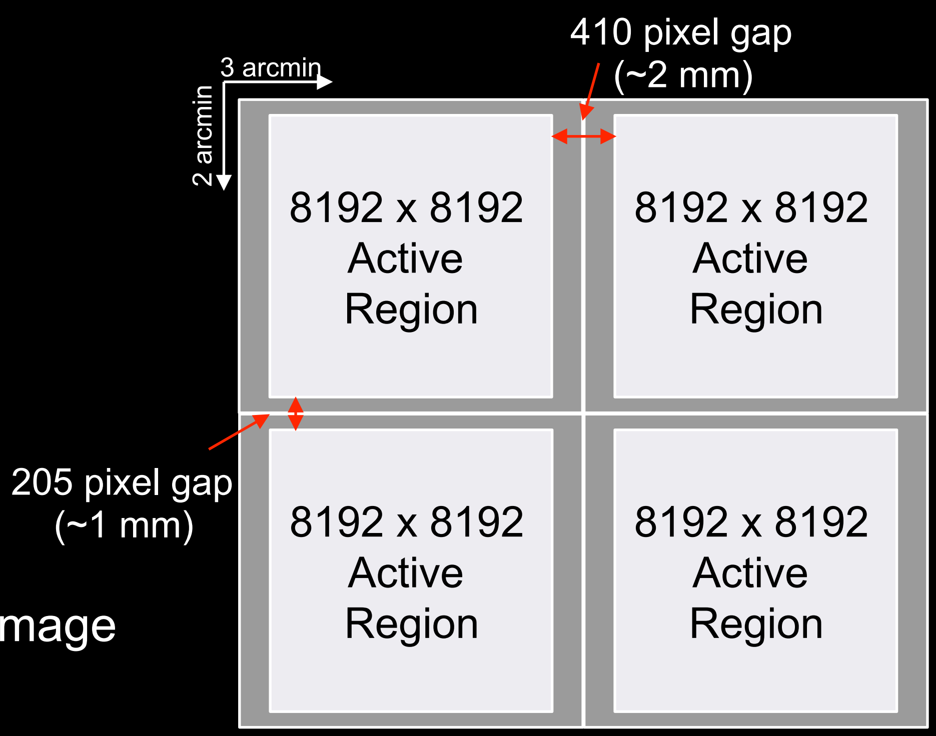
- Exposure times:
  - For most extragalactic sources and stellar population observations:
    - Total observation times of up to 200 hrs.
    - Composed of many exposures of 500-1000 s each
  - High-speed photometry with 50 ms exposures
    - Limited to small tiles of the focal plane at a time (~150 x 150 pixels)

HDI Detector Concept – UV/Vis Channel

- CMOS Detector
  - Pixel size = 5 μm
  - Nyquist sampled at 400 nm
    - Defined as: 1 pixel = λ / (2*D)
    - λ = 400 nm; D = 15.08 m; ◊ 1 pixel = 2.74 mas
  - Read noise: ~2.5 e-
  - Dark Current: Assume 0.001 e-/pix/s
  - Operating temperature ~120 K

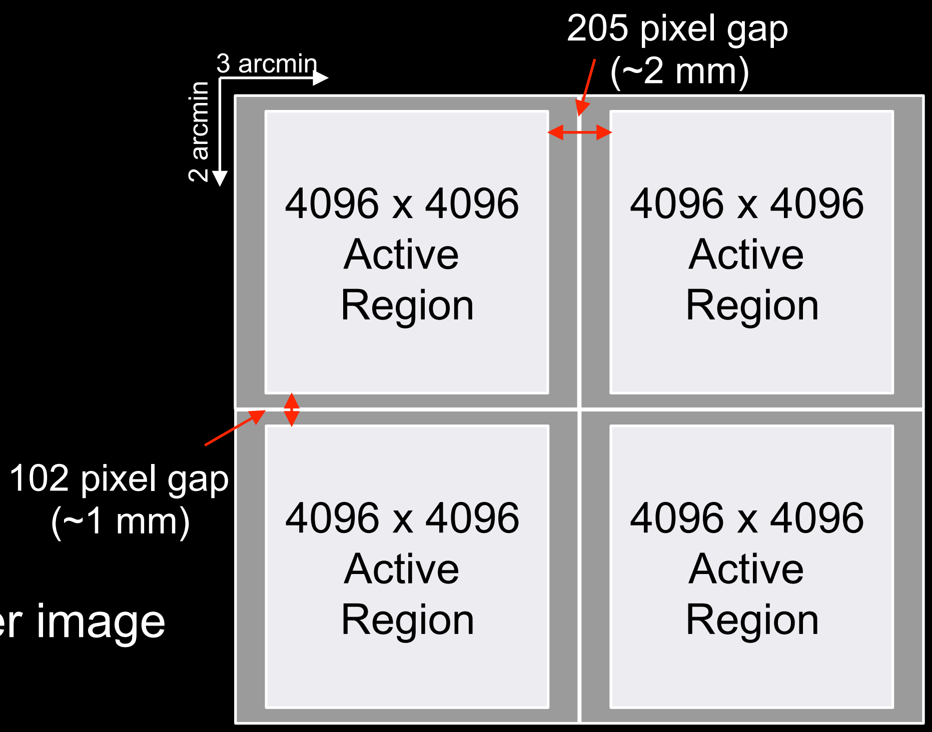
- Array of 8k x 8k detectors:
  - Use 5 x 8 tiling of arrays:
    - FOV = 1.90 x 3.12 arcmin
    - 40,960 x 65,536 pixels = 2.68 Gpix
    - 209 x 342 mm focal plane array (including gaps)

- Assume 16 bits/pixel: 5.4 Gbytes per image



HDI Detector Concept – NIR Channel

- H4RG Detector
  - Pixel size = 10 μm
  - Nyquist sampled at 1200 nm
    - Defined as: 1 pixel = λ / (2*D)
    - λ = 1200 nm; D = 15.08 m; ◊ 1 pixel = 8.2 mas
  - Read noise: < 5 e-
  - Dark Current: Assume 0.001 e-/pix/s
  - Operating temperature ~70 K



- Array of 4k x 4k detectors:
  - Use 4 x 5 tiling of arrays:
    - FOV = 2.28 x 2.91 arcmin
    - 16,384 x 20,480 pixels = 335 Mpix
    - 167 x 213 mm focal plane array (including gaps)

- Assume 16 bits/pixel: 0.671 Gbytes per image

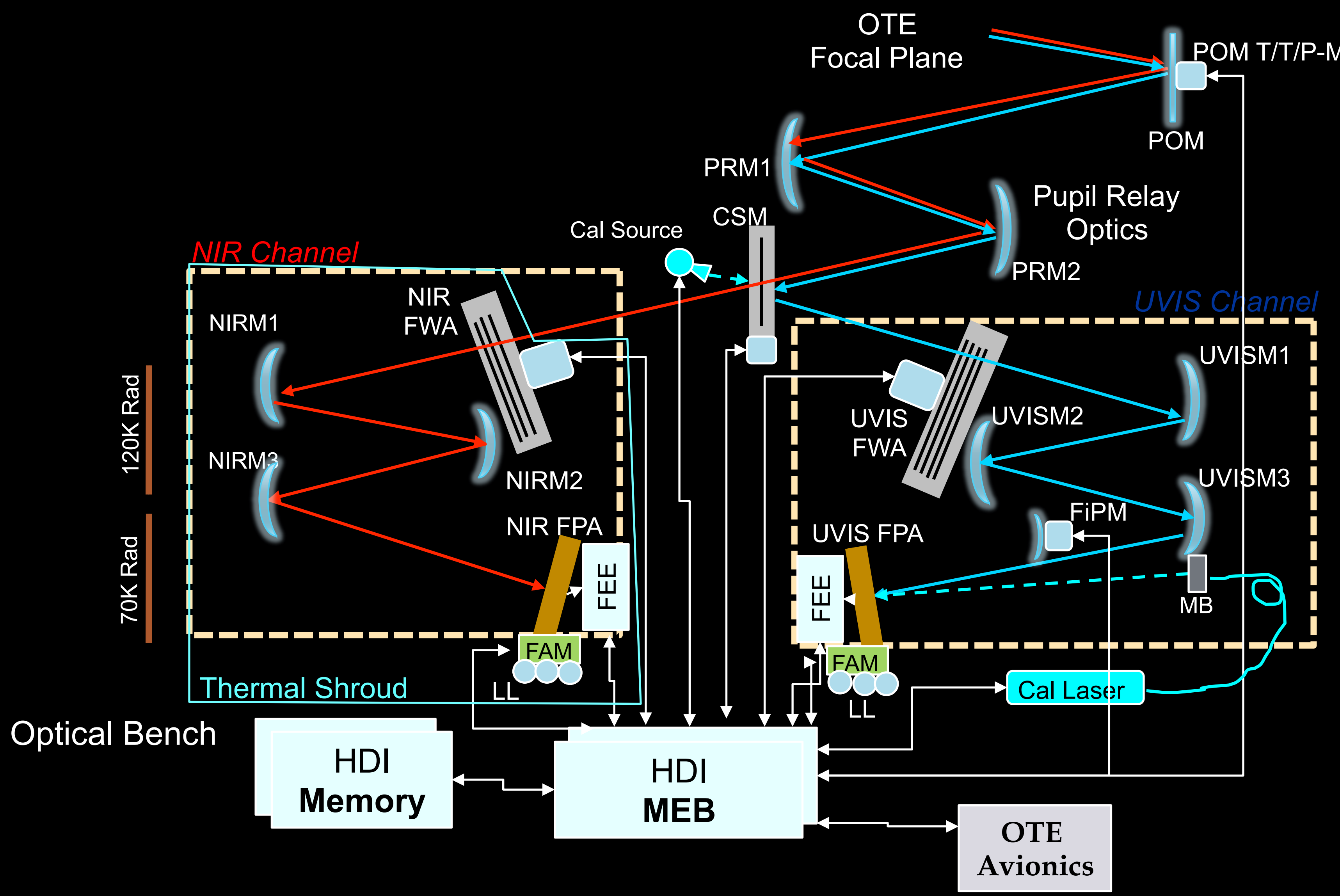
HDI Special Modes :

- High-Precision Astrometry (for measuring exoplanet mass)
  - Astrometric precision of < 5×10^{-4} pixels
  - Requires a Pixel Calibration System to calibrate pixel geometry

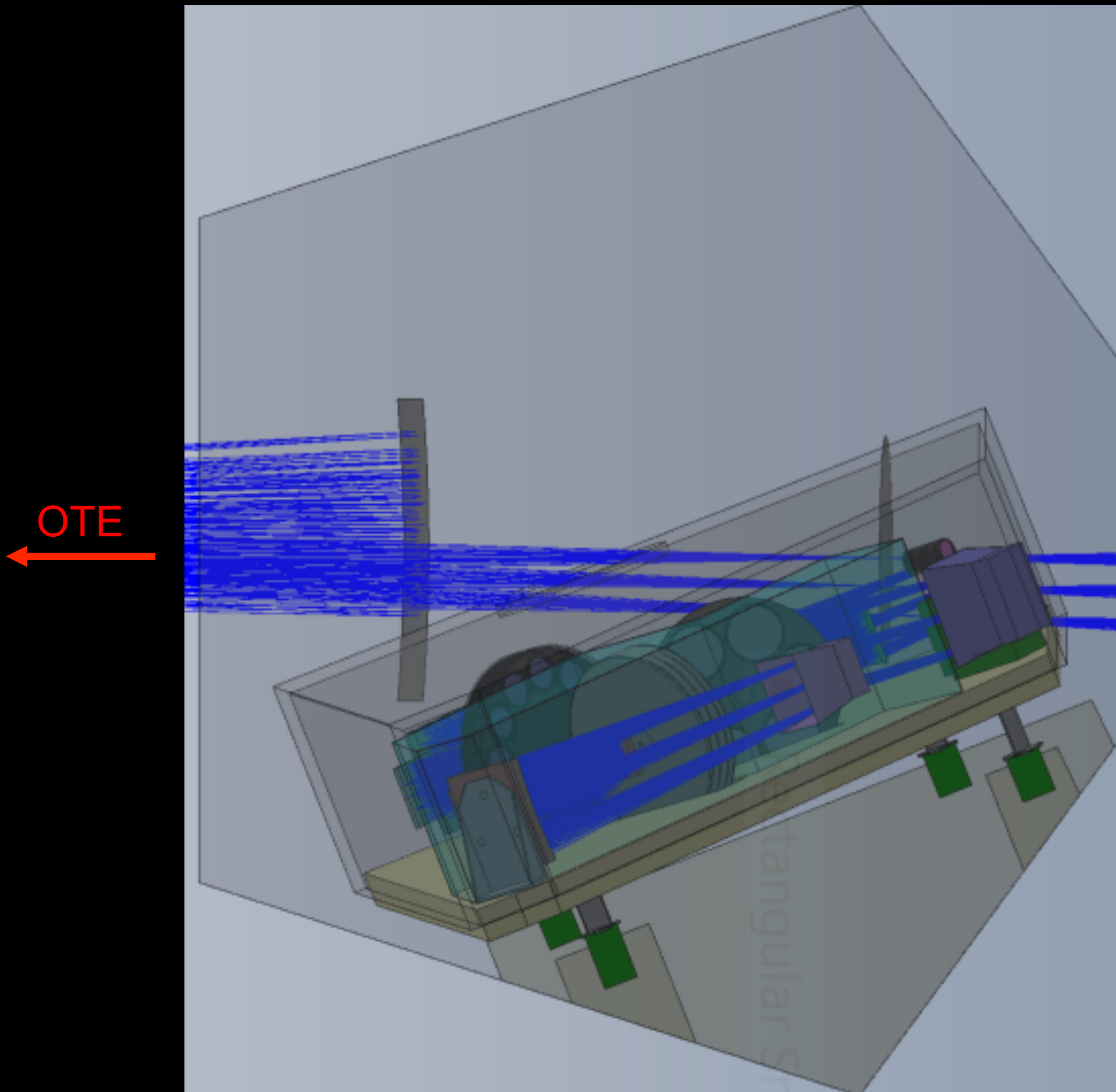
- Fine-guiding
  - HDI is the primary fine-guidance sensor for the LUVOIR observatory
  - Similar to WFIRST operation
    - Requires ability to define regions of focal plane with faster readout
    - Capability shared in both UV/Vis and NIR channels

- Image-based Wavefront Sensing (i.e. phase retrieval) for telescope commissioning and maintenance
  - Similar to role played by NIRCam on JWST
  - Elements included in UVIS channel filter wheel assembly:
    - Weak-lenses for generating defocused images
    - Dispersed Hartmann Sensor (DHS) gratings for coarse piston sensing
    - Pupil Imaging Lens (PIL) subsystem

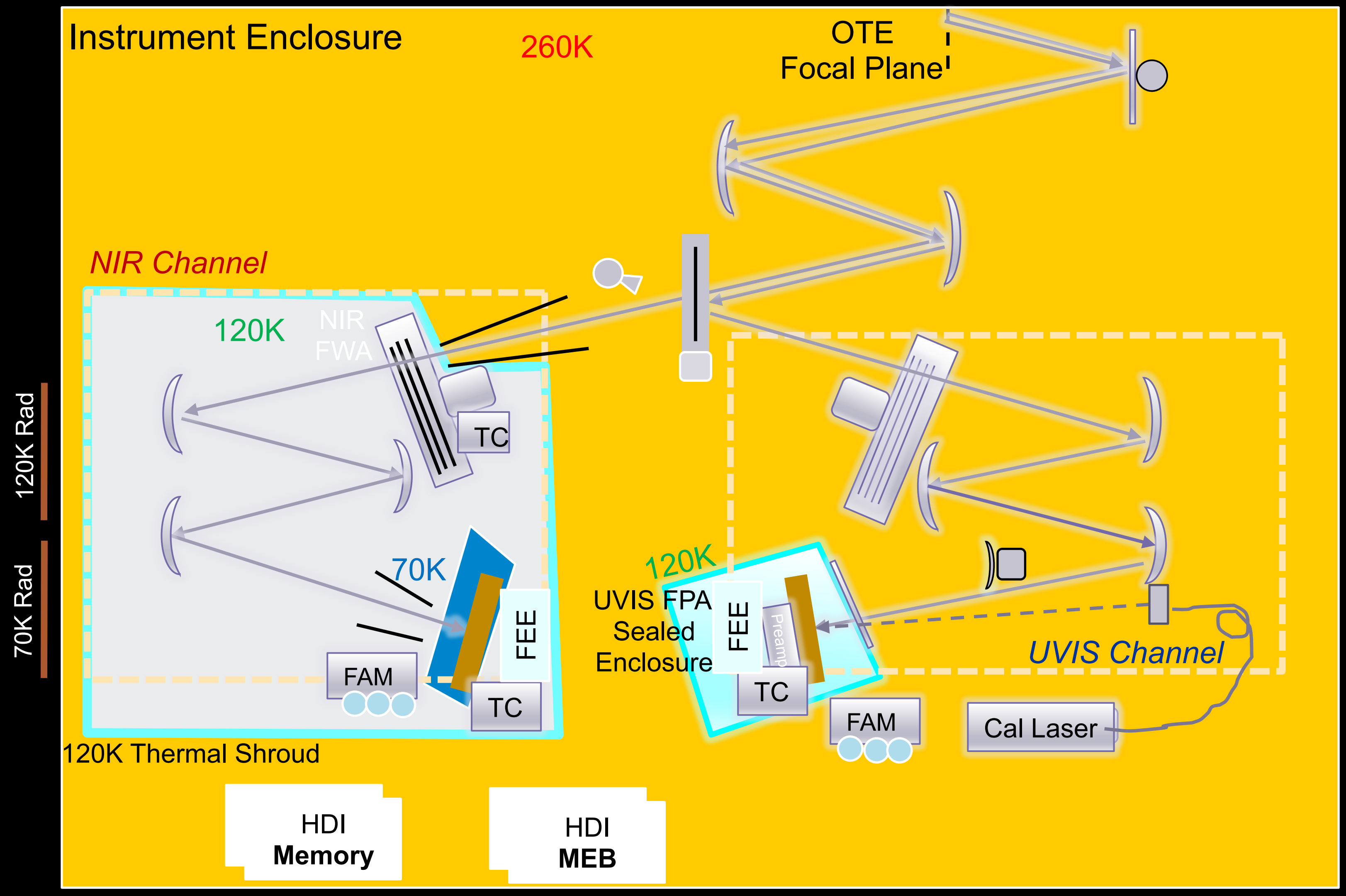
HDI System Block Diagram



HDI Mechanical Volume in the BSF



HDI Thermal Design



Questions / Discussion