TMT Science Instruments: First-Light and Beyond

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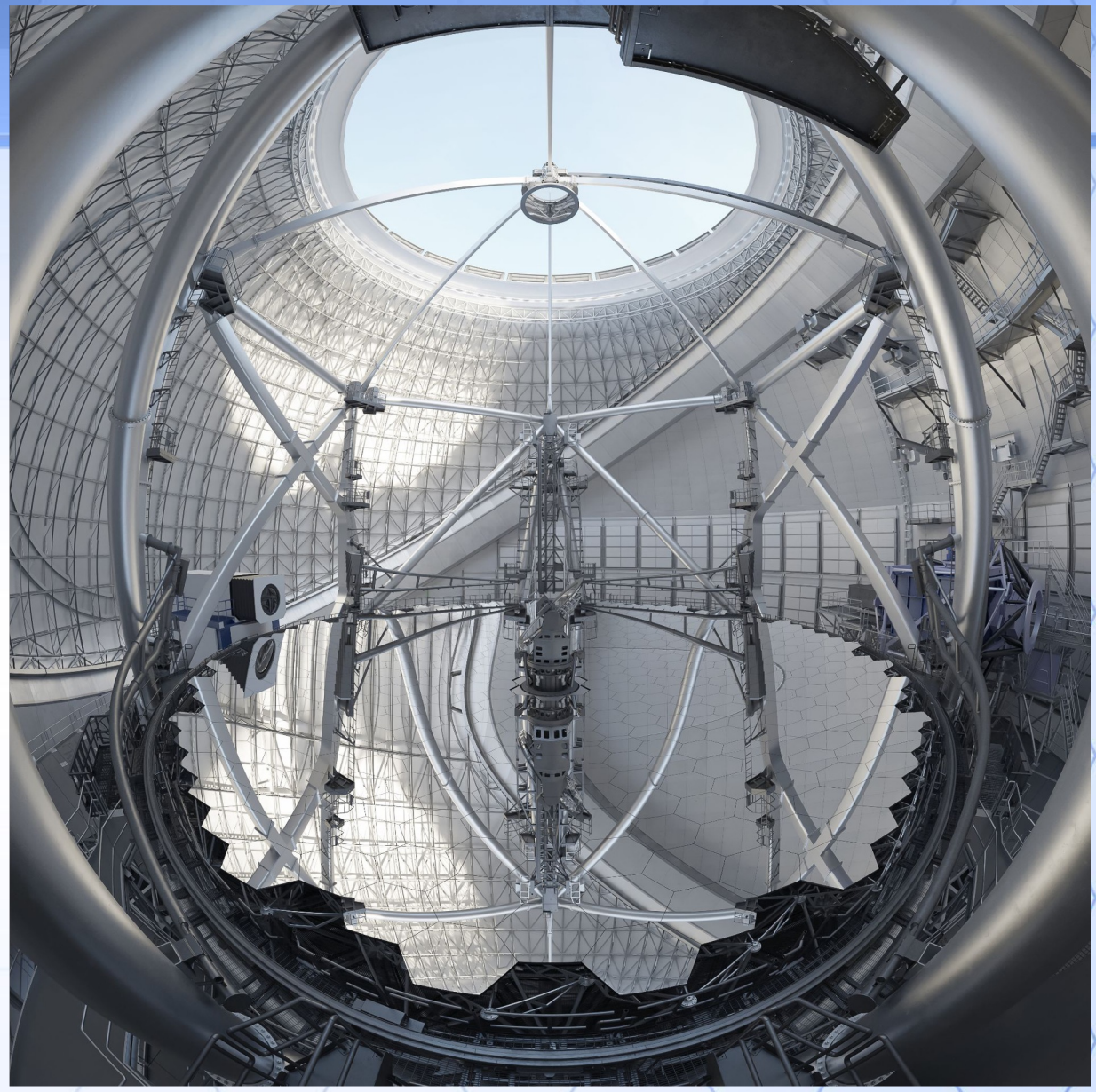
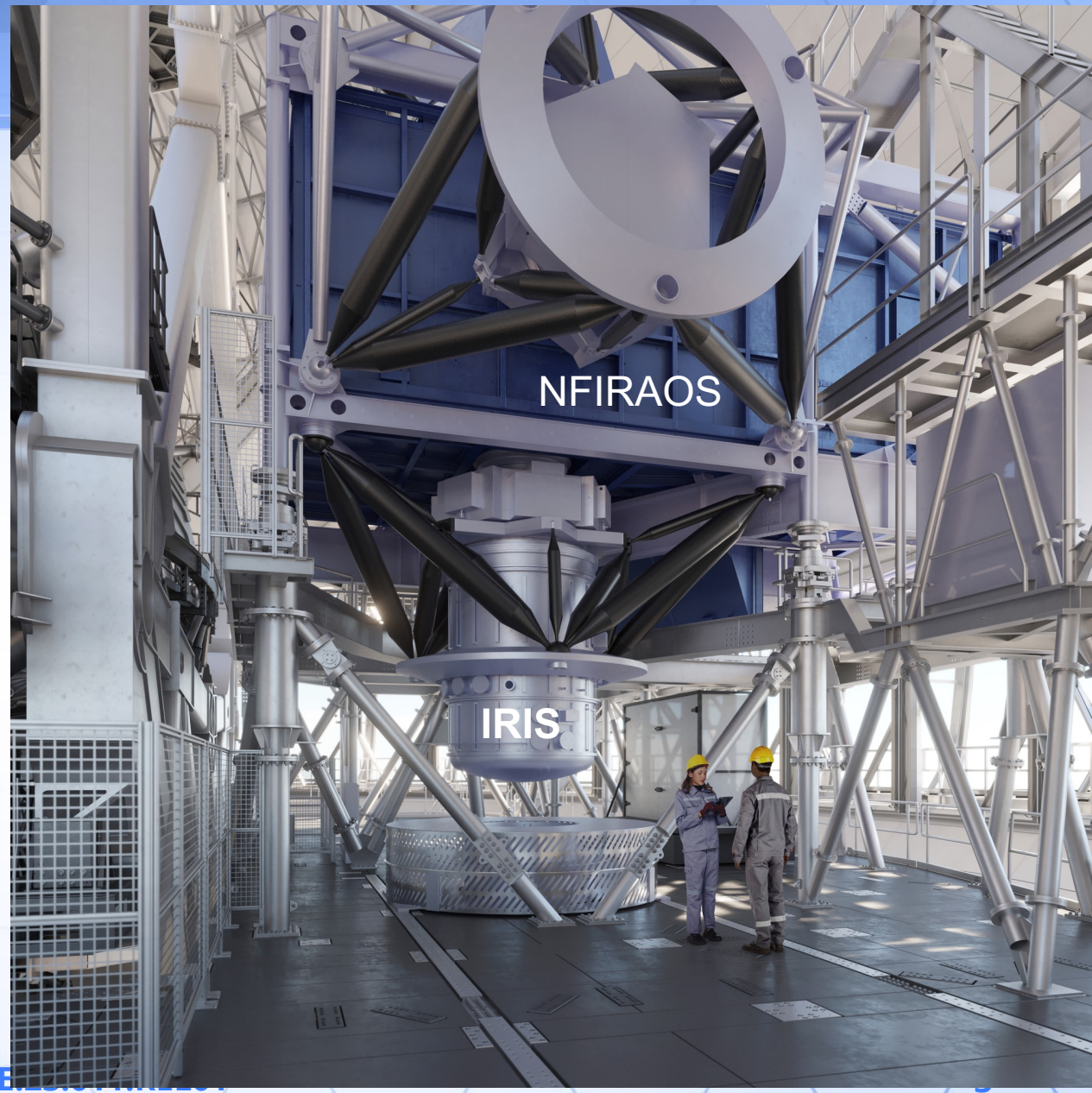
TMT at a "Sweet Spot"

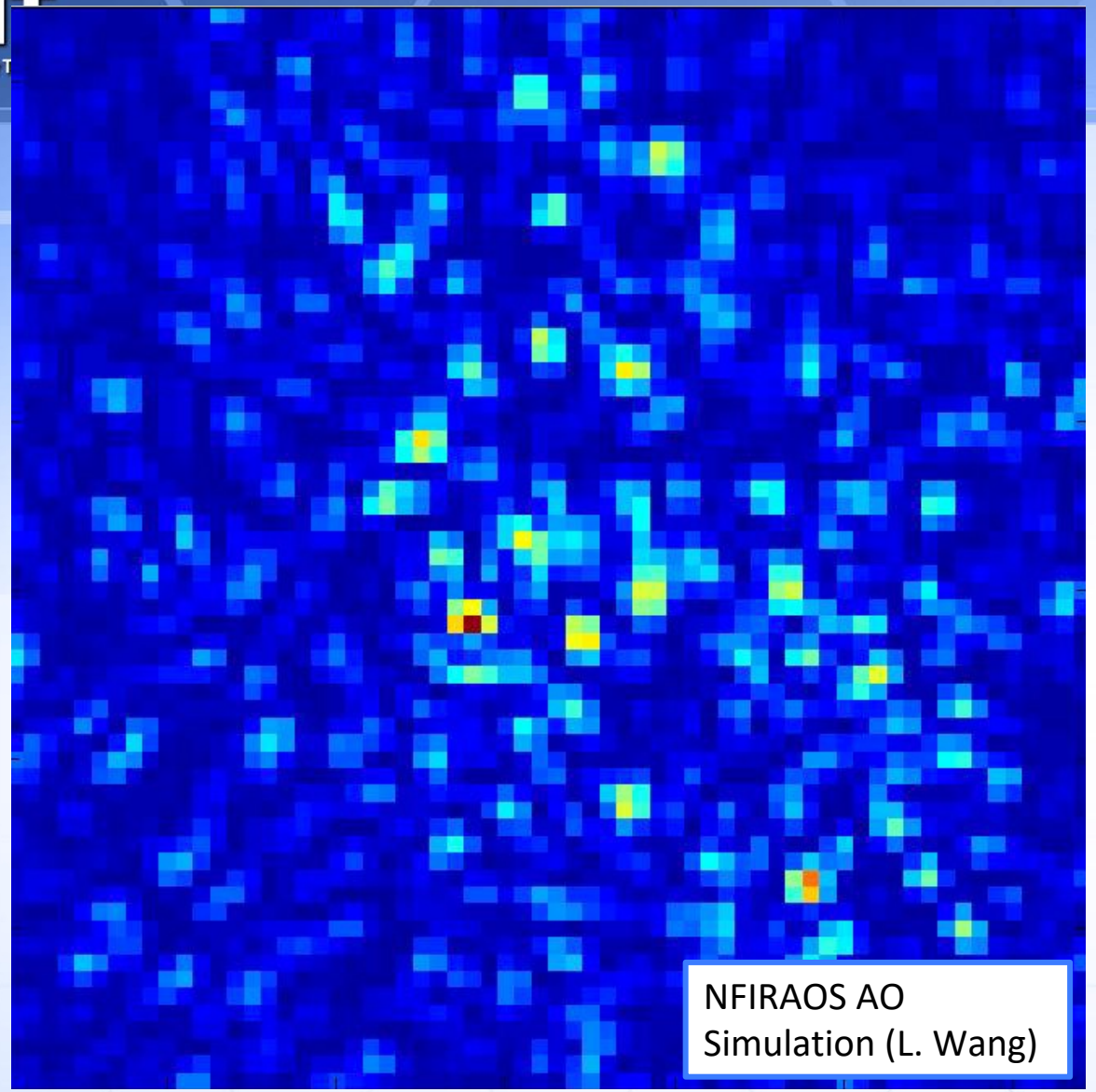
- Provides a **dramatic increase in science performance** compared to today's 8-10m telescope in terms of angular resolution ~ D^{-1} and sensitivity ~ D^2 (for AO, point source sensitivity scales as ~ D^4)
- While **maintaining cost and technical challenges at reasonable levels**
  - Simple RC optical design
  - Steerable M3
  - Instruments all on gravity-invariant Nasmyth platforms



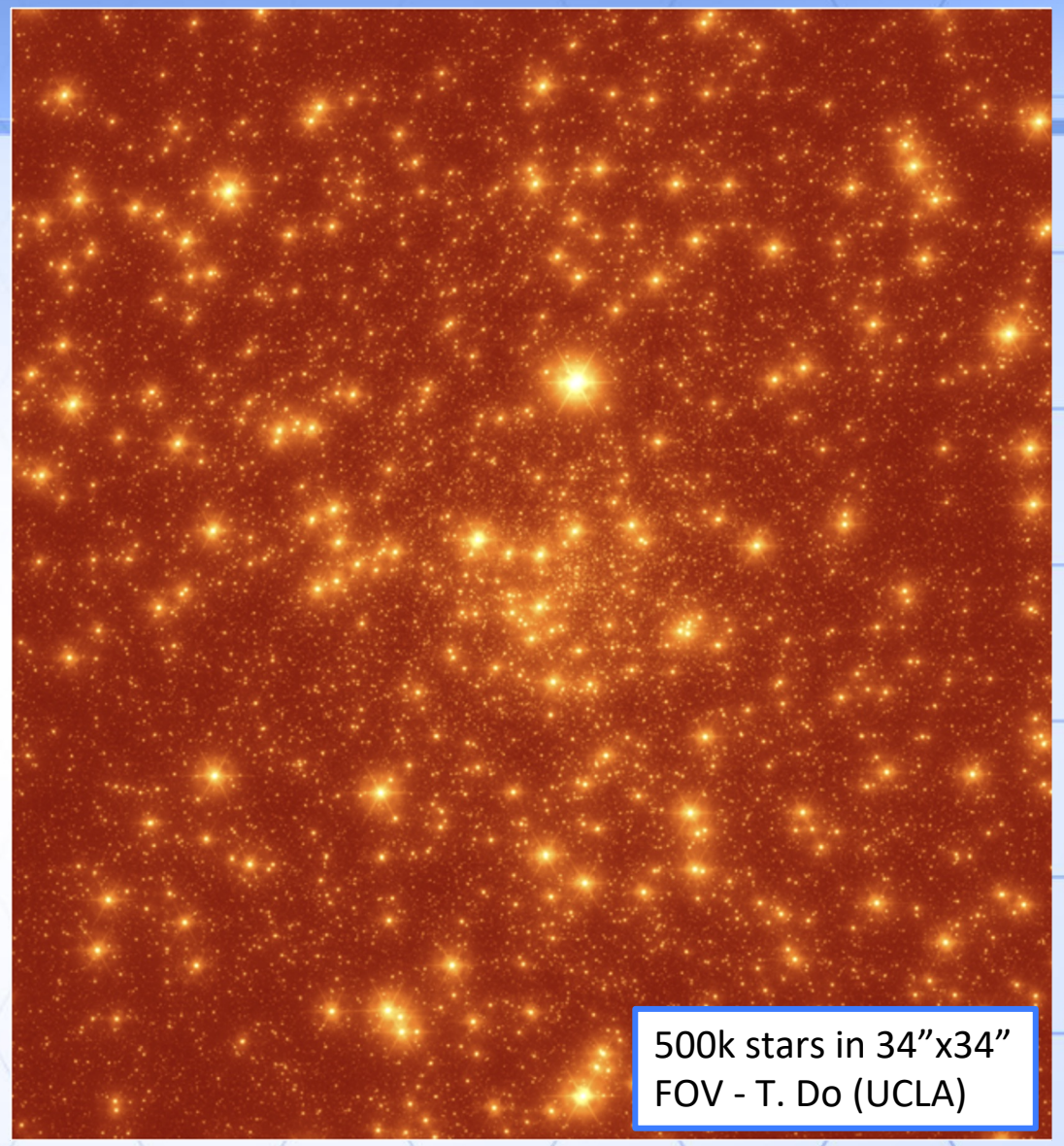
TMT Adaptive Optics

- TMT designed with Adaptive Optics (AO) in mind
  - Minimize vibration and uncorrectable errors
- AO Facilities
  - NFIRAOS – Multi-Conjugate Adaptive Optics (MCAO) system – **Completed Final Design Review**
  - Laser Guide Star Facility – **Preliminary Design Review in less than 6 months**
  - AO Software – **Real Time Controller** in production





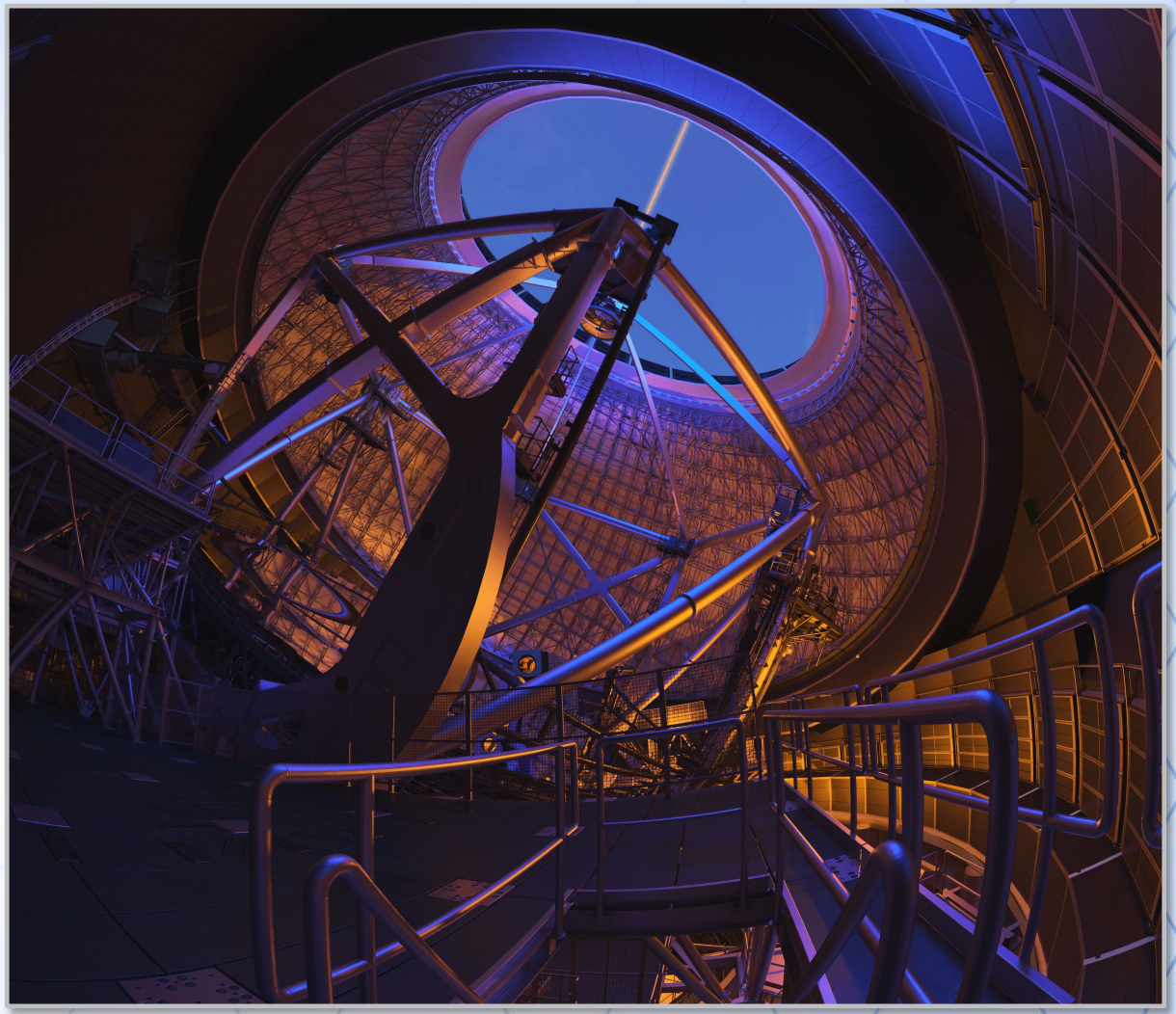
NFIRAOS AO Simulation (L. Wang)



500k stars in 34”x34” FOV - T. Do (UCLA)

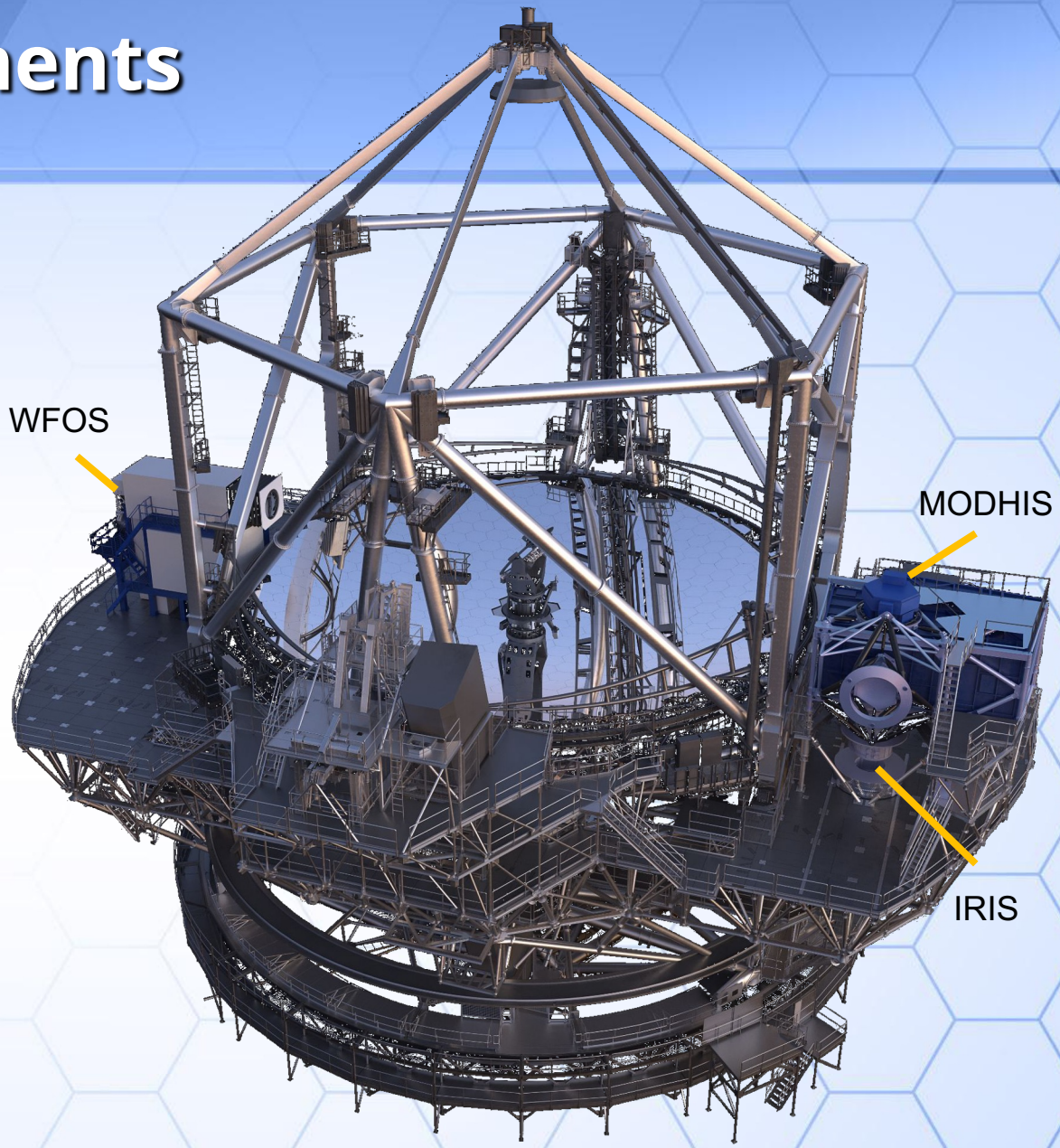
TMT Adaptive Optics Capabilities

- Uniform, high Strehl ratio (50% in H-band) performance over 30” field of view
- Designed to produce high sky coverage (>50% sky coverage near the North Galactic Pole)
- Enables high precision astrometry (<50 μas RMS)



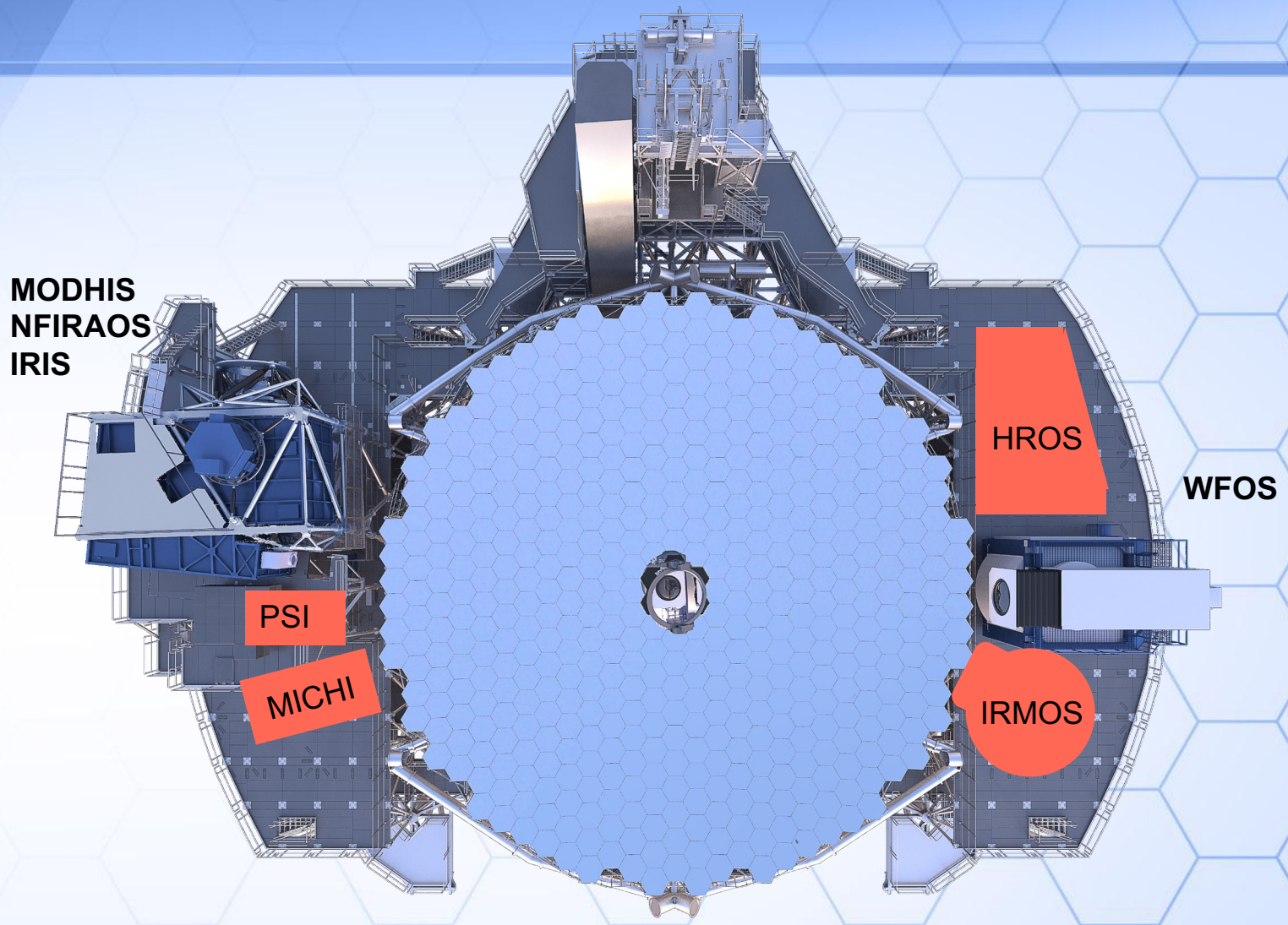
TMT First Light Instruments

- **IRIS - InfraRed Imaging Spectrograph**
  - Near Infrared Imager and Integral Field Spectrograph
  - Fed by MCAO system NFIRAOS
  - PI: Larkin (UCLA) PS: Wright (UCSD)
    - Team: UCLA, UCSD, CIT, NRC HAA, NAOJ, TIO
    - Final Design Phase
- **WFOS - Wide-Field Optical Spectrograph**
  - Optical Multi-Object Spectrograph with Imaging Capability
  - PI: Steidel (CIT) PS: Peng (NOIRLab)
    - Team: CIT, ITCC, NAOJ, TIO
    - Preliminary Design Phase
- **MODHIS - Multi-Objective Diffraction-limited High-resolution Infrared Spectrograph**
  - Near Infrared High Spectral Resolution Precision Radial Velocity Spectrograph
  - Fed by MCAO system NFIRAOS
  - PI: Mawet (CIT) co-PI: Fitzgerald (UCLA) PS: Konopacky (UCSD)
    - Team: UCLA, UCSD, CIT, TIO
    - Conceptual Design Phase



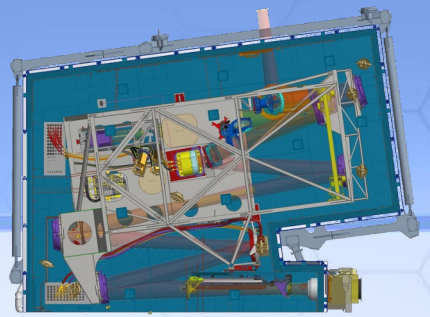
TMT Instrument Layout

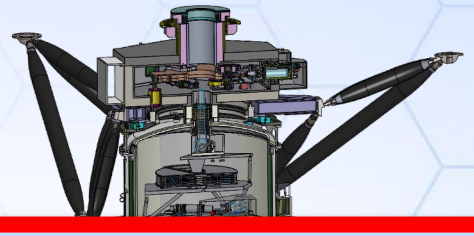
- Large Nasmyth Platforms will support all first decade instruments
- Flexible space will allow TMT instrumentation to grow and evolve over observatory lifetime

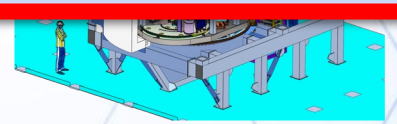


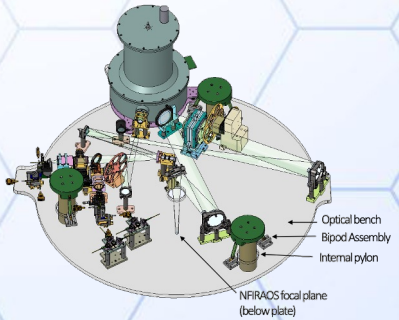
Instruments at First Light

Instrument and Description	λ Range (μm)	Spectral Resolution	Modes	Field of View
NFIRAOS/Narrow Field Infrared Adaptive Optics System	0.8 – 2.4	N/A	NGSAO, LGS MCAO, SL Enhanced	LGS MCAO 2.0′
IRIS/Diffraction-Limited NIR Imager and IFS	0.84 – 2.4	Z, Y, J, H, K, bandpass filters and multiple narrower band filters. 4,000 and 8,000 (some modes to 10,000)	NGSAO, LGS MCAO SL Enhanced	Imager: 34″ x 34″ @ 0.004″/pix IFU with two slicing techniques Lenslet: 0.512″ x 0.512″ @ 0.004″/spaxel Slicer: 2.25″ x 4.4″ @ 0.050″/spaxel
WFOS/Wide Field Optical Spectrometer	0.31 – 1.0	1,500 and 3,500 using 0.75″ slits. Goal of 5,000 currently achieved and higher R available with narrower slits.	Seeing-limited GLAO	25 (8.3 x 3)-arcmin² 500″ total slit length (up to 60 targets with 8″ slits) Imaging: full field @ 0.05″/pixel
MODHIS/Multi-Object Diffraction-Limited High-Resolution Infrared Spectrograph	0.95 – 2.4	> 100,000 with 30 cm/s (goal 10 cm/s) Doppler velocity precision	NGSAO, LGS MCAO	4" diameter field of regard with positionable diffraction limited fib bundle (target, sky, speckle, spare, calibration). 6"x6" imaging guider.







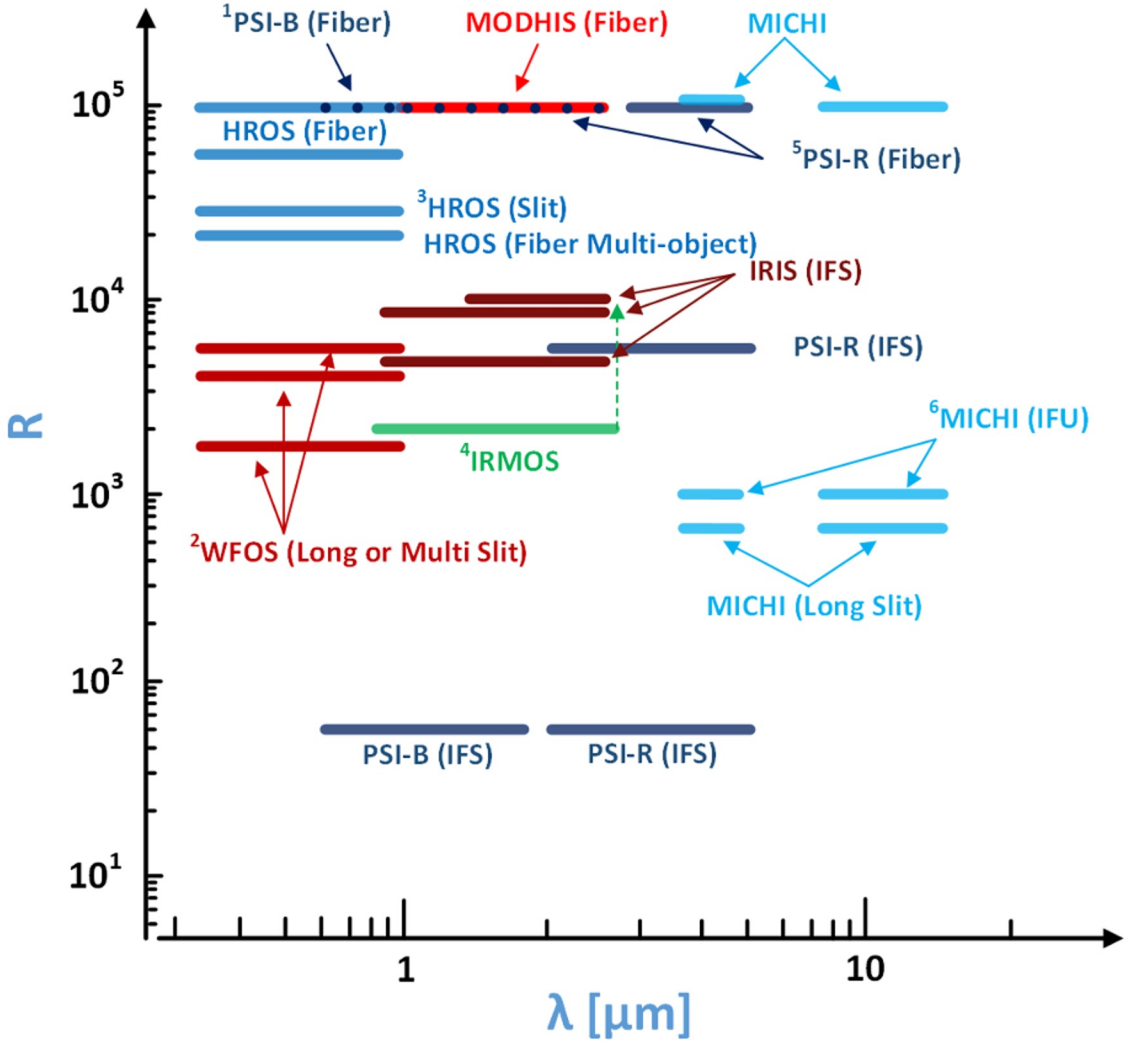


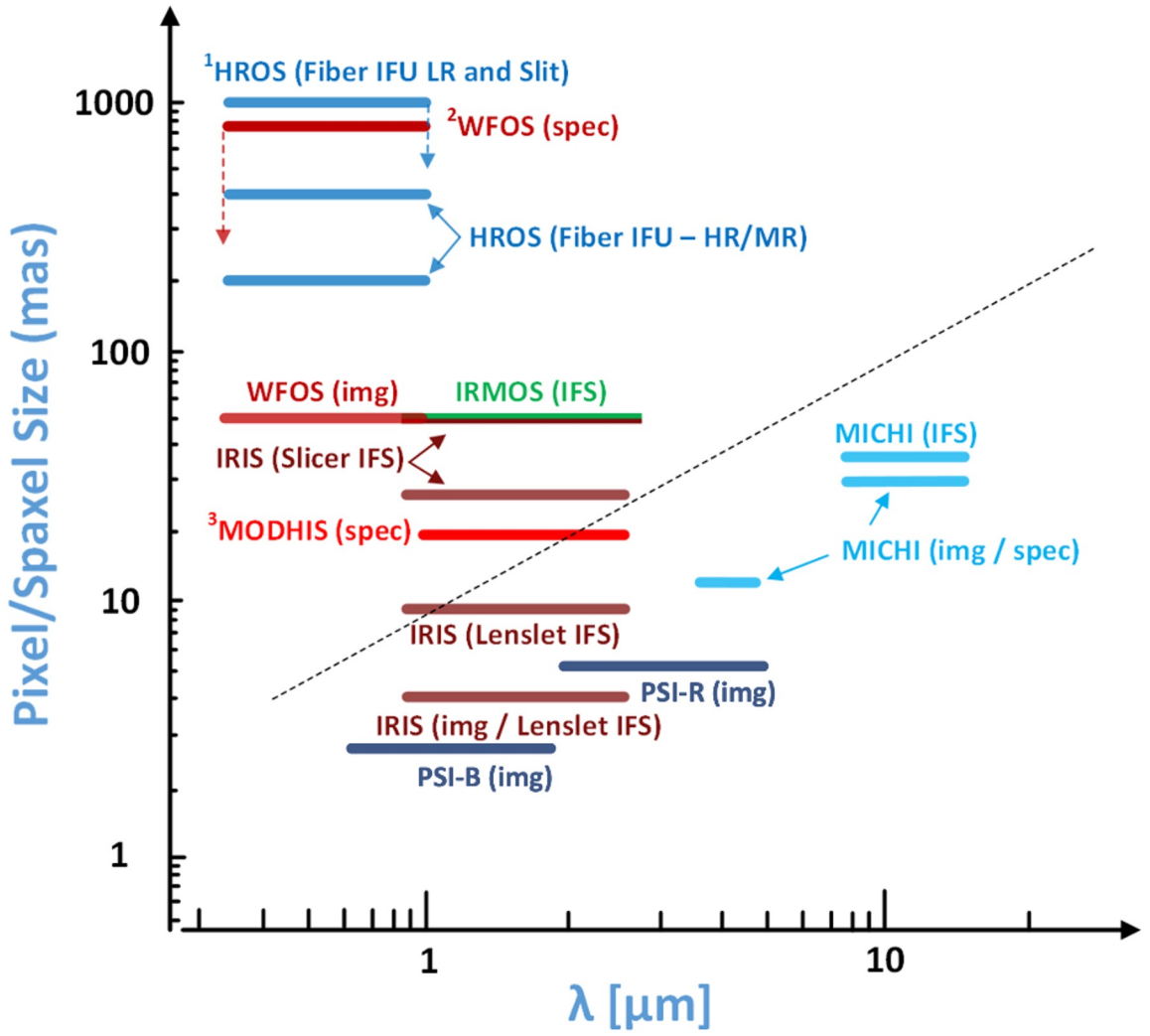
First light instruments match top priorities in Astro2020:
- Adaptive Optics
- Multi-Object Spectroscopy
- High-Resolution Spectroscopy

Instrumental Capabilities: Beyond First Light …

Instrument and Description	λ Range (μm)	Spectral Resolution	Modes	Field of View
GLAO/Ground Layer Adaptive Optics (feeds WFOS and HROS)	0.31 – 1.0	N/A	GLAO	Large enough to cover WFOS
MIRAO/Mid-Infrared **Adaptive** Optics (feeds MICHI)	4.5 – 28	N/A	LGS MIRAO, high contrast	>10″ (1′ goal)
PSI PFI/Planet Formation Instrument	0.6 – 5.3	(fiber fed) High resolution R > 100K (IFS) Medium resolution R > 5,000 (IFS) Low resolution R > 50	ExAO	2–5.3 μm only: 1.2″ x1.2″ (low resolution) 0.15″ x 0.15″ (medium resolution)
MICHI MIRES/ Mid-Infrared Echelle Spectrometer	3.4 – 13.8	Imager < 100, IFS 600–1,000, Spectrometer 120,000	MIRAO	Imager: 28.1″ x 28.1″ @ 11 mas/pix N band IFU: 0.175″ x 0.07″ (35 mas/spaxel)
HROS/High-Resolution Optical Spectrograph	0.31 – 1	Single Object: 100,000 & 50,000 (fibers) 40,000 & 20,000 (slits) Multi-Object: 25,000	Seeing-limited GLAO	> 10″ in diameter (single object mode) 10′–20′ diameter (multi-object mode)
IRMOS/IR Multi-Object Spectrograph	0.8 – 2.5	2,000 – 10,000	MOAO	> ten 3″ IFUs deployable within a 5′ diameter field

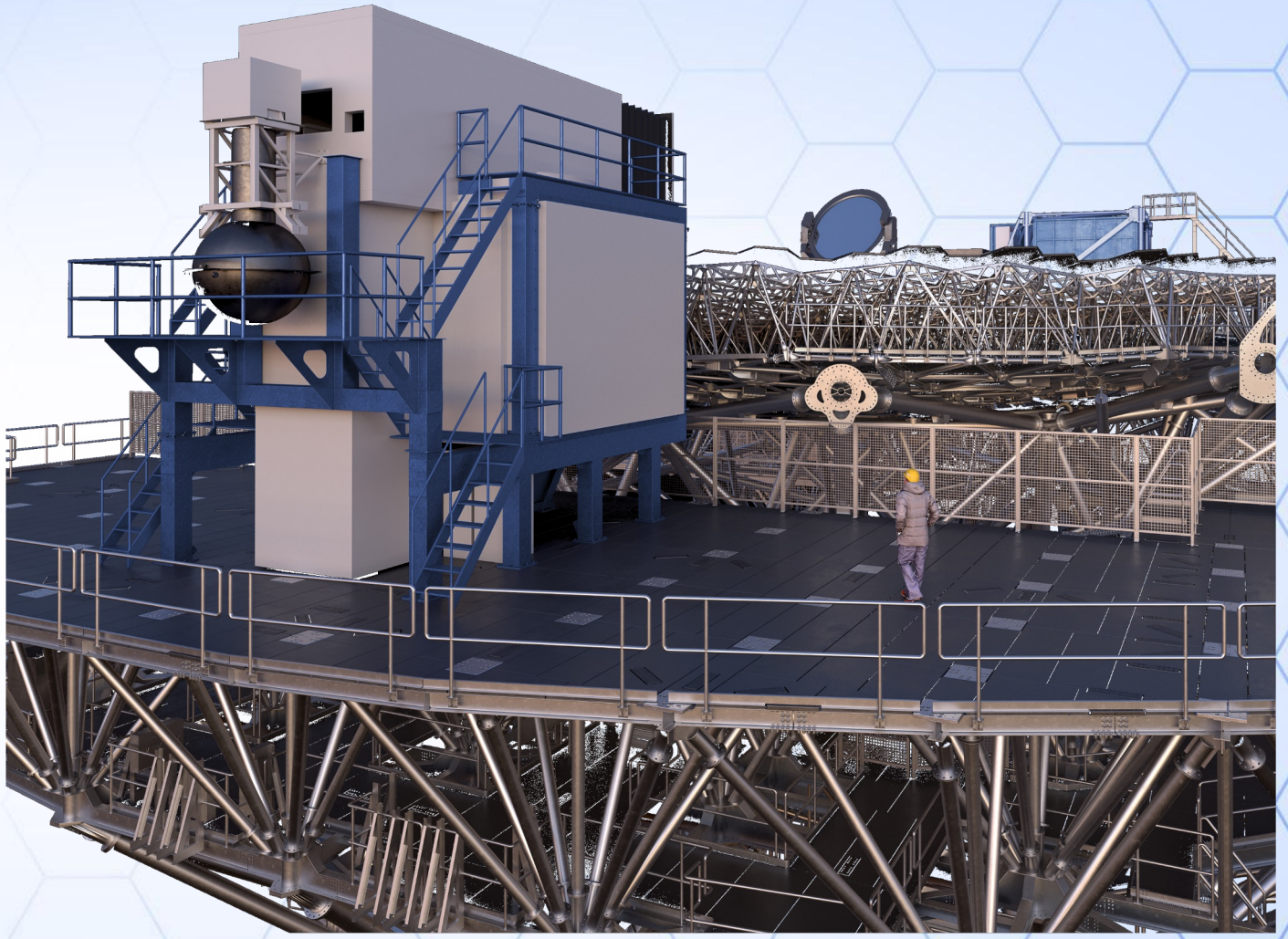
Discovery Space:
First-light & First-Decade Instruments





Want to learn more or get involved?

- TMT's web page (tmt.org) has up-to-date information on all the first light instruments and AO systems
- Contact me: dandersen@tmt.org
- Contact Warren Skidmore: was@tmt.org
- Reach out to any of the Principal Investigators or Project Scientists



Acknowledgments

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