The Thirty Meter Telescope: How California, Canada, China, India and Japan are Working Together to Build a Next Generation Extremely Large Telescope

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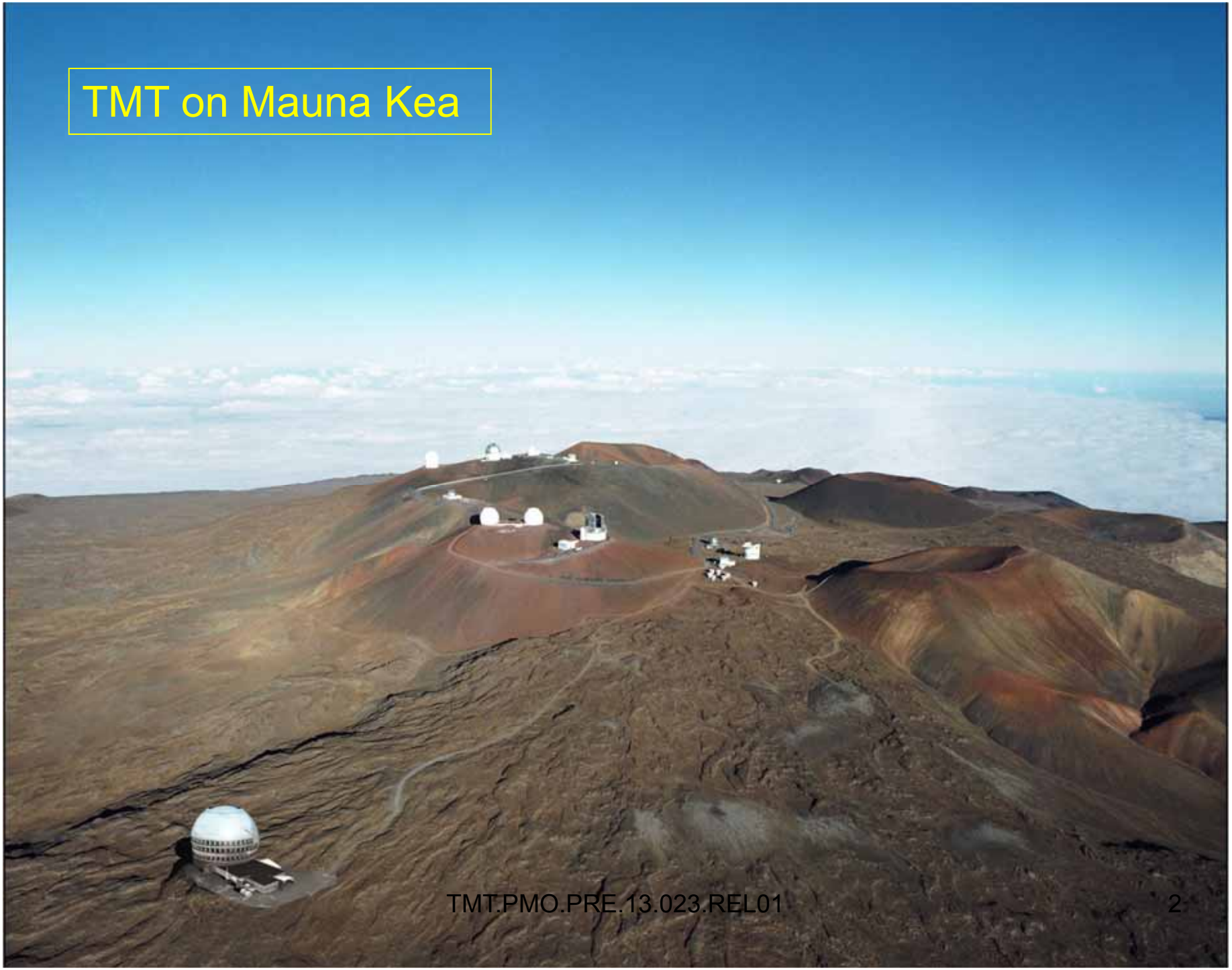
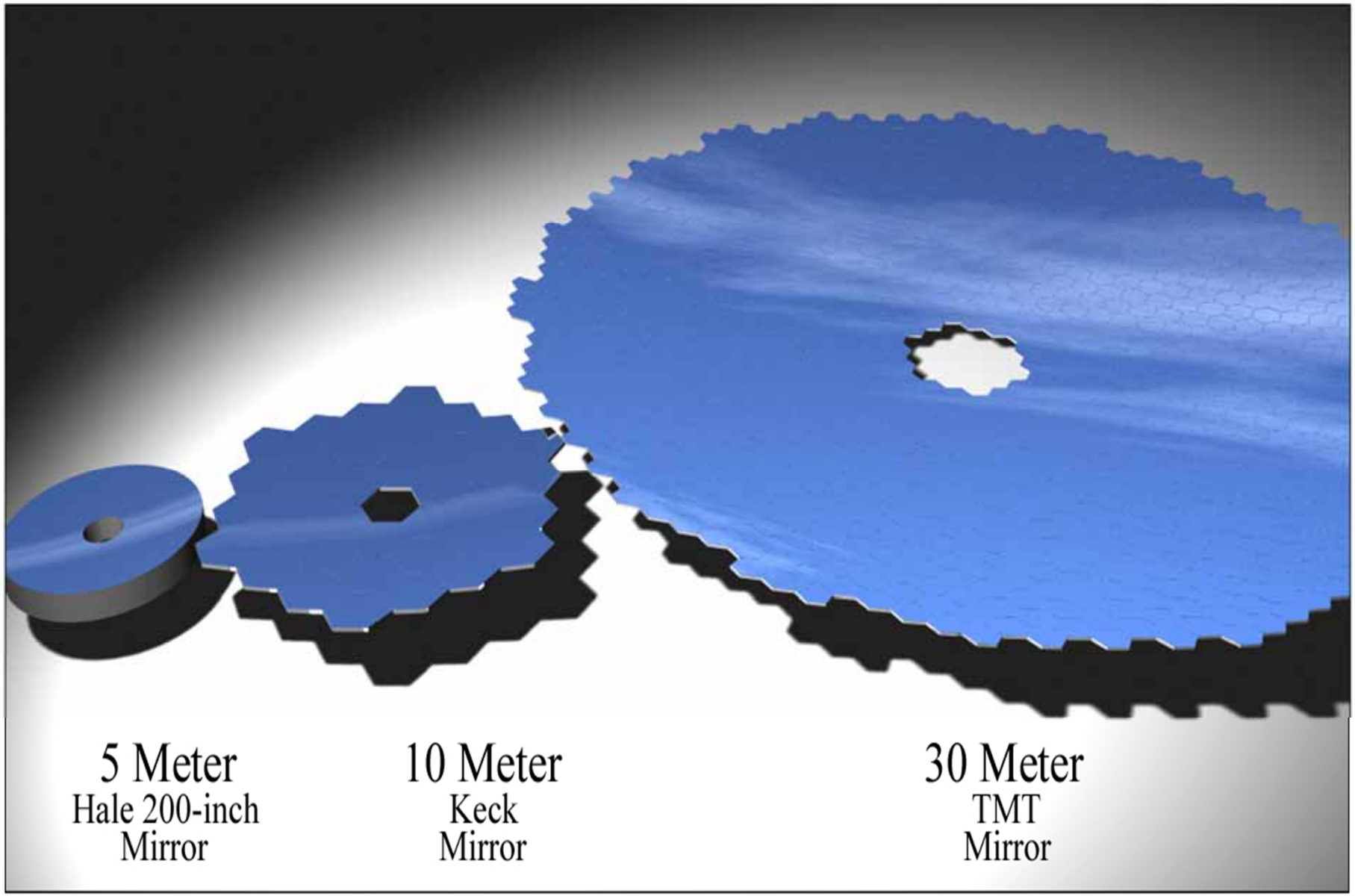
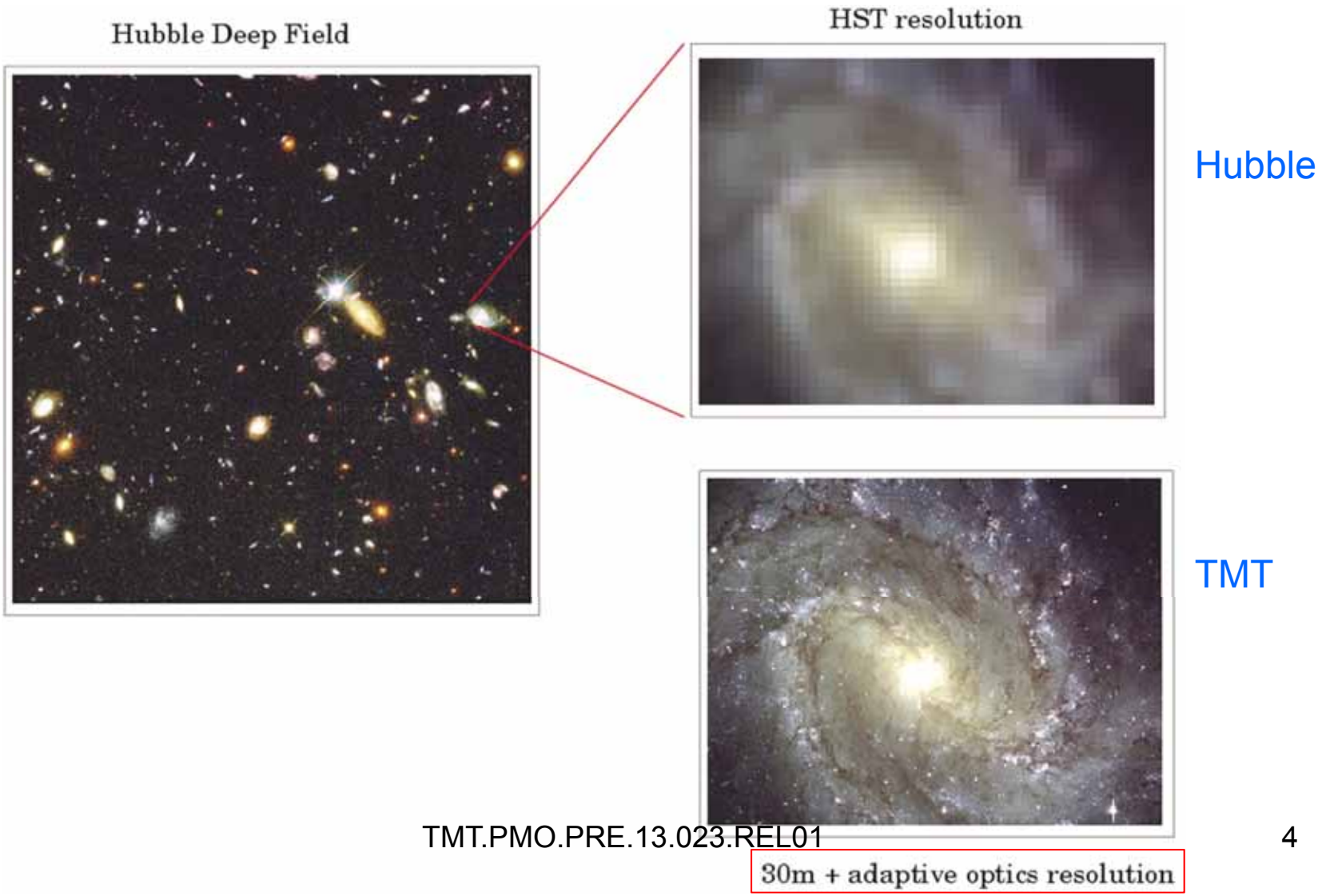
SLAC National Accelerator Laboratory
September 18, 2013

TMT on Mauna Kea




5 Meter
Hale 200-inch
Mirror
10 Meter
Keck
Mirror
30 Meter
TMT
Mirror

Sharper Vision with TMT: Distant Galaxies from Space and Hawaii Island



Why build a 30 meter telescope?

- Light collection ~ diameter^2 = D^2
  - Sets limit on sensitivity of "seeing-limited" observing
- TMT will have
  - 144 times the light collection and sharper optical resolution than the Hubble Space Telescope, and
  - 36 times the light collection of the Palomar telescope
  - 9 times the light collection of the Keck telescopes

A Vision of TMT (1908)

"It is impossible to predict the dimensions that reflectors will ultimately attain. Atmospheric disturbances, rather than mechanical or optical difficulties, seem most likely to stand in the way. But perhaps even these, by some process now unknown, may at last be swept aside. If so, the astronomer will secure results far surpassing his present expectations."

- Hale, Study of Stellar Evolution, 1908 (p. 242) writing about the future of the 100 inch.

- 100 years later, TMT is being designed end-to-end to correct atmospheric disturbances to approach the diffraction limited image quality of a 30 meter aperture

TMT Aperture Advantage

- Seeing-limited observations and observations of resolved sources

$$Sensitivity \propto \eta D^2 \quad (\sim 14 \times 8\text{m})$$

- Background-limited AO observations of unresolved sources

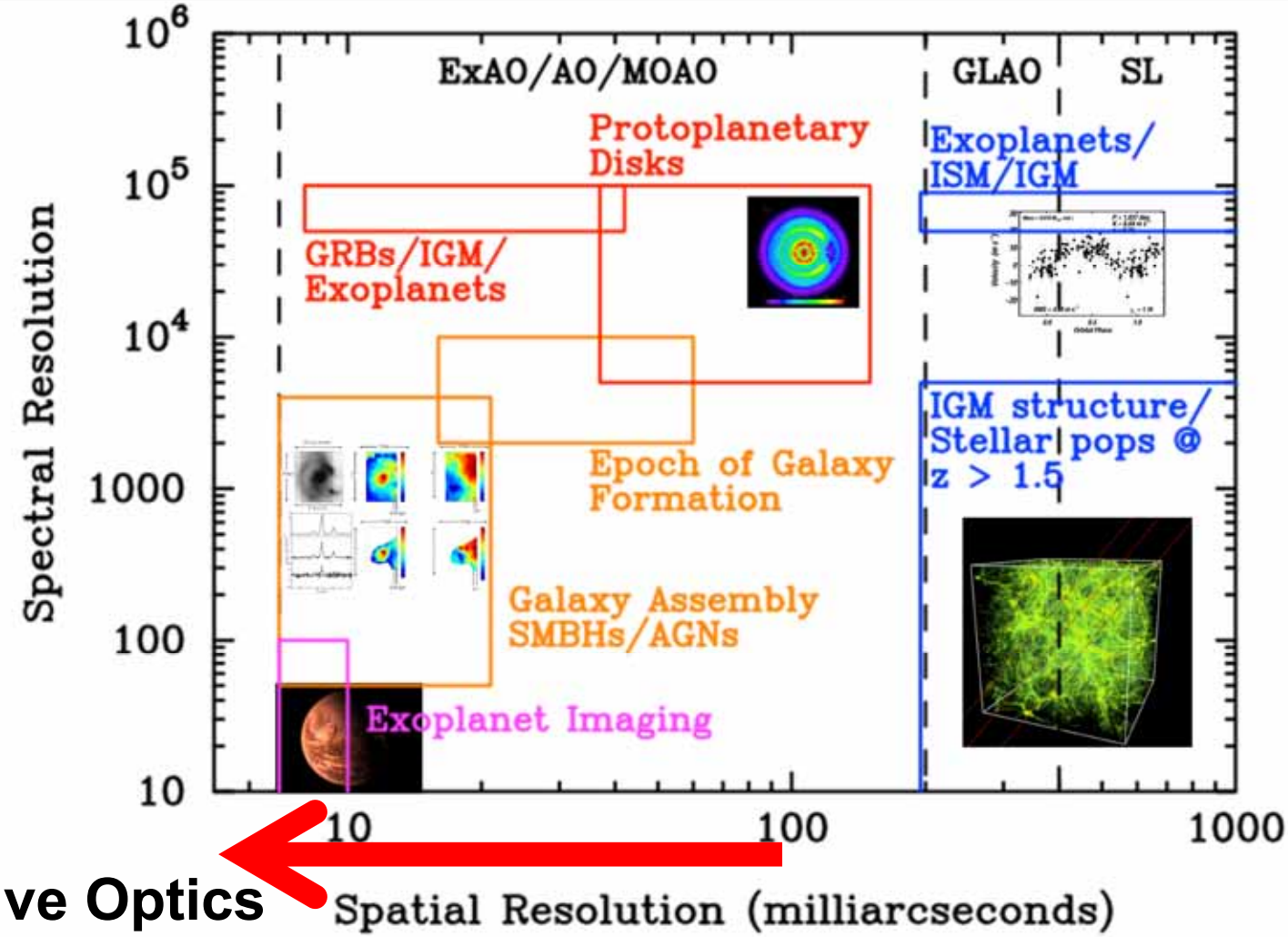
$$Sensitivity \propto \eta S^2 D^4 \quad (\sim 200 \times 8\text{m})$$

- High-contrast AO observations of unresolved sources

$$Sensitivity \propto \eta \frac{S^2}{1-S} D^4 \quad (\sim 200 \times 8\text{m})$$

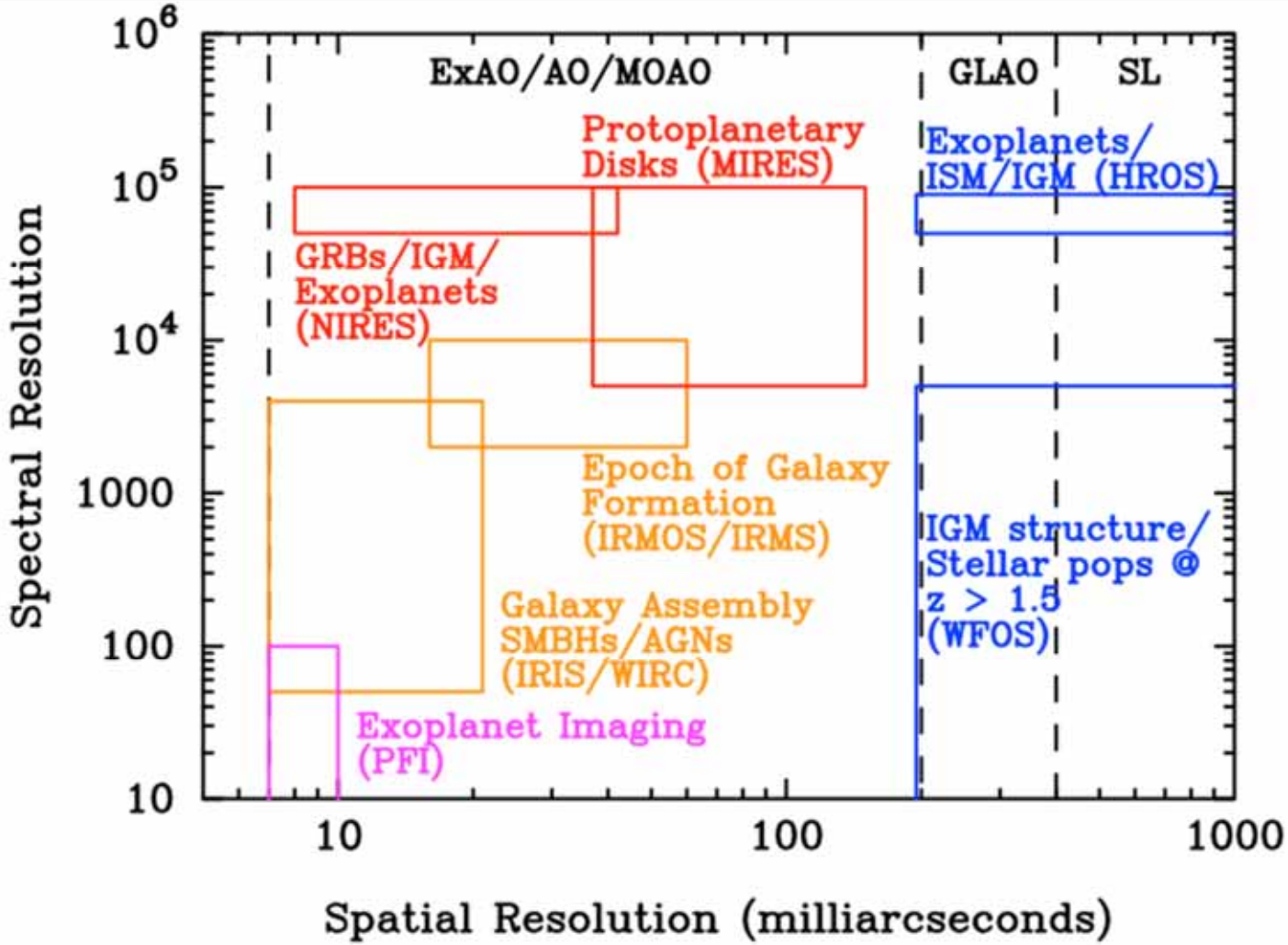
$Sensitivity = 1/\text{time required to reach a given s/n ratio}$
$\eta =$ throughput, $S =$ Strehl ratio. $D =$ aperture diameter

Defining Capabilities in the TMT Discovery Space



Adaptive Optics needed

Defining Capabilities in the TMT Discovery Space



Foundation Documents | Thirty Meter Telescope

Foundation Documents | Thirty ... | Inbox (16,990) - gary.h.sanders... | Google Calendar

www.tmt.org/documents

TMT Construction Proposal (PDF)

In May 2007, an initial TMT Construction Proposal was created by the project and reviewed by an external advisory panel (EAP). The EAP membership is nominated by the TMT Board. This Construction Proposal will be revised and updated as TMT design and development proceeds.

Editors: S. Dawson, S. Roberts
Last update: September, 2007

The Detailed Science Case (PDF)

The Detailed Science Case (DSC) is the highest level statement of the TMT science case. The DSC was created and is maintained by the TMT Science Advisory Committee (SAC). It provides examples of the kinds of exciting, groundbreaking science that will be enabled by a 30m telescope. Wherever possible, synergies with other major upcoming facilities (e.g. the James Webb Space Telescope and the Atacama Large Millimeter Array) are discussed. As appropriate, performance numbers (often conservative) are provided (e.g. sensitivities, integration times, spatial resolutions).

Editors: D. Silva, P. Hickson, C. Steidel, M. Bolte
Last update: October, 2007

The Science-based Requirements Document (PDF)

The Science-based Requirements Document (SRD) describes the science-driven requirements for the Thirty Meter Telescope (TMT) project. TMT will be the first of the next-generation giant optical/infrared ground-based telescopes and will be a flagship facility for addressing the most compelling areas in astrophysics: the nature of Dark Matter and Dark Energy, the assembly of galaxies, the growth of structure in the Universe, the physical processes involved in star and planet formation and the characterization of extra-solar planets.

Editors: J. Nelson
Last update: July, 2013

The Observatory Requirements Document (PDF)

The Observatory Requirements Document (ORD) contains the highest level system requirements for the observatory. Top level requirements are defined for the telescope and instrumentation, summit and support facilities, environmental health and safety, and high level software. The ORD also defines site specific environmental parameters and constraints.

Editors: G. Angeli, S. Roberts
Last update: June, 2012

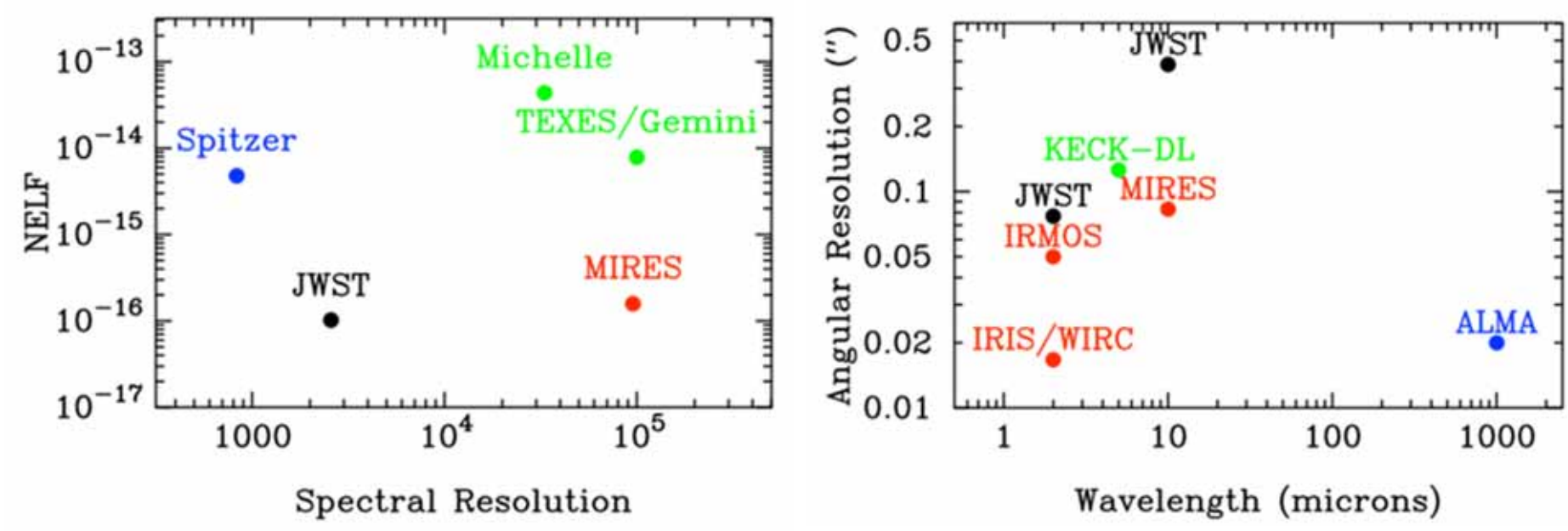
- Facility Design
- Safety Requirements and Guidelines
- Software, Computer & IT Network
- Statements of Work for TMT Partners
- Seismic Hazard Assessment

- February 2012: Segments Newsletter
- July 2011: Segments Newsletter
- Elevator Talk Brochure
- March 2011: Segments Newsletter
- November 2010: Segments Newsletter
- July 2010: Segments Newsletter
- April 2010: Segments Newsletter
- January 2010: Segments Newsletter
- TMT General Information Brochure
- TMT Scientific Information Brochure

Summary of TMT Science Objectives and Capabilities

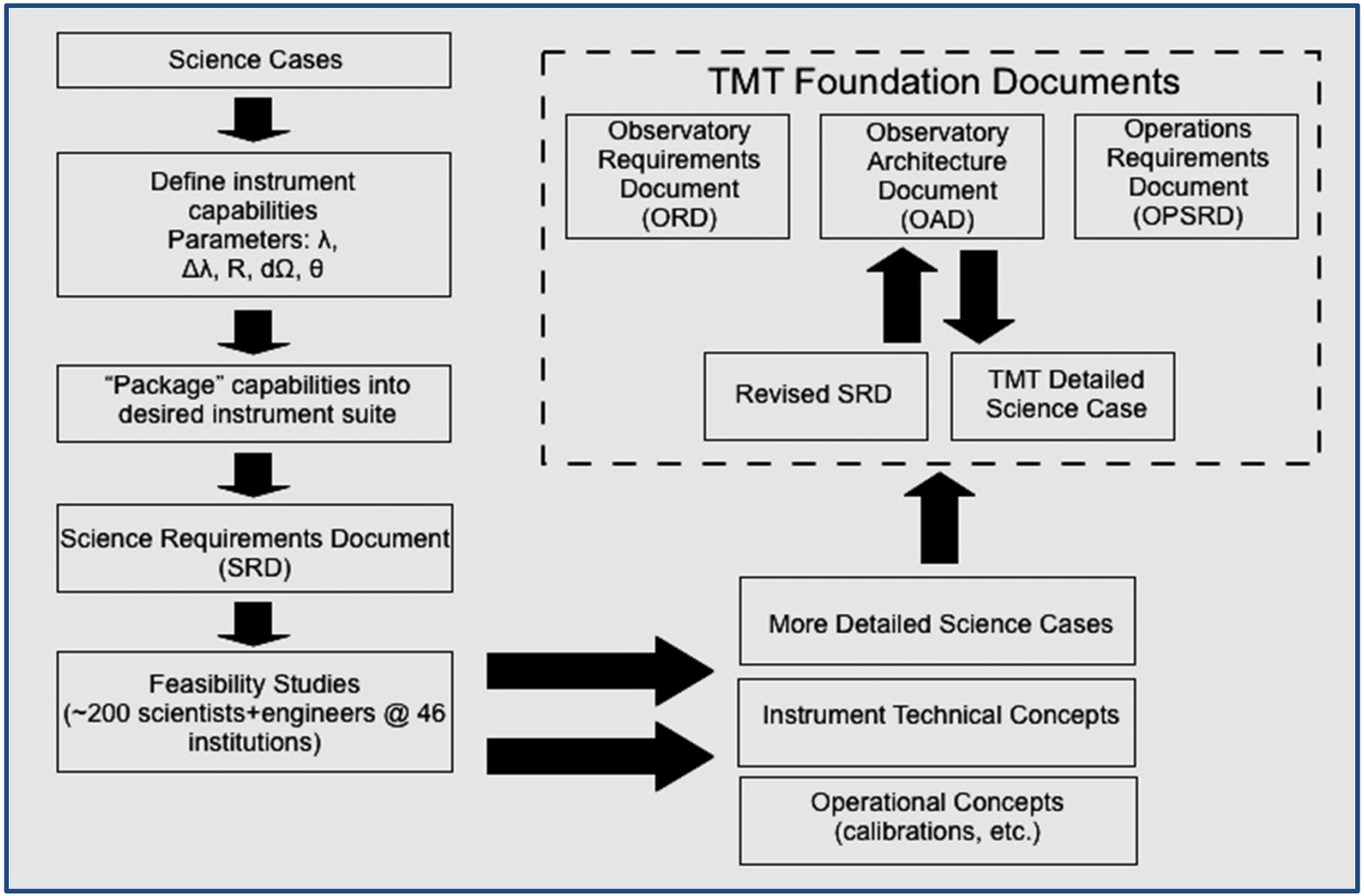
Theme	Science Objectives	Observations	Requirements	Capabilities
Cosmology and Fundamental Physics (Dark energy, dark matter, physics of extreme objects, fundamental constants; DSC Section 3)	Mapping distribution of dark matter on large and small scales (CFP-[1,2,3,4], GAN-[3,4], GCT-1) General Relativity in new mass regime◆ (GAN-[4,D], SSE-4) Very precise expansion rate of Universe (CFP-2) Mapping variations in constants over cosmological timescales Physics of extreme objects ◆ (SSE-[2,3,D])	Proper motions in dwarf galaxies Wide-field optical spectroscopy of R = 24.5 galaxies Microarcsecond astrometry Transient events lasting > 30 days High spectral resolution observations of quasars and GRBs	λ = 0.31-0.62μm, 2-2.4μm R = 1000 - 50000 Very efficient acquisition 0.05 mas astrometry stable over 10 years Field of view > 10'	SL/WFOS SL/HROS MCAO/IRIS/WIRC MCAO/ NIRES
The Early Universe (First objects, IGM at z > 7; DSC Section 4)	Detection of metal-free star formation in First Light objects◆ (GAN-2, GCT-4) Mapping topology of re-ionization (GCT-4) Structure and neutral fraction of IGM at z > 7 (CFP-1, GCT-4)	Multiplexed, spatially-resolved spectroscopy of faint objects High spectral resolution, near-IR spectroscopy	λ = 0.8 – 2.5 μm R = 3000 – 30000 F = 3 x 10-20 ergs $s^{-1}cm^{-2}Å^{-1}$ Exposure times > $15e^3$s	MCAO/ IRMS/IRIS MOAO/ IRMOS MCAO/ NIRES
Galaxy formation and the IGM (DSC Section 5)	Baryons at epoch of peak galaxy formation◆ (CFP-1, GAN-1, GCT-[1,2]) 2D Velocity, SFR, extinction & metallicity maps of galaxies at z = 5-6◆ (CFP-3, GAN-1, GCT-[1,2]) IGM properties on physical scales < 300 kpc◆ (GAN-1, GCT-2)	Optical/near-IR multiplexed diagnostic spectroscopy of distant galaxies & AGNs Optical/near-IR multiplexed identification spectroscopy of extremely faint high redshift objects (to R~27) Spatially-resolved spectroscopy	λ = 0.31 – 2.5 μm R = 3000-5000, 50000 Very efficient acquisition Multiplexing factor > 100	SL/WFOS SL/HROS MCAO/IRIS/IRMS MOAO/ IRMOS
Extragalactic supermassive black holes (DSC Section 6)	Demographics of black holes over new ranges in mass and redshift◆ (GAN-4, GCT-3) Dynamical measurements out to z = 0.4◆ (GAN-4,GCT-[1,3]) Scaling relations out to z = 2.5 and masses at z>6◆ (GAN-4, GCT-[1,3])	Spatially-resolved spectroscopy of galaxy cores	λ = 0.8 – 2.5 μm R = 3000-5000 Precise positioning	MCAO/IRIS MOAO/ IRMOS
Galactic Neighborhood (DSC Section 7)	Abundance of oldest stars in Milky Way (CFP-4, GAN-[2,3], SSE-2) Chemical evolution in Local Group galaxies◆ (GAN-2) Diffusion and mass loss in stars (GAN-1, SSE-1) Resolved stellar populations out to Virgo cluster◆ (GAN-[2,3])	High spectral resolution optical and near-IR spectroscopy High-precision photometry in crowded fields	λ = 0.33-0.9, 1.4-2.4 μm R = 4000, 40000-90000 Photometry precision of 0.03 mag at Strehl = 0.6	SL/HROS MCAO/ NIRES MCAO/IRIS/WIRC SL/WFOS
Planetary Systems and Star Formation (physics of star formation,proto-planetary disks, exoplanets; DSC Section 8, Section 9)	Origin of mass in stars (GAN-[1,2], PSF-1) Architecture of planetary systems (PSF-[2,3,D]) Deposition of pre-biotic molecules onto protoplanetary surfaces (PSF-2) First direct detection of reflected-light Jovians (PSF-2) Characterization of exo-atmospheres (e.g., oxygen) (PSF-[3,4,D])	High-precision, crowded field photometry Diffraction-limited, high spectral resolution mid-IR spectroscopy Very high Strehl AO-assisted imaging: precise wavefront control High spectral resolution optical and near-IR spectroscopy	λ = 1 – 25 μm R = 4000, 30000-100000 Low telescope emissivity Dry site (PWV < 5 mm) Fixed gravity vector and thermal control Very efficient acquisition Contrast ratio of 10^8–10^9	MCAO/IRIS MIRAO/ MIRES MCAO/ NIRES SL/HROS ExAO/PFI
Our Solar System (outer parts, surface physics and atmospheres; (DSC Section 10)	Composition of Kuiper Belt Objects and comets (PSF-2) Monitoring weather, (cryo-) vulcanism and tectonic activity◆	Spatially resolved spectroscopy of objects in solar system Transient events (hours to years)	λ = 1-10 μm R = 1000 – 100000 Non-sidereal tracking Fast response time	MCAO/IRIS/WIRC MCAO/ NIRES MIRAO/ MIRES

TMT instrument capabilities (in red) compared to JWST and ALMA

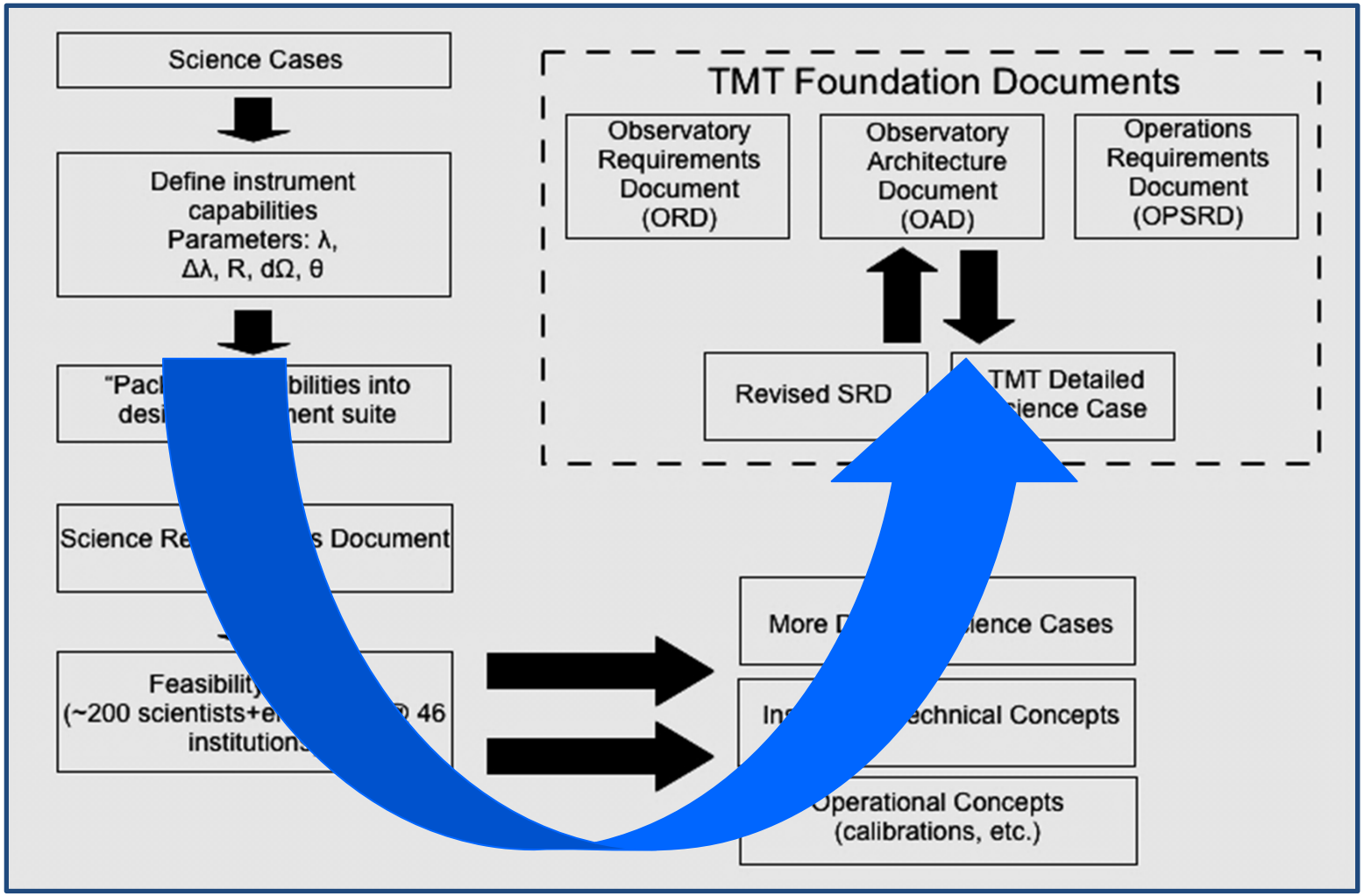


NELF is the Noise-Equivalent Line Flux in ergs s^{-1} cm^{-2}

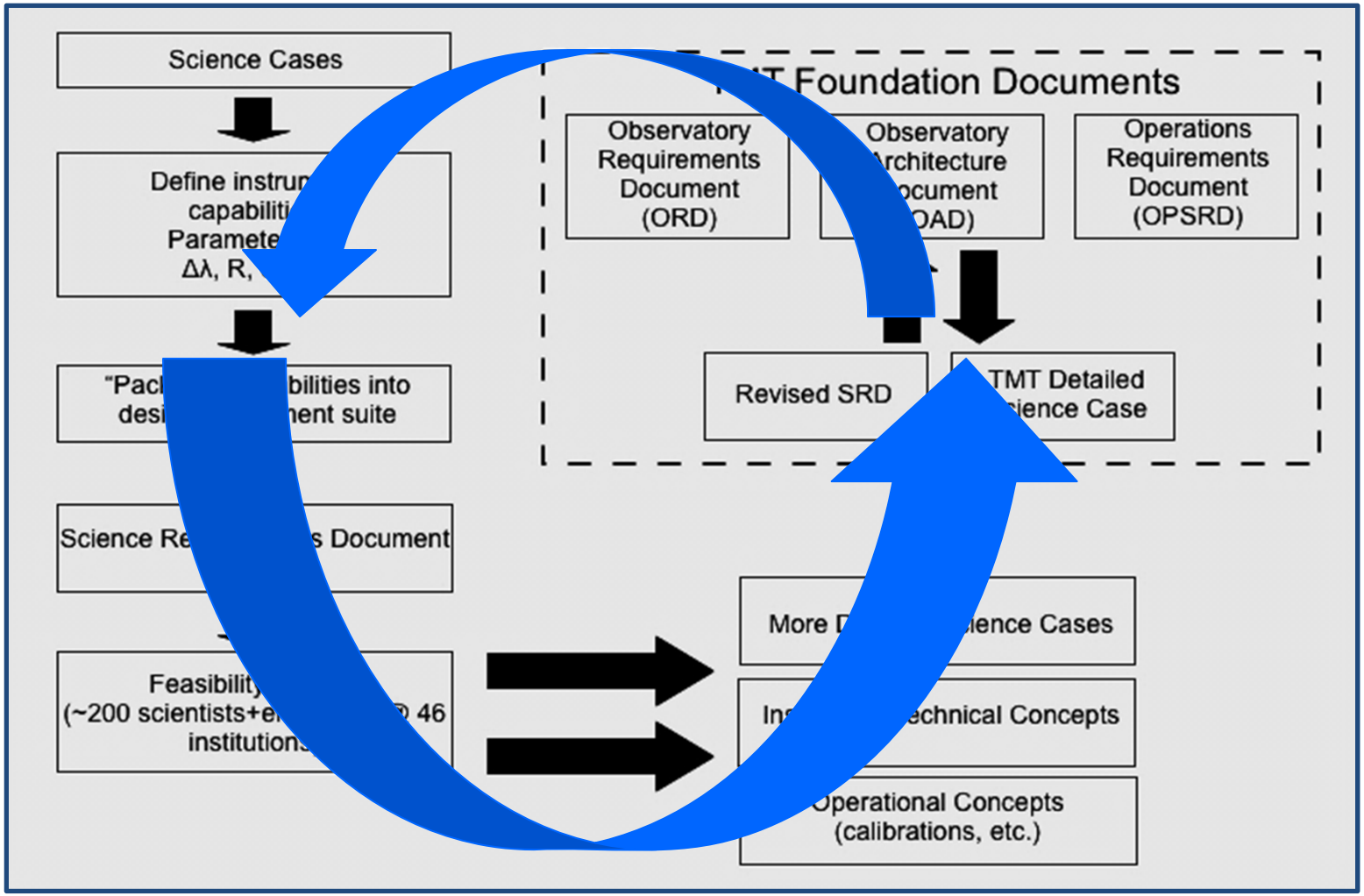
Science → Technical Requirements



Science → Technical Requirements



Science → Technical Requirements

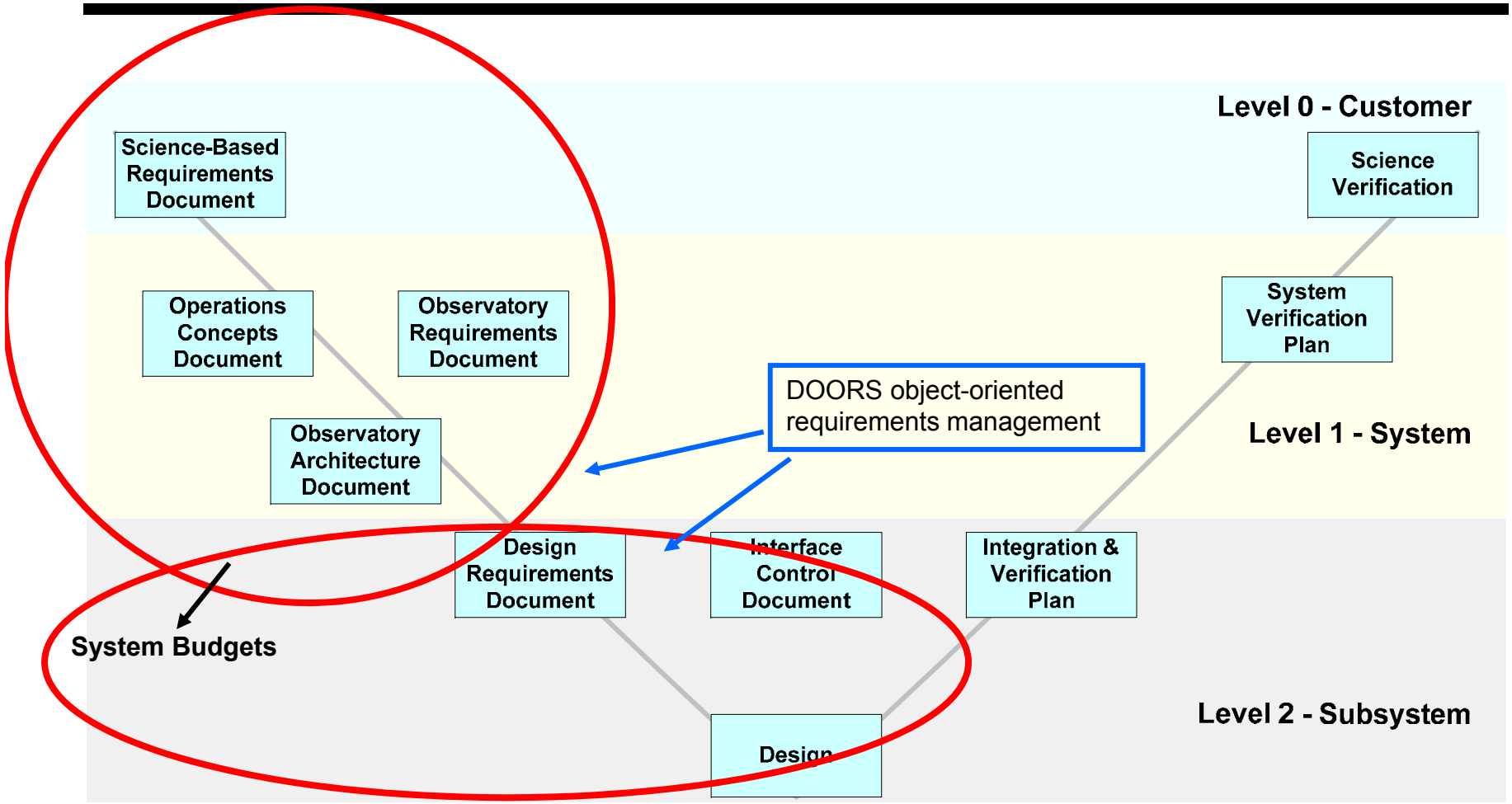


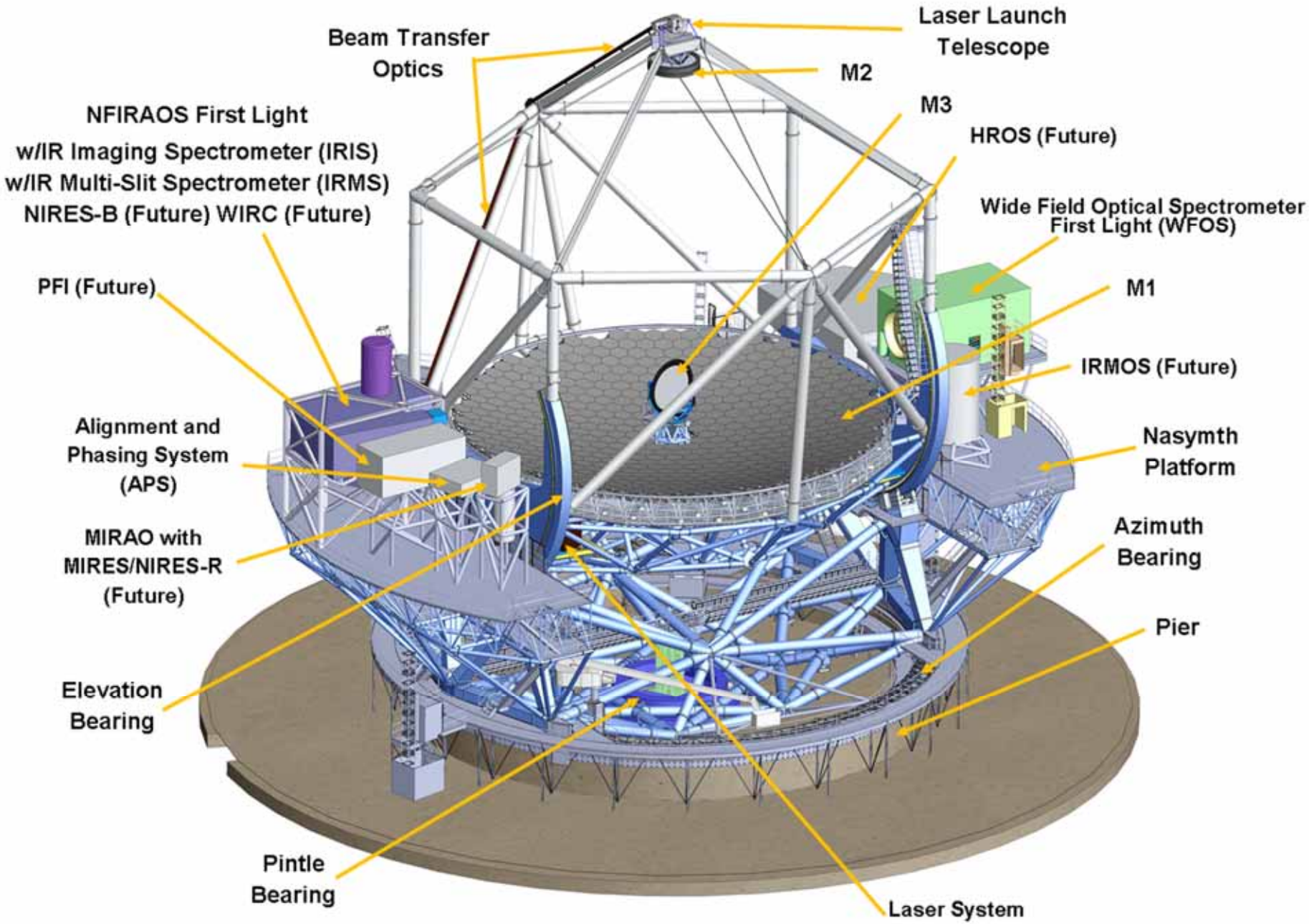
Science Flowdown Matrix Parameters		
Domain	**Parameter Name**	
Configuration	Observing Mode	
Spectral Parameters	Wavelength range	
	Spectral Resolution	
	Flux/radial velocity	Relative / absolute Precision Stability timescale
Spatial Parameters	Image quality	Resolution Strehl ratio / contrast ratio
	Geometry	Total areal coverage Field of view per observation Field overlap
	Astrometry	Relative / absolute Precision Stability timescale
Multiplexing	Sample size Number of observations	
Tracking	Rate	
Synoptic Signature	Baseline Cadence	

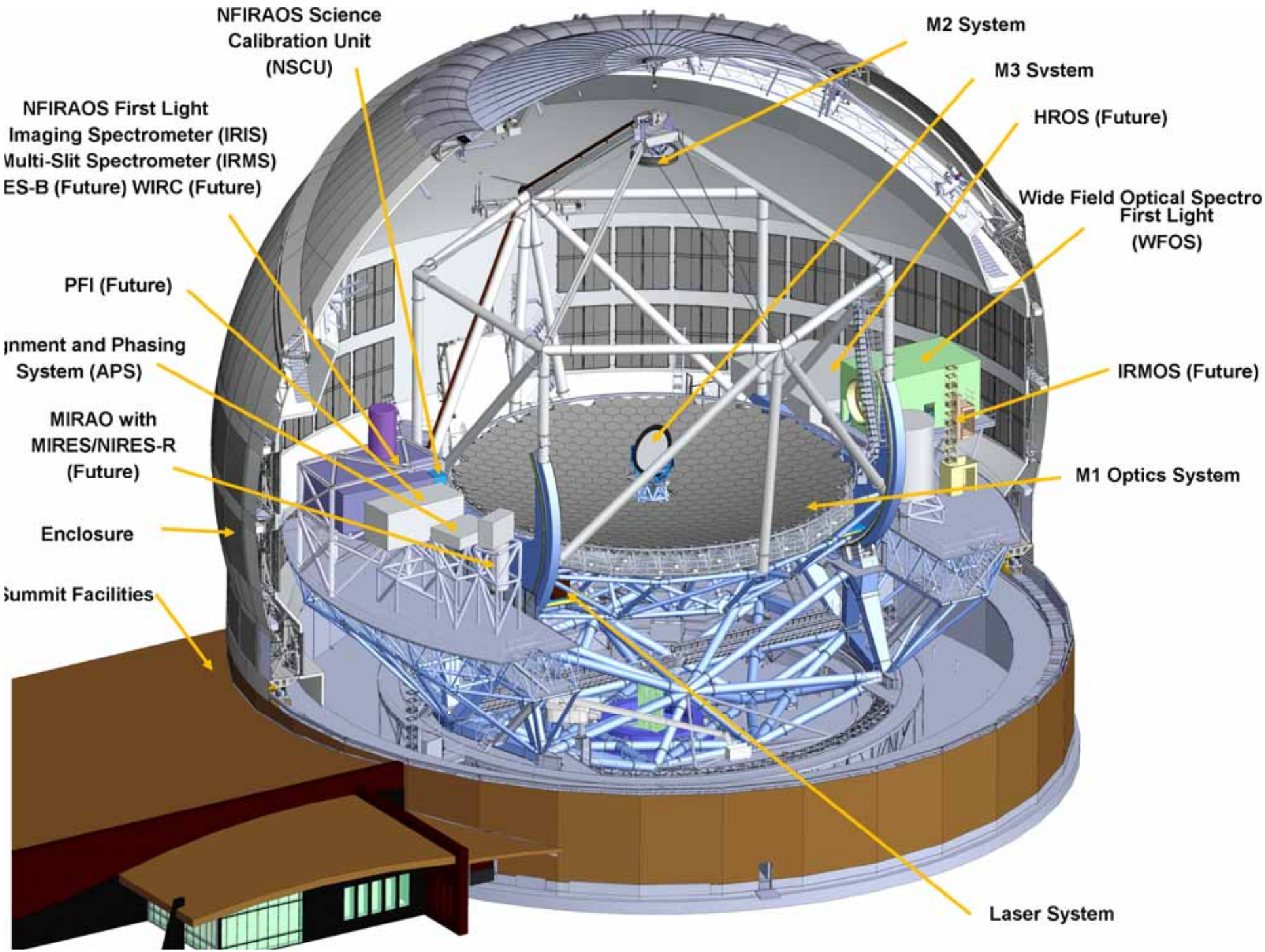
Science Flowdown Matrix - A small subsection

Science Program	Spatial Parameters									
	Image Quality			Geometry				Astrometry		
	Resolution (mas)	Strehl (S) / Contrast (C) ratio	SRD/ORD Requirement(s)	Total Areal Coverage (sq. arcmin)	Field of view / observation (sq. arcmin)	Field overlap (0-1)	SRD/ORD Requirement(s)	Relative/ absolute	Precision (mas)	Stability timescale (years)
Multiplexed spectroscopy of distant galaxies: rest-frame optical DSC 5.4	200		SRD-0070, 0075, 0100, 0105, 0110, 0115, 0120, 0145, [0405-0420], [0455-0470], [0565-0580], 1115	> 350	3.5	0.00	SRD-[0220-0230], 0250, 0260, 0265, 0805, 0815, 1105, 1120, 1140, 1305, 1315, 1320, 1330			
Spatial dissection of forming galaxies DSC 5.5	8	S = 0.5 [17]	SRD-0045, 0070, 0075, 0100, 0105, 0110, 0115, 0120, 0145, [0405-0420], [0455-0470], [0565-0580], [0820-0830], 0915, 1015, 1025, 1030, 1035, 1310	275 [18]	25 [18]	0.00 [18]	SRD-[0220-0230], 0250, 0260, 0265, 0270, 0280, 0805, 0850, 0885, 0890, 0905, 0910, 0920, 1005, 1010, 1030, 1035, 1305, 1315, 1320, 1330	Relative [18]	100 [18]	
IGM: Core samples during galaxy formation epoch DSC 5.6	800 [17]		SRD-0070, 0110, 0120, 0145, [0455-0470], [0565-0580], 1220, 1225, 1230, 1275, 1715, 1720	4 x 4032	40.3 [17]	0.01	SRD-0050, 0220, 0225, 1205, 1230, 1705, 1710, 1720			
Epoch of galaxy formation in 3D DSC 5.7	800 [17]		SRD-0070, 0110, 0120, 0145, [0455-0470], [0565-0580], 1220, 1225, 1230, 1275	4 x 4032	40.3 [17]	0.01	SRD-0050, 0220, 0225, 0250, 0255, 0265, 1205, 1230			
SMBHs in nearby galactic nuclei DSC 6.1	10 [17]	S = 0.5 [17]	SRD-0045,0070, 0075, 0100, 0105, 0110, 0115, 0120, 0145, [0405-0420], [0455-0470], [0565-0580], [0820-0830], 1015, 1025, 1030, 1035	< 10.2 [17]	< 0.03 [18]	0.00	SRD-[0220-0230], 0250, 0260, 0265, 0805, 0885, 0890, 1005, 1010, 1030, 1035	Relative [22]	2 [22]	

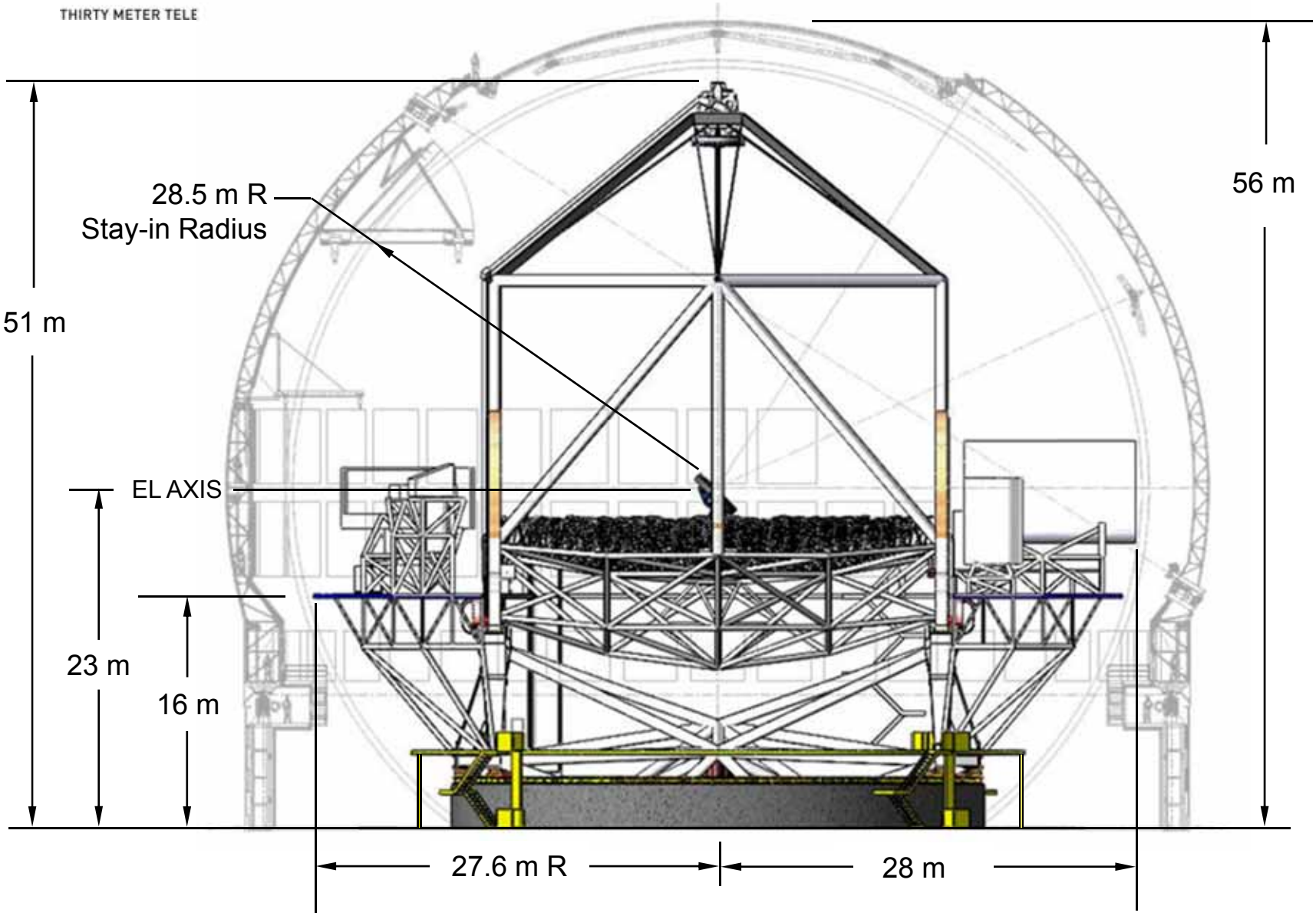
Science Flowdown → Technical Requirements



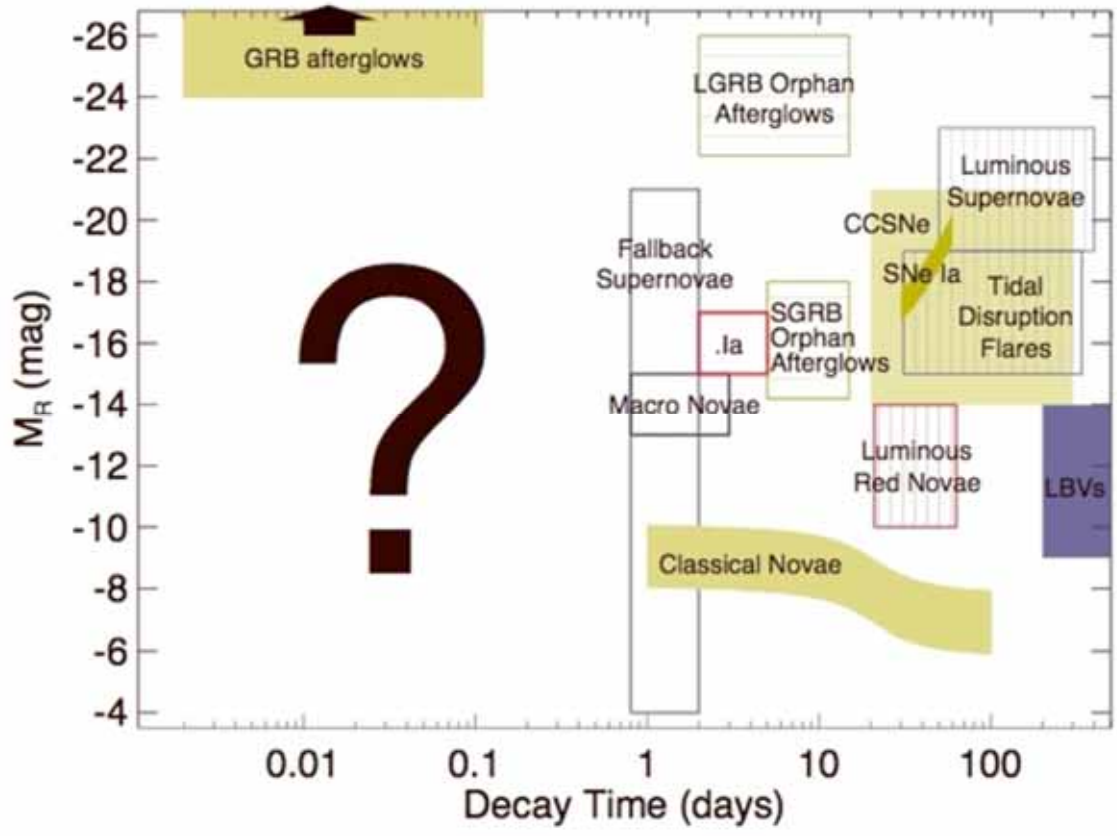

Laser Launch Telescope
Beam Transfer Optics
M2
M3
NFIRAOS First Light
w/IR Imaging Spectrometer (IRIS)
w/IR Multi-Slit Spectrometer (IRMS)
NIRES-B (Future) WIRC (Future)
HROS (Future)
Wide Field Optical Spectrometer First Light (WFOS)
PFI (Future)
M1
IRMOS (Future)
Alignment and Phasing System (APS)
Nasymth Platform
MIRAO with MIRES/NIRES-R (Future)
Azimuth Bearing
Pier
Elevation Bearing
Pintle Bearing
Laser System


NFIRAOS Science
Calibration Unit
(NSCU)
M2 System
M3 System
NFIRAOS First Light
Imaging Spectrometer (IRIS)
Multi-Slit Spectrometer (IRMS)
ES-B (Future) WIRC (Future)
HROS (Future)
Wide Field Optical Spectro
First Light
(WFOS)
PFI (Future)
nment and Phasing
System (APS)
IRMOS (Future)
MIRAO with
MIRES/NIRES-R
(Future)
M1 Optics System
Enclosure
Summit Facilities
Laser System

Key Telescope Dimensions



TMT as an Agile Telescope: Catching The "Unknown Unknowns"



Source: Figure 8.6, LSST Science Book

TMT target acquisition time requirement is 5 minutes

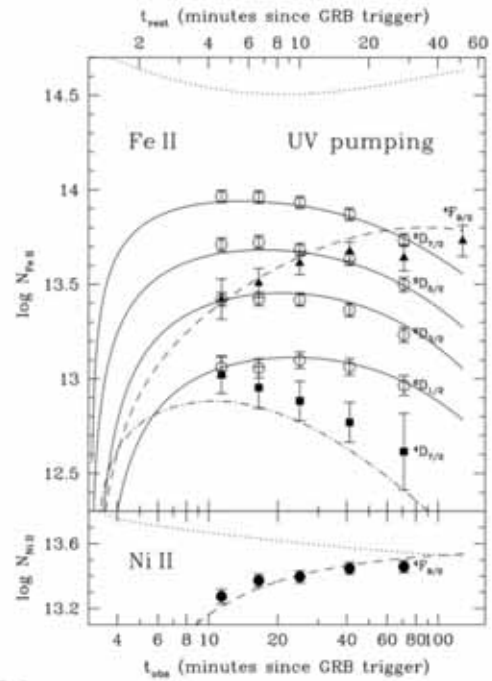
(i.e., 0.0034 day)

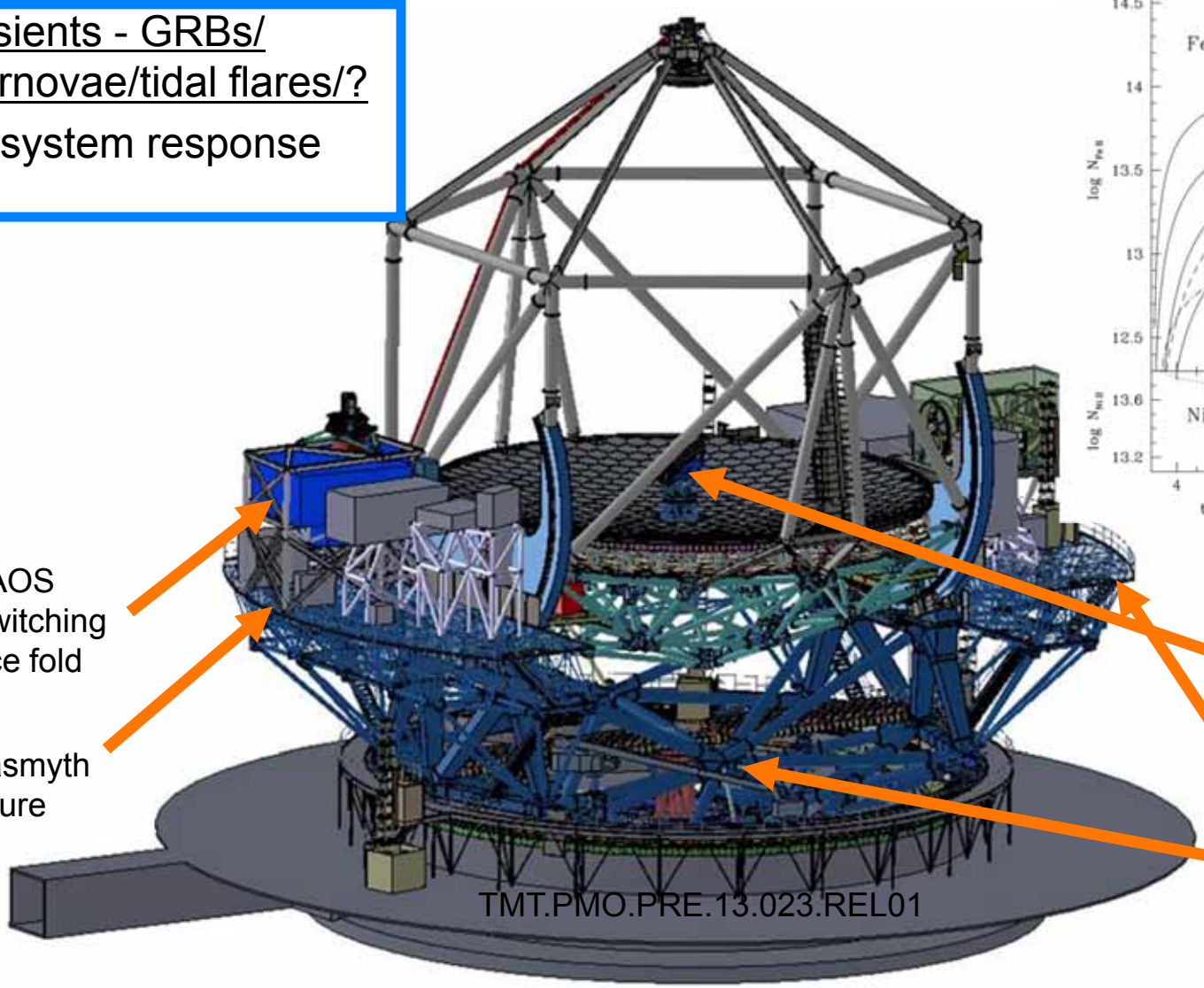
TMT is the only agile extremely large telescope and only system with plans to go to 310nm.

From Science to Subsystems

Transients - GRBs/ supernovae/tidal flares/?

Fast system response time





NFIRAOS fast switching science fold mirror

-X Nasmyth structure

Articulated M3 for fast instrument switching

+X Nasmyth structure

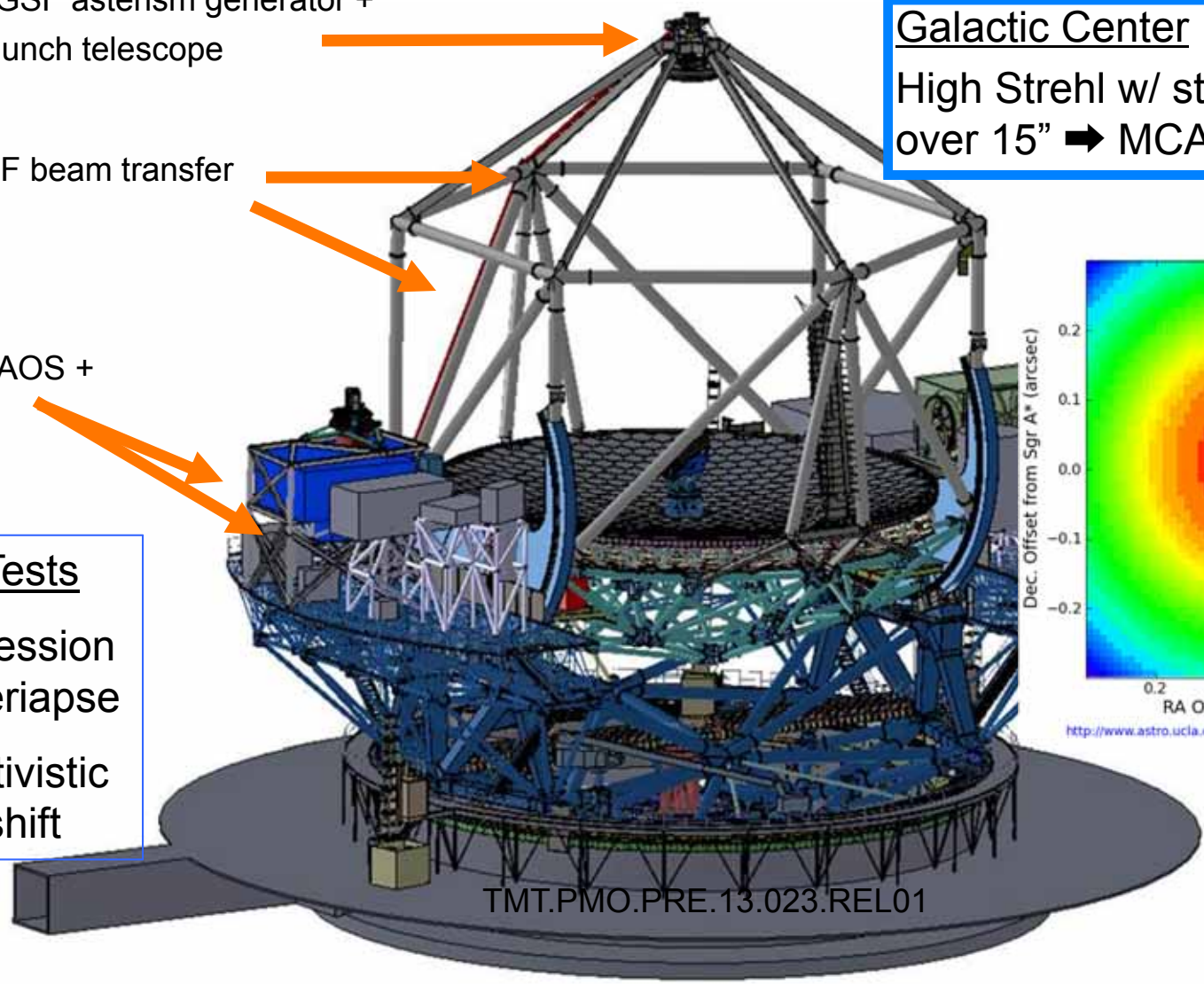
Fast slewing and acquisition

From Science to Subsystems (NFIRAOS + IRIS Imager)

LGSF asterism generator + launch telescope

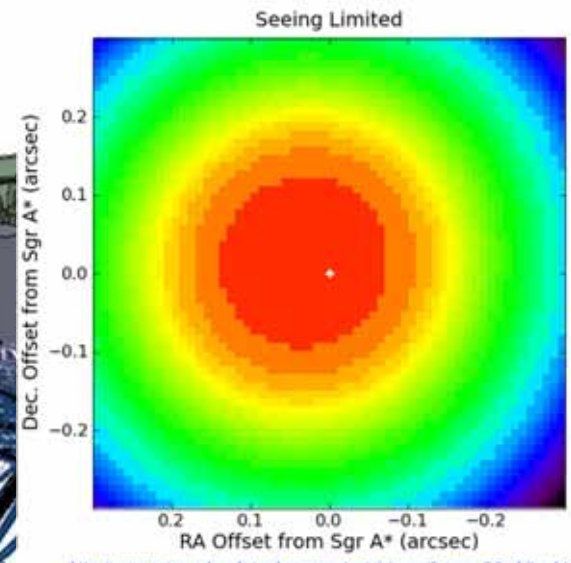
LGSF beam transfer

NFIRAOS + IRIS



Galactic Center

High Strehl w/ stable PSF over 15" ➡ MCAO



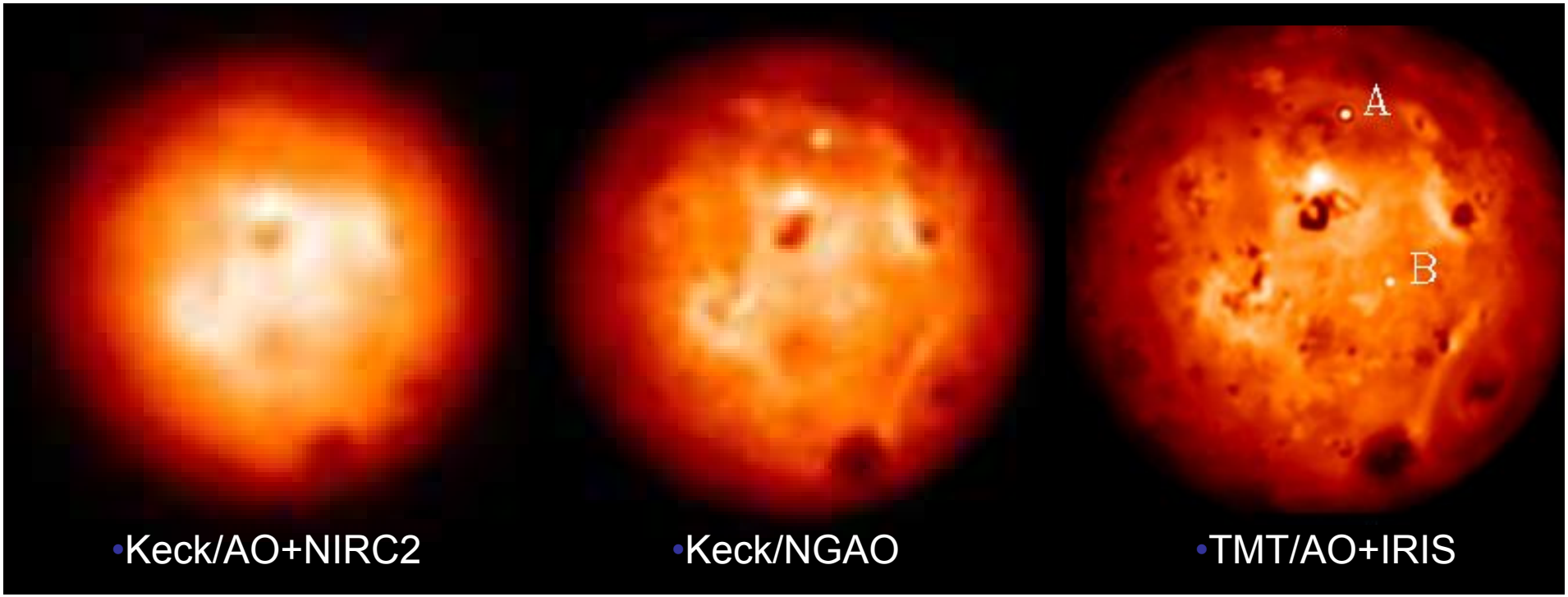
http://www.astro.ucla.edu/~ghezgroup/gc/pictures/Future_GCorbits.shtml

GR Tests

Precession of Periapse

Relativistic Redshift

Observing Io with AO on TMT



Simulations of Io Jupiter-facing hemisphere in H band (Courtesy of Franck Marchis)

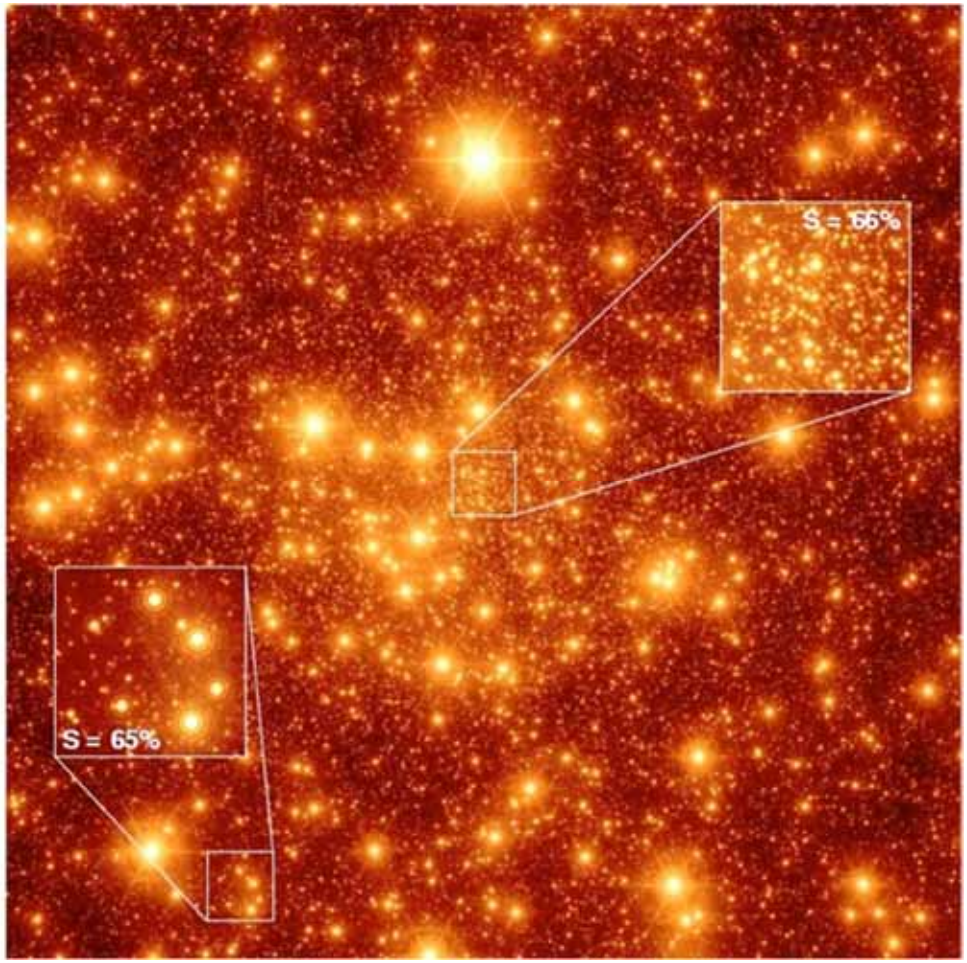
TMT resolution at 1µm is 7 mas = 25 km at 5 AU (Jupiter)
(0.035 AU at 5 pc, nearby stars)

Galactic Center with the IRIS Imager

K-band

t = 30s

K_{lim} = 25.5



17"

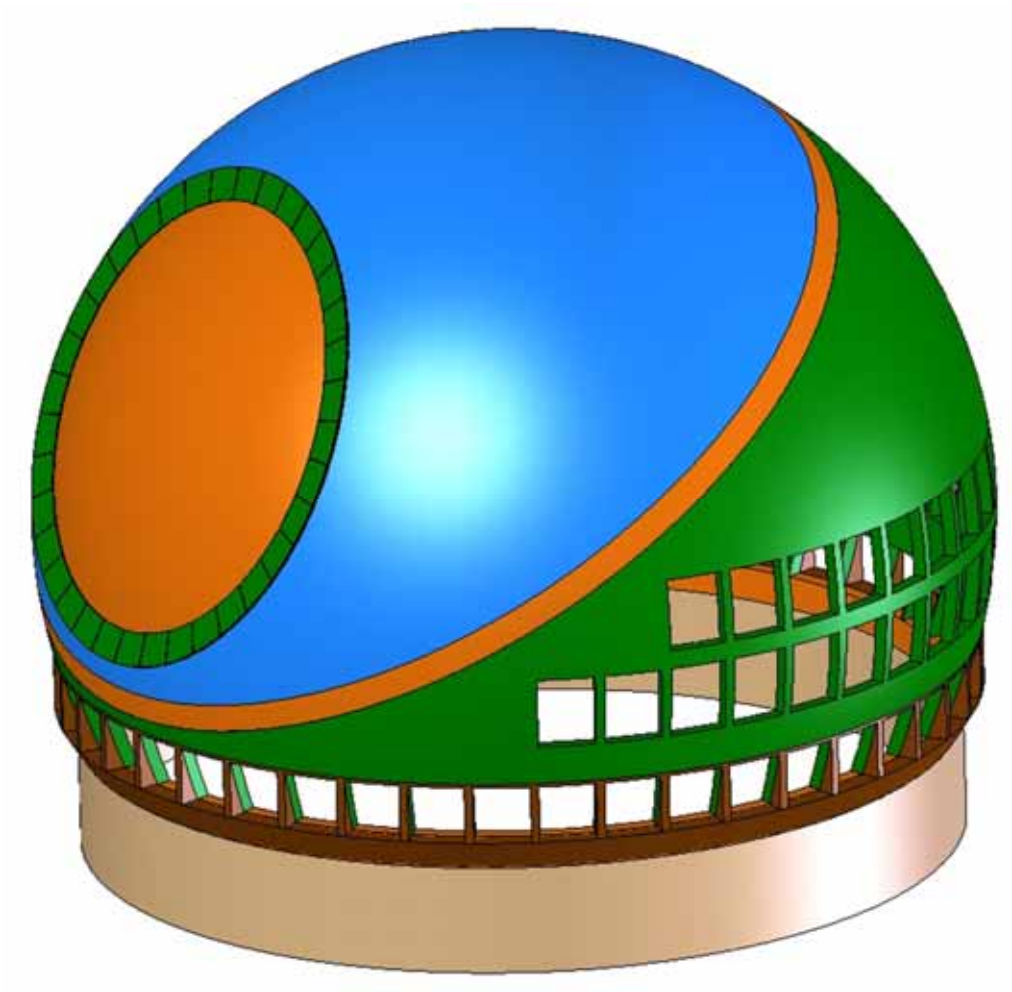
Over 100,000 stars

Courtesy: L. Meyer (UCLA)

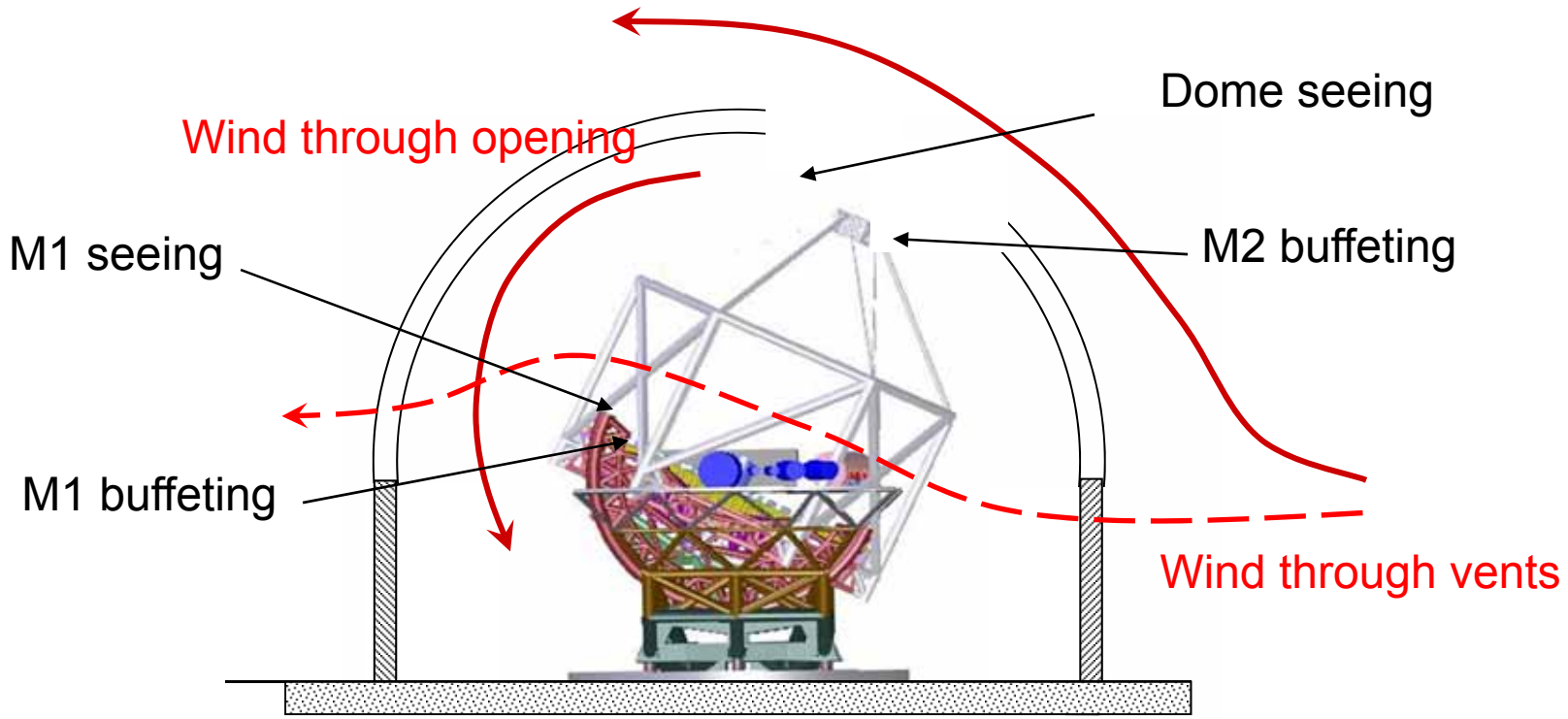
TMT on Mauna Kea

TMT on Mauna Kea

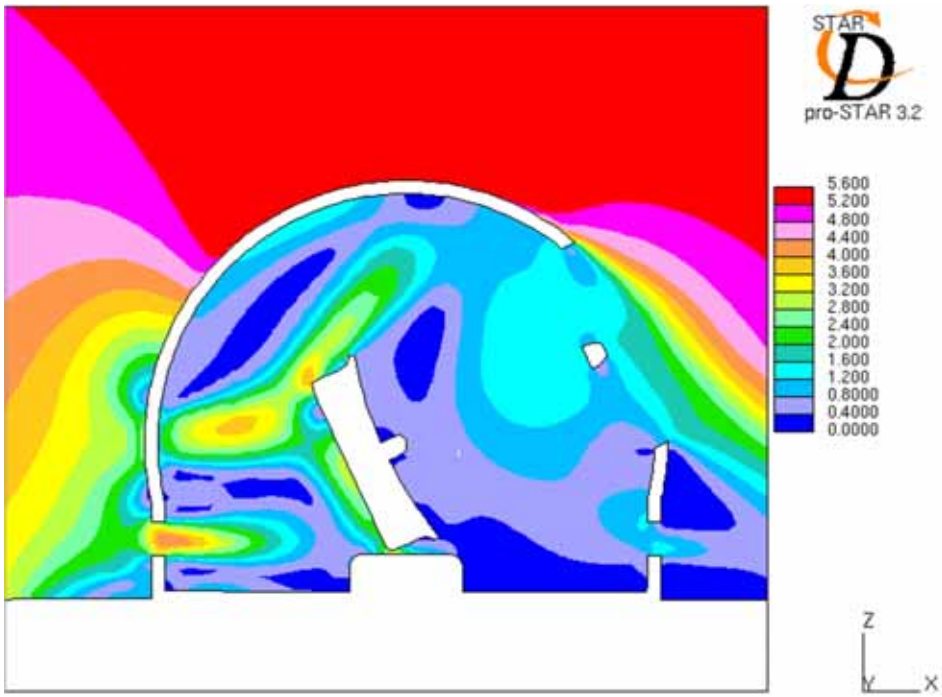
The TMT Calotte Enclosure

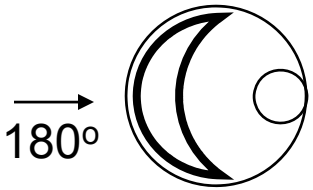


Aero-Thermal Effects Modeled



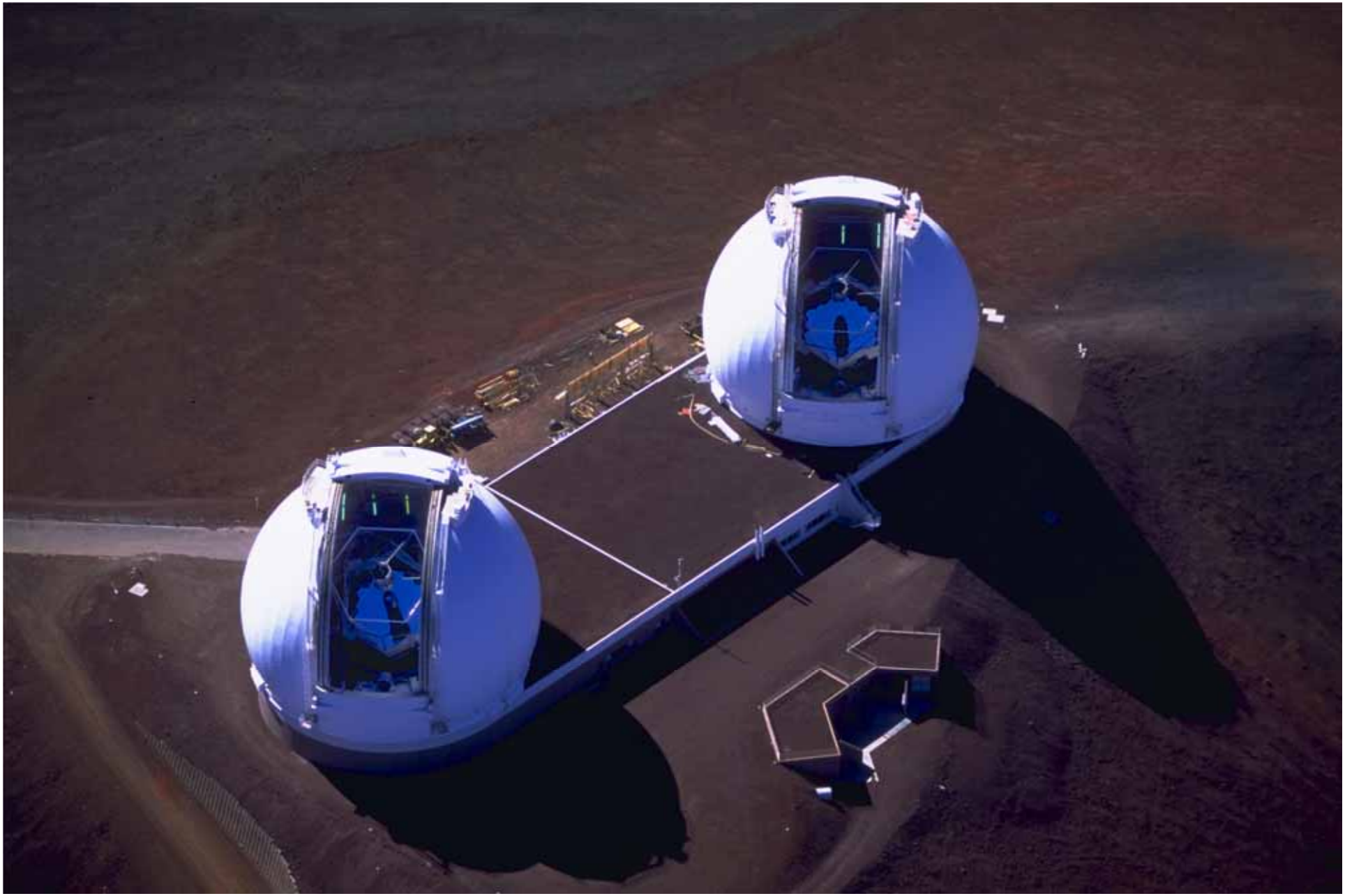
Z65°-A180°





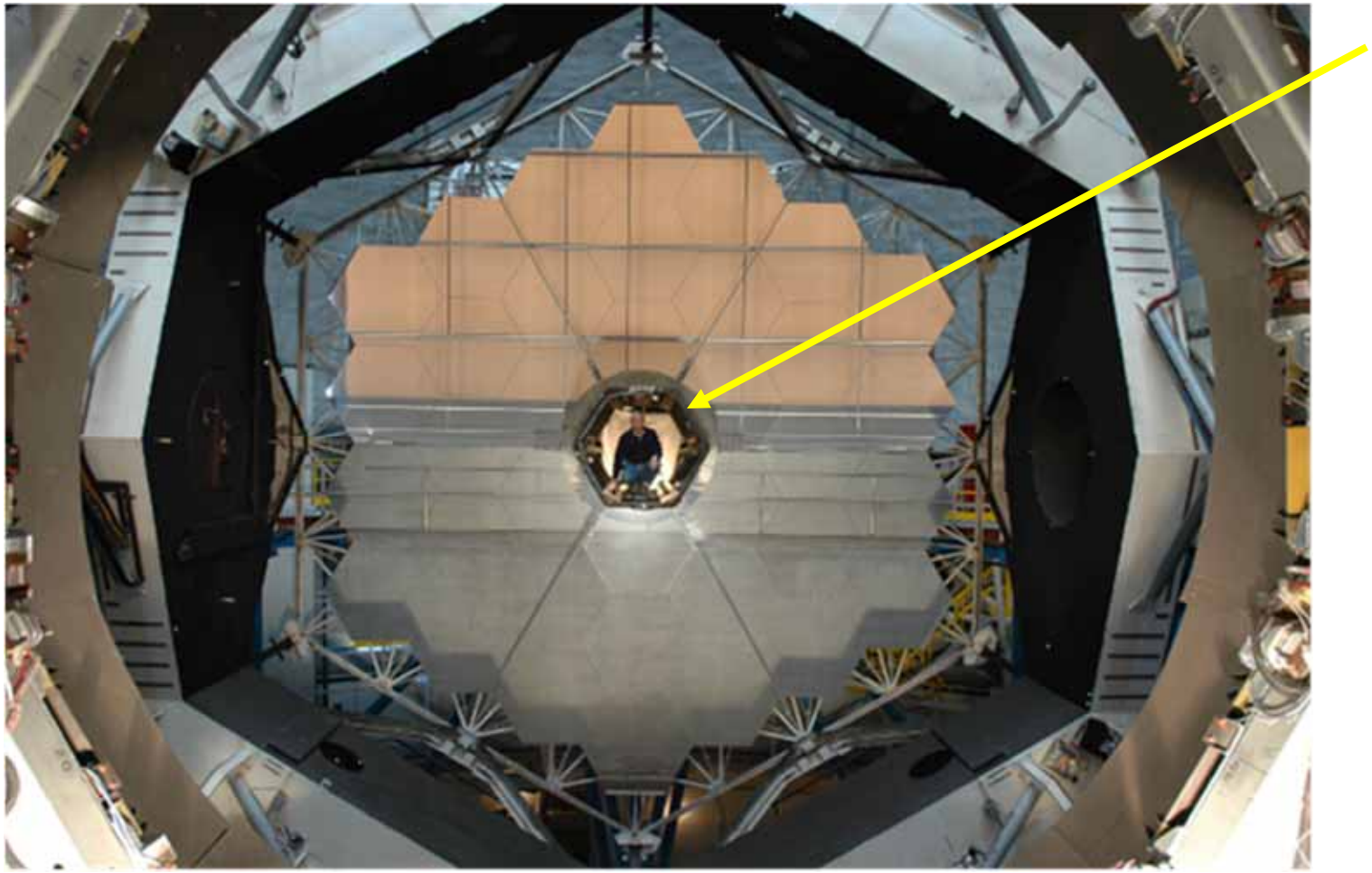
Wind speed contours with 100% vents open
(flow along x, U_o ~ 5 m/s)

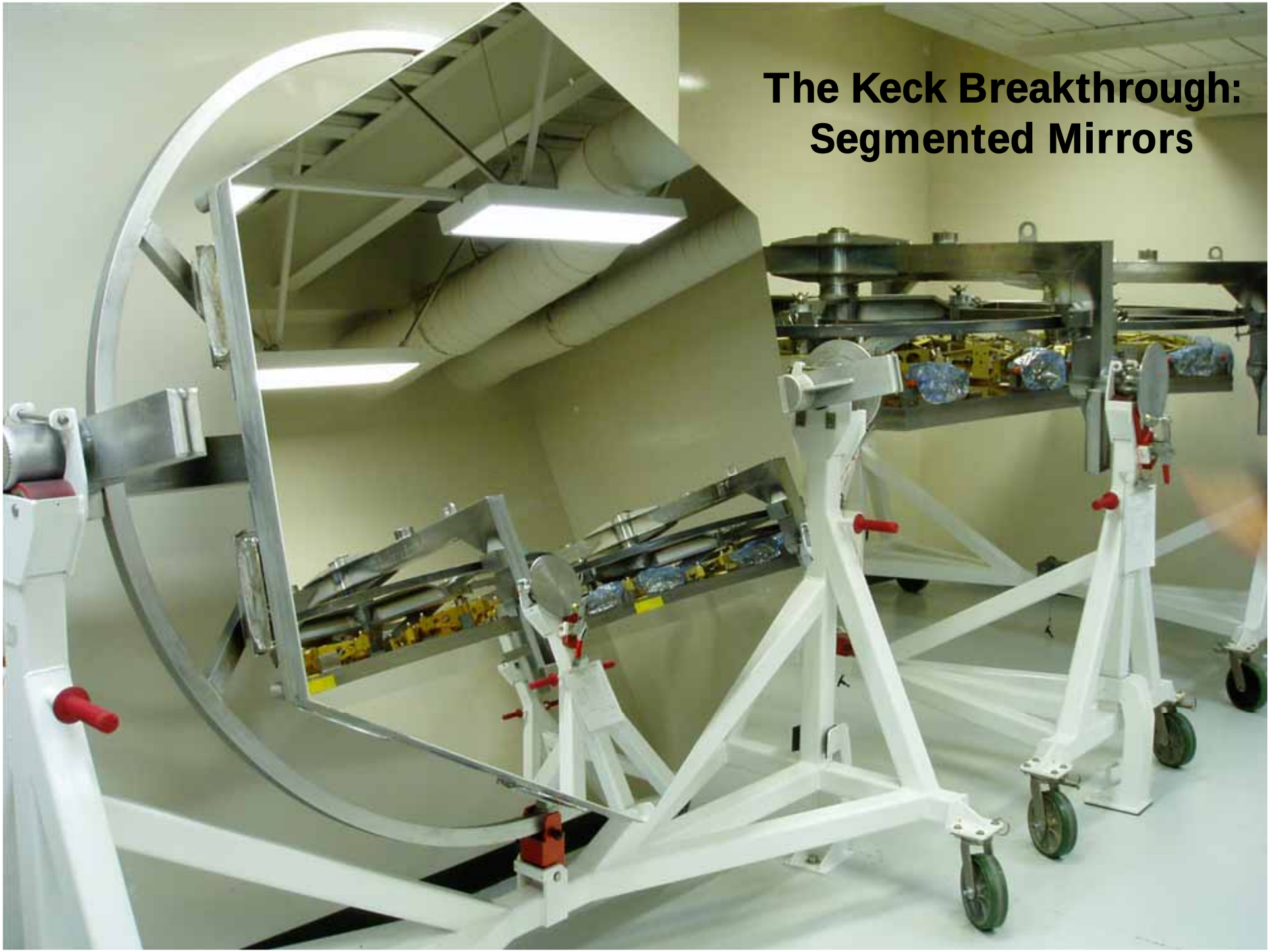
Keck 10-m (400”) Telescope (1992)
The technical heritage for TMT



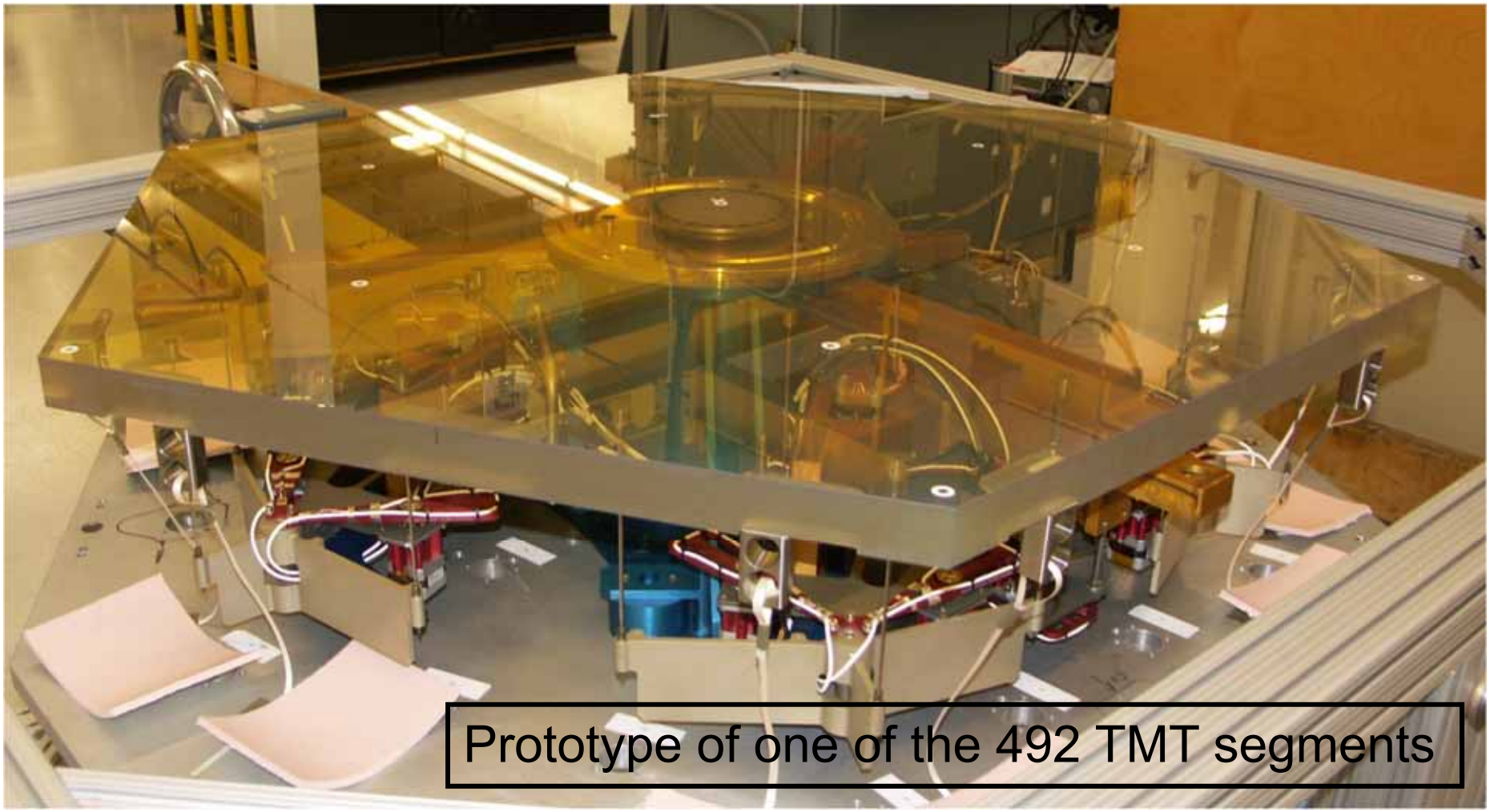
Keck Observatory, Mauna Kea, Hawaii

Keck 10m Segmented Mirror Telescope – 36 segments

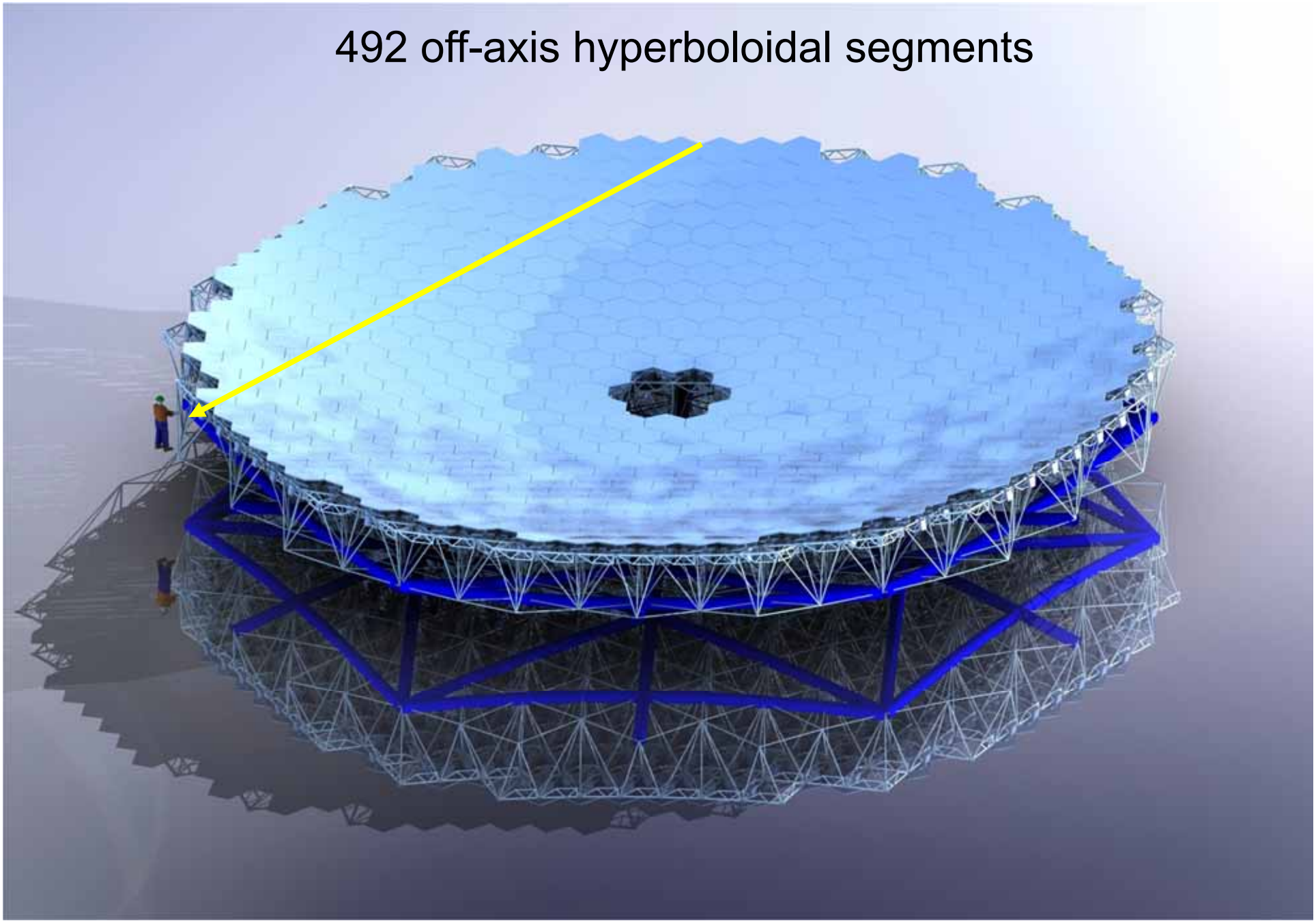



The Keck Breakthrough:
Segmented Mirrors

Full Scale Segment on Segment Support Assembly



492 off-axis hyperboloidal segments



Most aspheric TMT M1 Segment before hexing polished by Tinsley

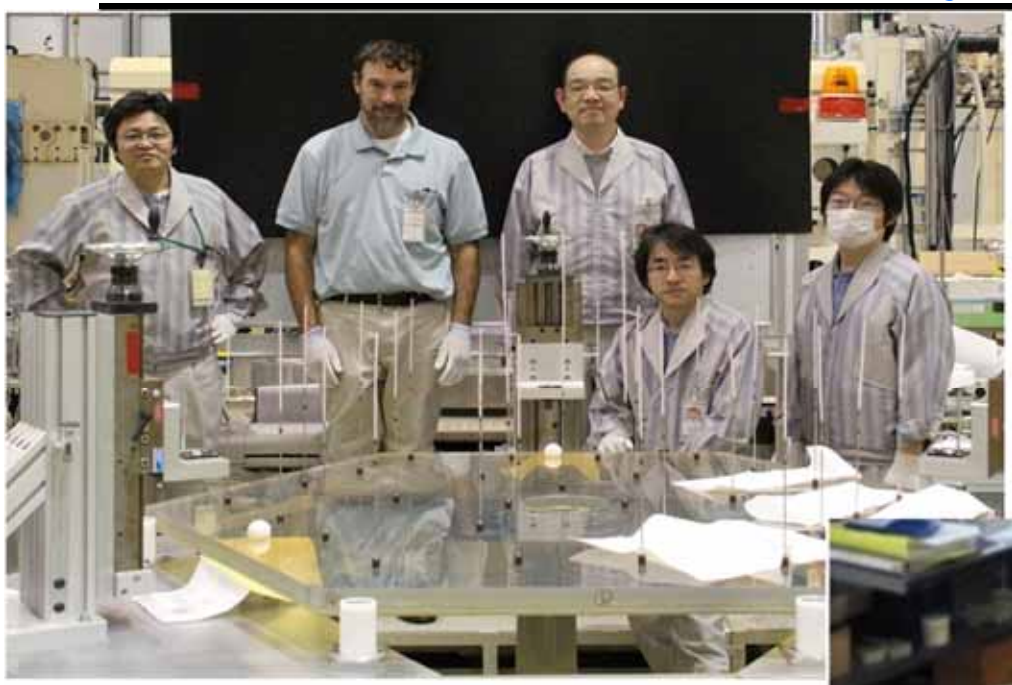
E-ELT Blank Polished at Tinsley With TMT Stressed Mirror Polishing Process

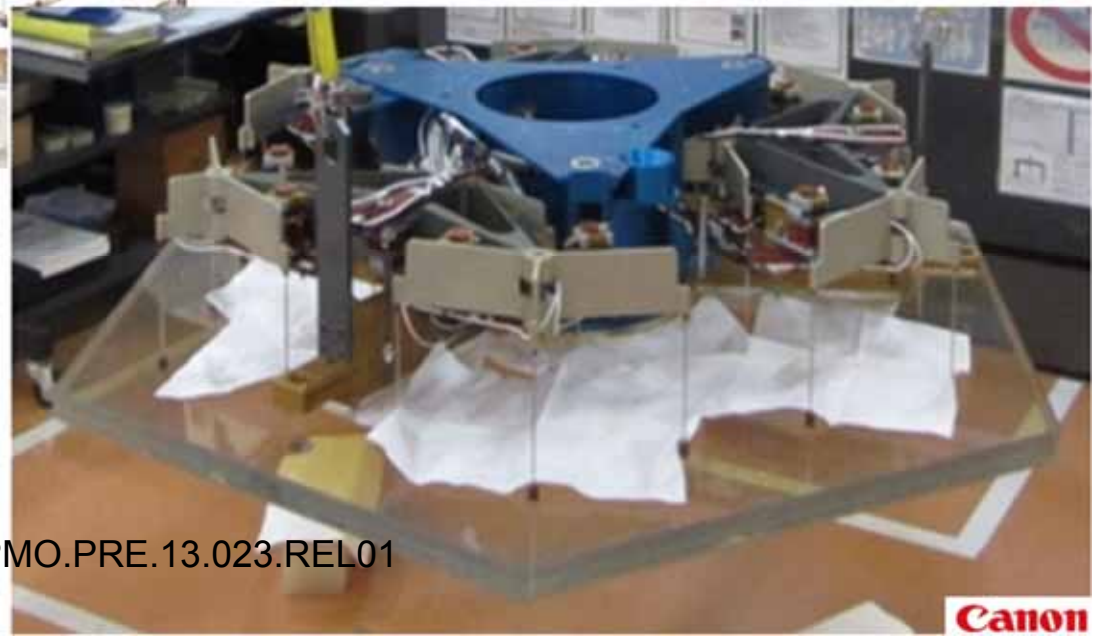
Most aspheric **E-ELT** M1 Segment before hexing polished by Tinsley 1/27/2012

And Another High-Asphericity Segment! Canon Type-82 Segment Prototype

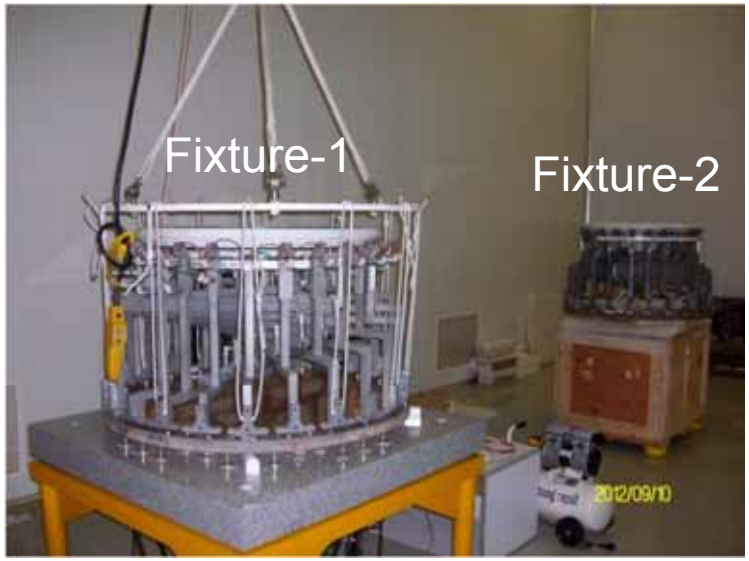
Most aspheric TMT M1 Segment polished as hexagon by Canon 1/18/2012

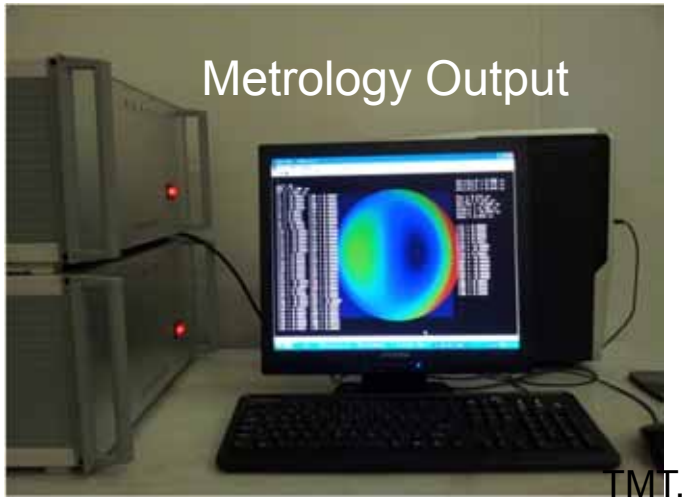
Segment Support Assembly Integration Completed by Canon and TMTJ

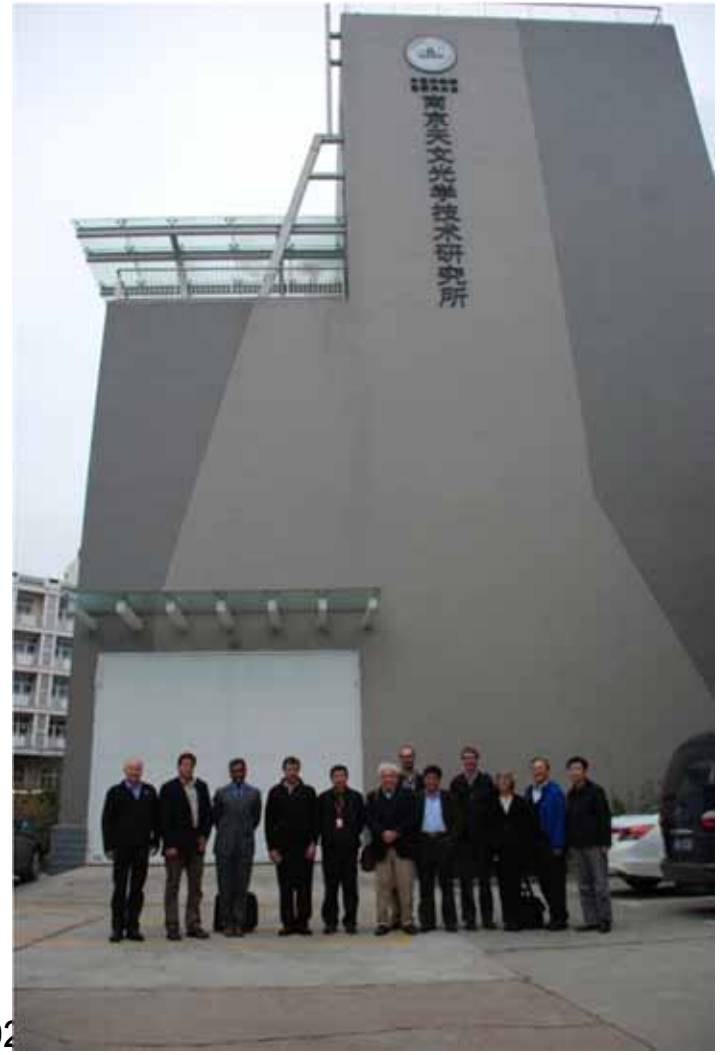




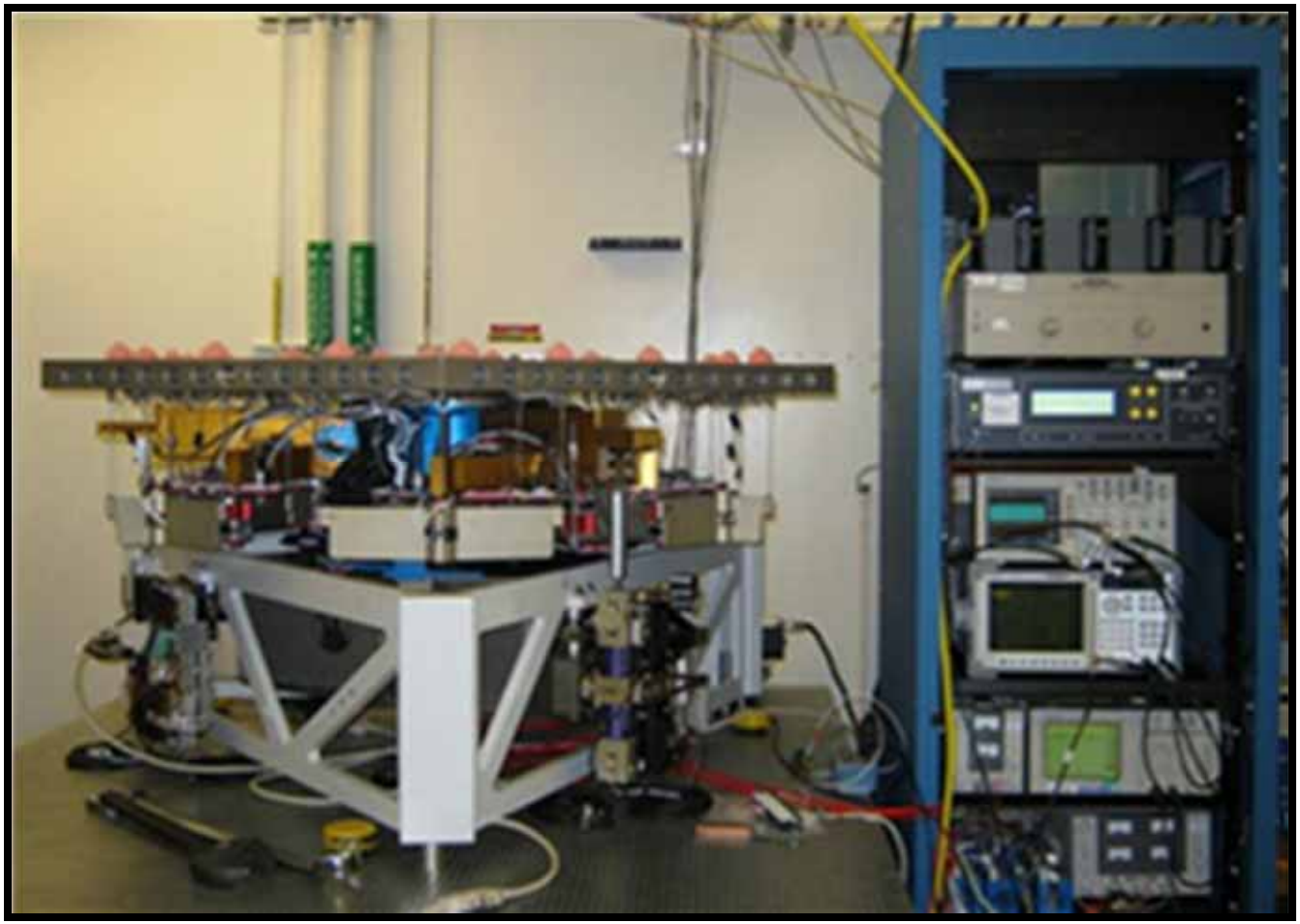
Nanjing: NIAOT Exercising Stressed Mirror Polishing (SMP)



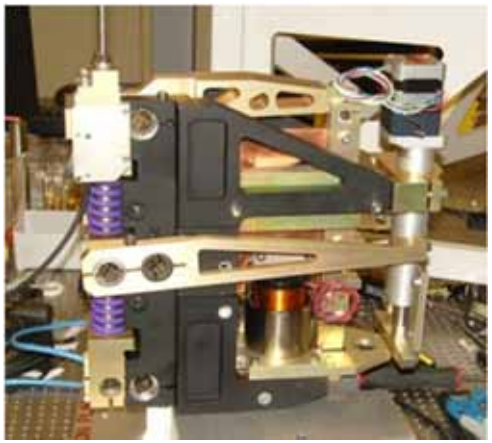


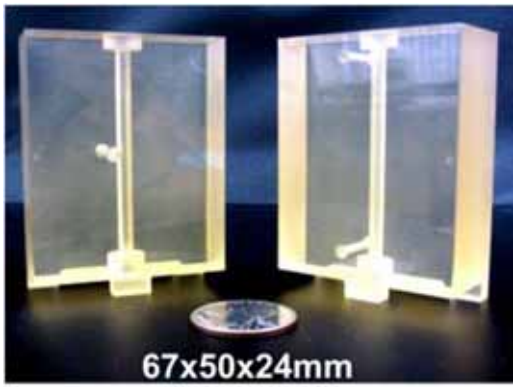


M1 System – Integrated Testing at JPL

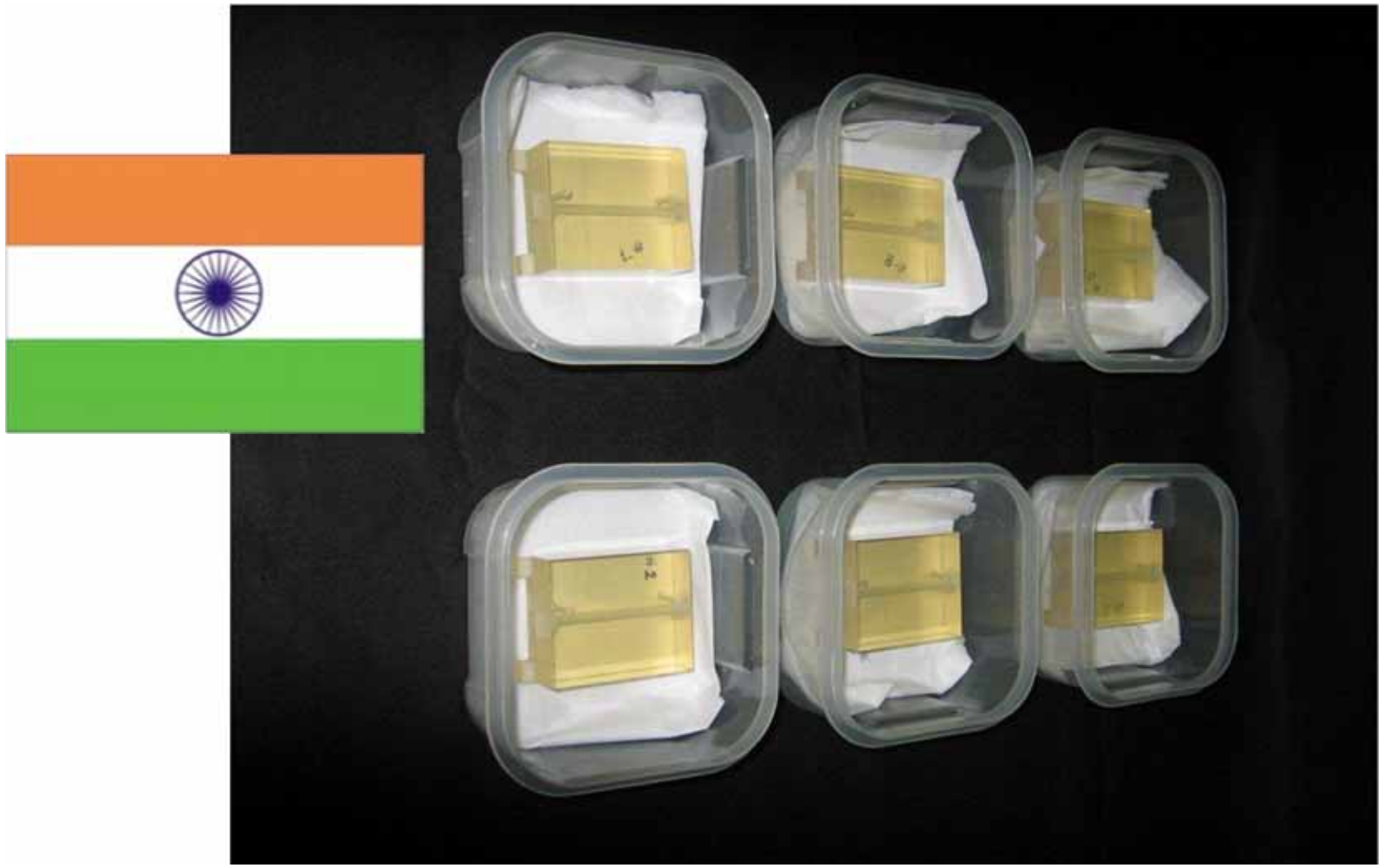


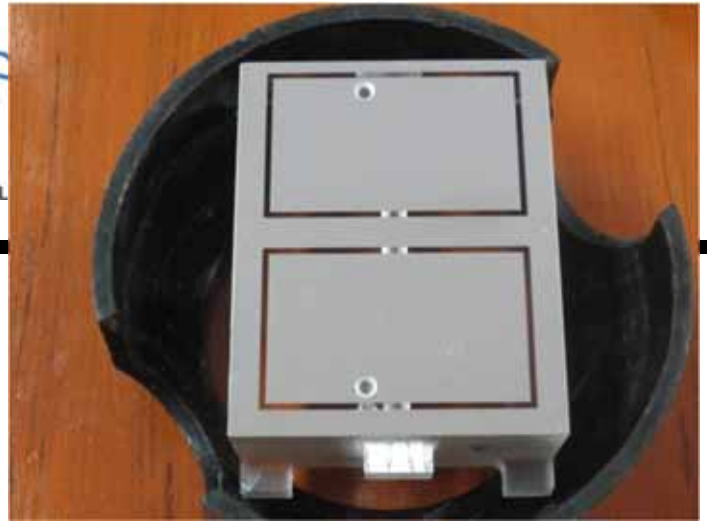
Telescope Controls Prototyping: Actuators, Edge Sensors, Mirror Supports





Uncoated Edge Sensor Prototypes at GOAL (Pondicherry, India)



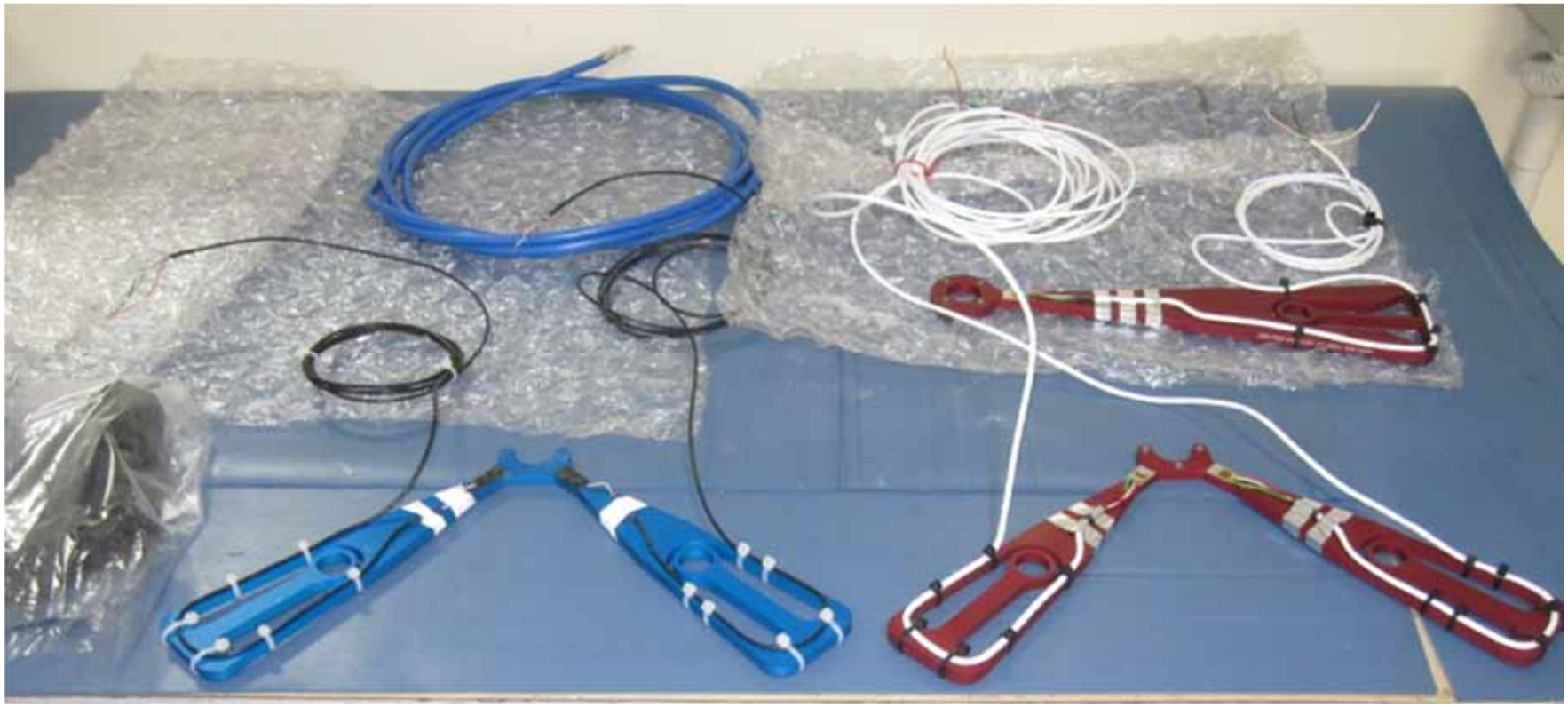


Prototype sensors at GOAL

Photolithography mask for sensor coating at GOAL

Test coupon for Indium soldering process at GOAL

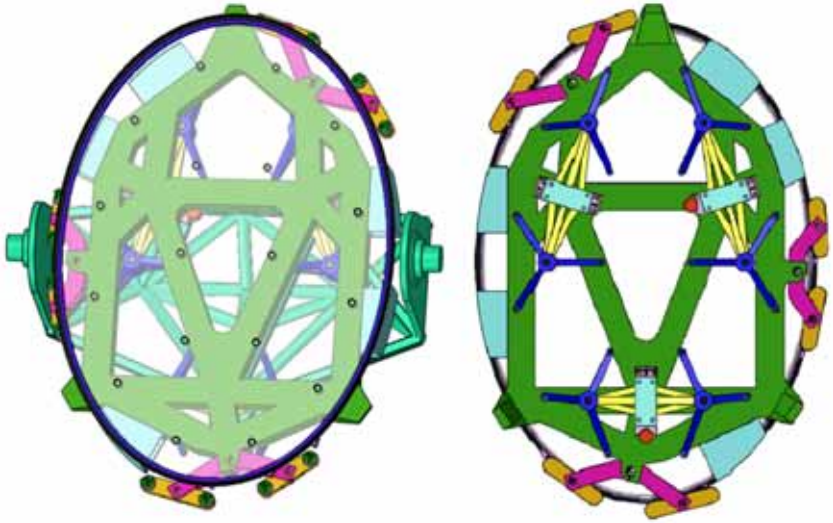
M1 Segment Support Assembly Leaf Spring Prototypes

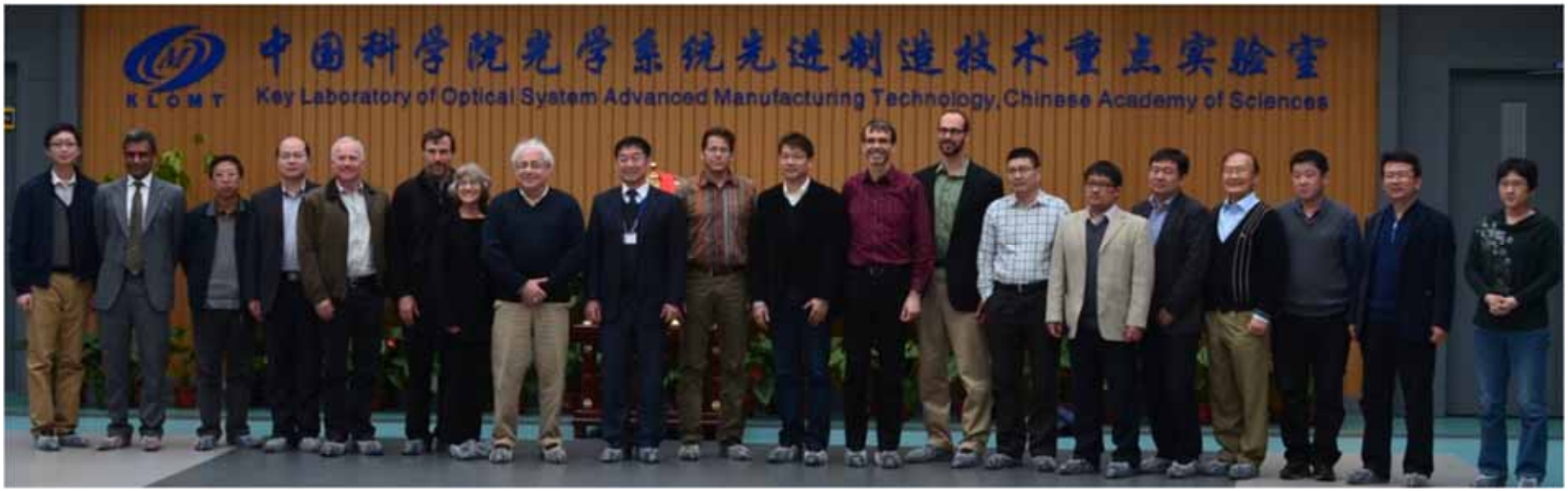


IPA India leaf spring left – US leaf spring Right

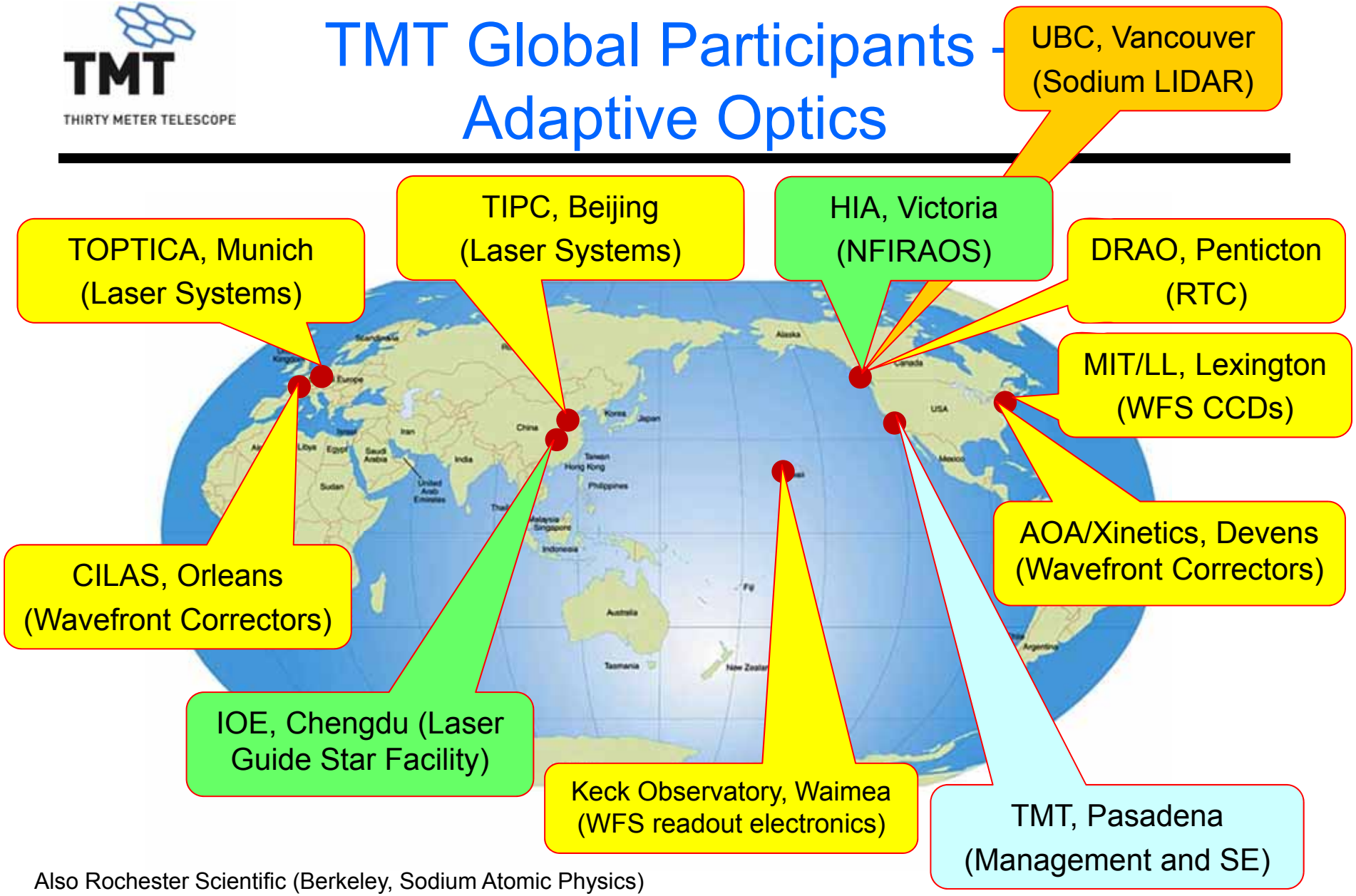
M3 System Progress at CIOMP, Changchun

- Conceptual Design Review (CoDR) for the M3 Cell Assembly **successfully completed 2013/04/26**



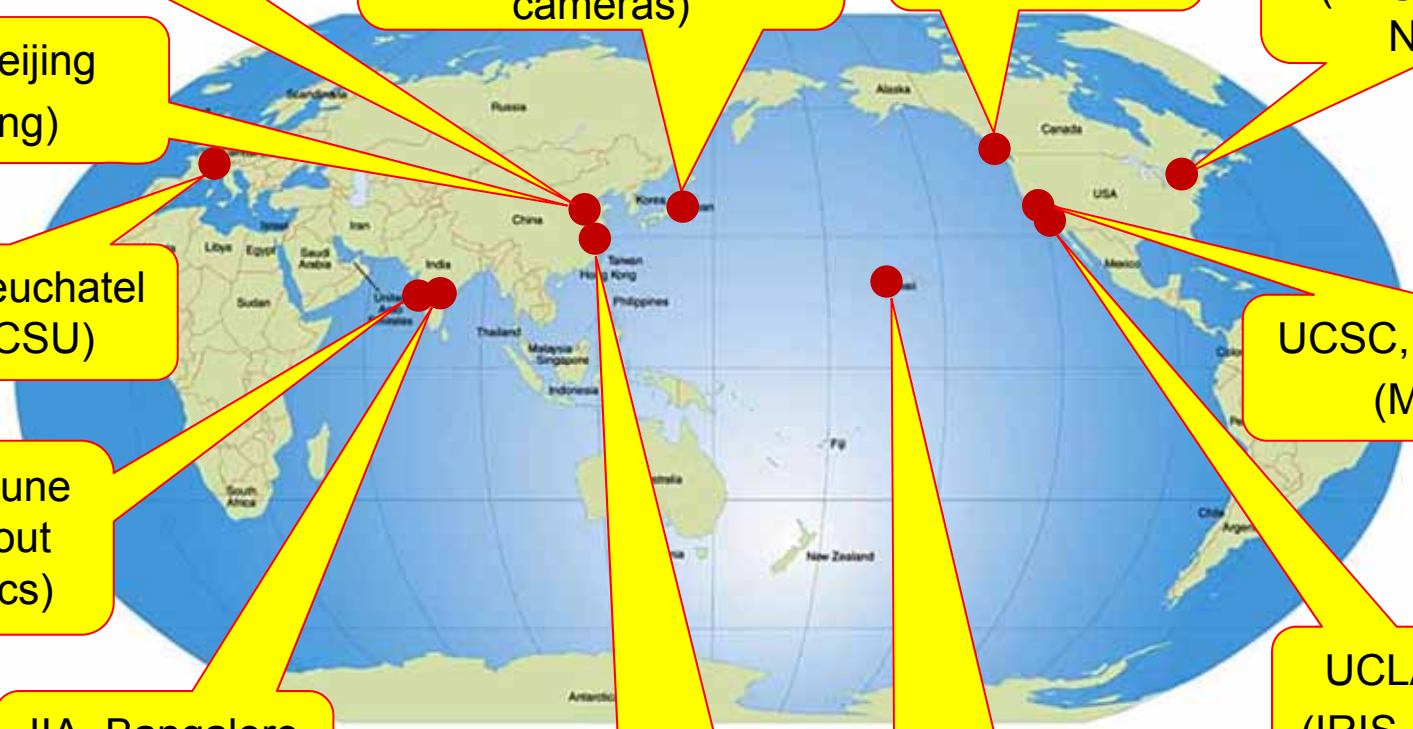


TMT Global Participants - Adaptive Optics

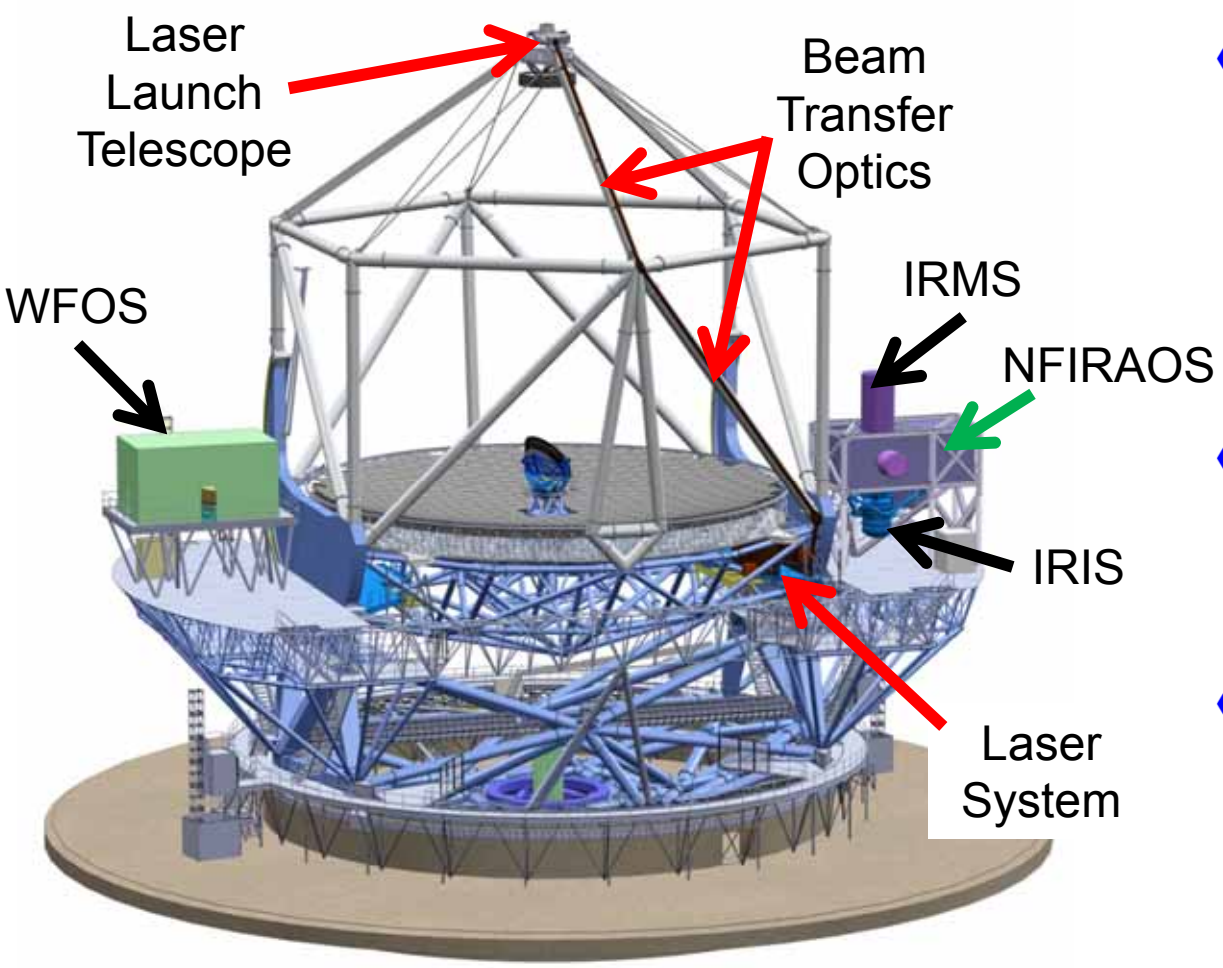


Also Rochester Scientific (Berkeley, Sodium Atomic Physics)

TMT Global Participants – First Light Science Instruments

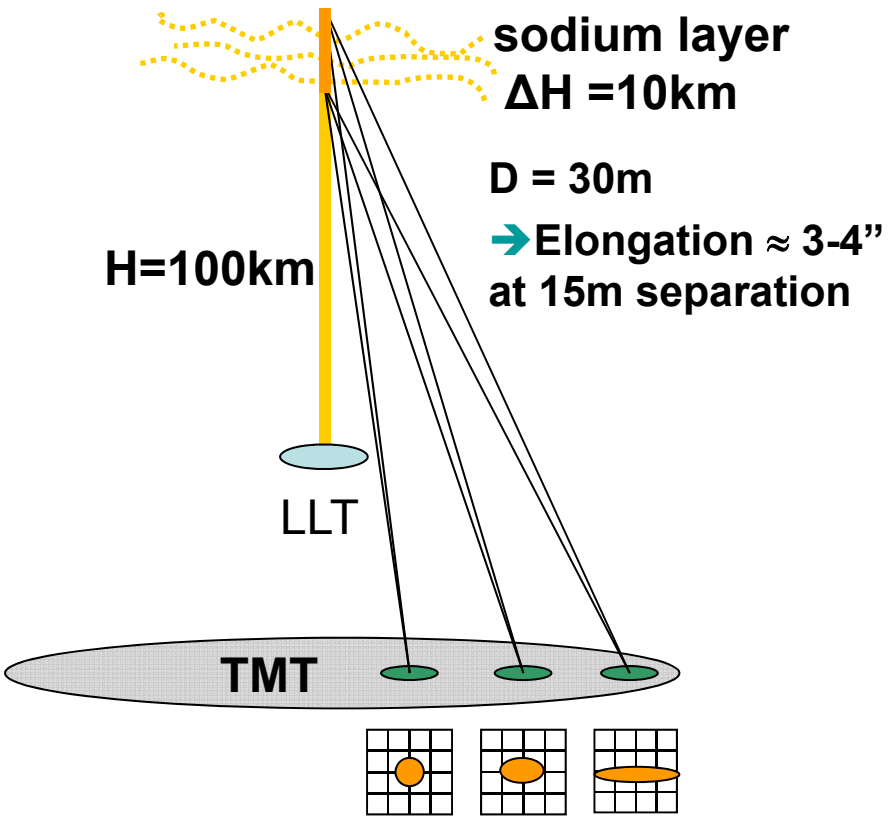


First Light Science Instruments and Adaptive Optics Systems



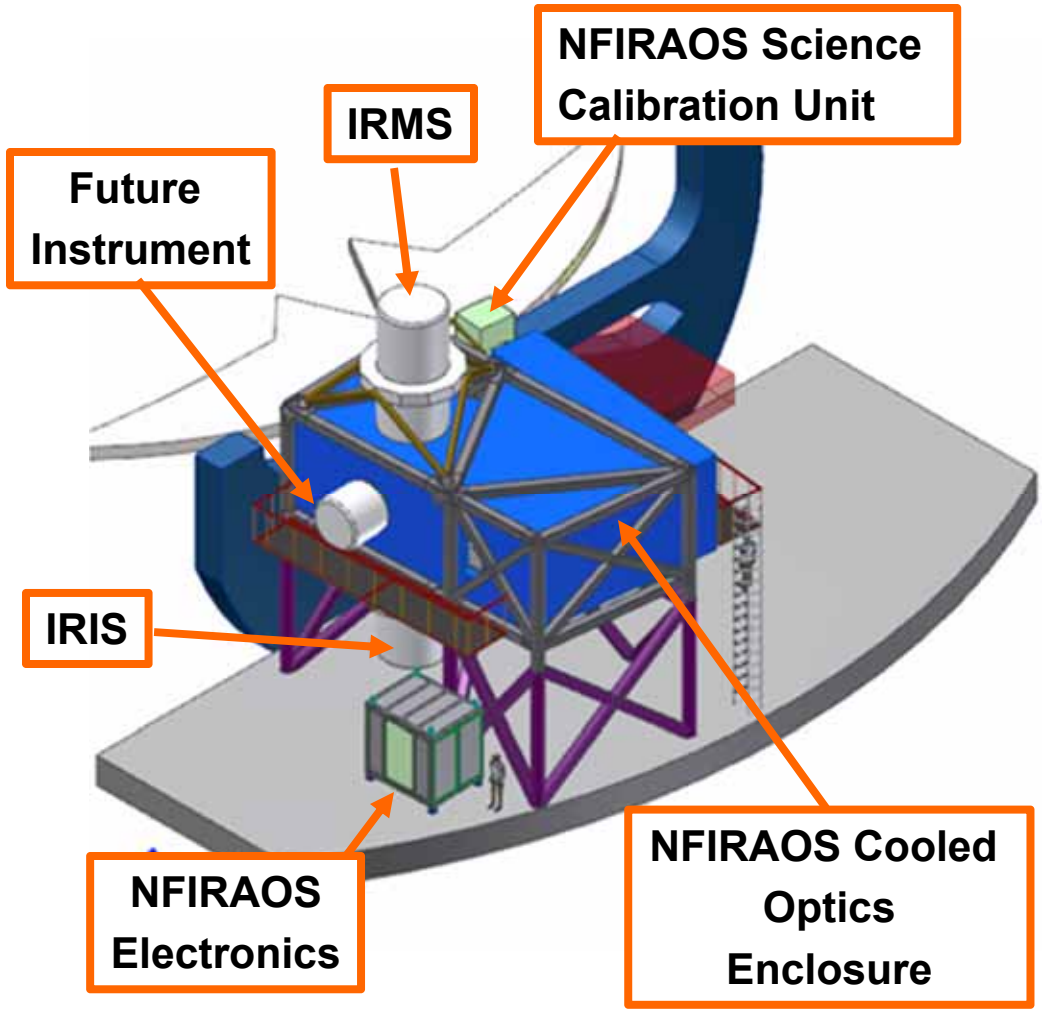
- Science instruments
  - IRIS
  - IRMS
  - WFOS
- Laser Guide Star Facility (LGSF)
- Narrow Field IR AO System (NFIRAOS)

589 nm Laser Light Produces Artificial Guide Stars

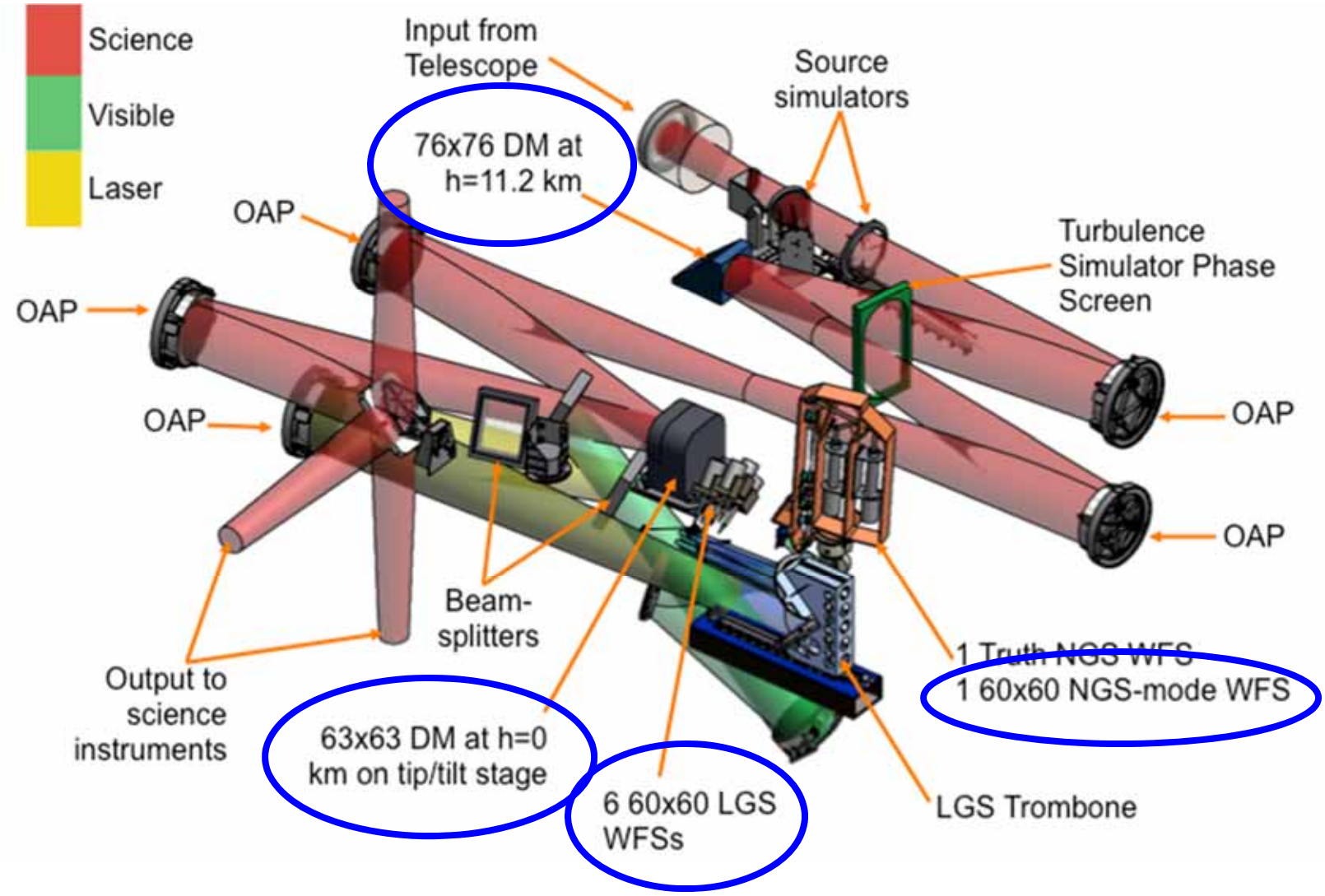


NFIRAOS Design at HIA (Canada)

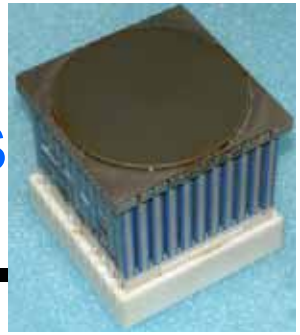
- Dual Conjugate Laser Guide Star (LGS) AO System
  - Feed 3 IR Instruments
  - 60x60 order system operating at 800Hz
  - 4 OAP relay to eliminate distortion
  - Operation at -30°C to reduce thermal emission
- Completed preliminary design phase in December 2011
  - Very successful review led by panel of external reviewers



NFIRAOS Opto-Mechanical Overview



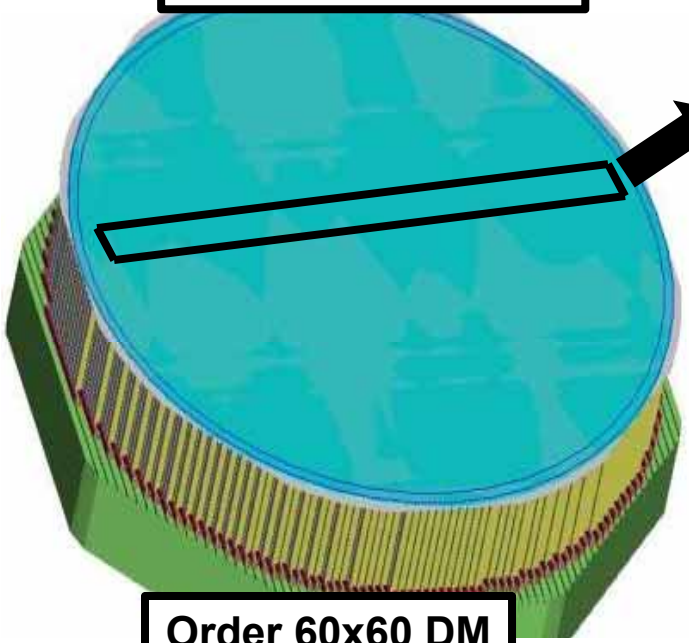
CILAS (France) Deformable Mirrors



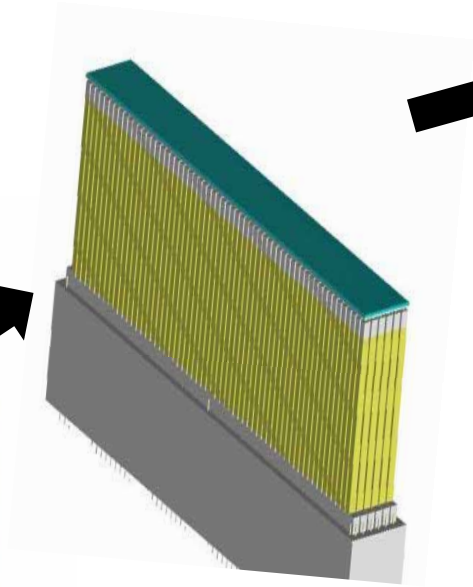
9x9 DM 2006

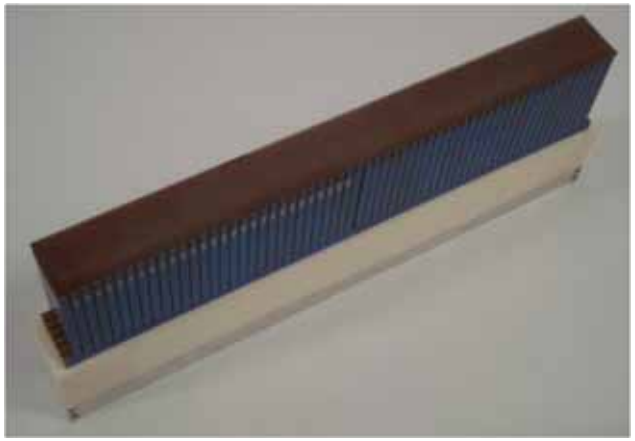
- Hard piezostack technology with high stroke, low hysteresis, operating at -30°C
- Sub-scales prototypes on-going

6x60 sub-scale DM CAD model



Order 60x60 DM CAD model





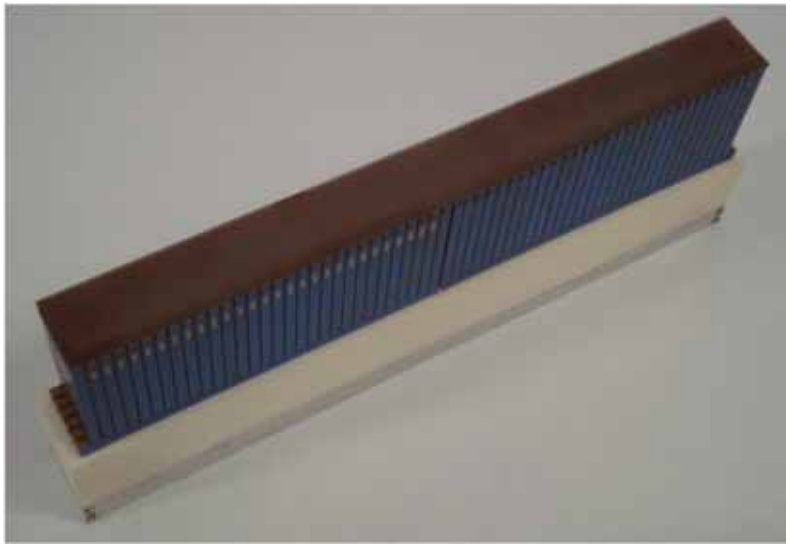
6x60 DM assembled before polishing

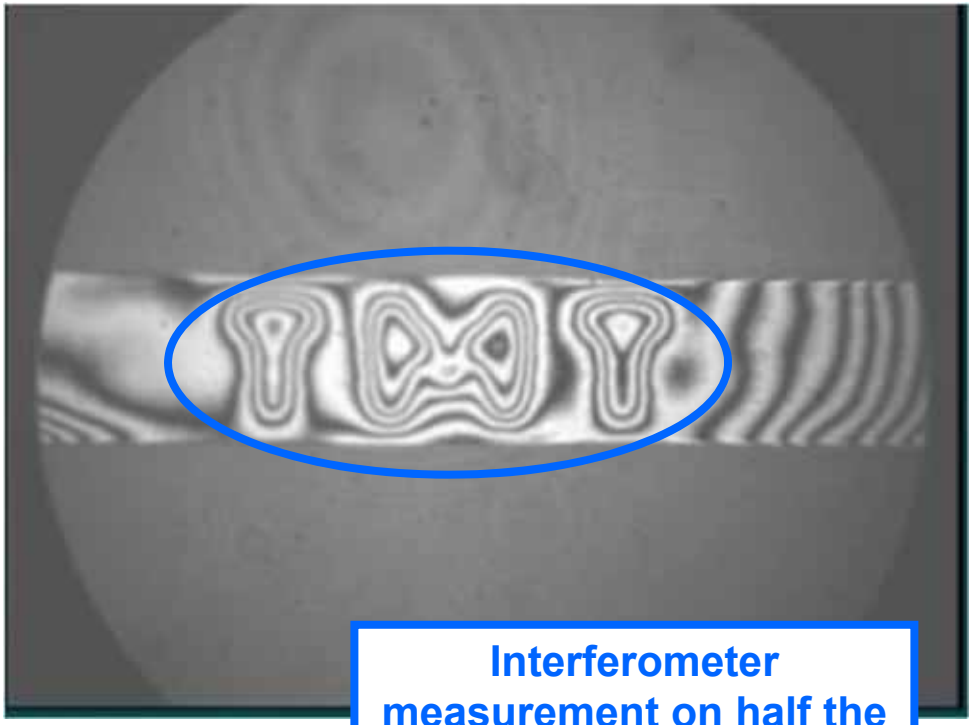
6x60 DM initial test results:

- **19 μm stroke (10μm requirement)**
- **Hysteresis ≤ 5% (10% requirement)**

AO: Deformable Mirror 6x60 Test at CILAS

6x60 DM before polishing

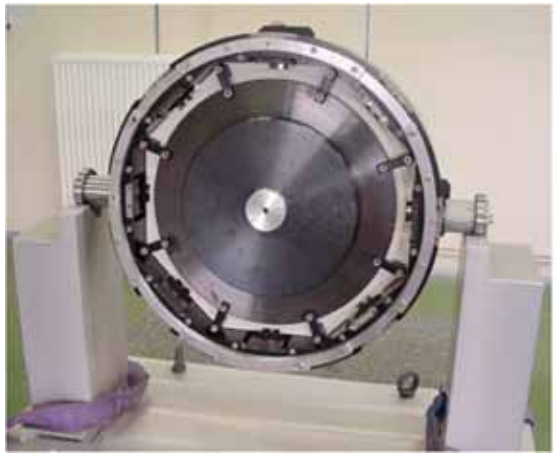


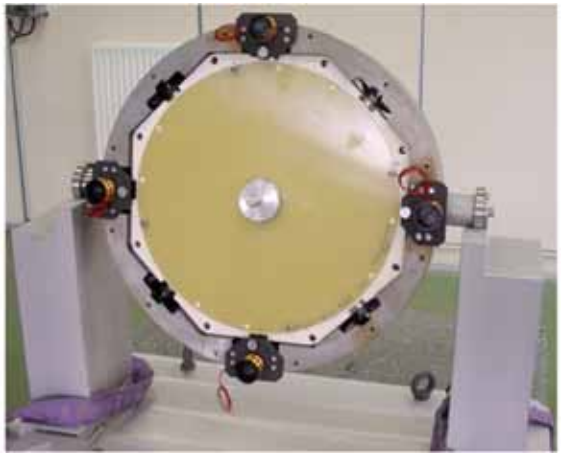


Interferometer measurement on half the DM Breadboard showing TMT shape

CILAS Tip-Tilt Stage

Full scale prototype

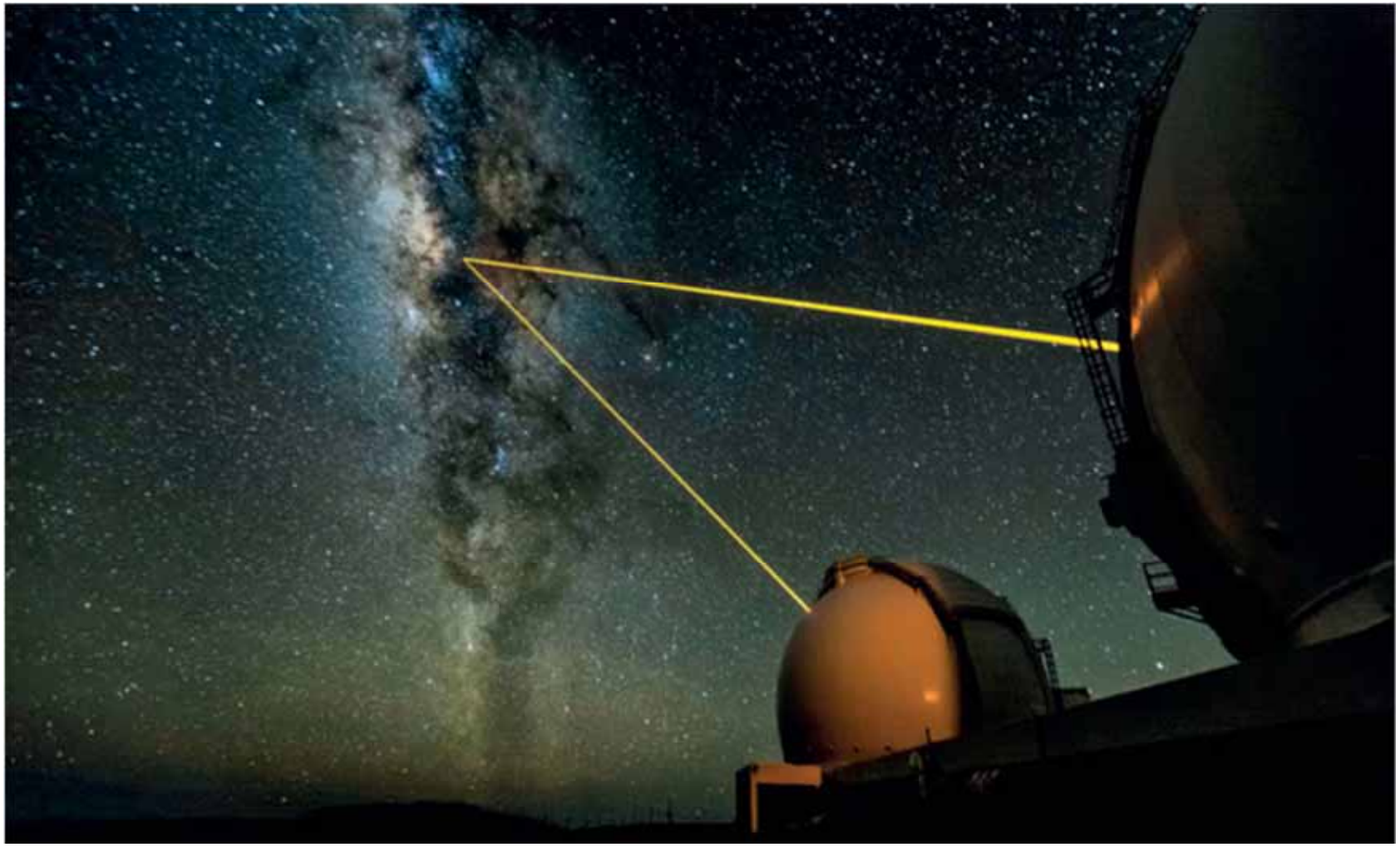




Details of Y axis (front and back view)

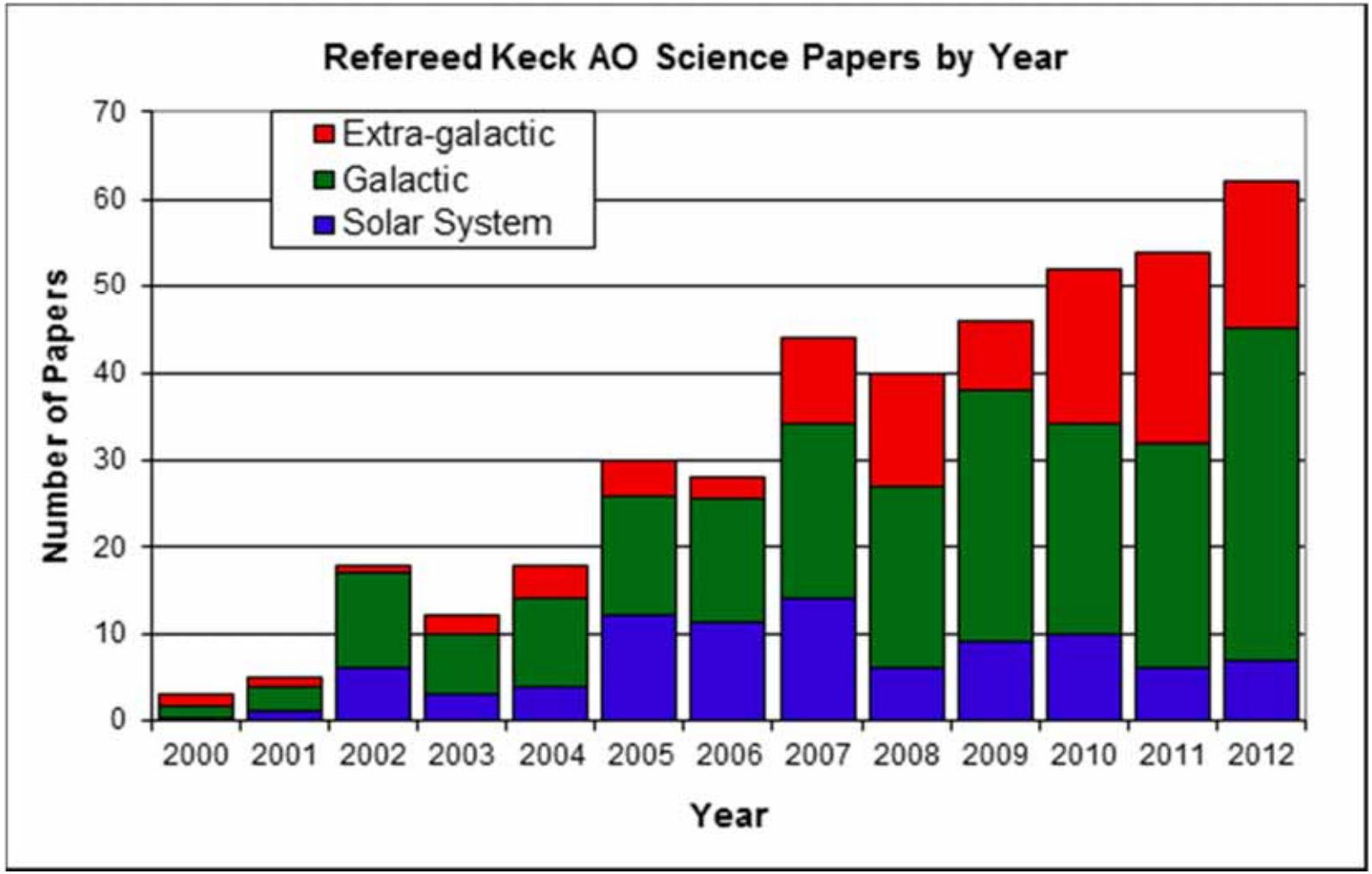
Full scale prototype demonstrated at -30°C
Closed loop bandwidth of ~100Hz (>> 20Hz Requirement)

Keck I and Keck II Guide Star Lasers May 2011

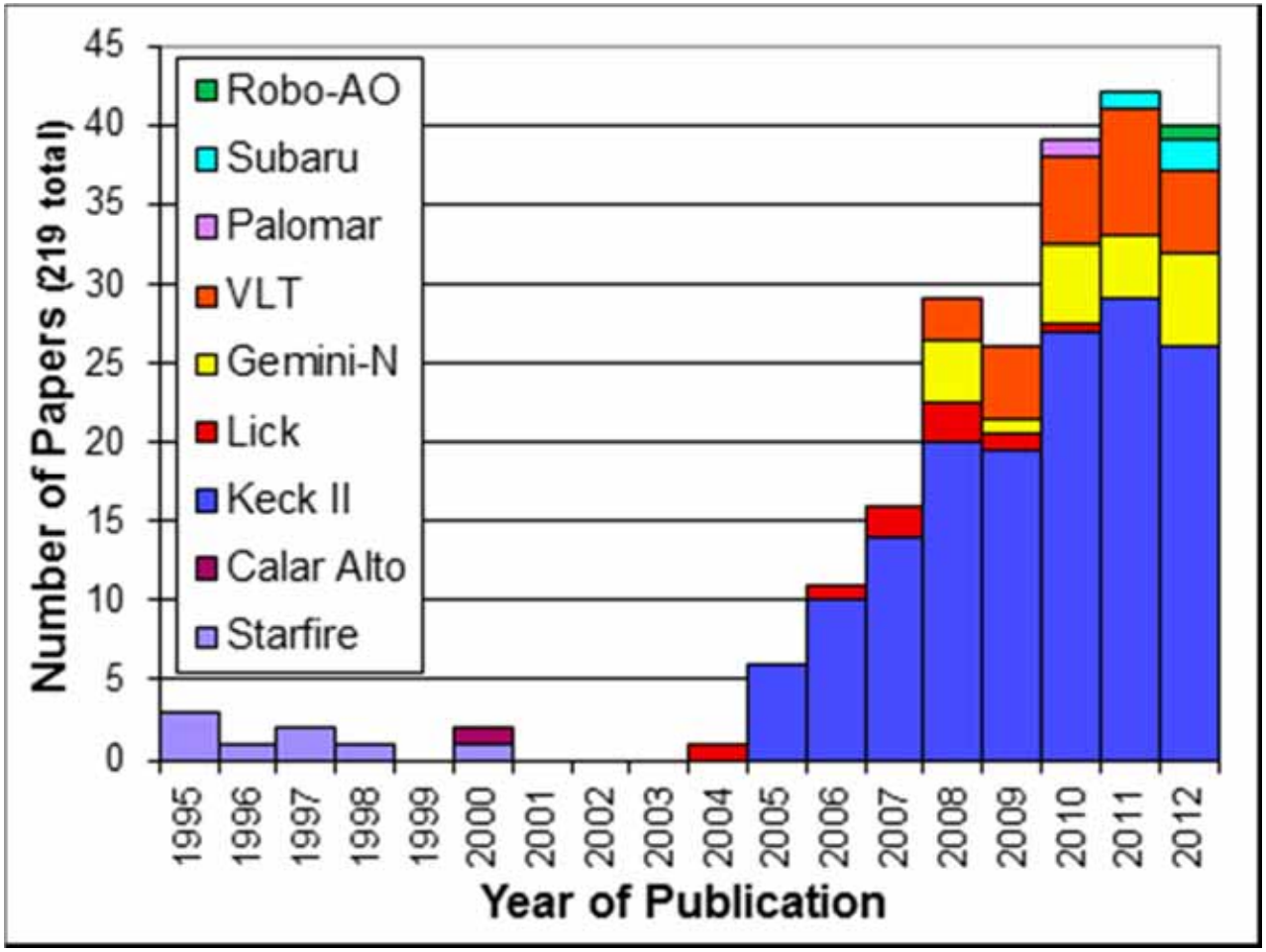


Gemini South Guide Star Laser 5-Star Artificial Constellation – January 2011

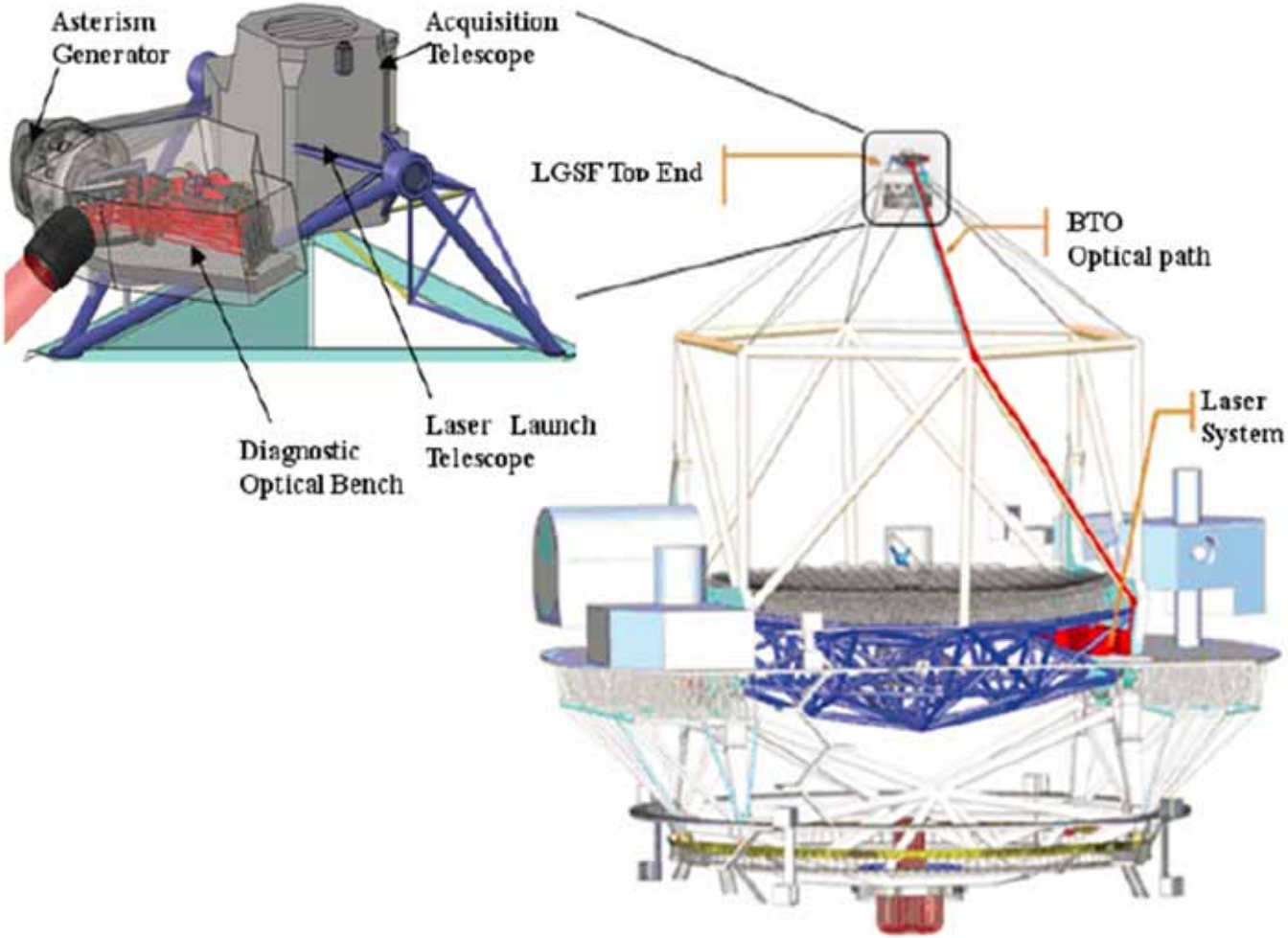
Refereed Keck AO Science Papers by Year



Laser Guide Star AO Astronomy Refereed Papers by Year

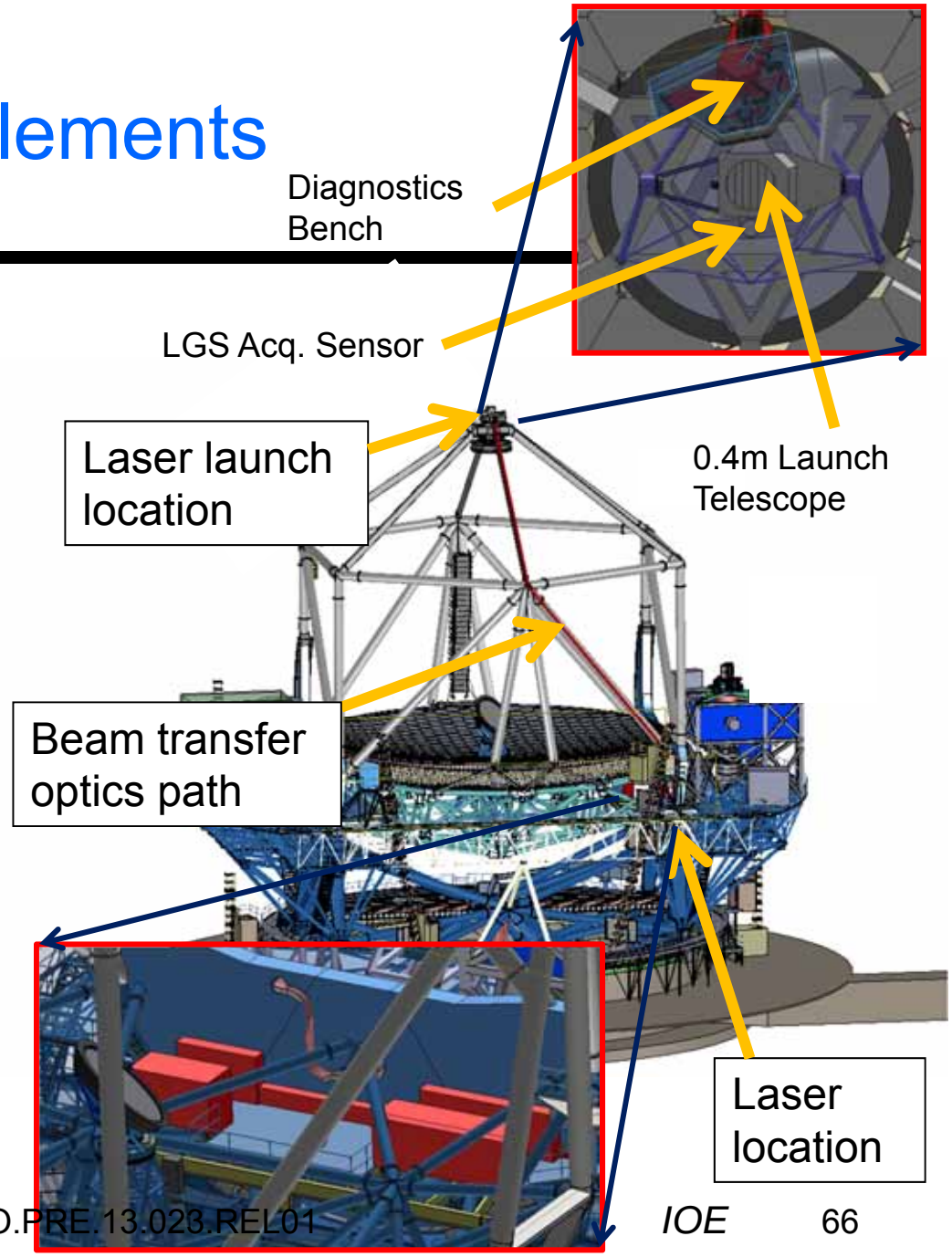


Chengdu LGSF: BTO/LLT/E&SW update

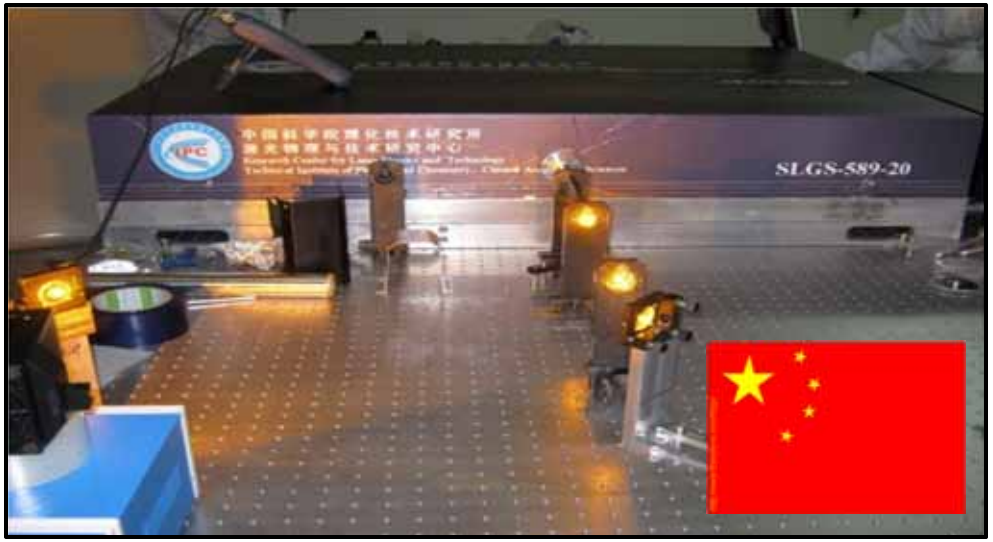


LGSF Design Elements

- 6 (eventually 9) laser systems mounted on telescope elevation journal
  - Possible with current generation of compact, efficient, low(er)-maintenance designs
- Reflective launch telescope and diagnostics located behind TMT M2
- Mirror-based beam transport due to path length and beam power
- Safety systems (personnel, equipment, aircraft, satellites)



Laser Development at TIPC (China) and Toptica/MPB (Germany/Canada)



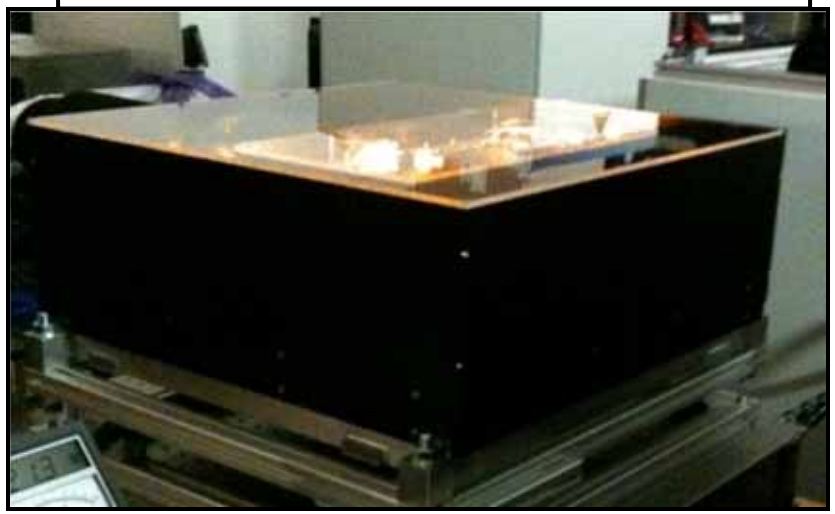
TIPC 20W field test TIPC prototype

- Nd:Yag sum frequency generation

On sky tests of the TIPC prototype in China: 8.7 mag. LGS

Toptica/MPB 20W Prototype

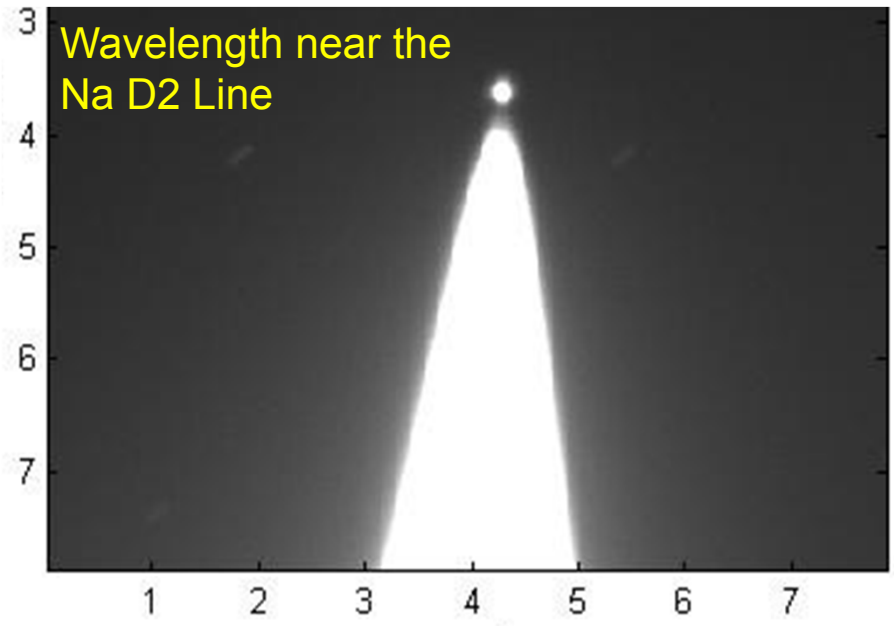
- Raman fiber doubled second harmonic generation
- Pre-Production Unit Tested for ESO

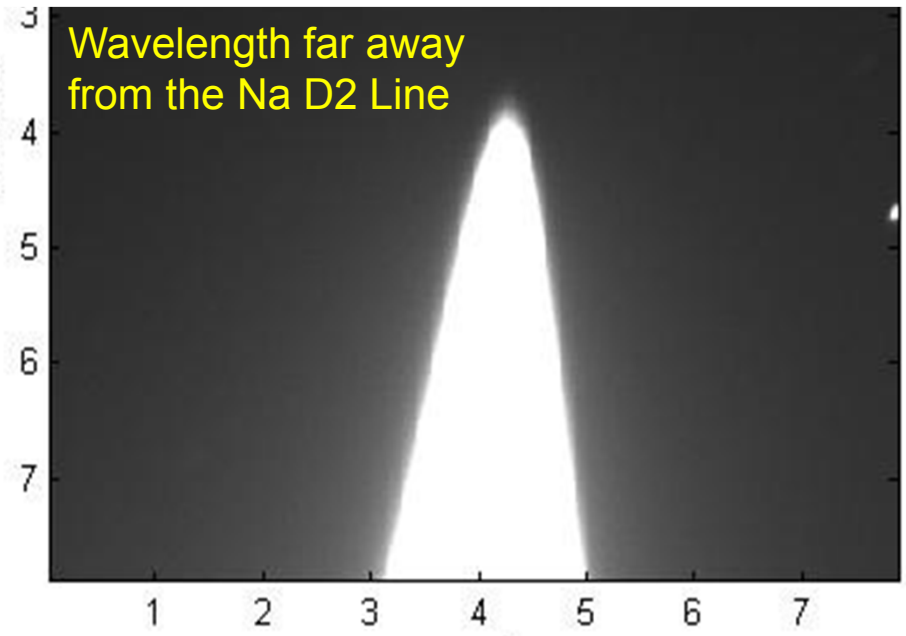


Yunnan Laser Test
Sodium Laser and 1.8m Telescope

First Light with the TIPC Guide Star Laser

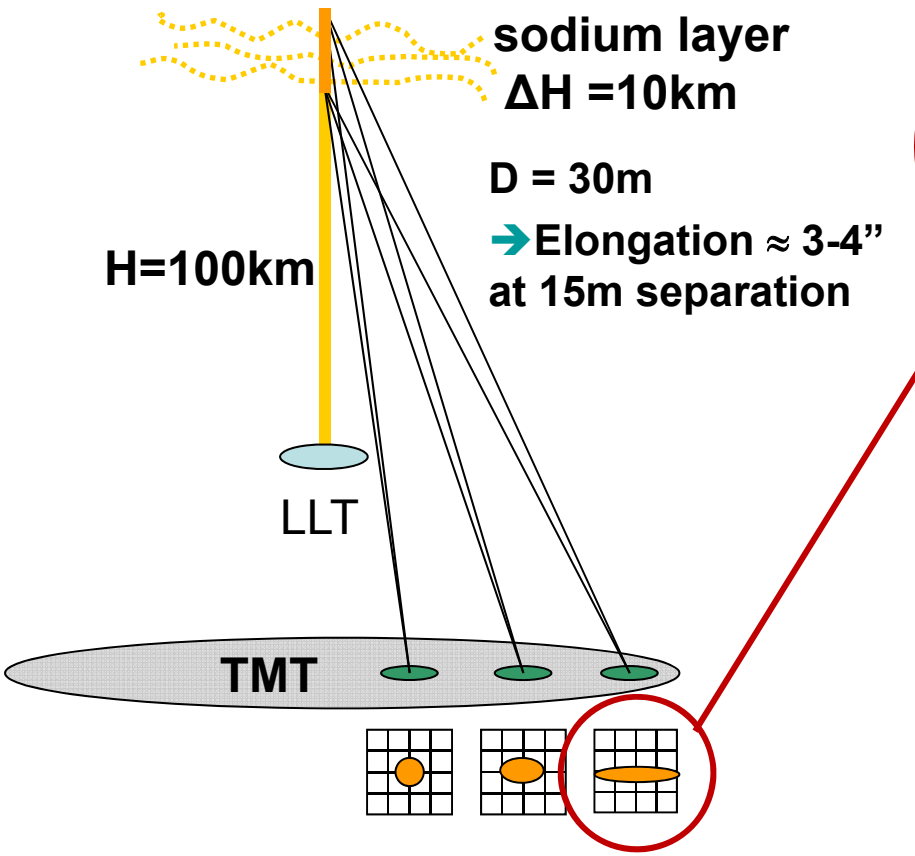
- The exposure time was 1s

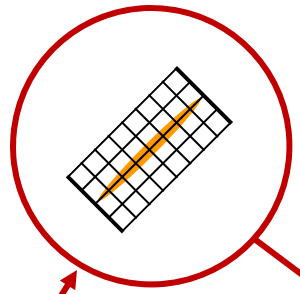




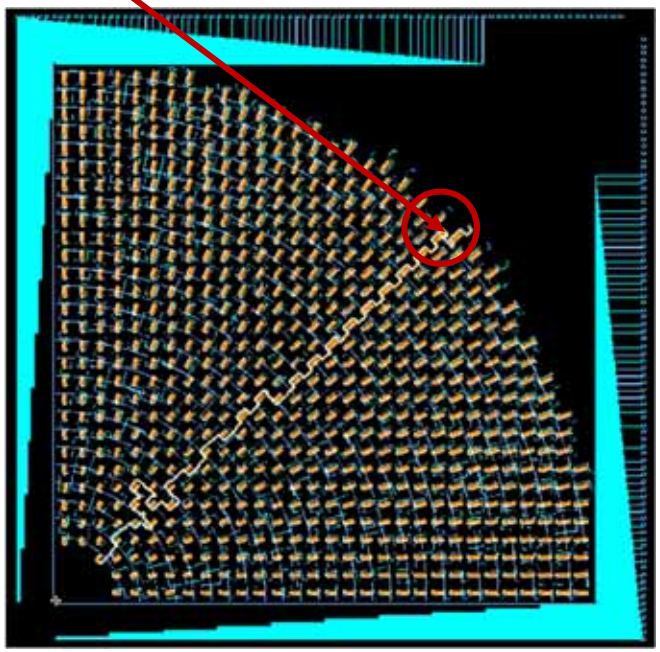
"Polar Coordinate" CCD Array for Wavefront Sensing with Elongated Laser Guidestars

Fewer illuminated pixels reduces pixel read rates and readout noise



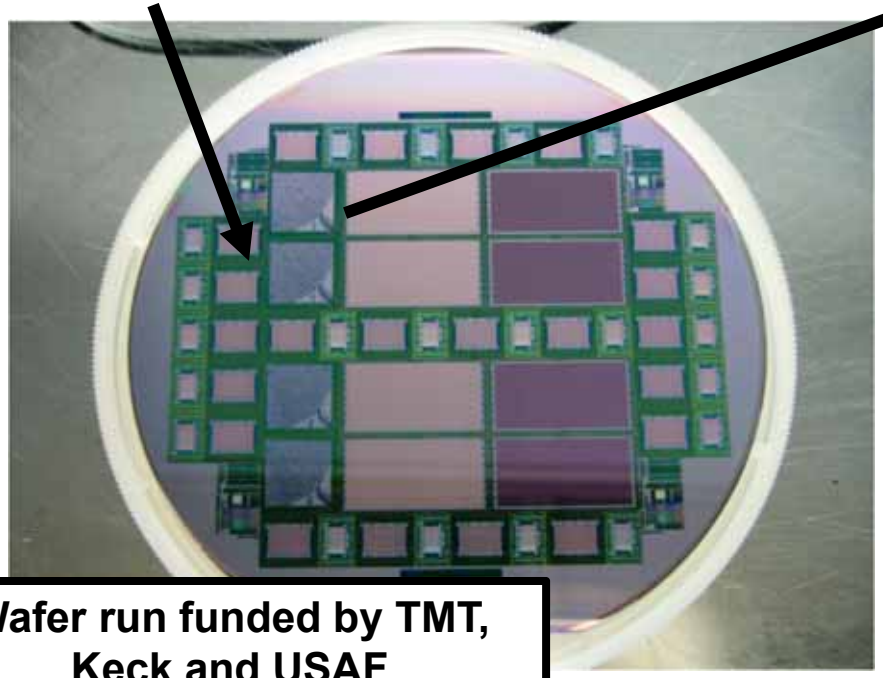


MIT/LL CCD Design

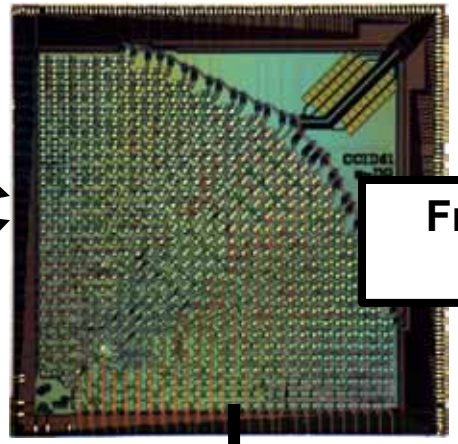


High-Order LGS and NGS Shack Hartmann Wavefront Sensor CCDs

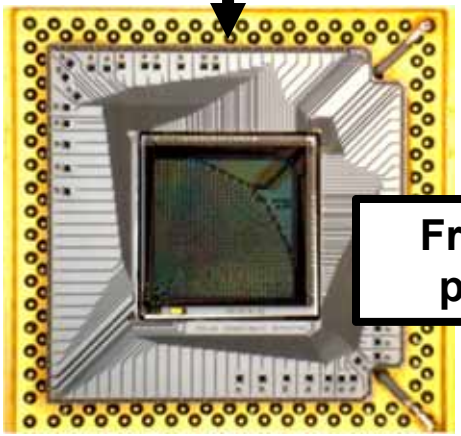
- MIT/LL prototype detectors:
  - Quadrant of polar coordinate LGS WFS detector
  - 256^2 visible NGS WFS CCD



Wafer run funded by TMT, Keck and USAF



Front-side device



Front-side package

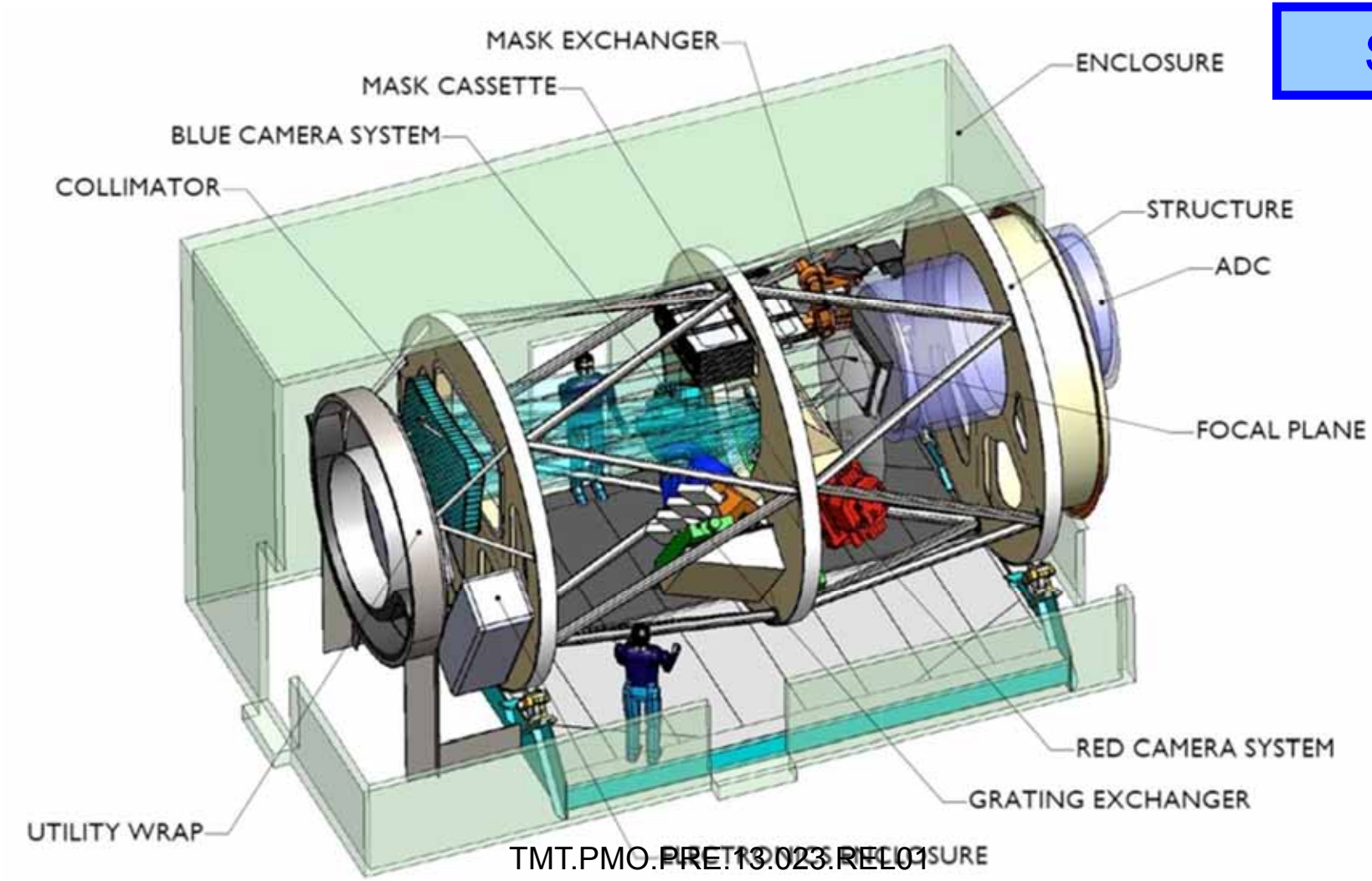
3.5 electrons read noise initial results

TMT **First Light** Instrument Suite

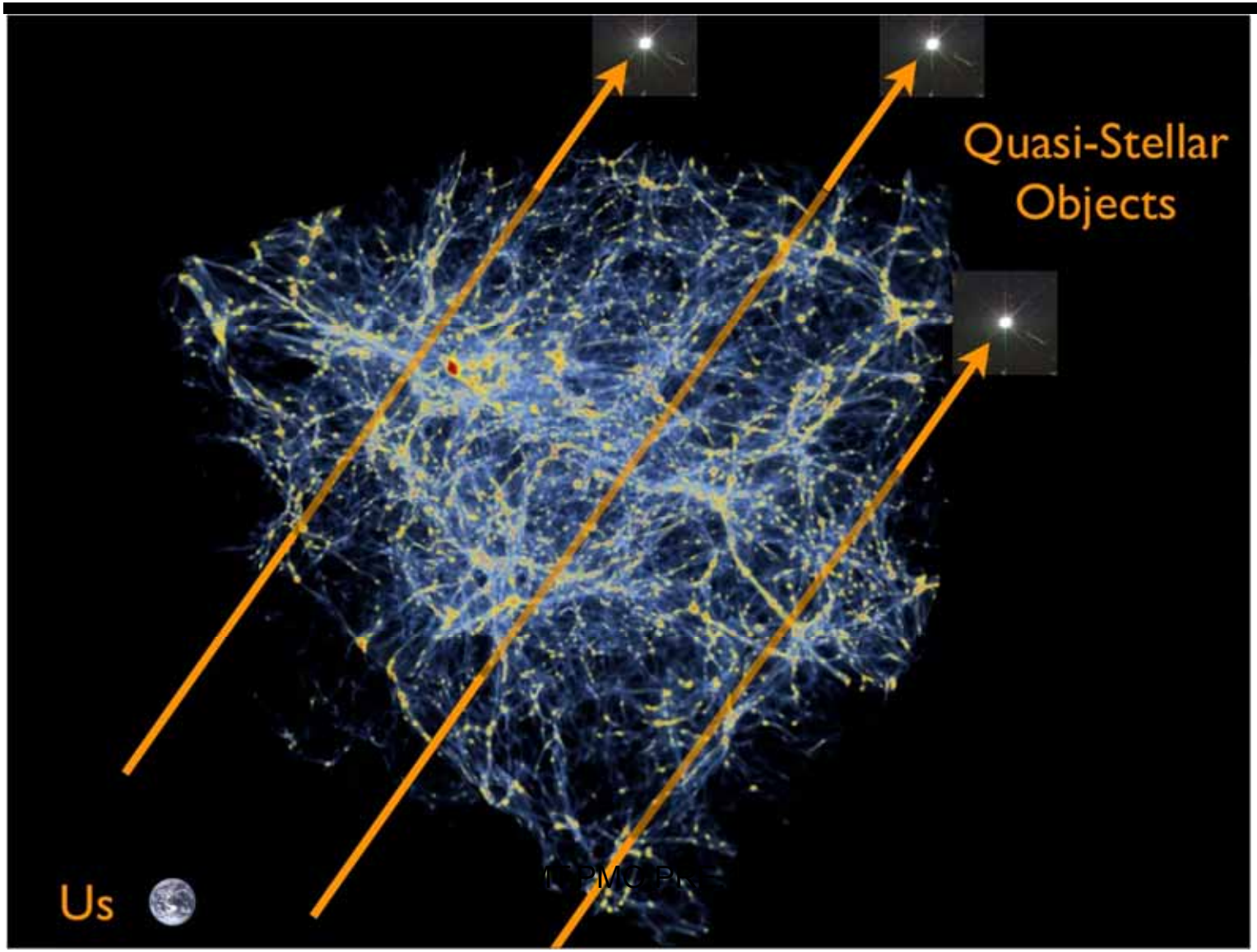
Instrument	λ (μm)	Field of view/ Slit length	Spectral resolution	Science Cases
InfraRed Imager and Spectrometer (IRIS)	0.8 – 2.5 0.6 – 5 (goal)	<3″ IFU >15″imaging	> 3500 5-100 (imaging)	• Assembly of galaxies at high z • Black holes/AGNs/Galactic Center • Resolved stellar populations in crowded fields
Wide-field Optical spectrometer and imager (WFOS)	0.31 – 1.0	>40 arcmin^2 >100 arcmin^2 (goal) Slit length>500″	1000-5000@0.75″ slit >7500 @0.75″ (goal)	• IGM structure and composition at 2 < z < 6 • Stellar populations, chemistry and energetics of z > 1.5 galaxies
InfraRed Multislit Spectrometer (IRMS)	0.95 – 2.45	2 arcmin field, up to 120″ total slit length with 46 deployable slits	R=4660 @ 0.16 arcsec slit	• Early Light • Epoch of peak galaxy building • JWST follow-ups
Deployable, multi-IFU, near-IR spectrometer (IRMOS)	0.8 – 2.5	3″ IFUs over >5′ diameter field	2000-10000	• Early Light • Epoch of peak galaxy building • JWST follow-ups
Mid-IR AO-fed Echelle spectrometer (MIRES)	8 – 18 4.5 – 28 (goal)	3″ slit length 10″ imaging	5000-100000	• Origin of stellar masses • Accretion and outflows around protostars • Evolution of gas in protoplanetary disks
Planet Formation Instrument (PFI)	1 – 2.5 1 – 5 (goal)	1″ outer working angle, 0″.05 inner working angle	R≤100	• 10^8 contrast ratio (10^9 goal) • Direct detection and spectroscopic characterization of exoplanets
Near-IR AO-fed echelle spectrometer (NIRES)	1 - 5	2″ slit length	20000-100000	• IGM at z > 7, gamma-ray bursts • Local Group abundances • Abundances, chemistry and kinematics of stars and planet-forming disks • Doppler detection of terrestrial planets around low-mass stars
High-Resolution Optical Spectrometer (HROS)	0.31 – 1.1	5″ slit length	50000	• Doppler searches for exoplanets • Stellar abundance studies in Local Group • ISM abundance/kinematics • IGM characteristics to z~6
"Wide"-field AO imager (WIRC)	0.8 – 5.0	30″ imaging field	5-100	• Precision astrometry (e.g., Galactic Center) • Resolved stellar populations out to 10 Mpc

MOBIE Schematic View

SL



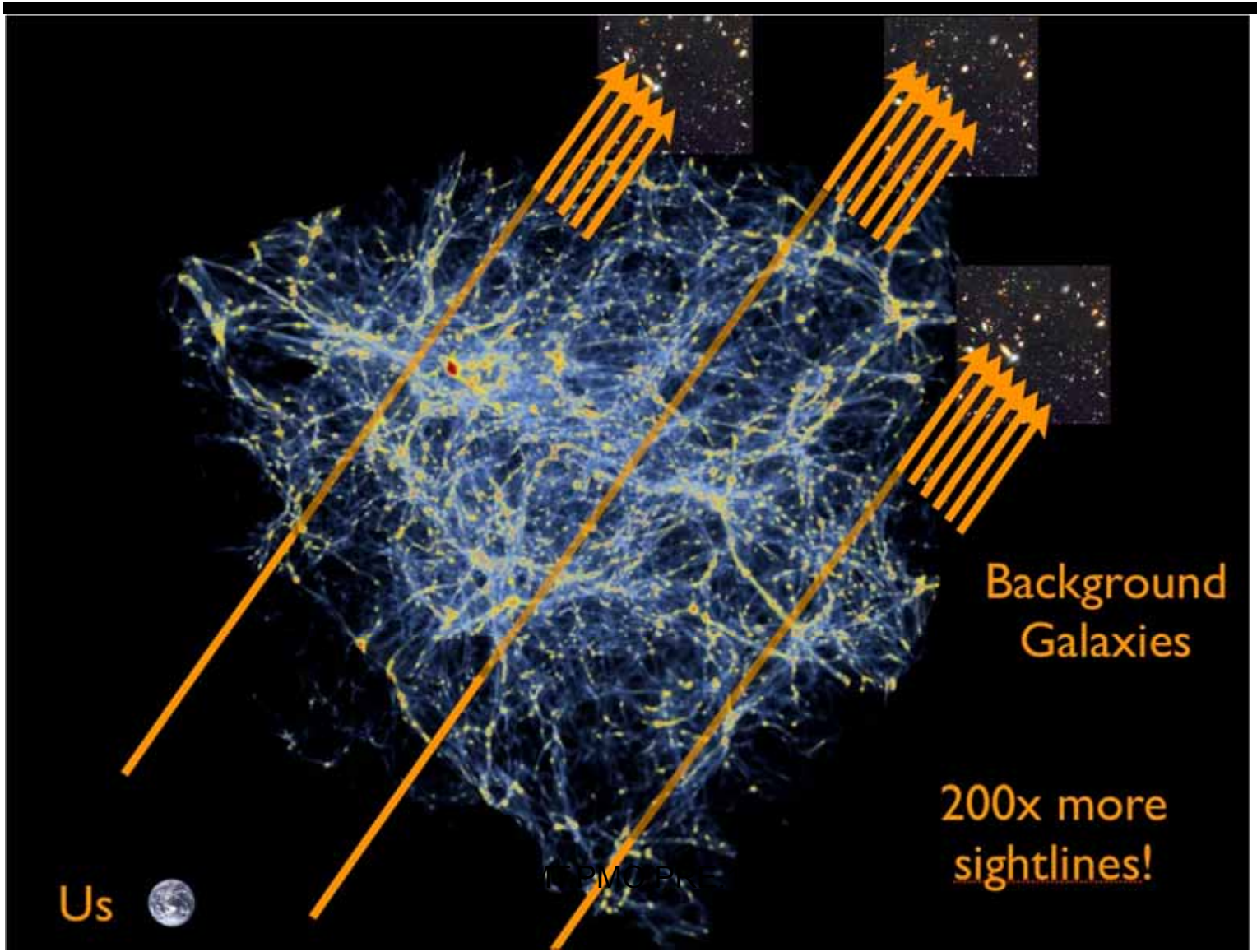
Inter-Galactic Medium Tomography: Now



SL

(Simulation: M. Norman, UCSD)

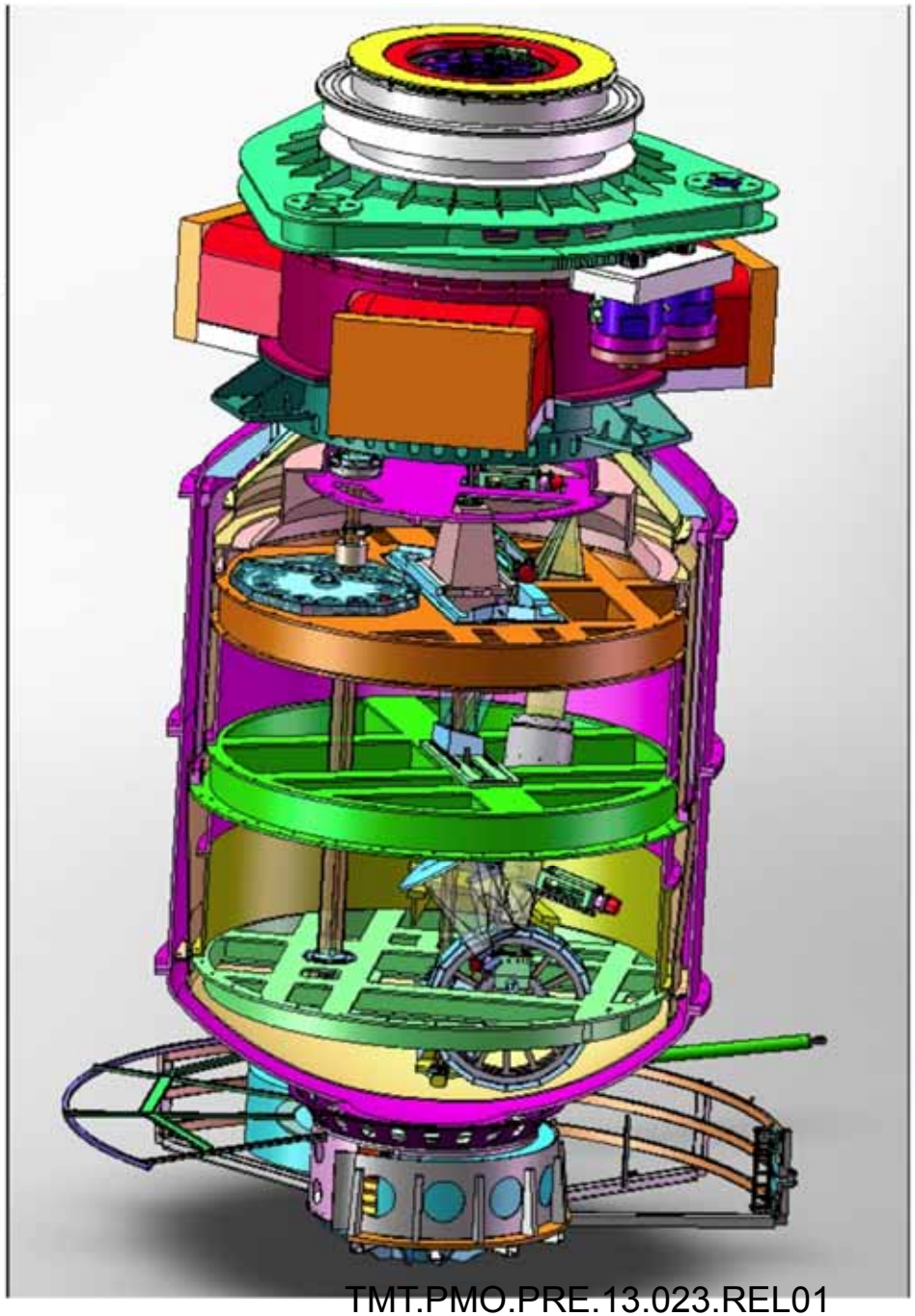
Inter-Galactic Medium Tomography: TMT



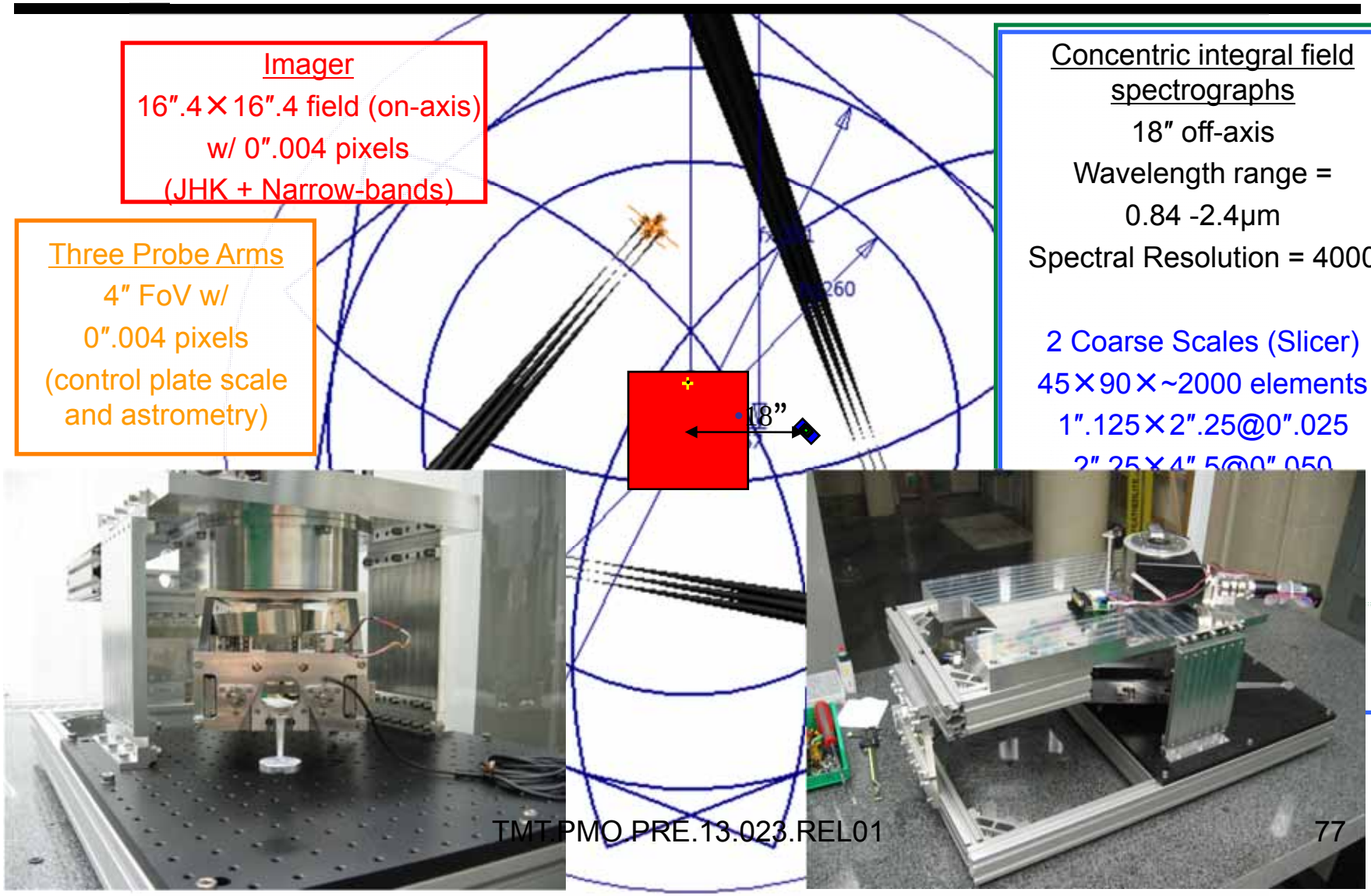
SL

(Simulation: M. Norman, UCSD)

IRIS Solidworks Model



The IRIS Focal Plane: Imager + 2 IFUs + 3 Guide Stars



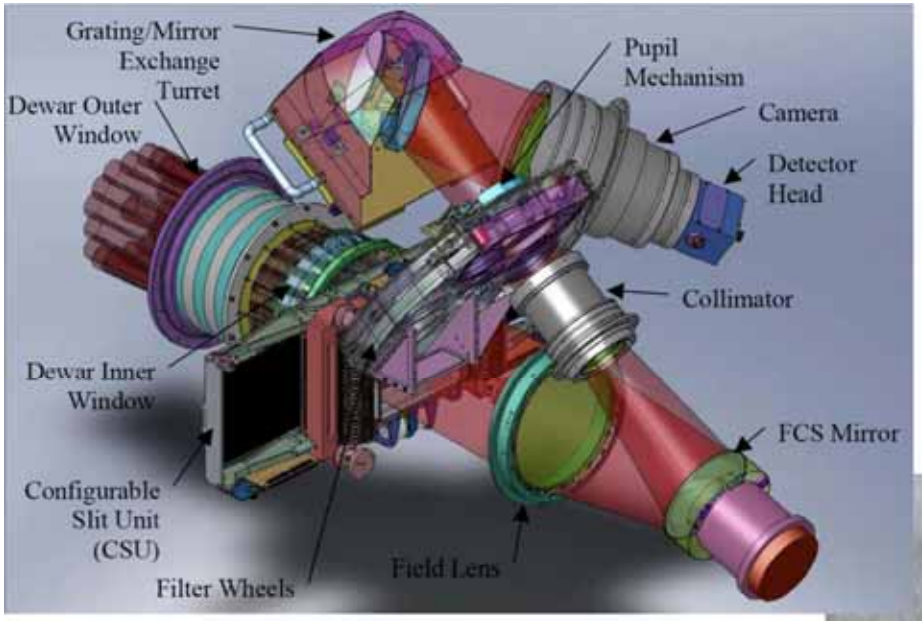
Imager
16″.4×16″.4 field (on-axis)
w/ 0″.004 pixels
(JHK + Narrow-bands)

Three Probe Arms
4″ FoV w/
0″.004 pixels
(control plate scale and astrometry)

Concentric integral field spectrographs
18″ off-axis
Wavelength range = 0.84 -2.4μm
Spectral Resolution = 4000

2 Coarse Scales (Slicer)
45×90×~2000 elements
1″.125×2″.25@0″.025
2″.25×4″.5@0″.050

InfraRed Multi-slit Spectrometer (IRMS)



TMT/IRMS

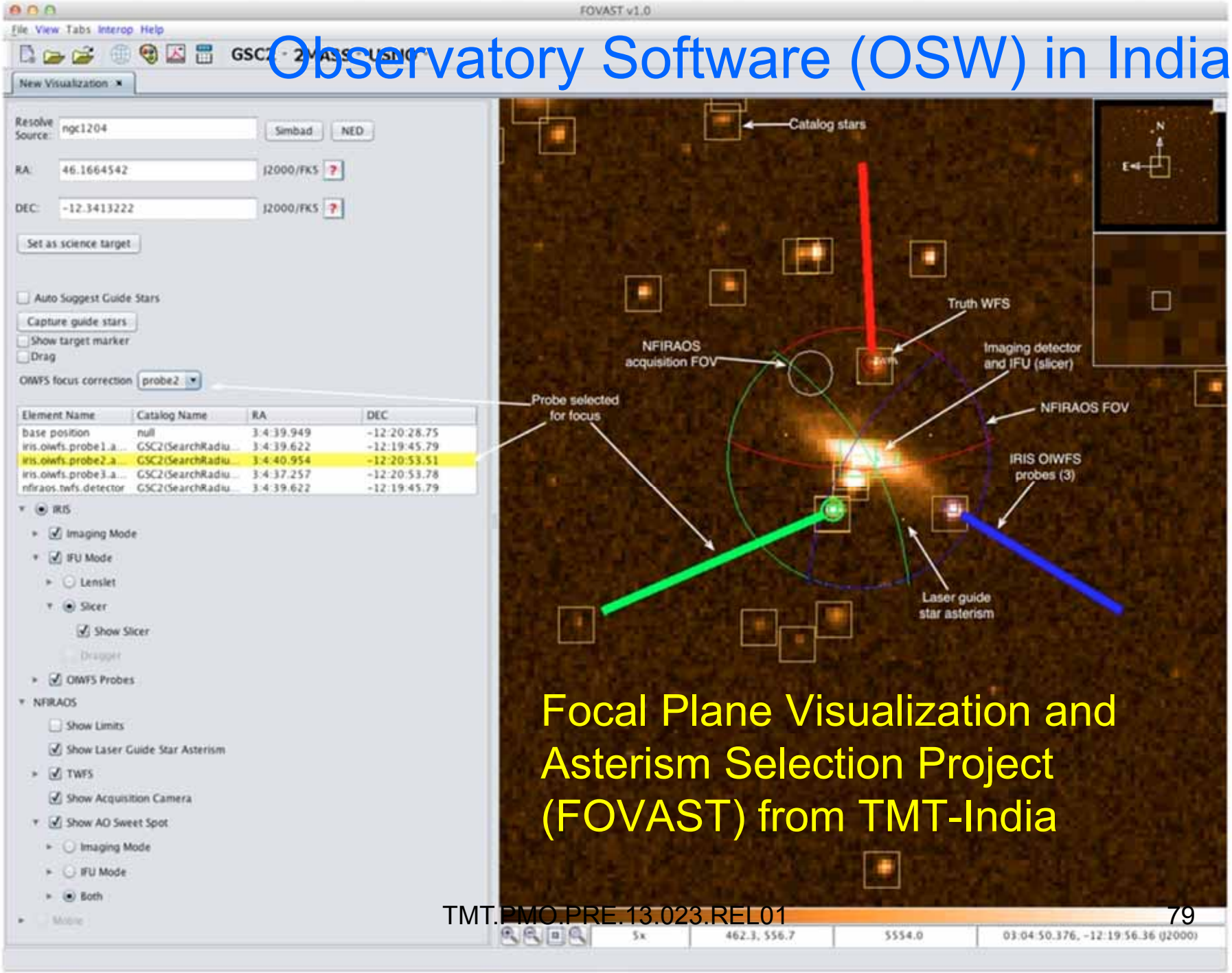
=

Keck/MOSFIRE clone!

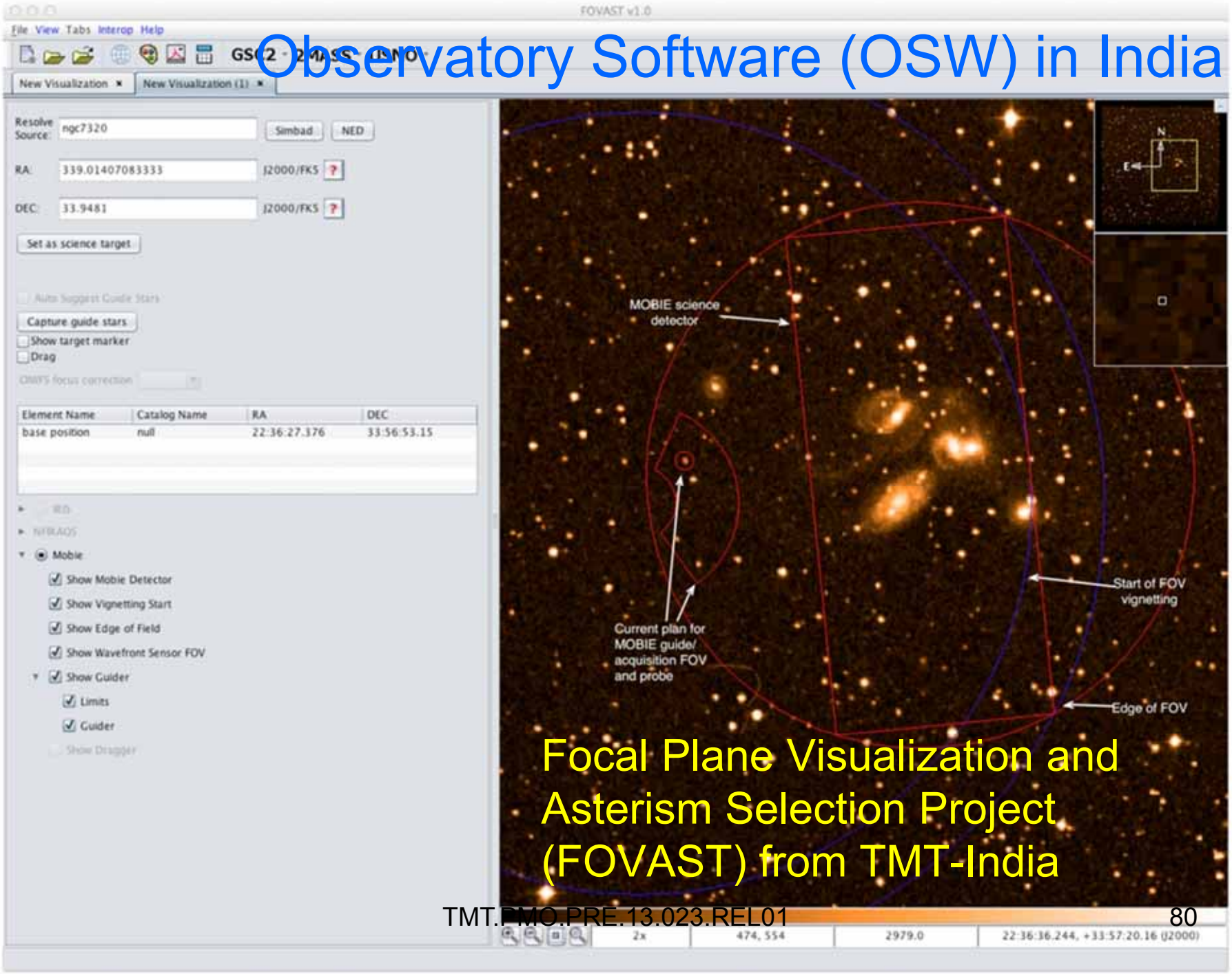
Keck, February 2012

MOSFIRE on-sky commission very successful

Observatory Software (OSW) in India



Observatory Software (OSW) in India



Focal Plane Visualization and Asterism Selection Project (FOVAST) from TMT-India

Public Participation in Permitting TMT in Hawaii

Democracy is hard work!

TMT CDUP Contested Case hearings August 2011

TMT

VIDEO: MKMB OK on TMT » Big Island Video News - Windows Internet Explorer

http://www.bigislandvideonews.com/2010/05/20/video-mkmb-ok-on-tmt/

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May 20, 2010 | Hilo, Mauna Kea | 1 Comment

Plan for $1 billion Thirty Meter Telescope on Mauna Kea summit now goes to chancellor

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TMT Takes Step Towards Construction after Approval by the Board of Land and Natural Resources

04.13.2013

Friday marked another important step forward for the future of astronomical discovery and economic opportunity on Hawaii Island. The Hawaiian Board of Land and Natural Resources (BLNR) announced that it has granted a permit to the Thirty Meter Telescope (TMT) project to build and operate the next-generation observatory near the summit of Mauna Kea.

With this approval, the BLNR has recognized TMT's goal of responsible development and environmental stewardship of Mauna Kea in close partnership with local interests. The carefully considered conditions in the permit help ensure the protection of sensitive environments in Hawaii.

"Over the last several years, the TMT project has welcomed the support it has received from all sectors of the Hawaiian community, from education to cultural to business to labor," said Sandra Dawson, TMT's Manager of Hawaii Community Affairs. "We look forward to beginning construction and becoming a neighbor of the outstanding observatories on Mauna Kea."

In February 2011, the BLNR issued a preliminary decision conditioned on the successful conclusion of a contested case. The contested hearings began later that year. The final approval followed a hearing held February 12, 2013 in Hilo, HI. At this time, the BLNR reviewed a report by the hearing officer regarding the contested case.

"We are delighted that the TMT project has now been granted a Conservation District Use Permit," said Edward Stone, the Morrisroe Professor of Physics at the California Institute of

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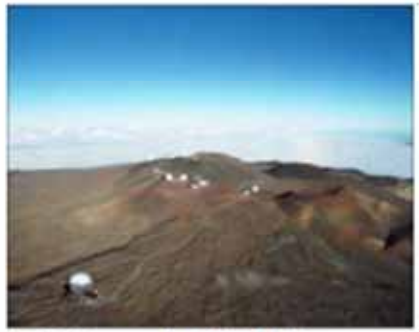
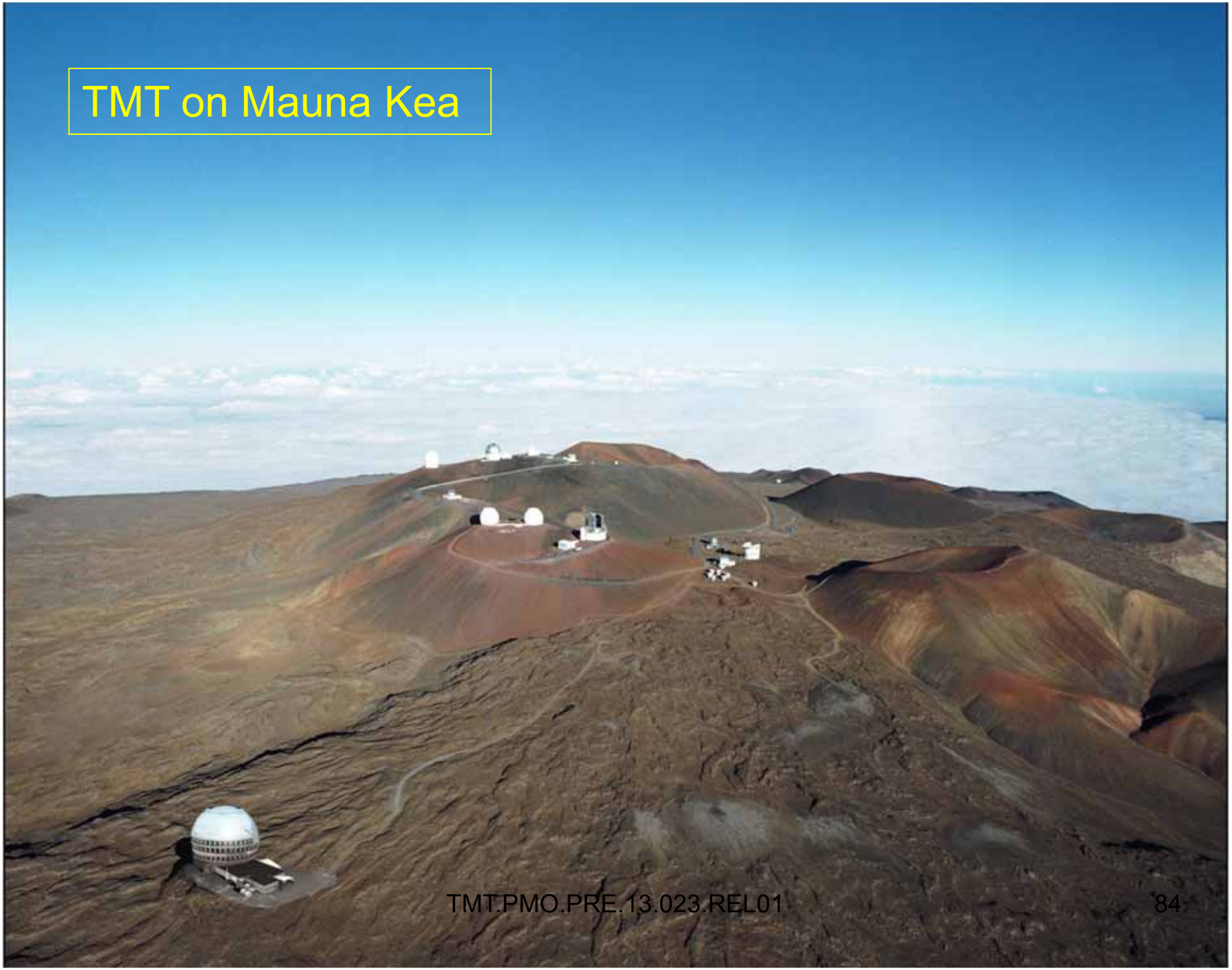
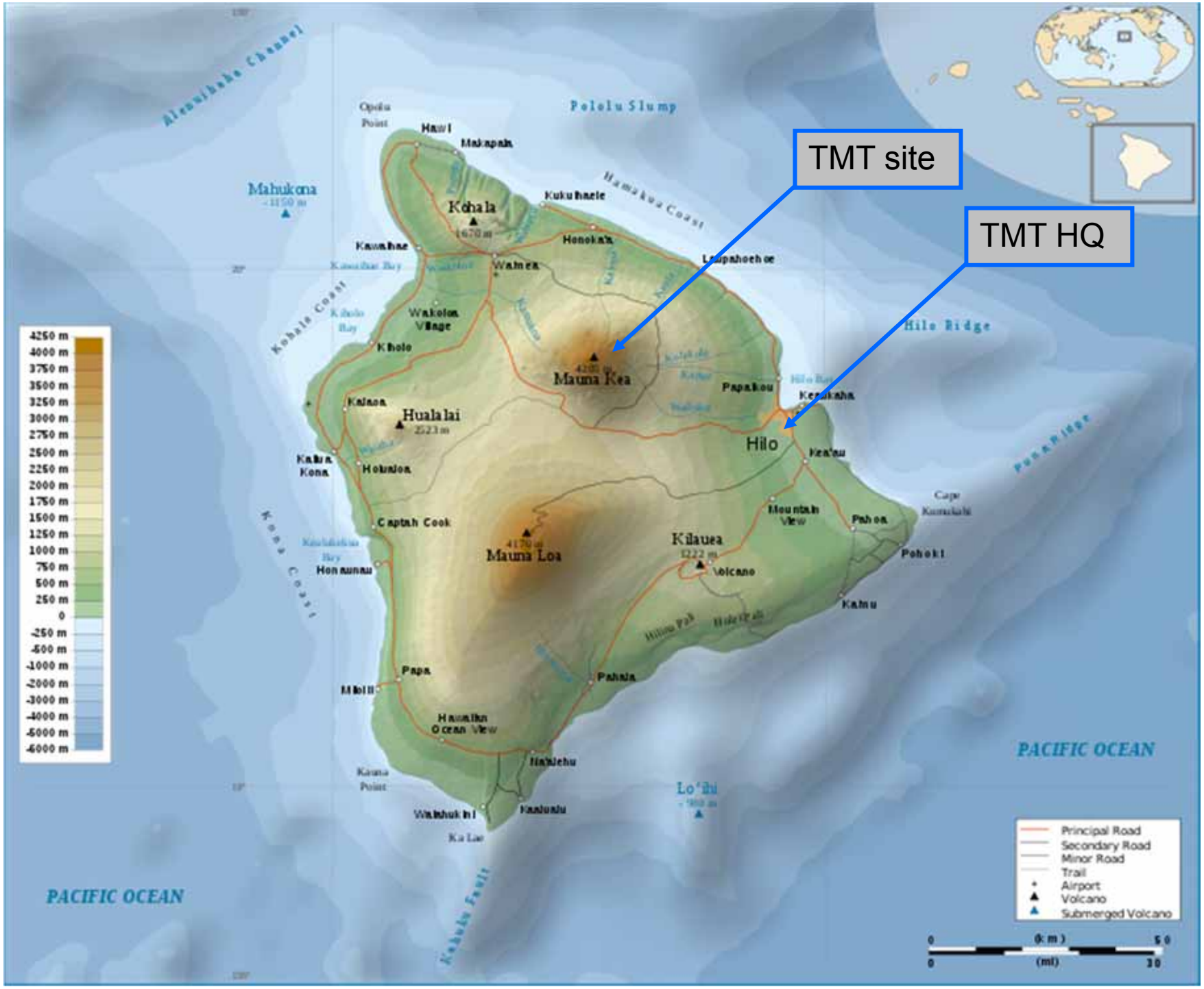
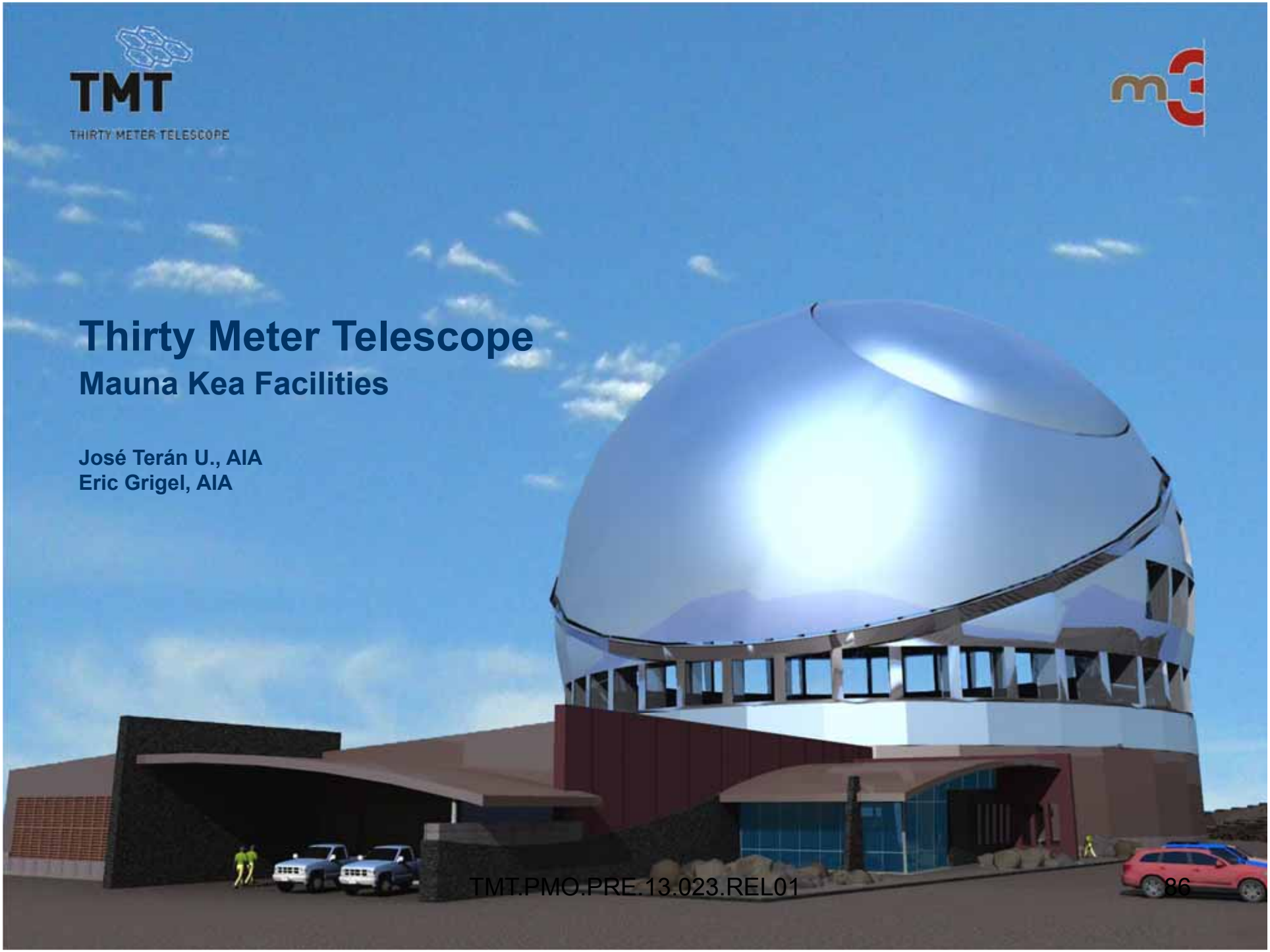


Artist Concept of the TMT Observatory on Mauna Kea
An artist concept illustrating the TMT Observatory at the proposed site on Mauna Kea.

TMT on Mauna Kea




TMT site
TMT HQ
Alenuihaha Channel
Pololu Slump
Opolu Point
Hawi
Makapala
Mahukona
Kohala
Kukuihaele
Hamakua Coast
Honokaa
Laupahoehoe
Kawaihae
Waimea
Kohala Coast
Wakolom Village
Kholo
Mauna Kea
Papaikou
Kealakaha
Hilo Ridge
Kalaoa
Hualalai
Hilo
Kailua Kona
Holualoa
Ka'u
Puna Ridge
Cape Kumukahi
Mountain View
Pahoa
Captain Cook
Mauna Loa
Kilauea
Volcano
Pohoiki
Kona Coast
Honaunau
Kahua
Papa
Milolii
Pahala
Hawaiian Ocean View
Na'alehu
Kaena Point
Lo'ihi
Waiohinu
Kaalualu
Ka Lae
Kahuku Fault
PACIFIC OCEAN
PACIFIC OCEAN
4250 m
4000 m
3750 m
3500 m
3250 m
3000 m
2750 m
2500 m
2250 m
2000 m
1750 m
1500 m
1250 m
1000 m
750 m
500 m
250 m
0
-250 m
-500 m
-1000 m
-2000 m
-3000 m
-4000 m
-5000 m
-6000 m
Principal Road
Secondary Road
Minor Road
Trail
Airport
Volcano
Submerged Volcano
0
(km)
50
0
(mi)
30

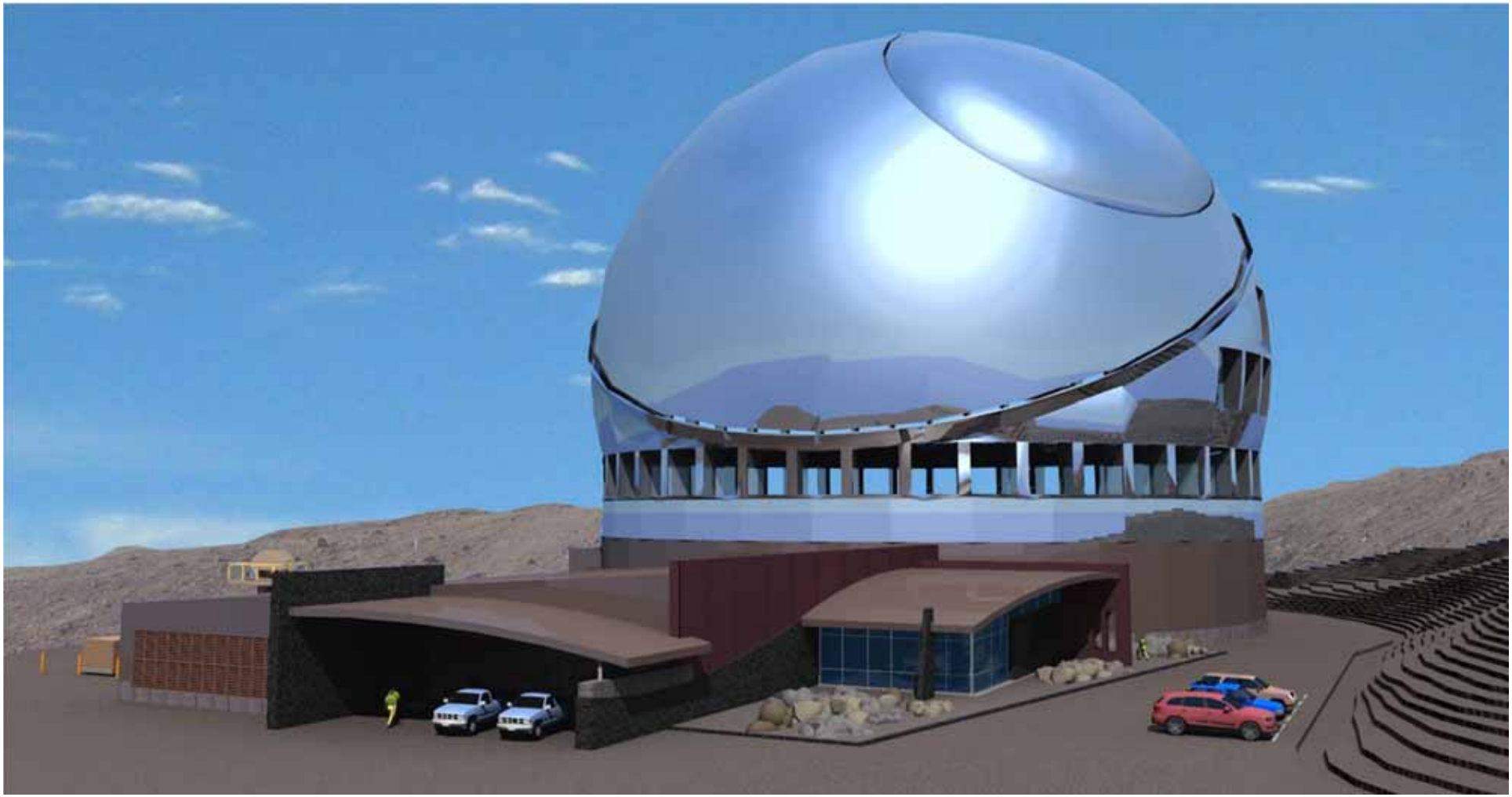


Thirty Meter Telescope

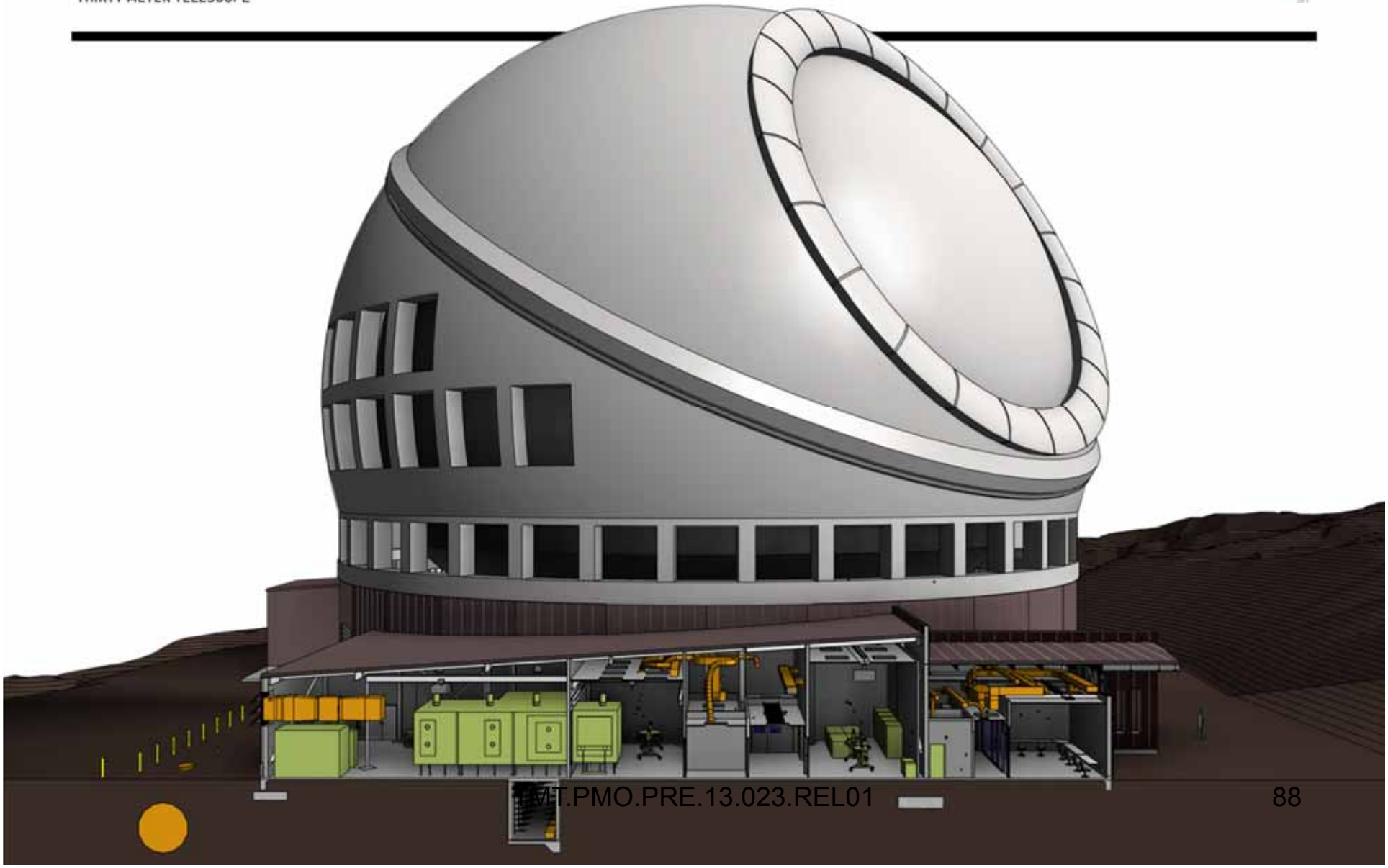
Mauna Kea Facilities

José Terán U., AIA
Eric Grigel, AIA

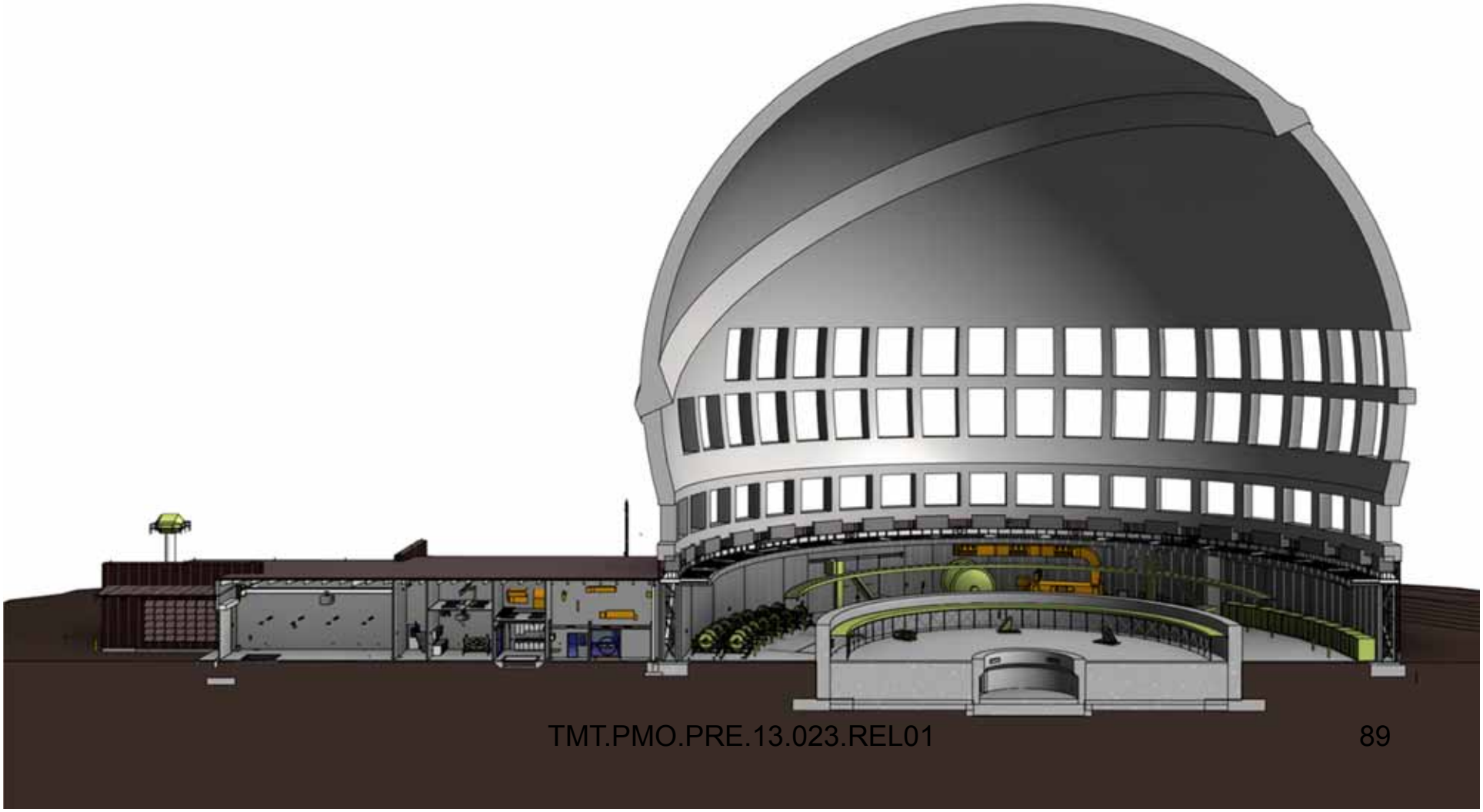
Southwest View

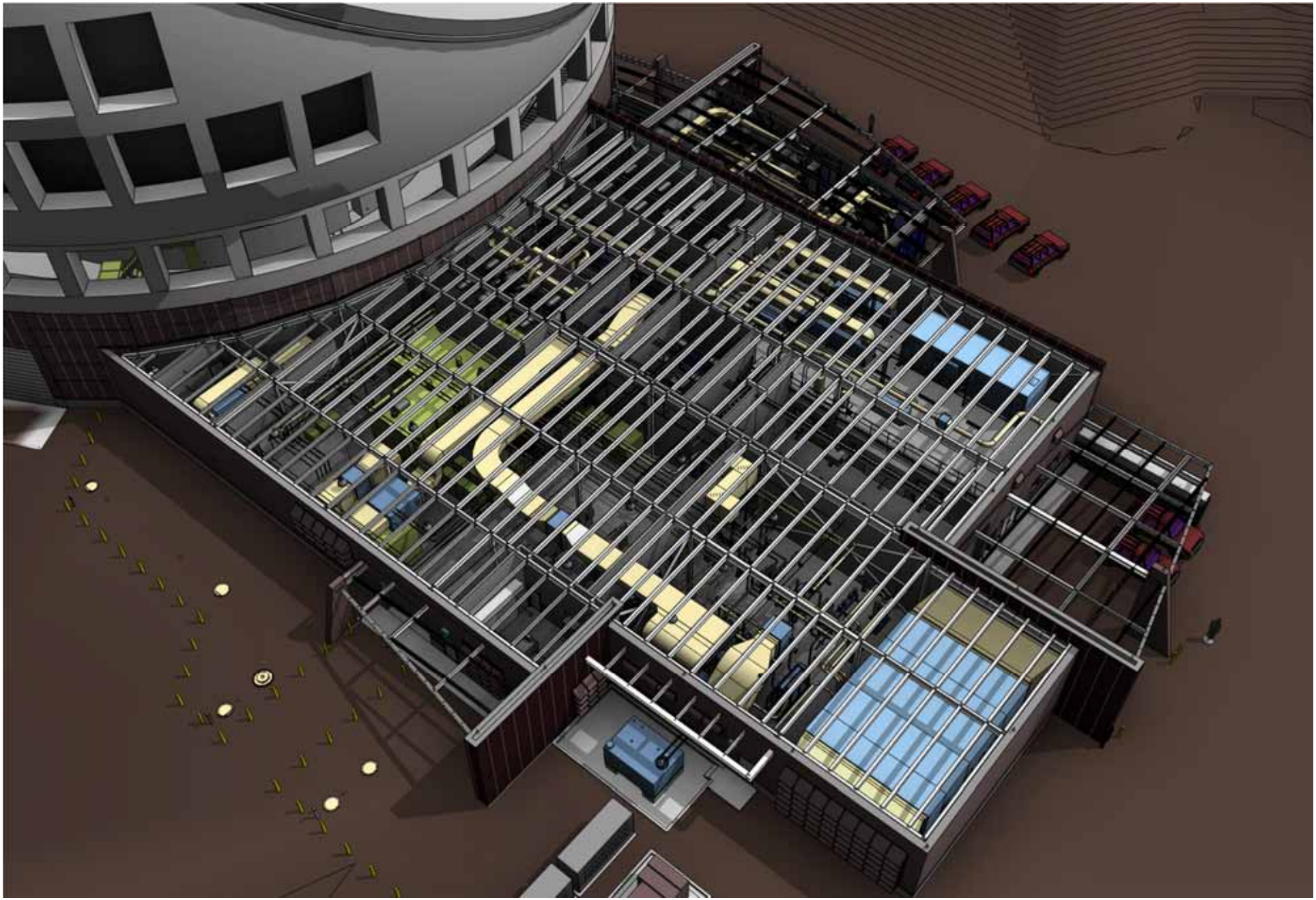


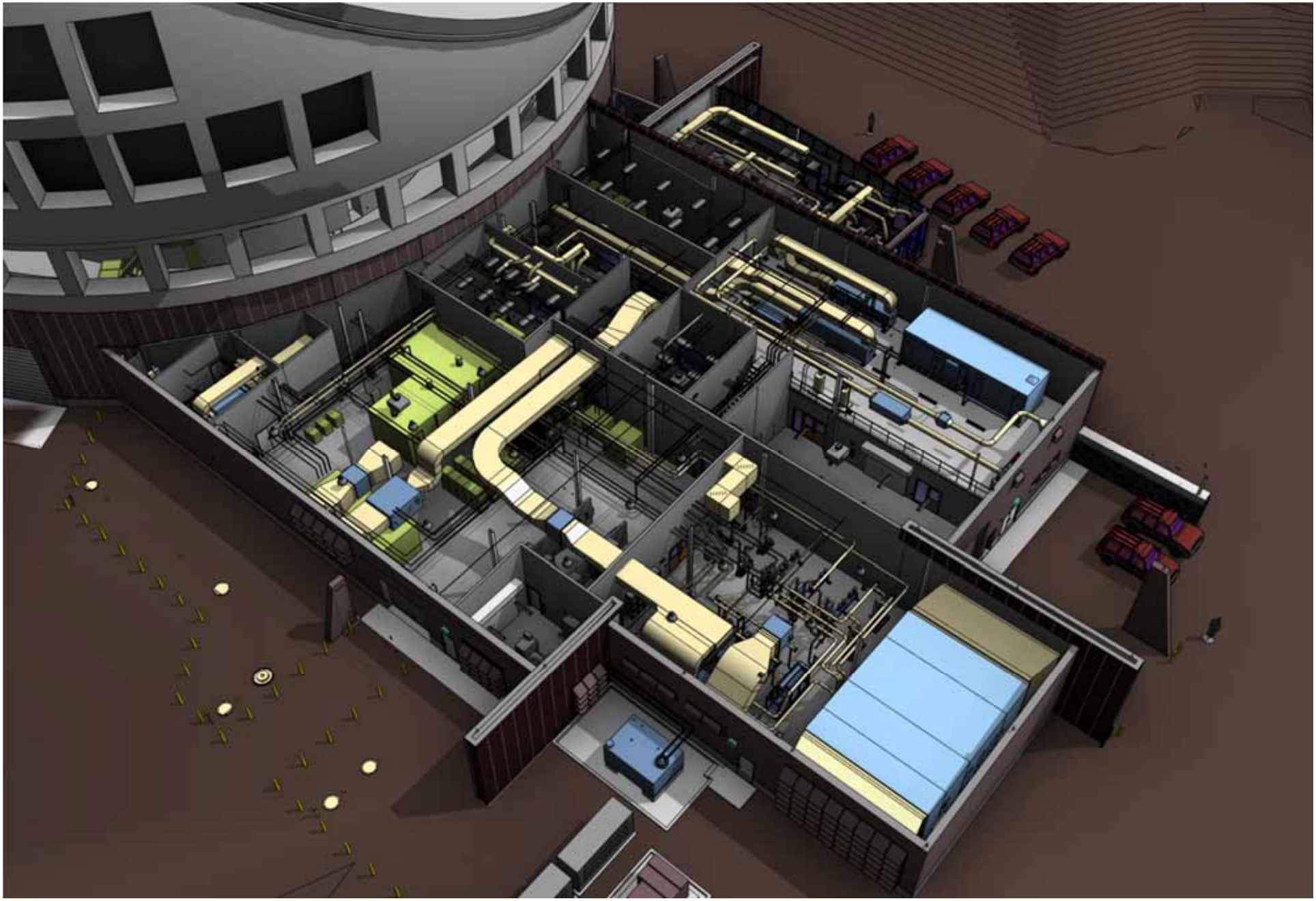
Summit Facility Section



Enclosure Section

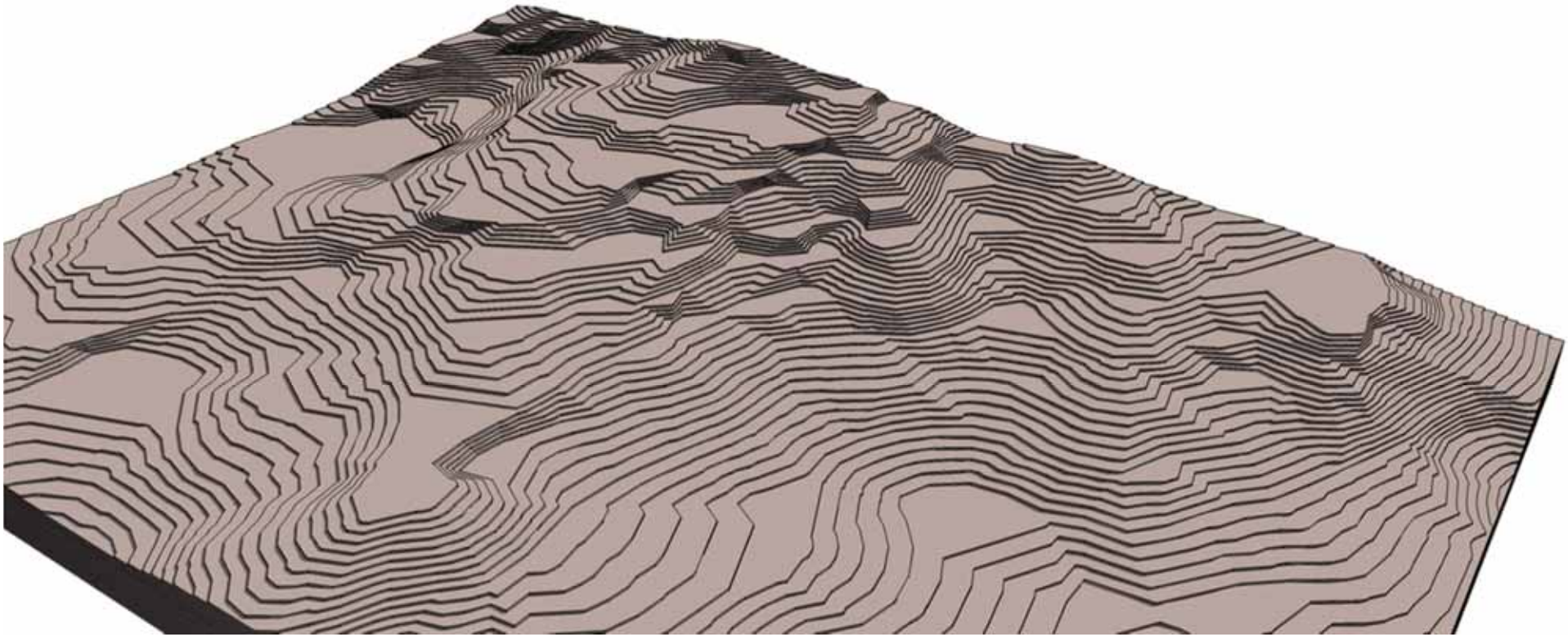






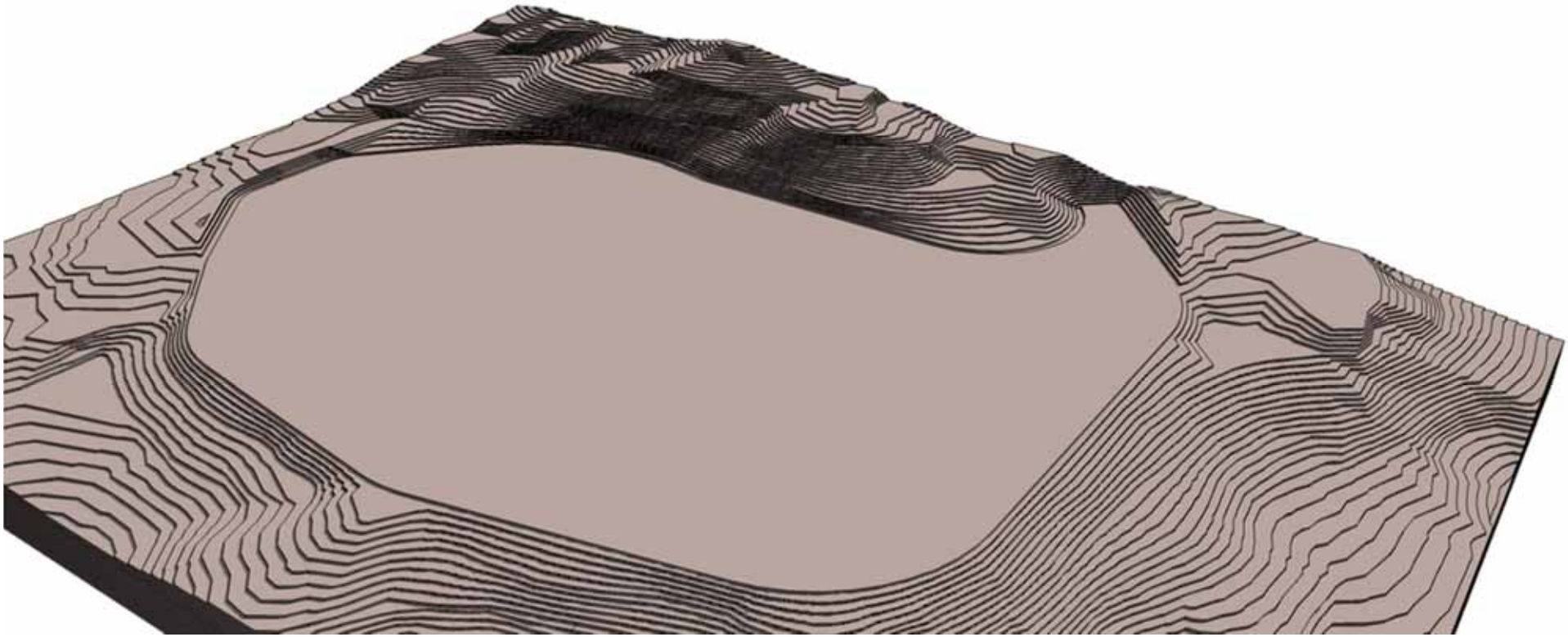
Construction Sequence
Access Road

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



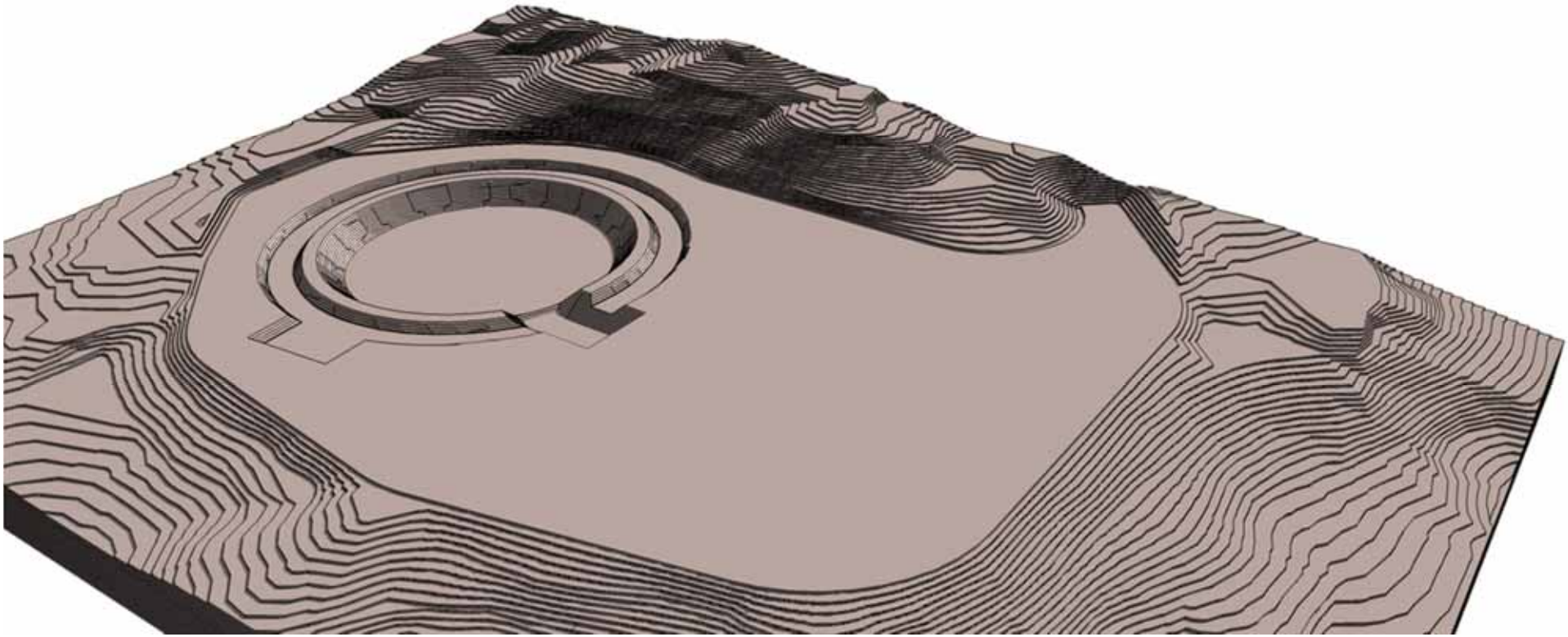
Construction Sequence
Rough Grading

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



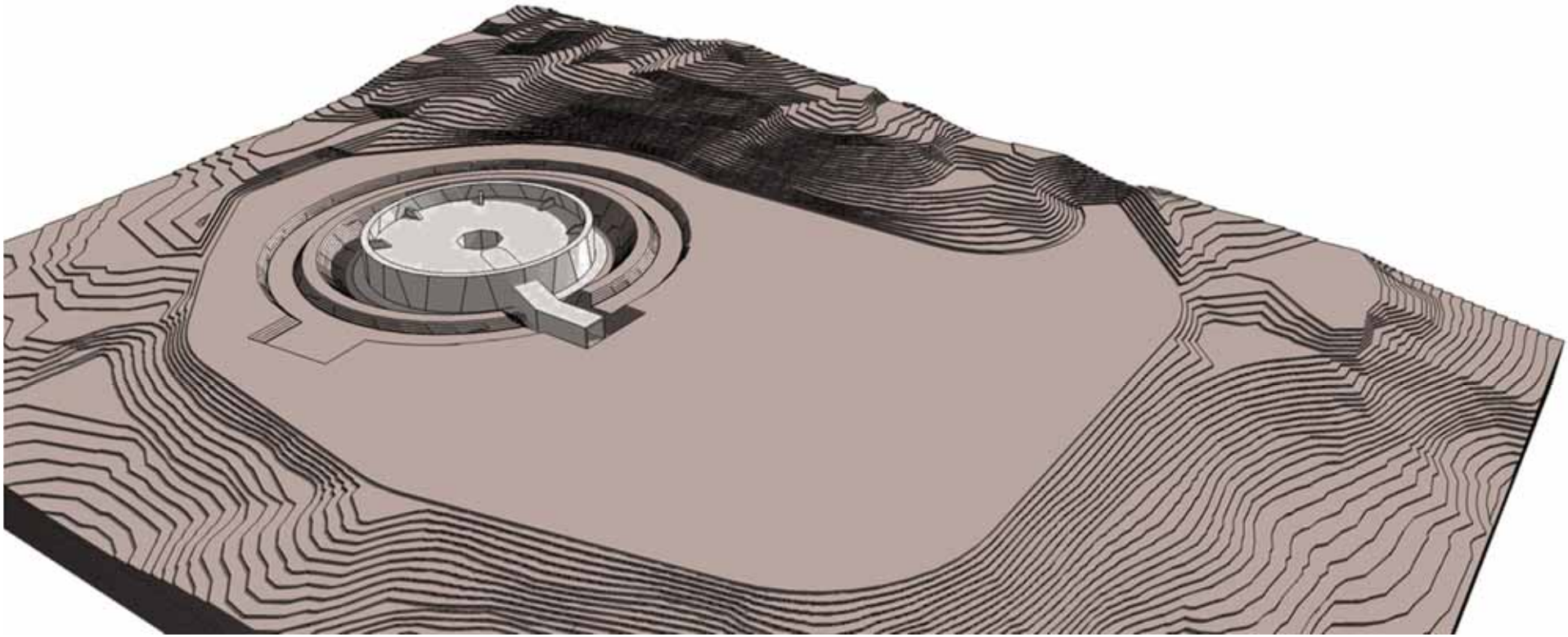
Construction Sequence
Enclosure Excavation & Utilities

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



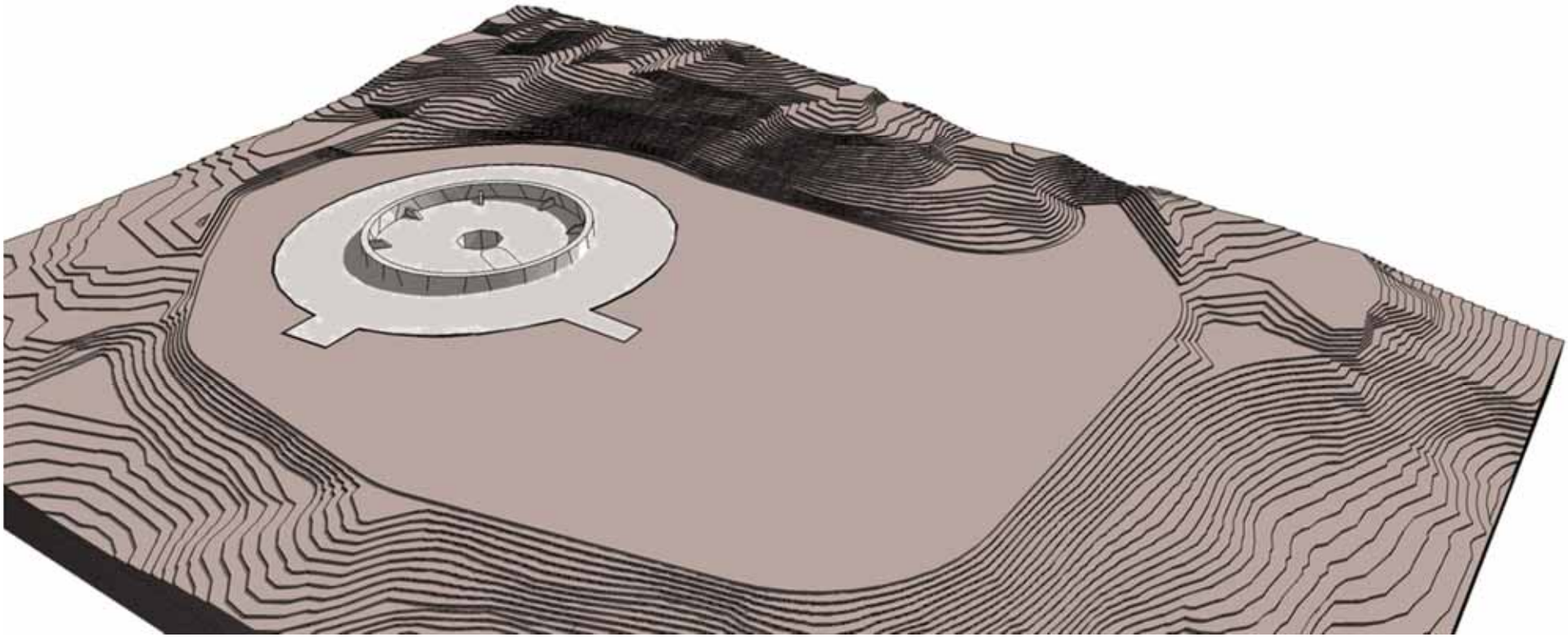
Construction Sequence
Pier and Tunnel Concrete

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



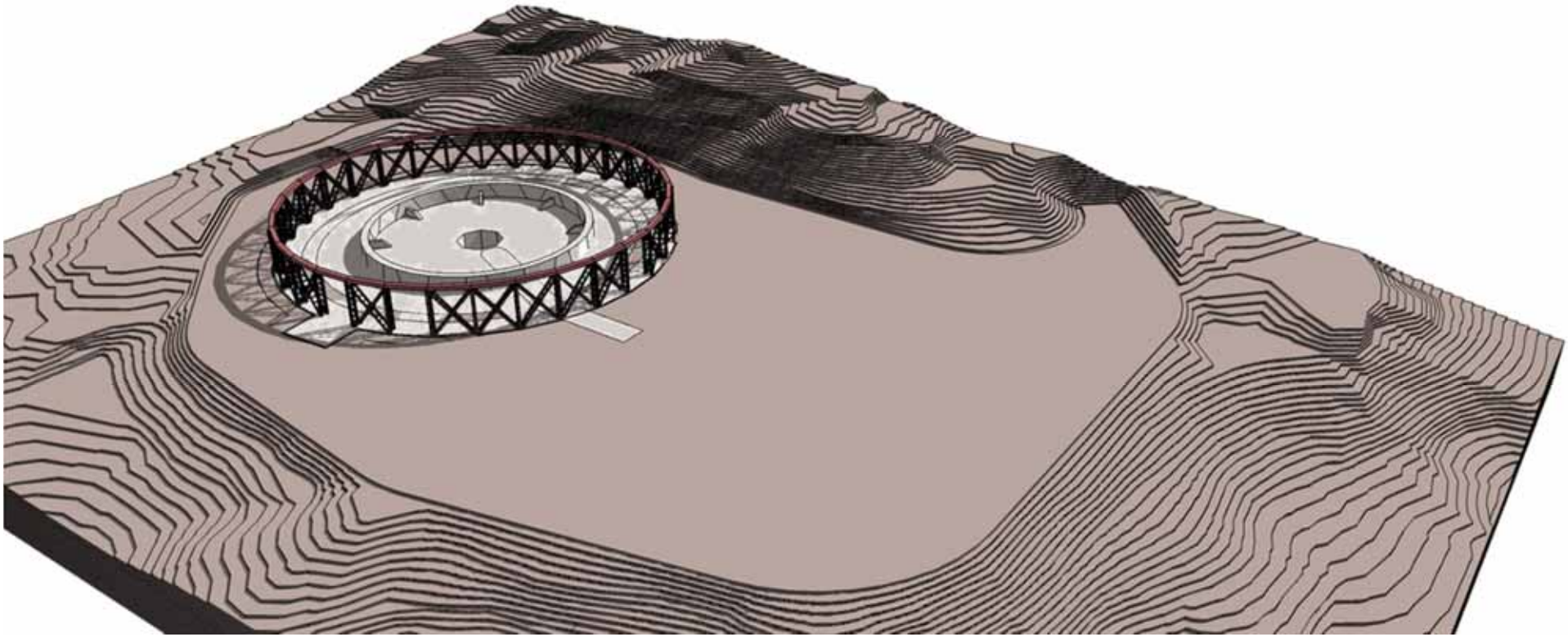
Construction Sequence
Fixed Enclosure Foundation & Slab

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

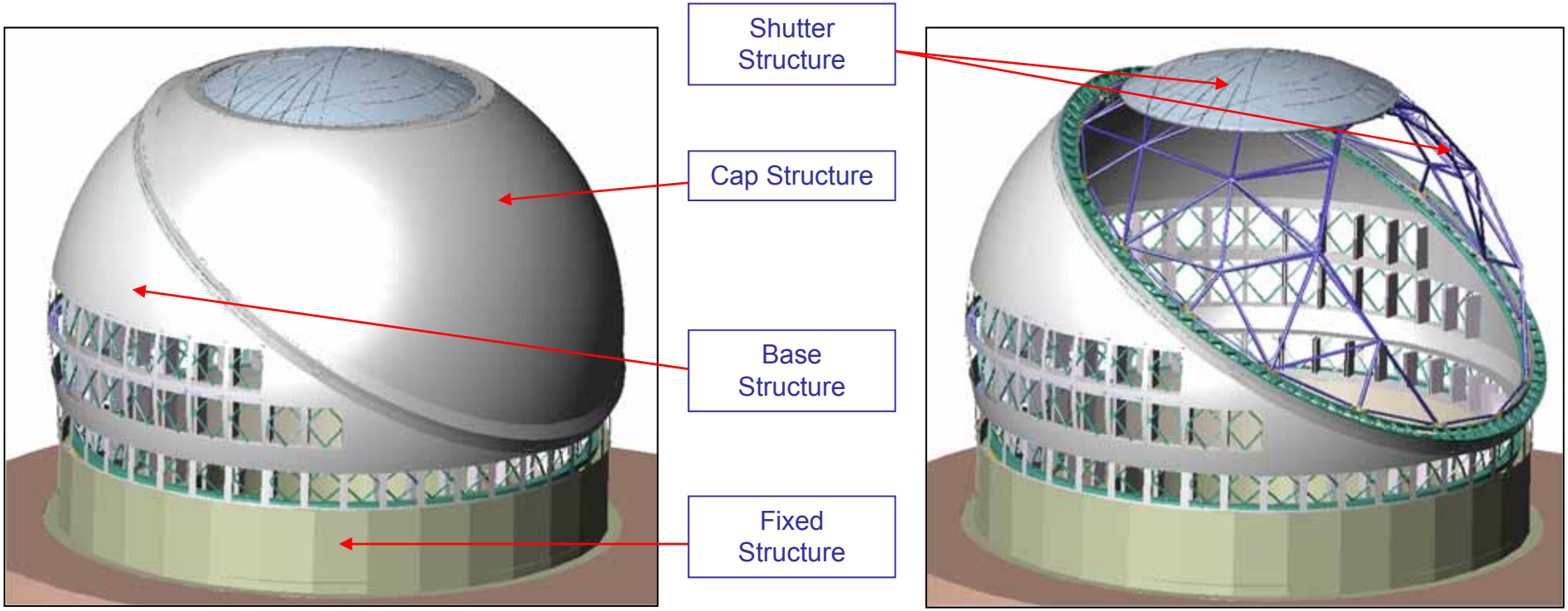


Construction Sequence
Fixed Enclosure Structural Steel

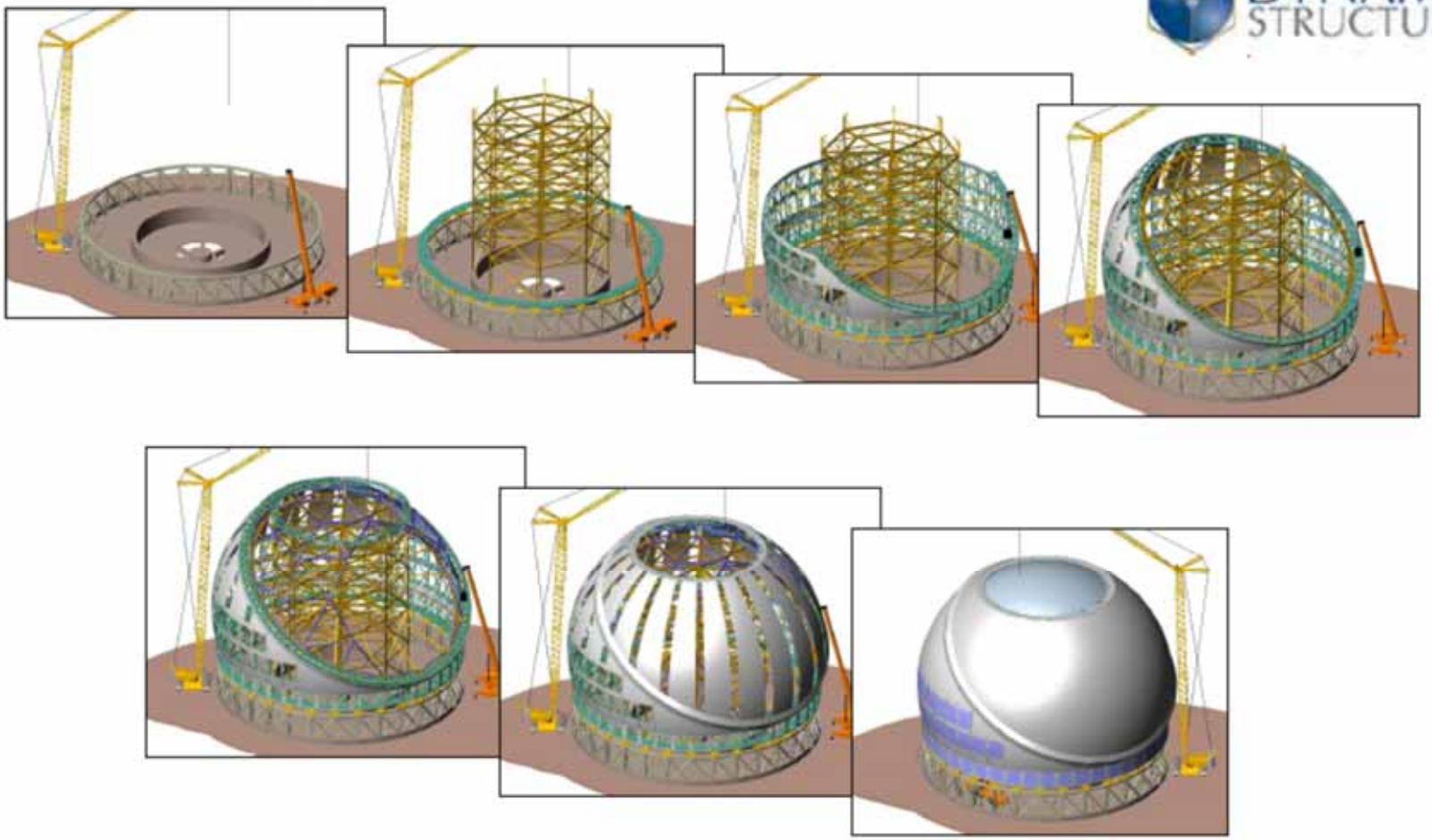
2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



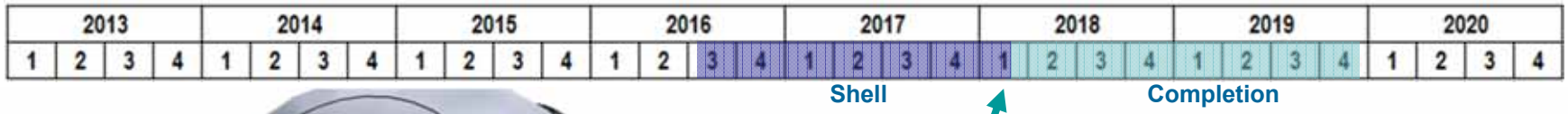
Rotating “Calotte” Enclosure

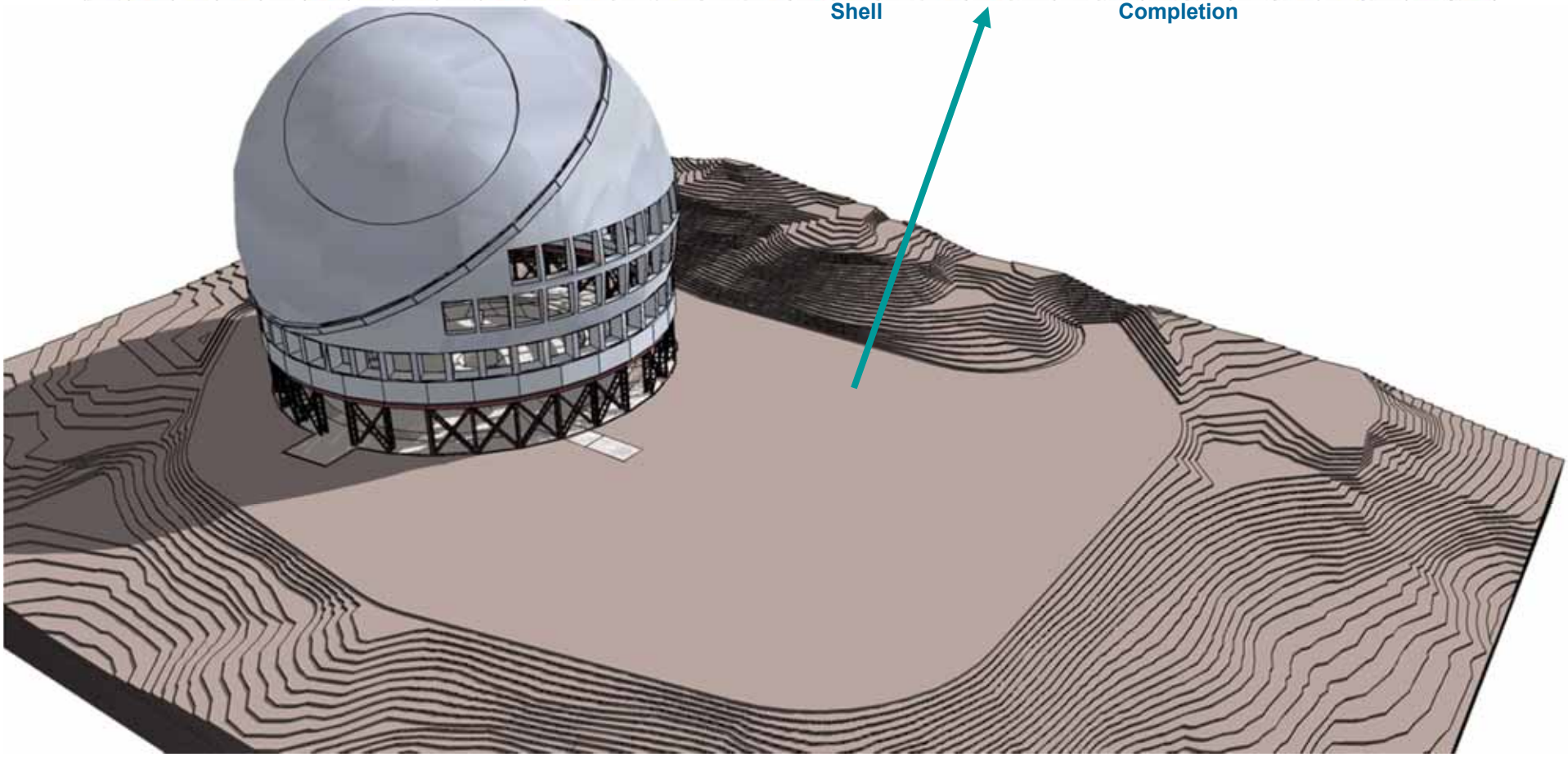


Enclosure Construction Sequence



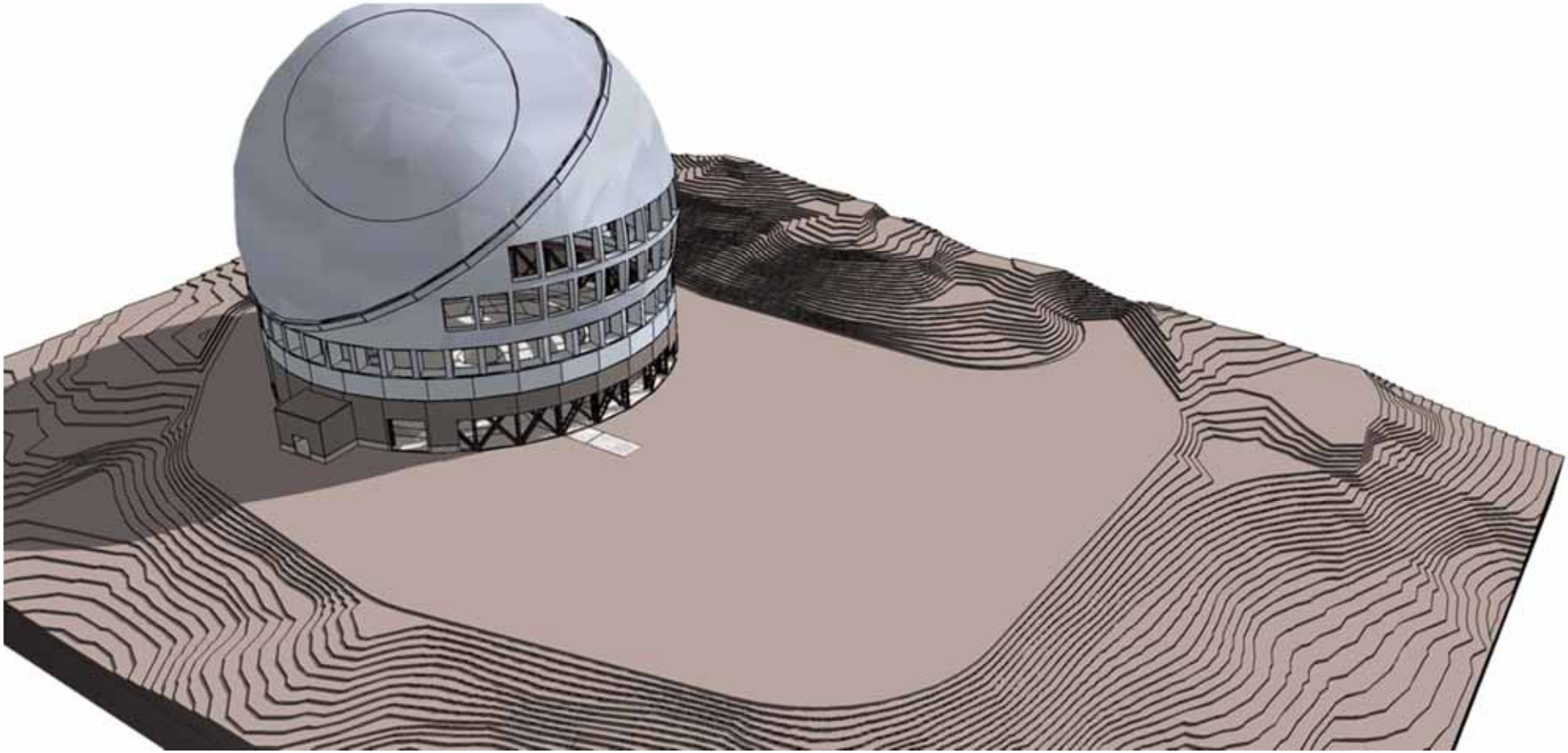
Construction Sequence
Rotating Enclosure Erection





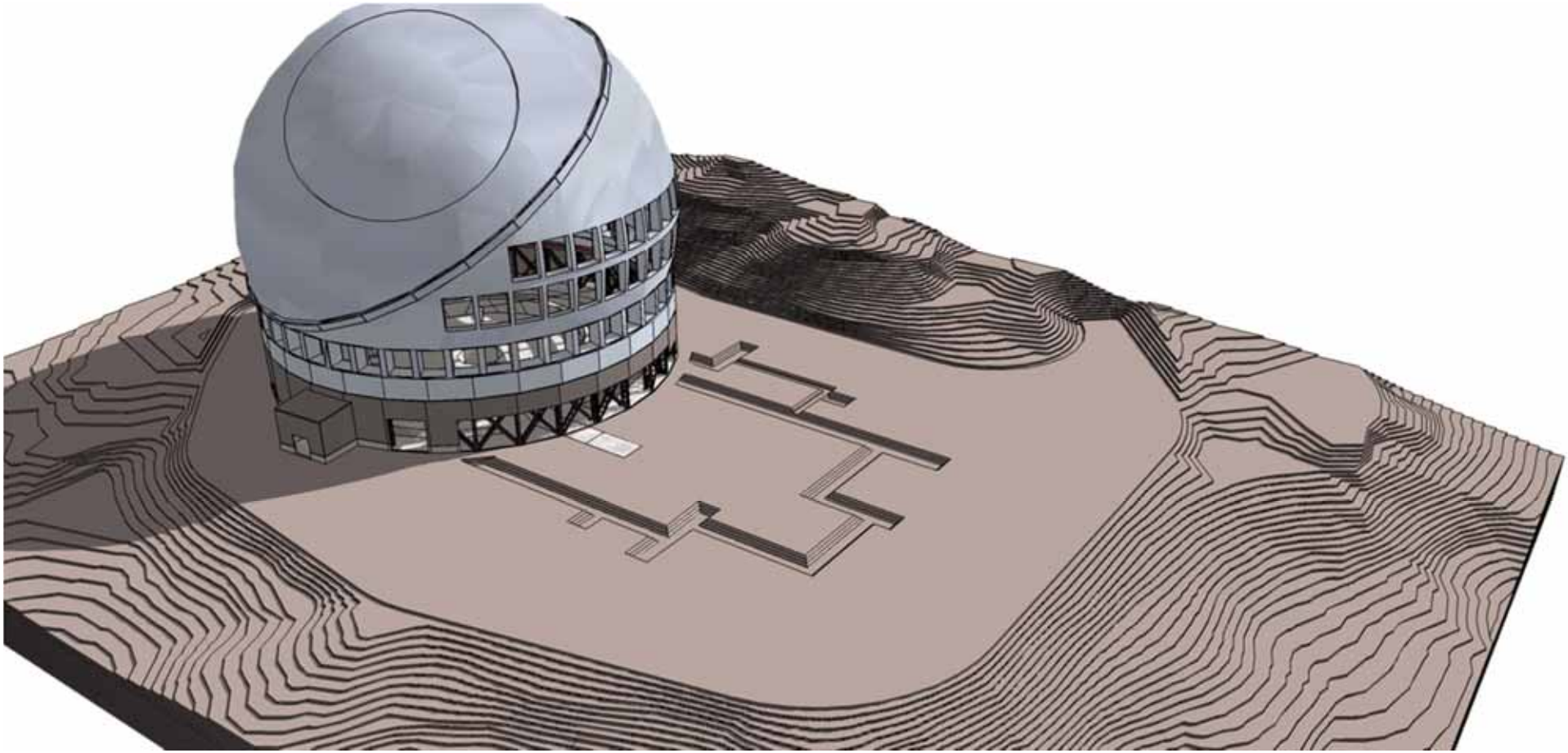
Construction Sequence
Fixed Enclosure Wall Panels

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



Construction Sequence
Facility Excavation

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



Construction Sequence
Facility Foundation

2013				2014				2015				2016				2017				2018				2019				2020			
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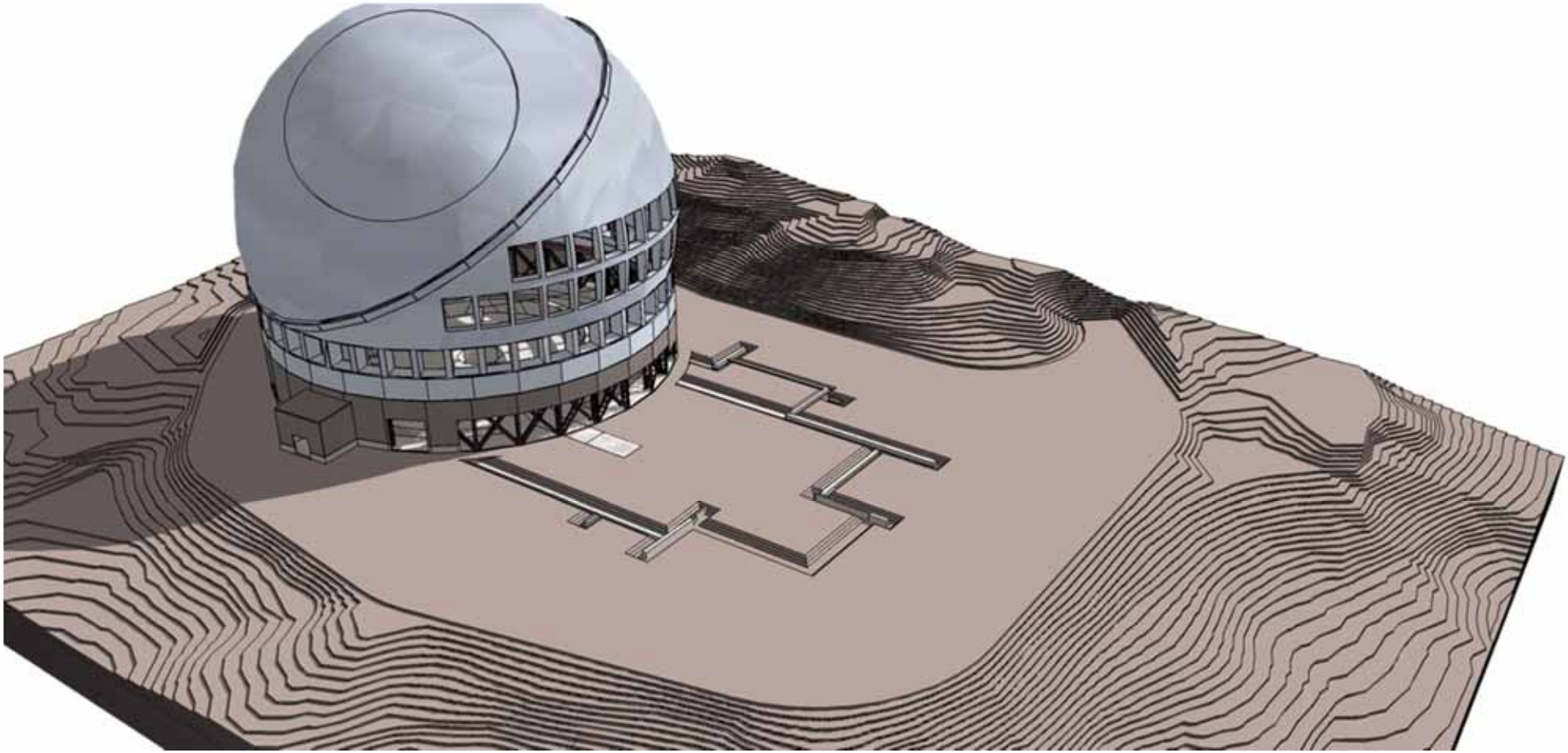
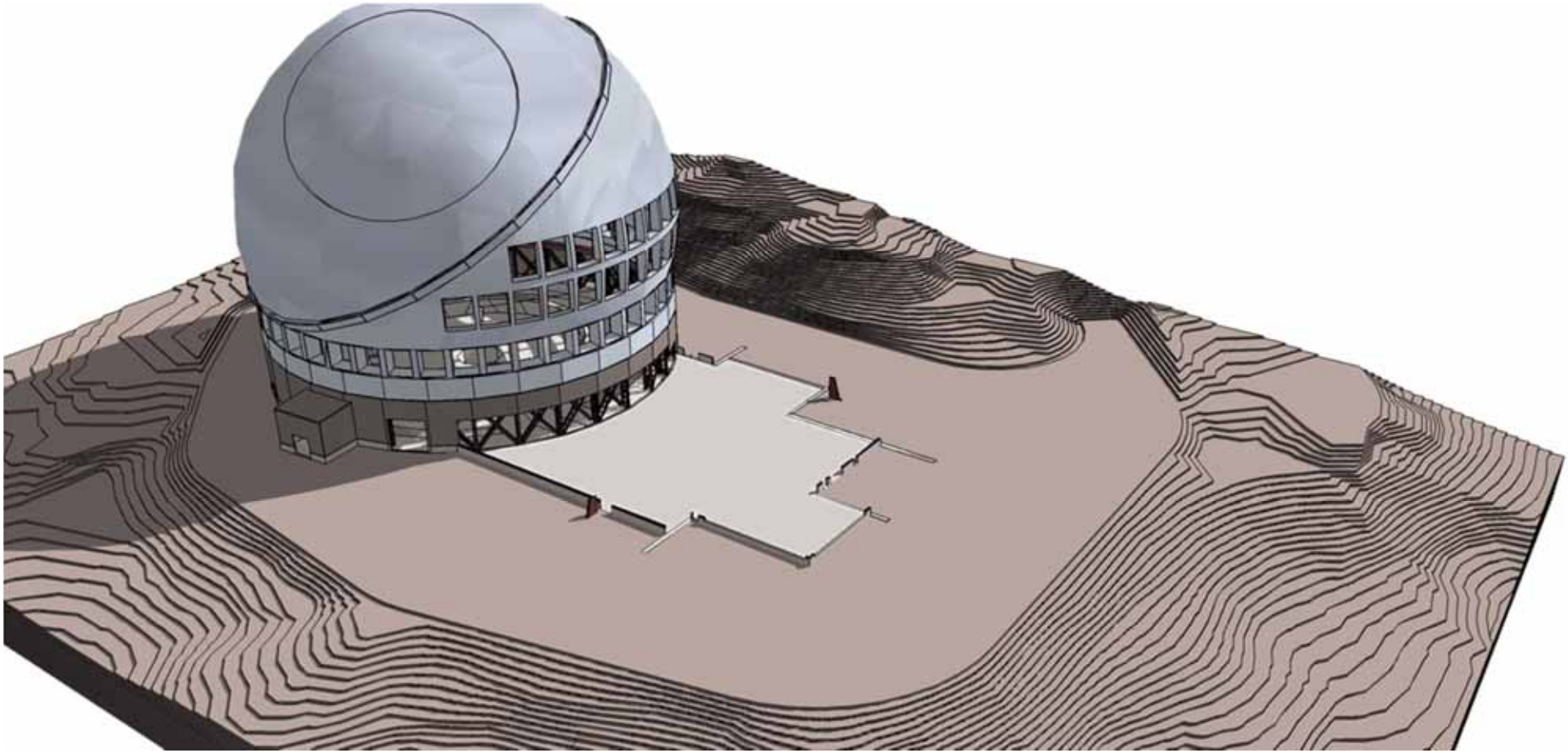


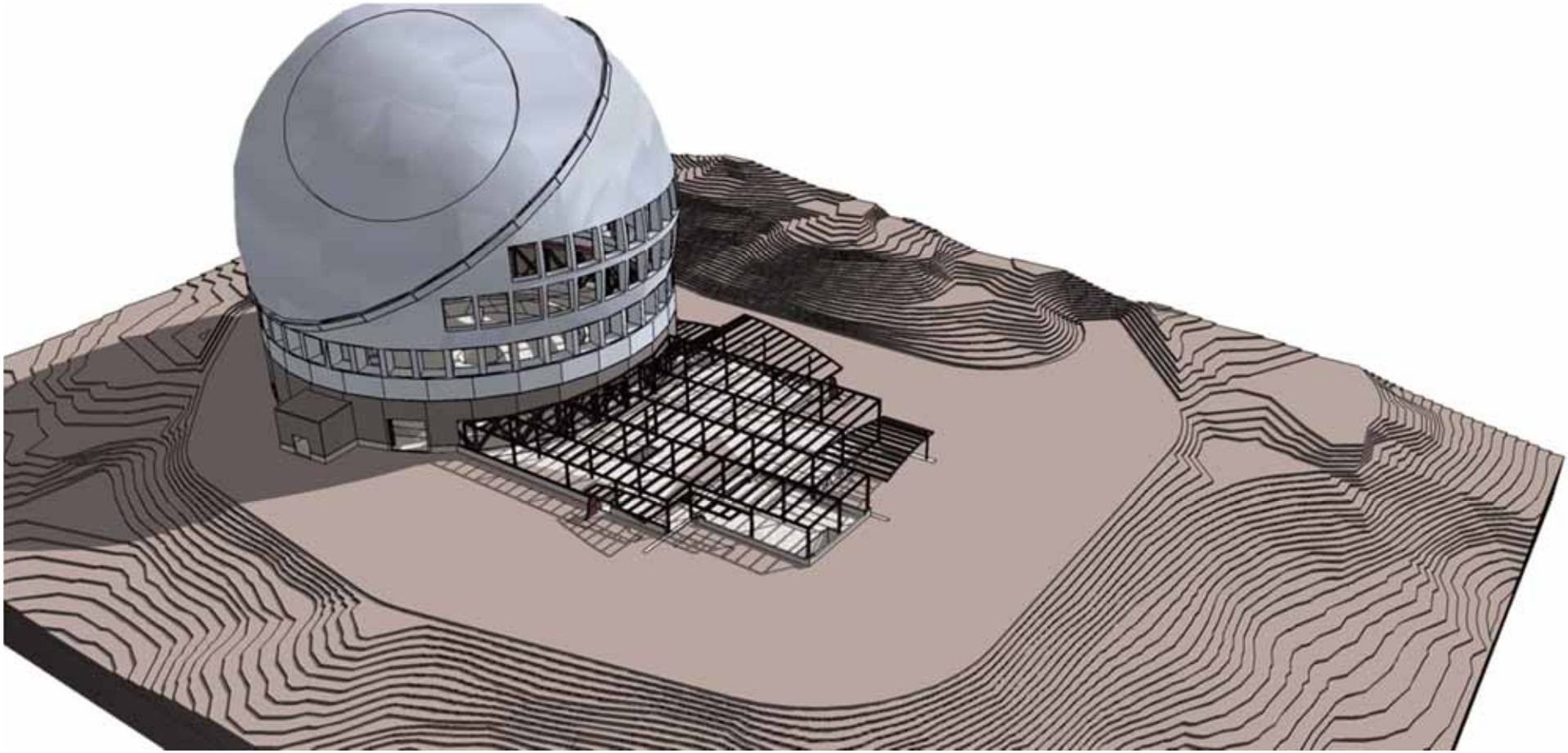
Construction Sequence
Facility Concrete Slab & Backfill

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



Construction Sequence
Facility Steel

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



Construction Sequence
Facility Shell & Finishes

2013				2014				2015				2016				2017				2018				2019				2020			
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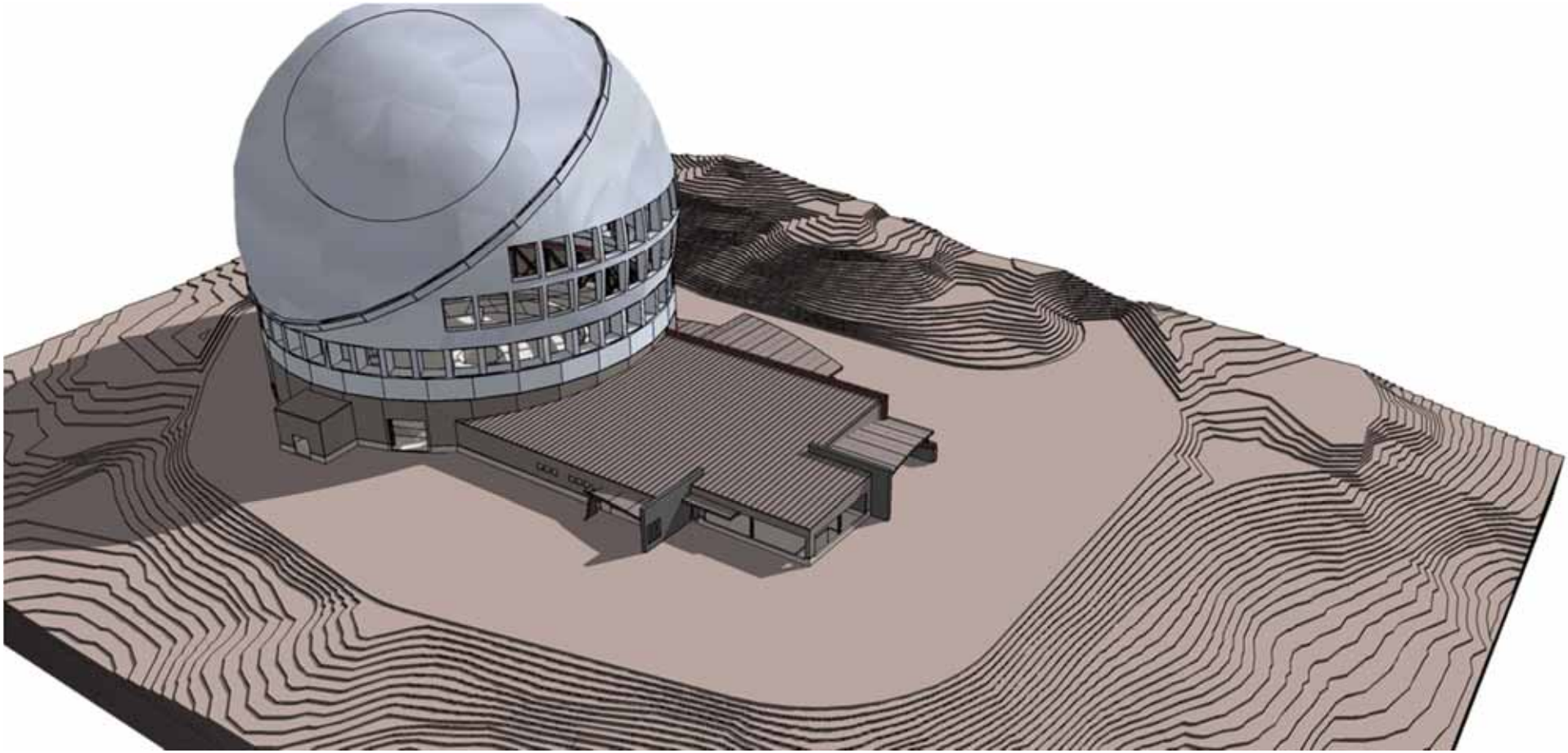
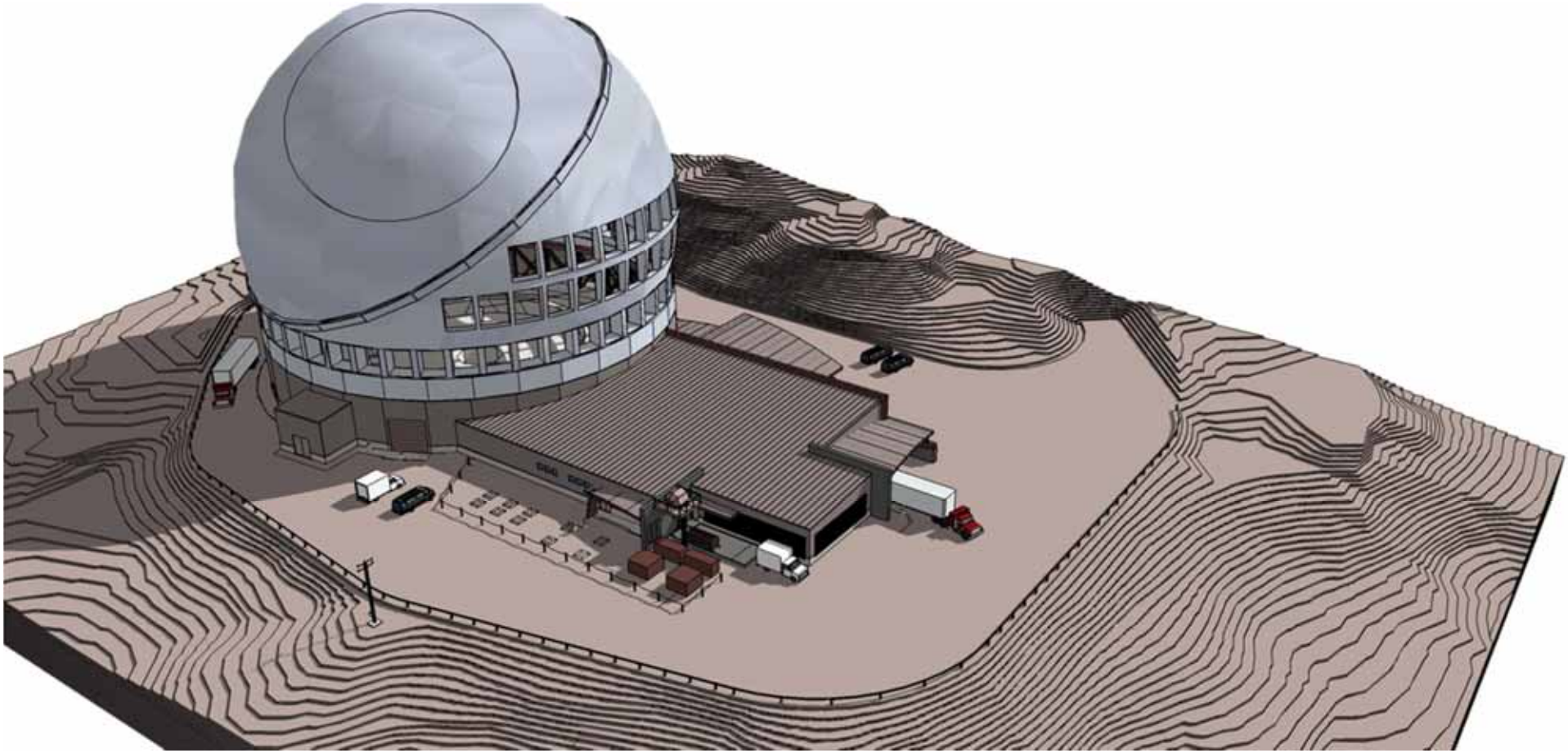


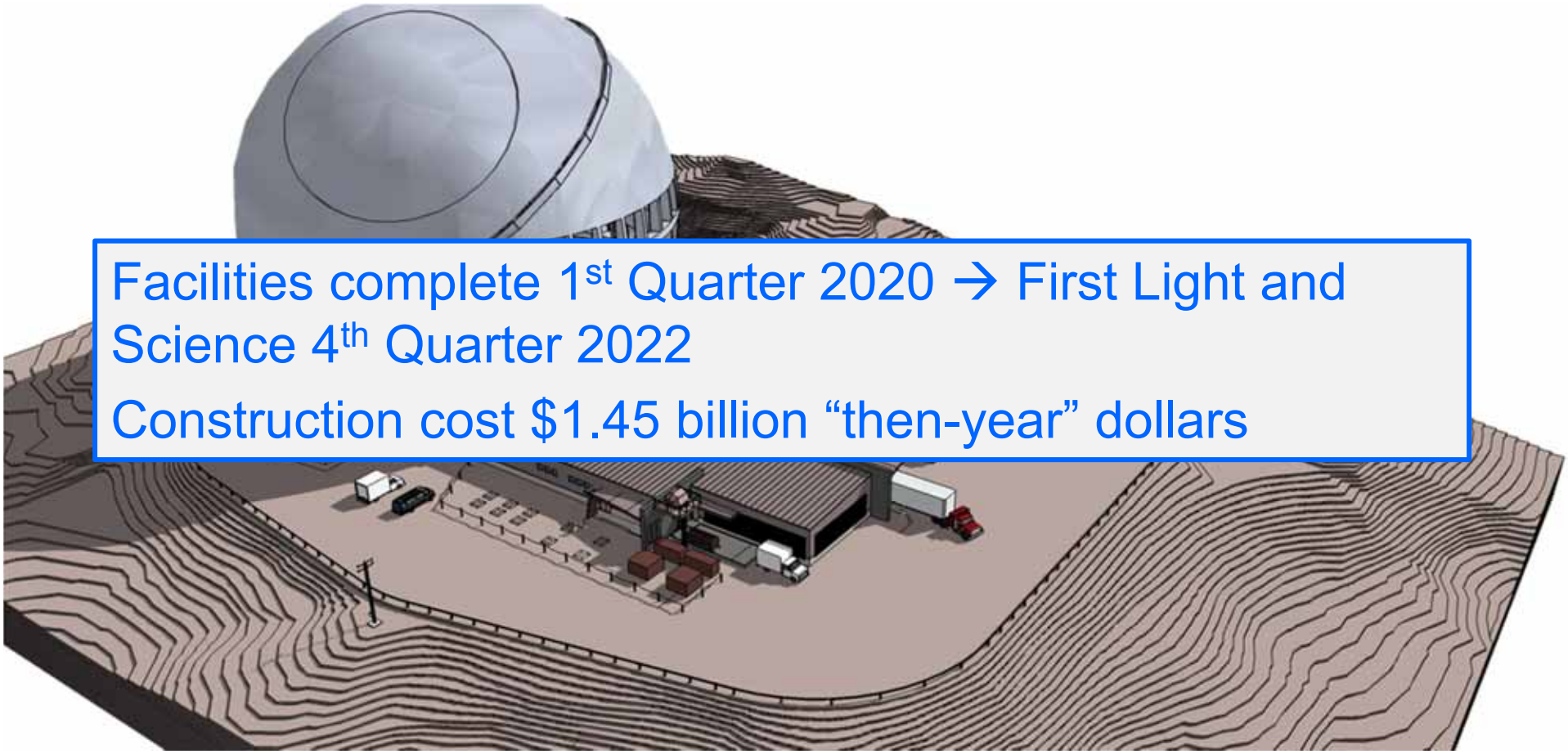
Construction Sequence Completion

2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



Construction Sequence Completion

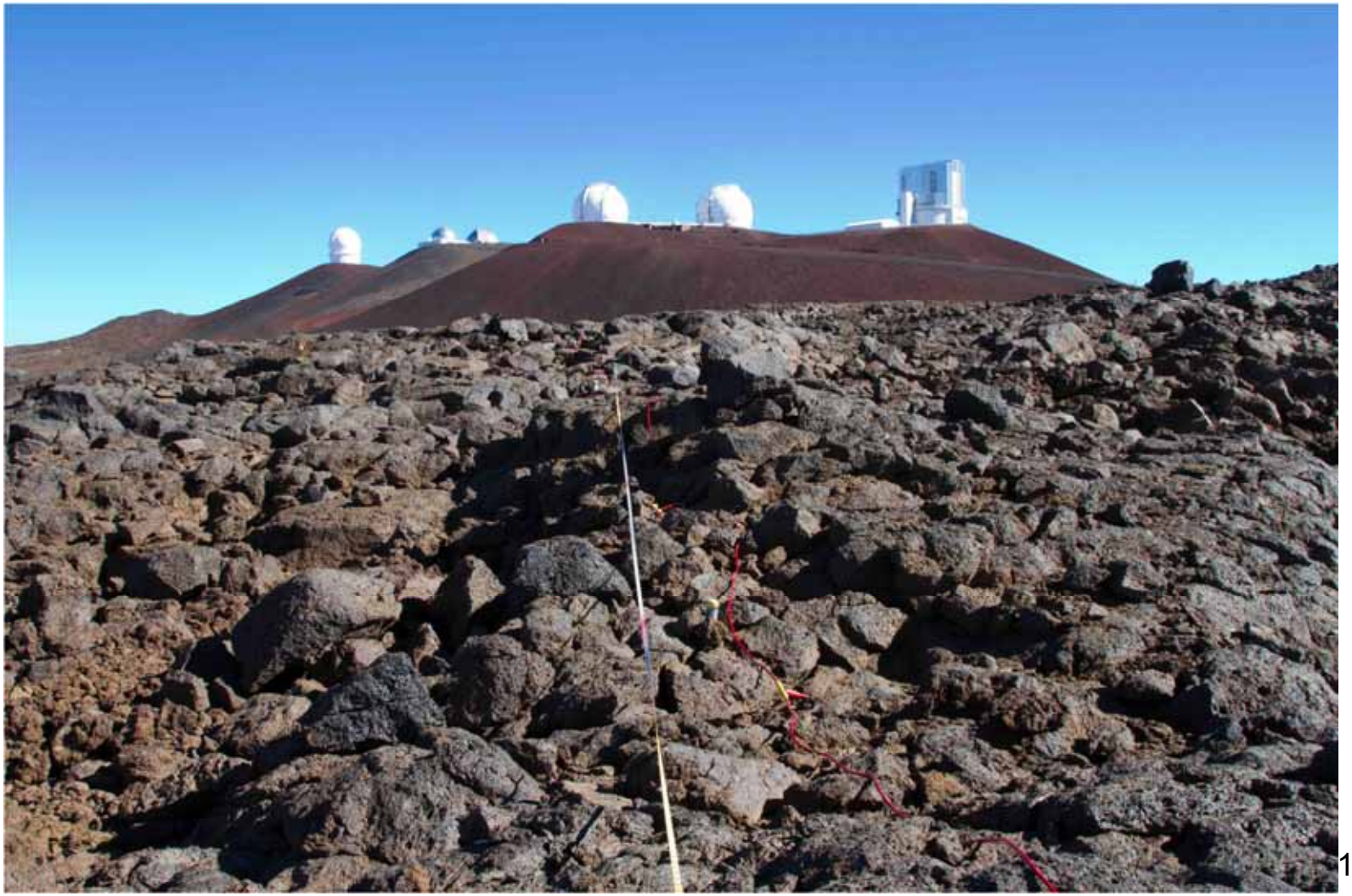
2013				2014				2015				2016				2017				2018				2019				2020			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4



Facilities complete 1st Quarter 2020 → First Light and Science 4th Quarter 2022

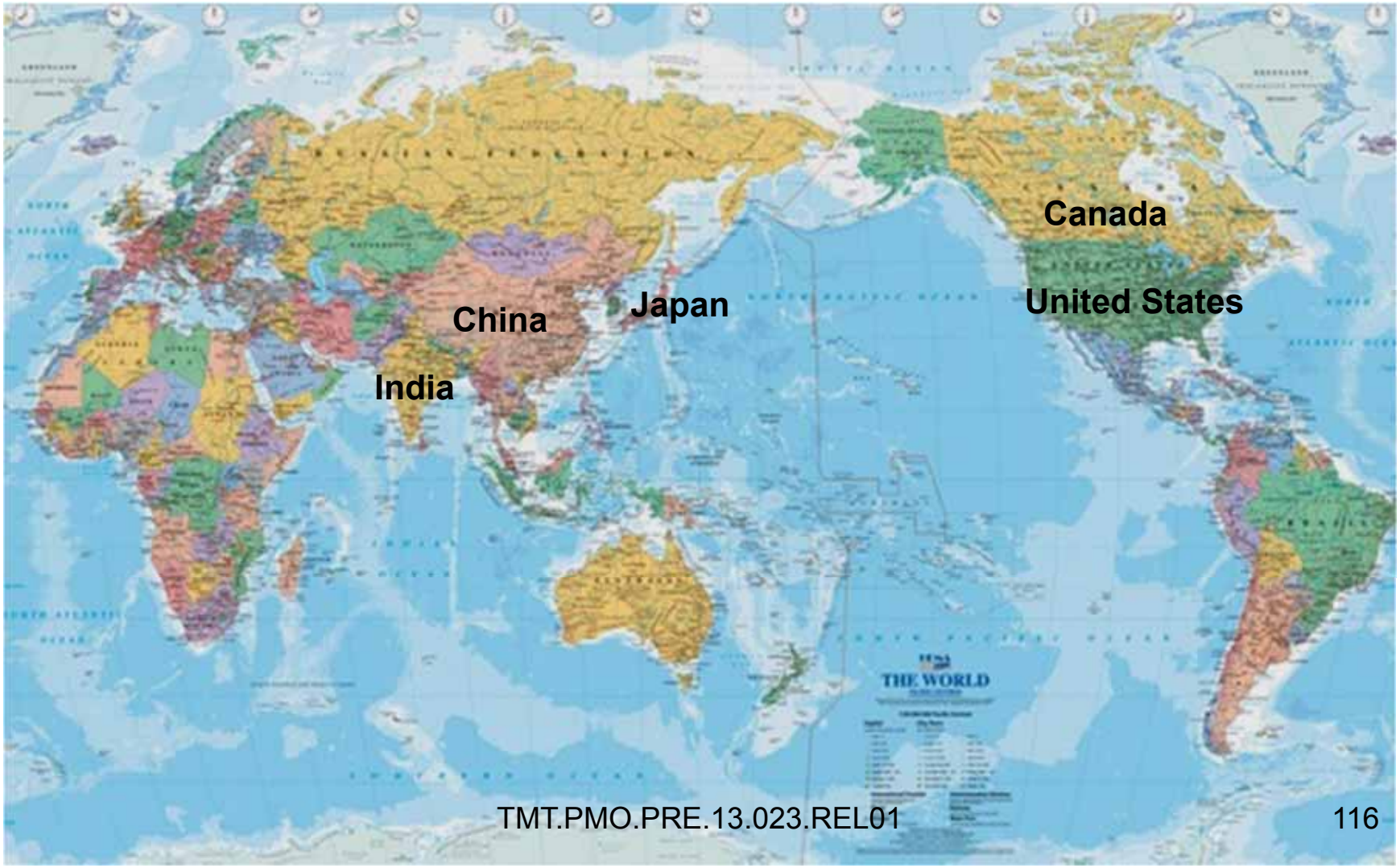
Construction cost $1.45 billion "then-year" dollars

First TMT Geotechnical Studies on Mauna Kea

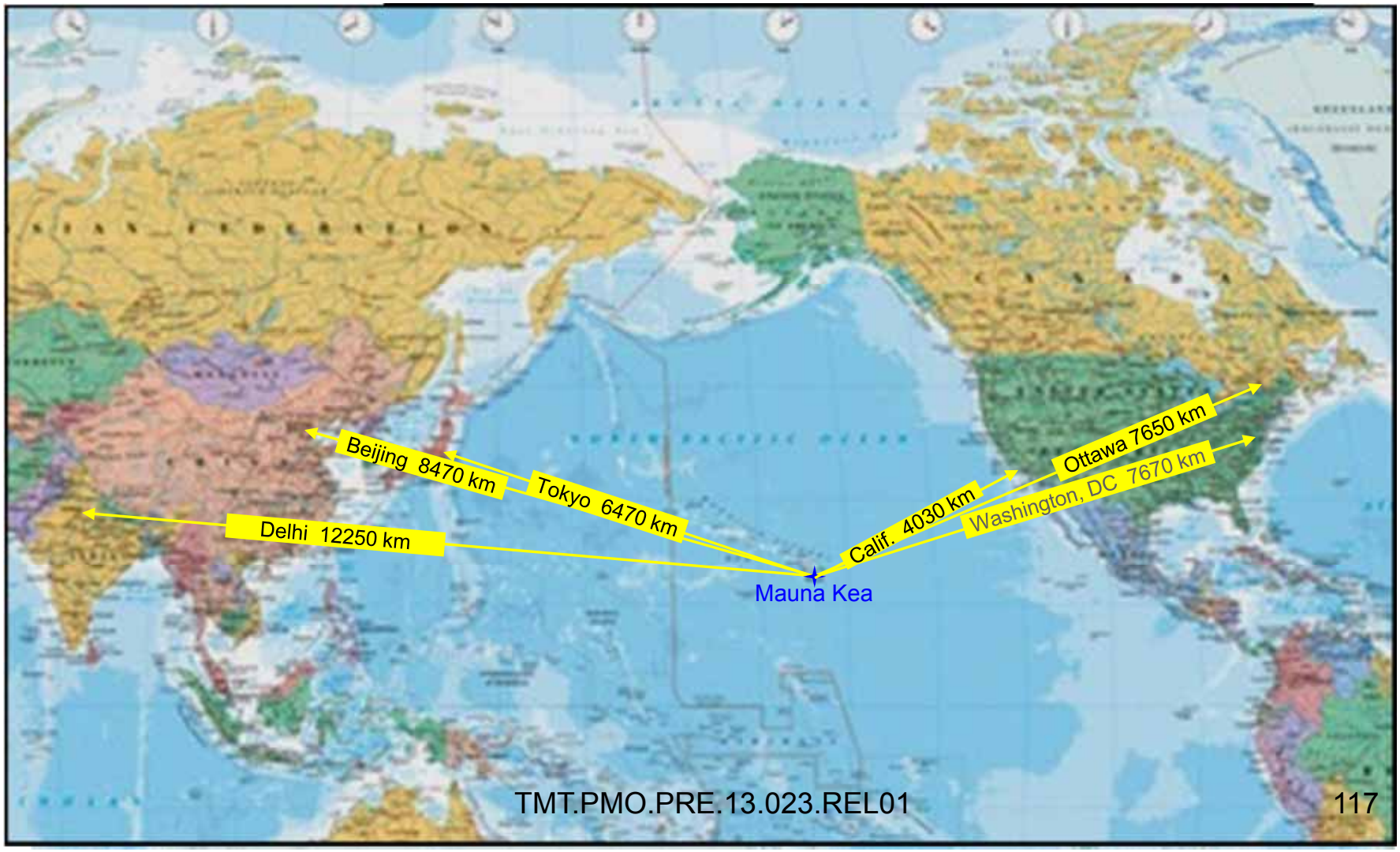


First TMT Geotechnical Studies on Mauna Kea (Last Week)

TMT Collaboration



TMT Collaboration



TMT

THIRTY METER TELESCOPE

India TMT Commitment June 13, 2012

THIRD INDIA-US STRATEGIC DIALOGUE 2012

These include the new initiatives between India's Department of Science and Technology and U.S. National Science Foundation on a Virtual Institute on Mathematics and Statistical Sciences and DST-NSF Summer Internship; the recent initiative (PC3) of the Department of Electronics and Information Technology and U.S. NSF to jointly fund collaborations between universities and institutions in the two countries on the application of electronics and IT for societal challenges, which has already resulted in five collaborations in the areas of wildlife management, air quality, water sustainability, healthcare and smart electric grids; India's recent commitment of more than $100 million to the California Institute of Technology's Thirty-Meter Telescope Project; the exchange of weather and monsoon forecasting, climate change information and global precipitation under the Civil Space Working Group; and the collaborative project of the U.S. National Science Foundation and the Indian Department of Atomic Energy and Department of Science & Technology to develop a Laser Interferometer Gravitational Wave Observatory, with a likely contribution of $100 million from India.

TMT
THIRTY METER TELESCOPE

Japanese parliament allocates money for Thirty Meter Telescope in new budget

THE ASSOCIATED PRESS
June 06, 2013 - 9:04 am EDT

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HONOLULU — A group building what will be the world's largest and most advanced optical telescope atop Mauna Kea says the Japanese government has allocated key funding for the construction of the project.

The Thirty Meter Telescope said Wednesday the Japanese parliament last month approved a budget including more than $12 million for the telescope.

TMT says Japan is expected to manufacture the main telescope structure and the mirror blanks for the segmented primary mirror. In total, Japan is expected to fund one-fourth of the total cost of construction.

The telescope is being built by a group including the California Institute of Technology, the University of California and the

TMT

THIRTY METER TELE

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Chinese vice premier meets US university presidents

English.news.cn | 2013-04-26 22:25:22 | Editor: Fang Yang

Chinese Vice Premier Liu Yandong (C) meets with Mark Yudof (2nd L), the President of the University of California (UC) and Henry Yang (2nd R), the Chancellor of UC Santa Barbara, in Beijing, capital of China, April 26, 2013. (Xinhua/Xie Huanchi)

BEIJING, April 26 (Xinhua) -- Chinese Vice Premier Liu Yandong met with Mark Yudof, the president of the University of California (UC) and Henry Yang, the chancellor of UC Santa Barbara on Friday.

During the meeting, Liu spoke highly of cooperations between the UC and Chinese universities, adding that China hopes the two sides will promote collaborations in education, technology and personnel exchanges.

TMT
THIRTY METER TELESCOPE

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Saturday, September 14, 2013 | 02:52 AM IST

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Press Trust of India | Beijing September 11, 2013 Last Updated at 20:06 IST

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- Poor can also open zero balance account in foreign banks: RBI
- India refuses visa to a Pak team for Twenty20 tournament
- Tewari takes on Modi, rakes up issue of fake encounters in Gujarat

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After a gap of 11 years, India and China held talks on Science and Technology and agreed to step up cooperation in earthquake prediction, disaster management, astronomy, traditional medicine and climate change.

An Indian delegation of top scientists headed by Dr Thirumalachari Ramasami, Secretary of the Department of Science and Technology, held the sixth dialogue on Science and Technology with their Chinese team led by Vice Minister for Science Technology Cao Jianlin here.

The talks, held during the last two days, were focussed on earthquake prediction and disaster management, astronomy, traditional medicine and climate change, officials told PTI.

The talks on earthquake predictions included exchange of notes on the movement of Indo-Tibetan plate which was stated to be the reason of a number of earthquakes in the Himalayan region, specially China's Sichuan province causing wide spread damage to life and property.

The two sides also discussed disaster management. The talks on Astronomy focussed on cooperation specially in Thirty Metre Telescope in Hawaii in which both the countries are taking part.

They discussed cooperation in areas of glaciology and climate change on which lot of work has been done by both sides.

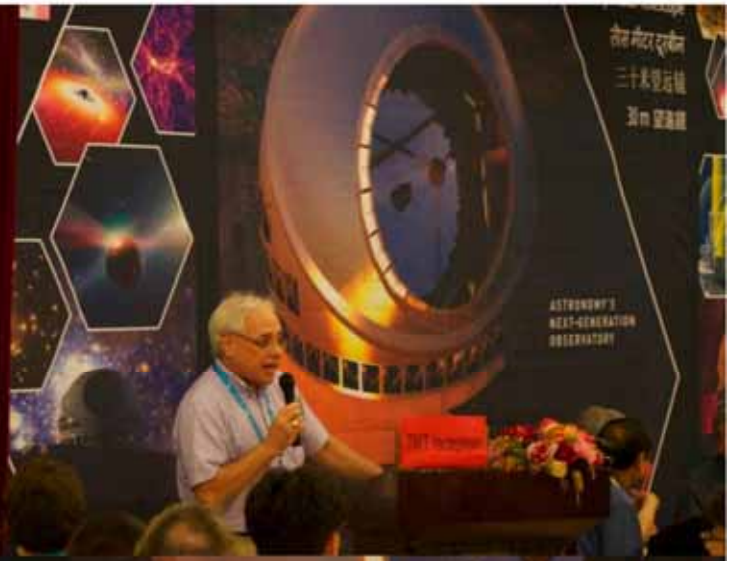

Pan-STARRS 1
TMT
THIRTY METER TELESCOPE

TMT Board Meeting – Tokyo
October 9-10, 2012

TMT Board Agreement Development Team – Kona – December 1, 2012

TMT Board Meeting – Delhi
January 21-22, 2013

TMT Reception at IAU Beijing



TMT

THIRTY METER TELESCOPE

Engaging the US astronomy community -- NSF awards partnership-planning grant to TMT

March 18th, 2013

This image depicts the Thirty Meter Telescope (TMT) near the summit of Mauna Kea, Hawaii. Construction of TMT is planned for 2014 with science operations beginning in 2021. Credit: TMT Observatory Corporation

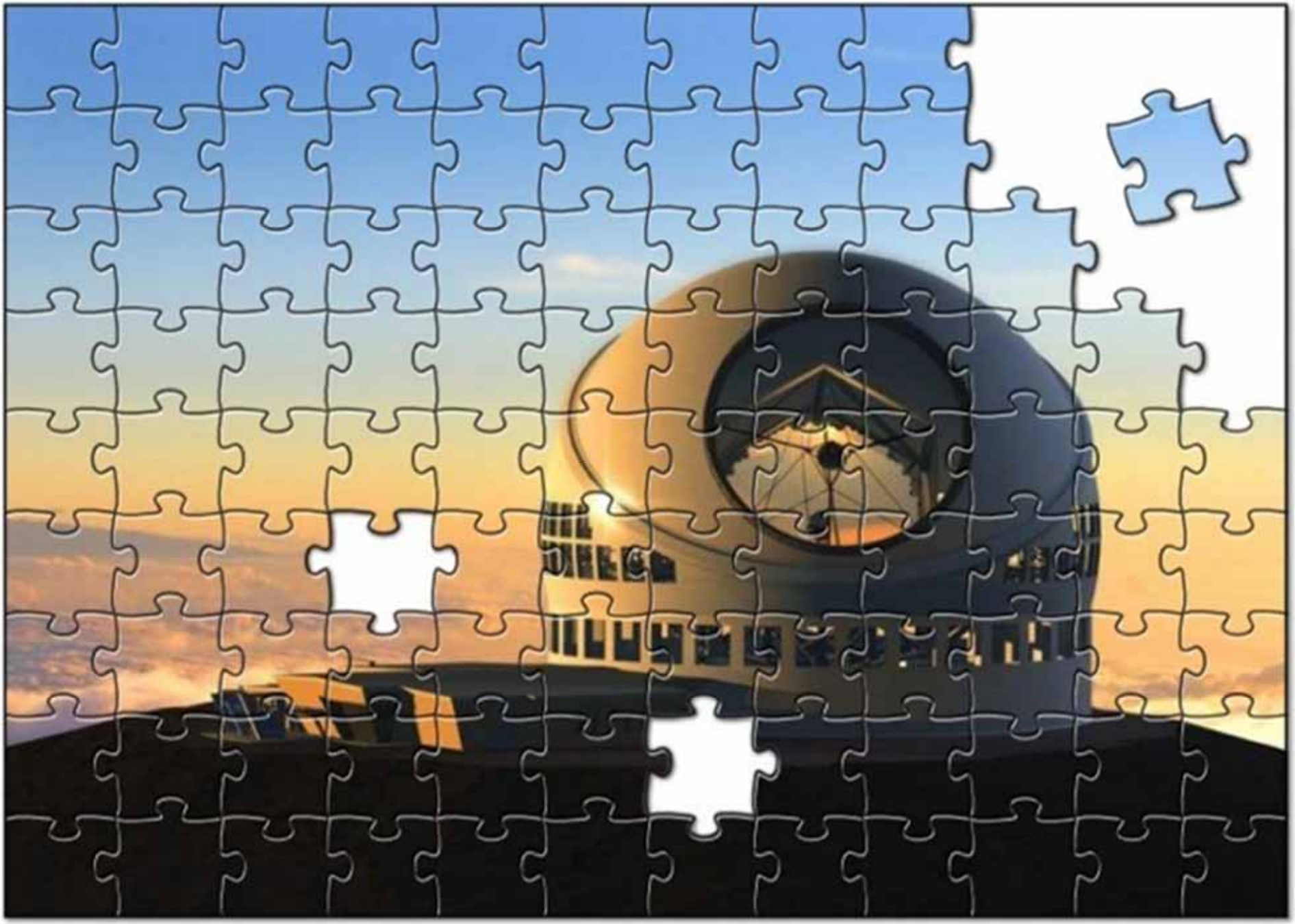
Today the National Science Foundation (NSF) awarded a cooperative agreement to the Thirty Meter Telescope (TMT) Observatory Corporation to explore a potential partnership between the organizations.

The award is a milestone for the TMT project, initiating a broad dialog between TMT, the NSF and the United States' astronomical community. The partnership-planning award also paves the way for the NSF to confer with TMT's international partners.

The Annual TMT Forum

1st one - July 22-23, 2013 at the Marriott Waikoloa, Hawaii

- Full partner meeting and introduction of TMT to the US community, 150+ people
- Project status, TMT science, Instruments
- Collaborative program – International Science Development Teams
- Also the Collaborative Board signed the Master Agreement



Acknowledgments

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