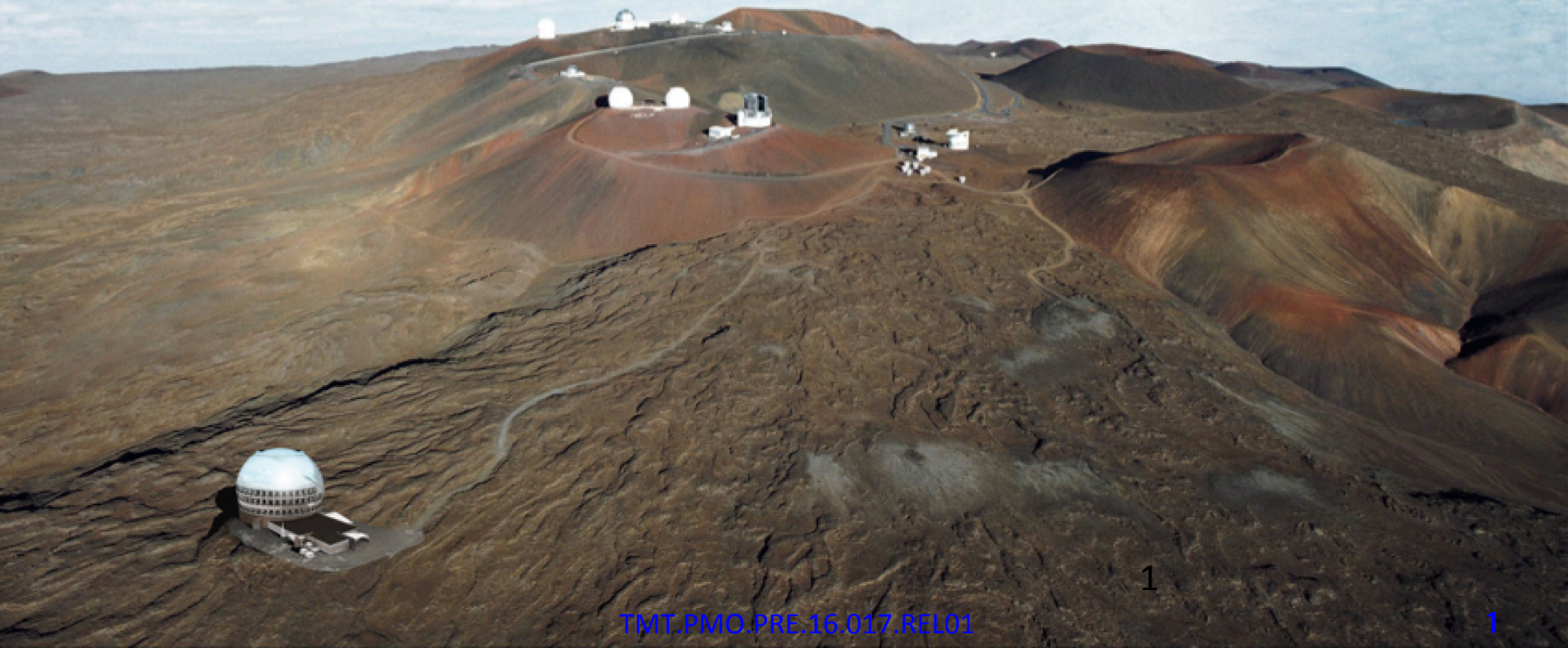
TMT Project Status

(presented by C. Dumas)

Gary H Sanders Kyoto May, 2016



Plan

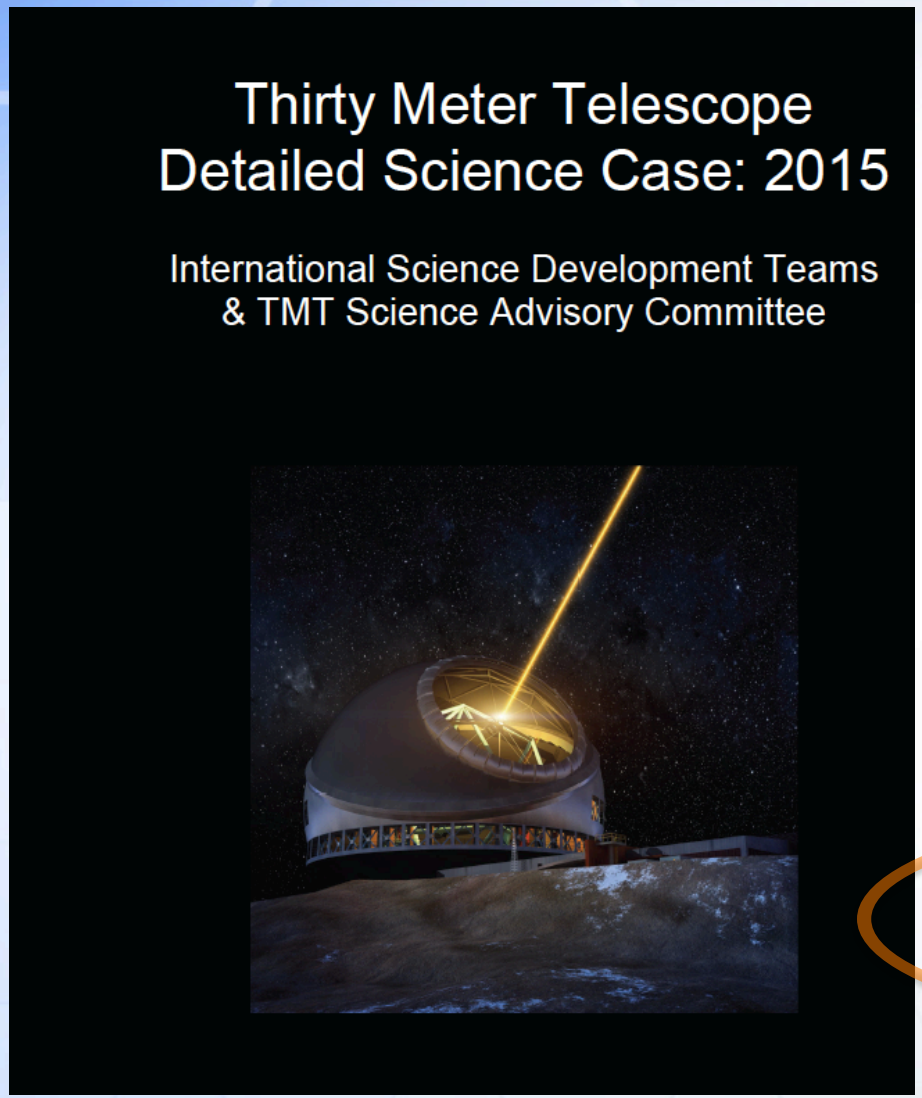
- **Brief overview / Project background**
- Status of progress made wrt (sub-)systems design, instrumentation, etc
- Alternate sites

TMT Science Forum 2016

- May 24-26, Kyoto, Japan
  - *"International Partnership for Global Astronomy"*
  - May 23: MICHI Workshop (Thermal-IR instrument for TMT)

- International TMT Key Project science
- Cross-partnership collaboration and the *International Science Development Teams*
- Second-generation TMT instrumentation and AO development
- Effective strategies for observatory operations
- Coordinating science planning with other observatories and facilities within the TMT partnership

ISDT cross-partnership: TMT Science case



- Fundamental physics & cosmology
- Early Universe & galaxy formation
- Super massive black-holes
- Nearby-galaxies & Milky-way
- Star formation & exoplanets
- Time-domain science
- Solar-system

See W. Skidmore's poster about science flow-down

TMT Partnership

- Members
  - Canada, National Research Council
  - California Institute of Technology
  - China, Chinese Academy of Sciences
  - India, Department of Science and Technology and Department of Atomic Energy
  - Japan, National Institutes of Natural Sciences
  - University of California
- Observer/associate
  - NOAO/AURA through US NSF Cooperative Agreement
  - Gordon and Betty Moore Foundation

Quick History & Status of TMT

- TMT project (~1,400M$) formed in 2004 (AURA, ACURA, Caltech, UC)
- Site studies 2004 → 2008 (Chile, Mexico, Hawaii)
- Mauna Kea, Hawaii selected as site in 2009
- In May 2014, TMT Board decided to start the TMT Construction Phase
  - Offsite construction activities are proceeding well, according to plan
  - Onsite construction started September 17, 2014 but was interrupted by demonstrations and a recent Hawaii court mandated rehearing of construction permit

Quick History & Status of TMT *(Cont'd)*

- Hawaii remains the preferred site, however, risks in Hawaii process exist and TMT is now investigating other sites, as part of its definition of a solid "plan B"
- Meanwhile, in Hawaii:
  - April 1: Judge Riki May Amano chosen as the hearings officer to conduct the new contested case (she was affirmed on May 6)
  - May 17: Pre-hearing meeting between attorneys of UH and petitioners to define schedule and participants for next steps
  - June 17: There will be a hearing in Hilo to determine the actual parties
  - . . .
- *TMT is planning to resume construction early in 2018*

TMT in a nutshell

- Wide-field, Alt-Az Ritchey-Chretien telescope
- 30 meter diameter primary mirror (492 hexagonal segments, 1.44m across corners)
- Active secondary mirror (not adaptive)
- Flat tertiary mirror beam light to Nasmyth focus
- Up to 8 instruments, over 2 Nasmyth platforms, to cover visible to infrared wavelengths
- First-light AO system (NFIRAOS):
  - Laser Guide Star Facility (LGSF) Multi-Conjugate-AO (MCAO)
  - Diffraction-limit at J, H, and K bands, can feed 3 instruments.

TMT System Architecture
Optical Design

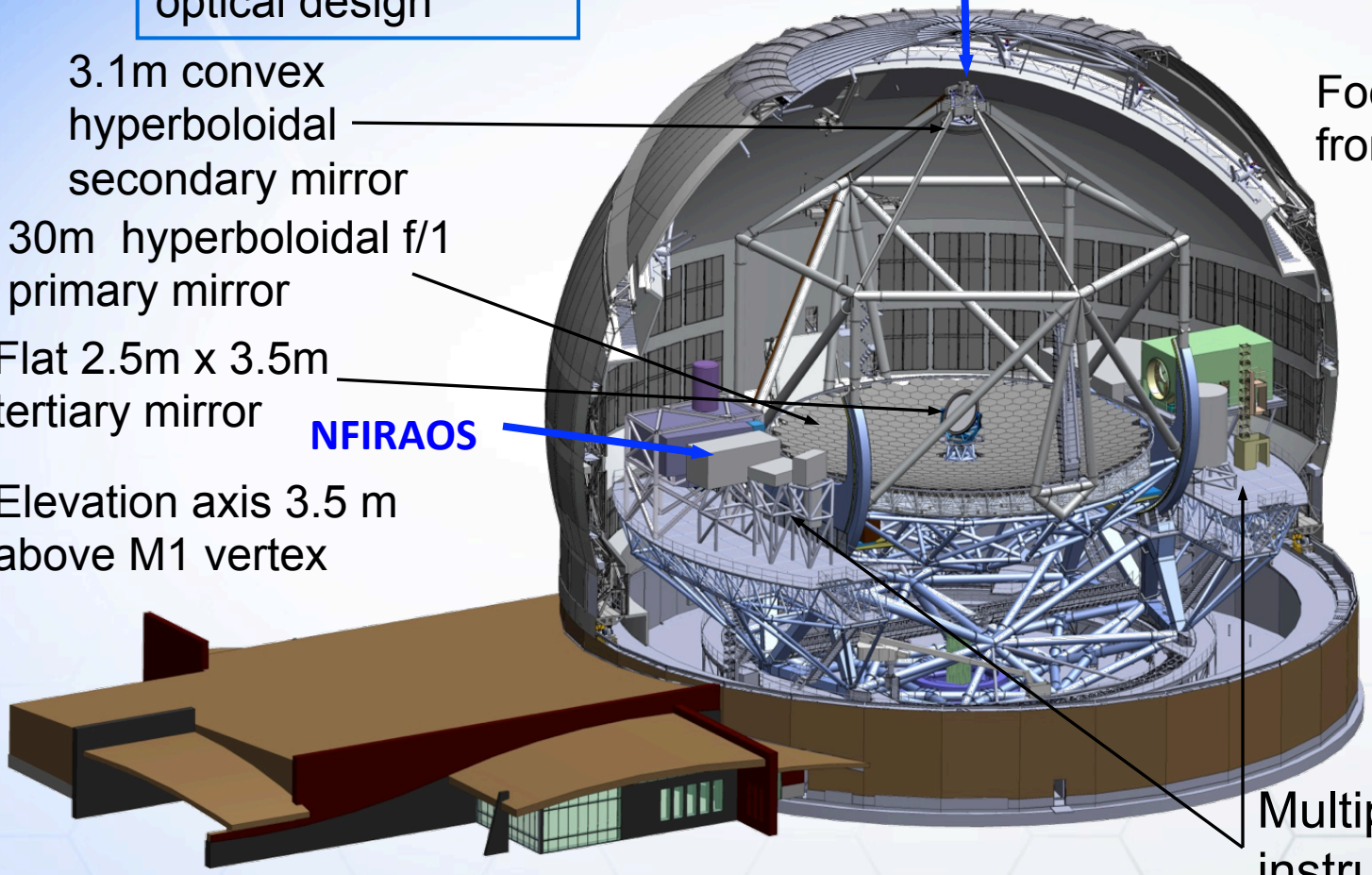
Ritchey-Chrétien optical design

3.1m convex hyperboloidal secondary mirror

30m hyperboloidal f/1 primary mirror

Flat 2.5m x 3.5m tertiary mirror

Elevation axis 3.5 m above M1 vertex



f/15 final focal ratio
450m focal length

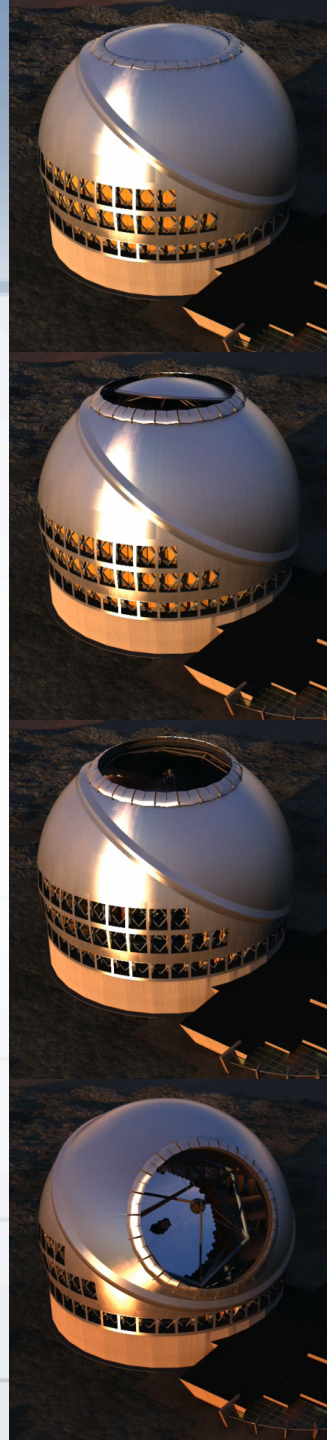
Focal surface 20m from tertiary mirror

20 arcmin field of view, 2.62 m diameter

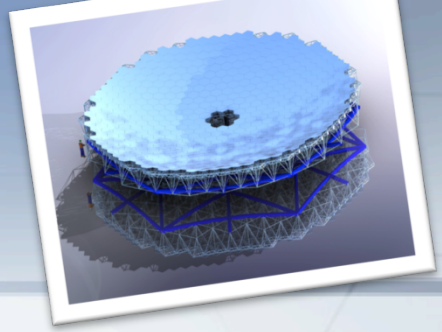
Multiple science instruments mounted on Nasmyth platforms

Innovative dome design

- Improved wind profile
  - Less wind resistance & "shaking", improved 'dome seeing', hence better image quality
- Enhanced telescope protection
  - Minimize telescope exposure by matching aperture and FoV
- Wind-flow controlled via flaps and vents
  - Aperture flaps are aerodynamically designed to direct air flow over the aperture
- Design is cost effective for increasingly larger telescope diameters



TMT performances



- TMT (ELTs) will **transform** ground-based astronomy (*OK . . . 'Astronomy at large' . . .*) for decades to come
- Sensitivity:
  - Proportional to D^2, hence TMT will have **~10 times the collecting area of Keck**, or **~150 times that of the Hubble Space Telescope** (HST)!
    - For background limited observations of point sources with Adaptive Optics, sensitivity becomes ~ D^4, hence **~200 times that of the VLT, Gemini, or Subaru (8m telescopes)**!
- Angular resolution:
  - **TMT will provide 12 times better spatial resolution than HST,** thanks to its AO system NFIRAOS!!

TMT 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 [illegible].5 – 28 (goal)	3″ slit length [illegible]	[illegible]	• Origin of stellar masses • [illegible] around protostars • [illegible] protoplanetary disks
Planet Formation Instrument (PFI)	1 – 2.5 1 – 5 (goal)	1″ outer working angle, [illegible] angle	[illegible]	• 10^8 contrast ratio (10^9 goal) • [illegible] pic 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

A call to start studies for 2nd generation instruments will be released next year

Plan

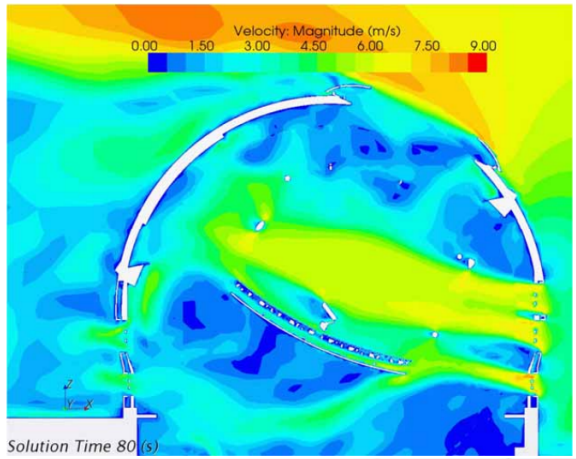
- Brief overview / background of project
- **Status of progress made wrt (sub-)systems design, instrumentation, etc**
- Alternate sites

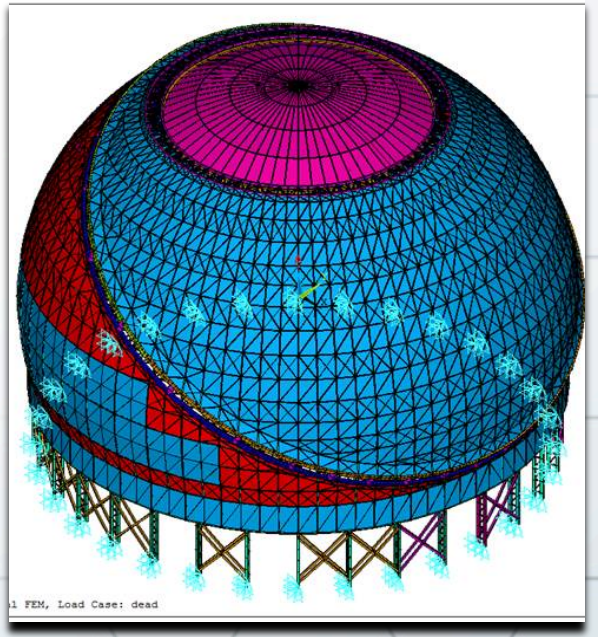
Enclosure

Enclosure: Ongoing Work

- Enclosure system level finite element model update
- Enclosure vibration source characterization
- Construction sequence engineering
  - Analysis of loading conditions including wind, seismic, snow and ice, temperature, mechanical forces, etc
- Systems Engineering Progress
  - Interface Control Document (ICD) updates
- Failure modes, effects and criticality analysis (FMECA)

Computational fluid dynamics



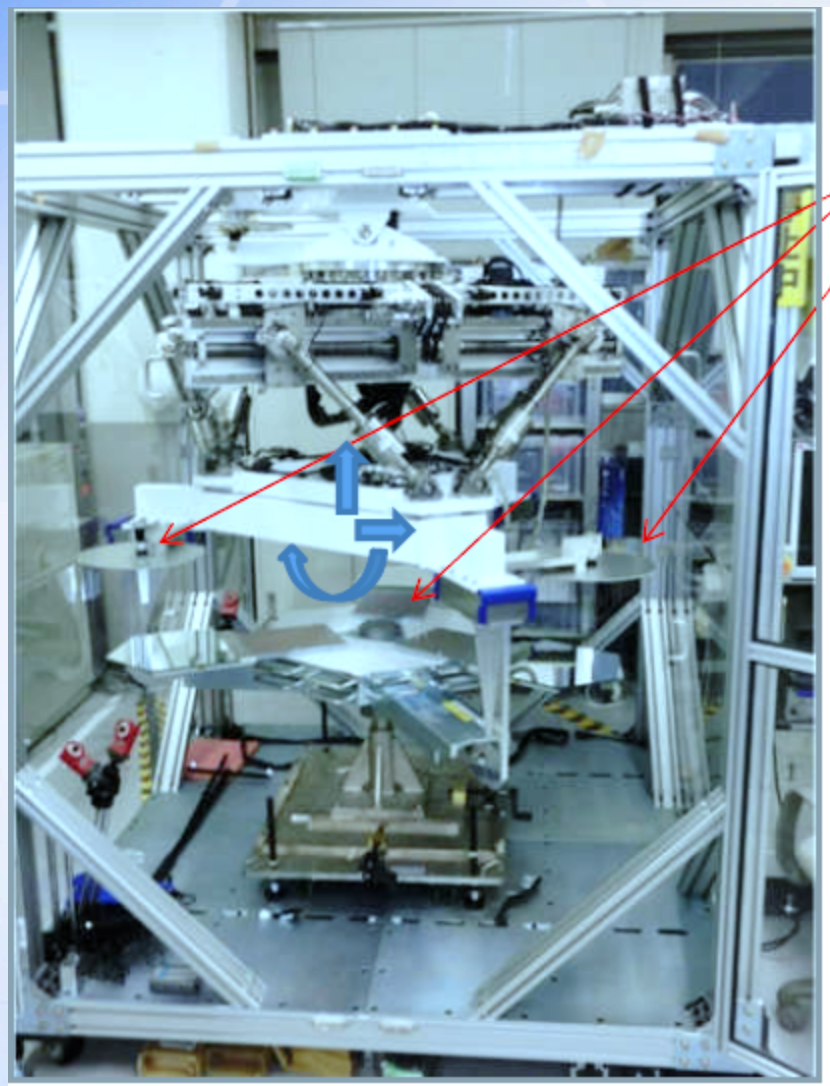


Telescope Structure

Telescope Structure: Progress Reviews

- Conducted update of the controls Final Design Review of the telescope structure, February 24 – 26
- The review achieved its primary objectives:
  - Excellent progress was made
    - Proposed control processor shows excellent performance
    - Design is robust to changes in mass due to different instrument configurations
    - The system configuration is well defined
- Segment Handling System FDR is planned for December, 2016
- Final Design Review Completion (FDRC) originally planned for early 2018

Telescope Structure: SHS Machine Vision System

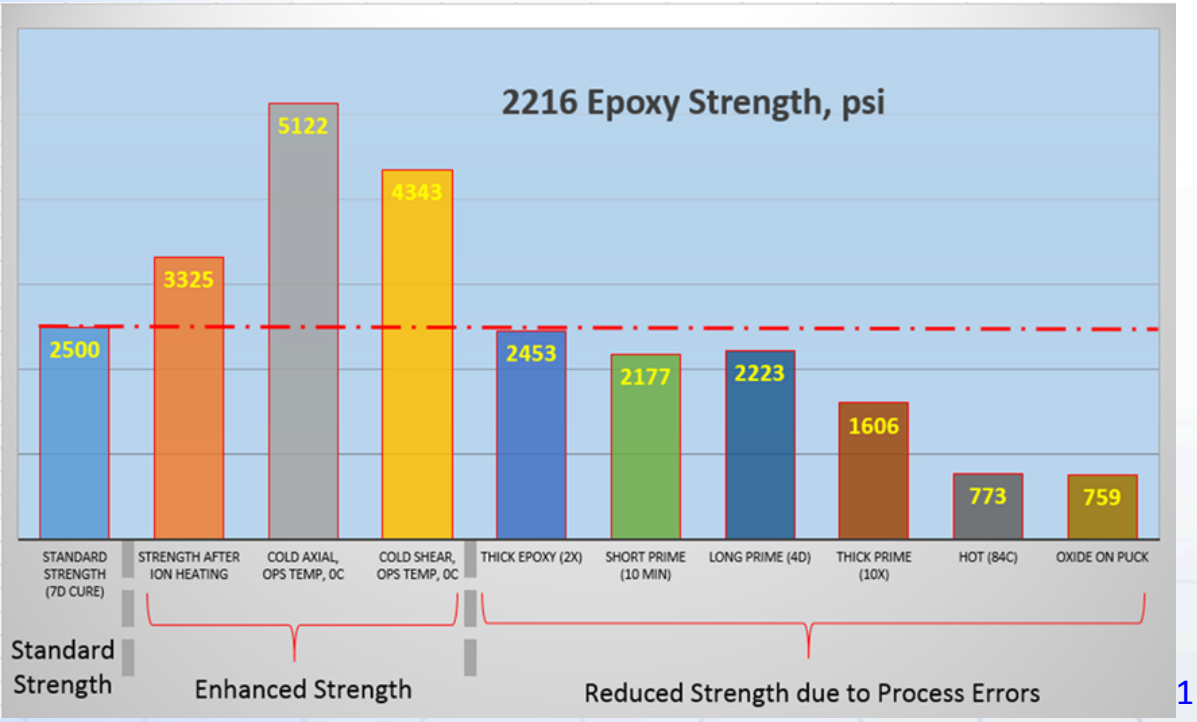


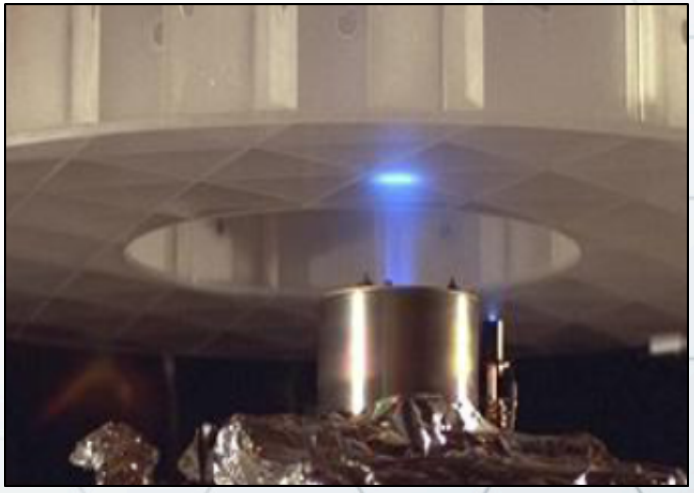
- Development and Testing
  - Mirror position detection process
  - Accuracy
  - Robustness for dark environment in enclosure

Telescope Optics

Optics: Bond Design Qualification Testing

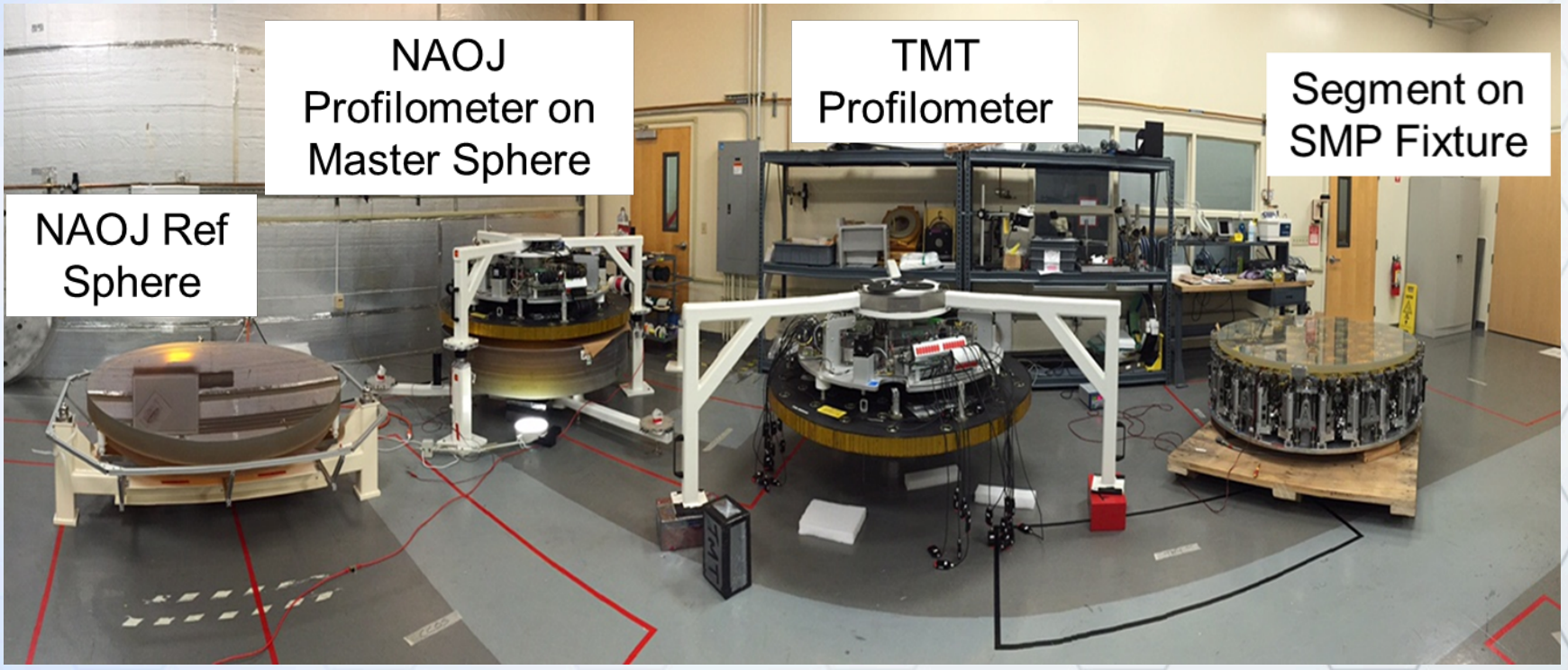
- Bond failure spotted last Aug. at attachment points with segment support
- Now, with the correct process, strength measurements are above expectations
- Accelerated aging tests done by thermal and stress cycling prior to testing to failure





Optics: M1 Progress at Coherent IOS

- First suite of production tooling will be complete in 3Q 2016
- Production contract with Coherent drafted for 148 roundels providing options for spares, starts delivery as soon as mid 2018
  - Maintaining blank supply is critical to avoid production delays and maintain best pricing



Optics: M1 Segment Polishing

- TMT formally accepted the first 29 M1 Blanks for overseas partners
- Canon aspherically ground 9 additional blanks in the last quarter
- Polishing will continue using the newly commissioned 2DP and reference sphere

Optics: M1 Segment Polishing

- ITCC Executive Council has given approval for facility construction to proceed

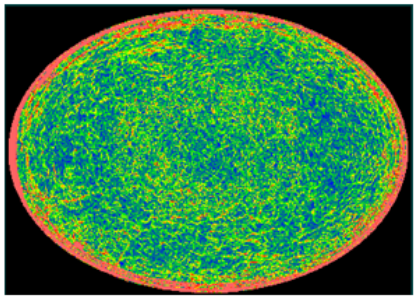
Optics: CIOMP Prototype GSSM Mirror Progress

- Finished polishing the prototype mirror
  - Completing mirror surface measurements
    - Processing stitched subaperture interferometer data
    - Testing with scanning pentaprism to more accurately measure low frequency Zernikes

Run 68

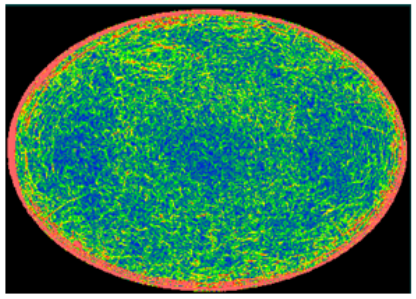
Tool	Medium	Run Time	Pressure	Stroke	Pin-to-edge	Revolution	Grid
15mm	1.5+PUR	5 hrs	55kpa(8.0psi)	5 mm	5mm min.	8k	W3 CeO_2

Before: 20160315_132



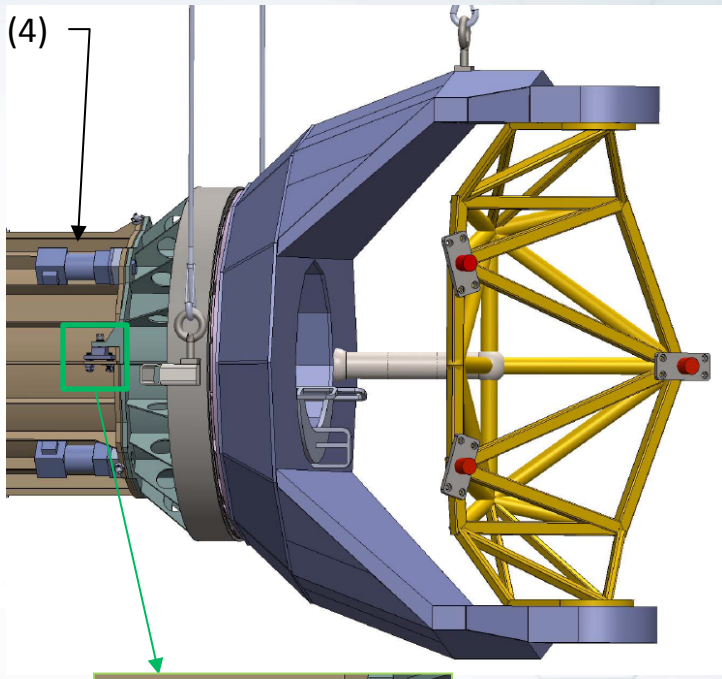
umPV	0.351	→	0.454
umRMS	0.010	→	0.011
Slope(in)	1.75	→	1.38
Slope(BP)	1.90	→	2.17

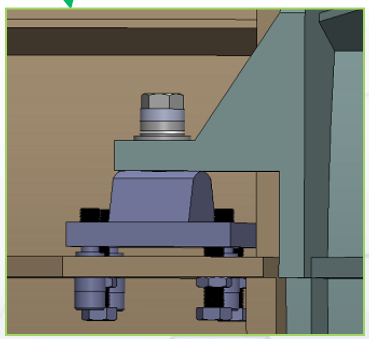
After: 20160318_135



Optics: STR-M3S Interface Design Modification

- Concept for STR-M3S interface modified by OPT/STR groups
  - Installation modification:
    - Incorporated electromechanical clamps to fasten M3S to the M3 Tower in horizon pointing direction
    - Clamps will be released when the telescope is oriented zenith pointing and M3S is fastened for adjustment
  - Adjustment modification:
    - Push-pull adjustment devices added for X-Y and Rz adjustment





PUSH-PULL ADJUSTMENT DEVICES (3)

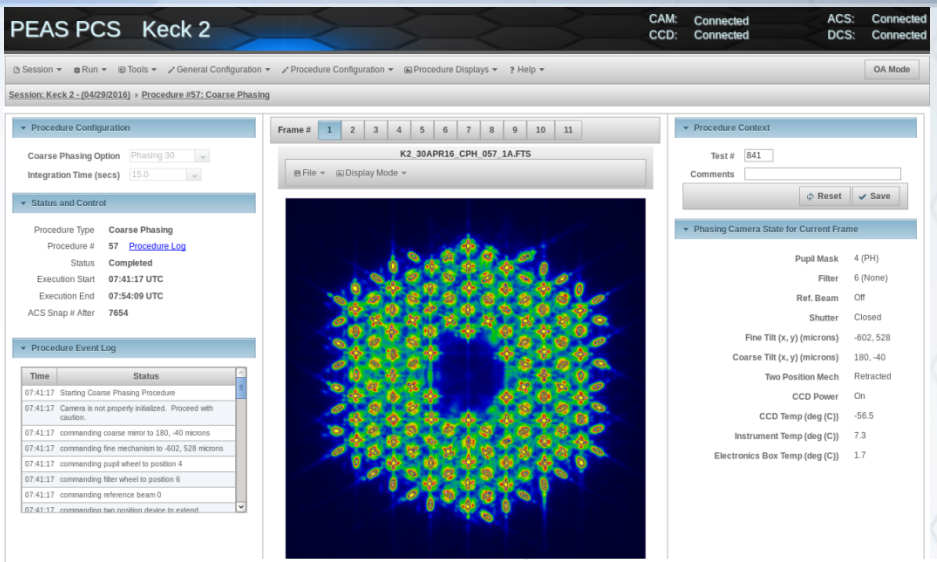
Telescope Controls

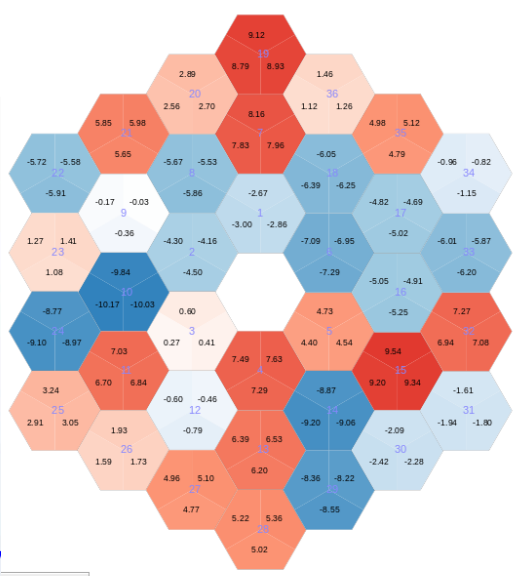
Controls: Telescope Control System (TCS)

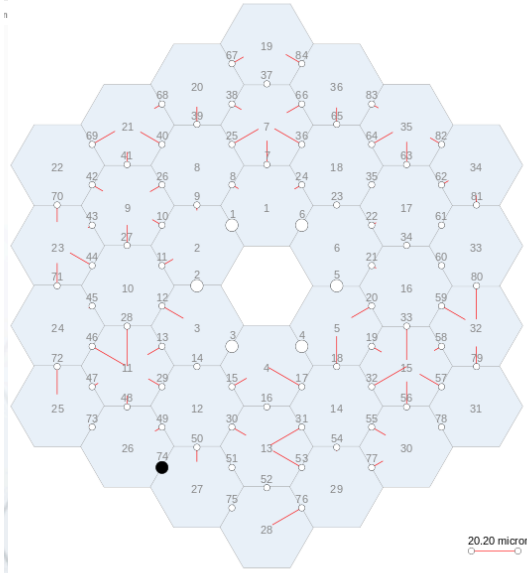
- ITCC, with TMT PO support, successfully completed the RFP evaluation for the TCS Start-Up phase and awarded a contract to Honeywell India
- An intensive two week work-shop was held at the PO to kick off the TCS effort. Honeywell, ITCC, and TMTPO staff participated. The work-shop was very successful and included trips to Keck and Subaru on Mauna Kea as well as watching observing from Keck HQ

Controls: APS Progress
PEAS-PCS Successfully Deployed at Keck

- Joint TMT/Keck effort to prototype the TMT APS software/ algorithms and use them operationally at Keck for PCS
- Risk, cost and schedule reduction effort for APS and TMT
- As of April 2016 all required operational modes for Keck have been tested and validated on-sky.
- **Will be used for segment exchanges on Keck 2 starting in May of 2016, with a planned operational readiness review in July.**

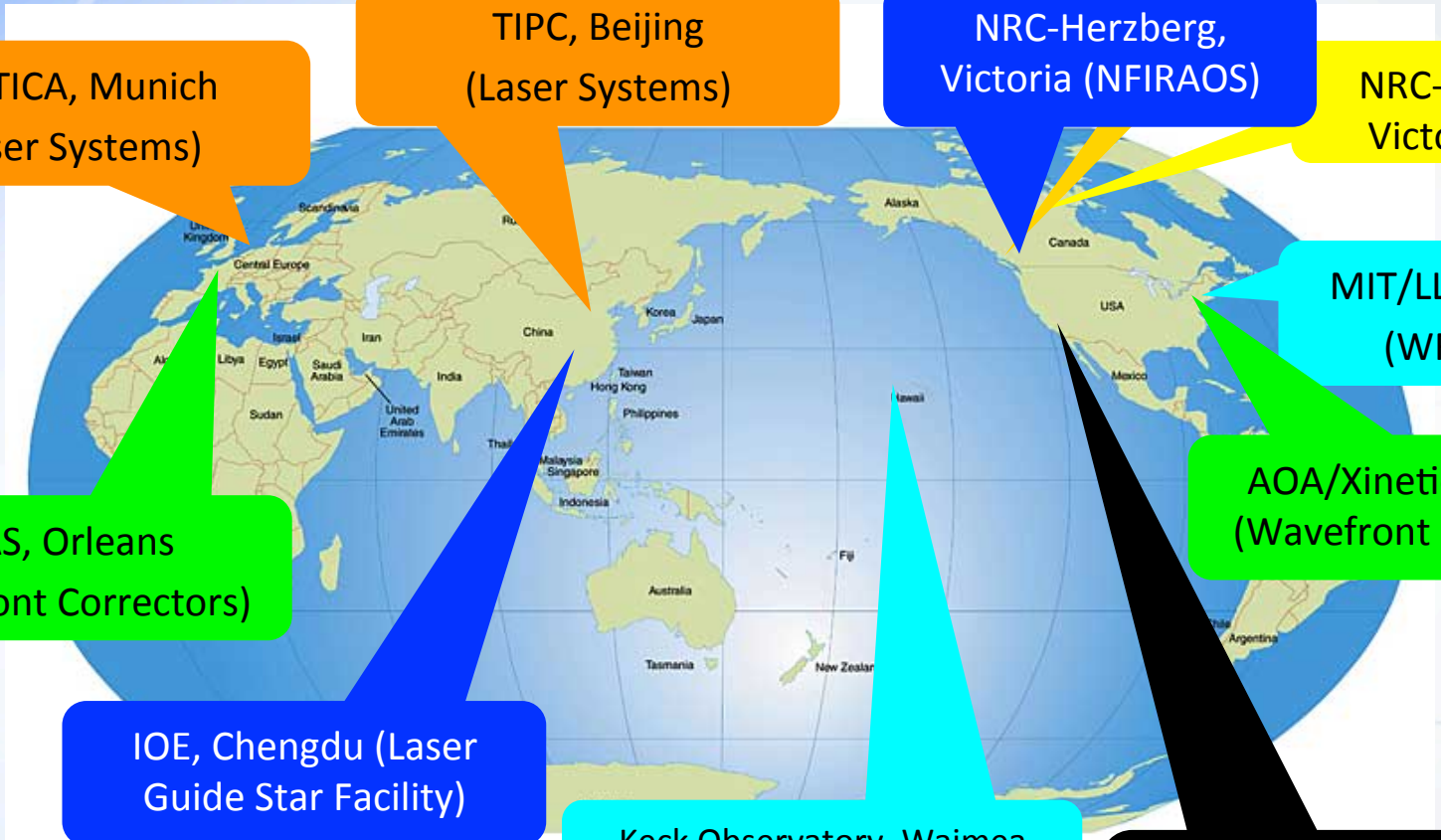






Adaptive Optics

TMT Global AO Participants



UBC, Vancouver (Sodium LIDAR)

TOPTICA, Munich (Laser Systems)

TIPC, Beijing (Laser Systems)

NRC-Herzberg, Victoria (NFIRAOS)

NRC-Herzberg, Victoria (RTC)

MIT/LL, Lexington (WFS CCDs)

AOA/Xinetics, Devens (Wavefront Correctors)

CILAS, Orleans (Wavefront Correctors)

IOE, Chengdu (Laser Guide Star Facility)

Keck Observatory, Waimea (Visible Camera oversight)

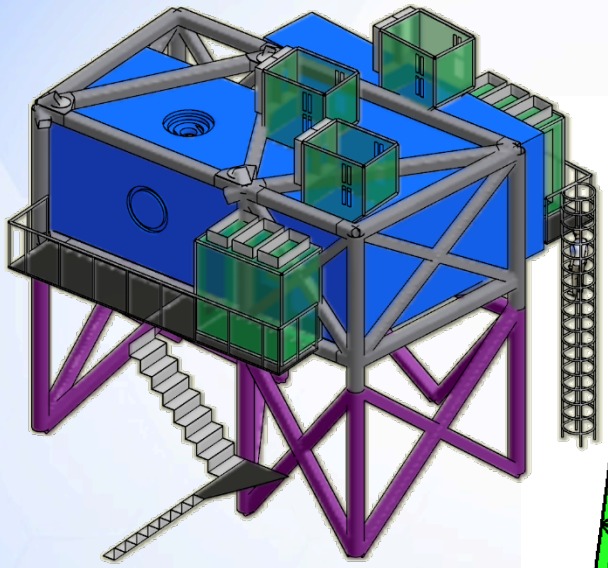
TMT, Pasadena (Management, SE, AOESW)

AO Progress Summary

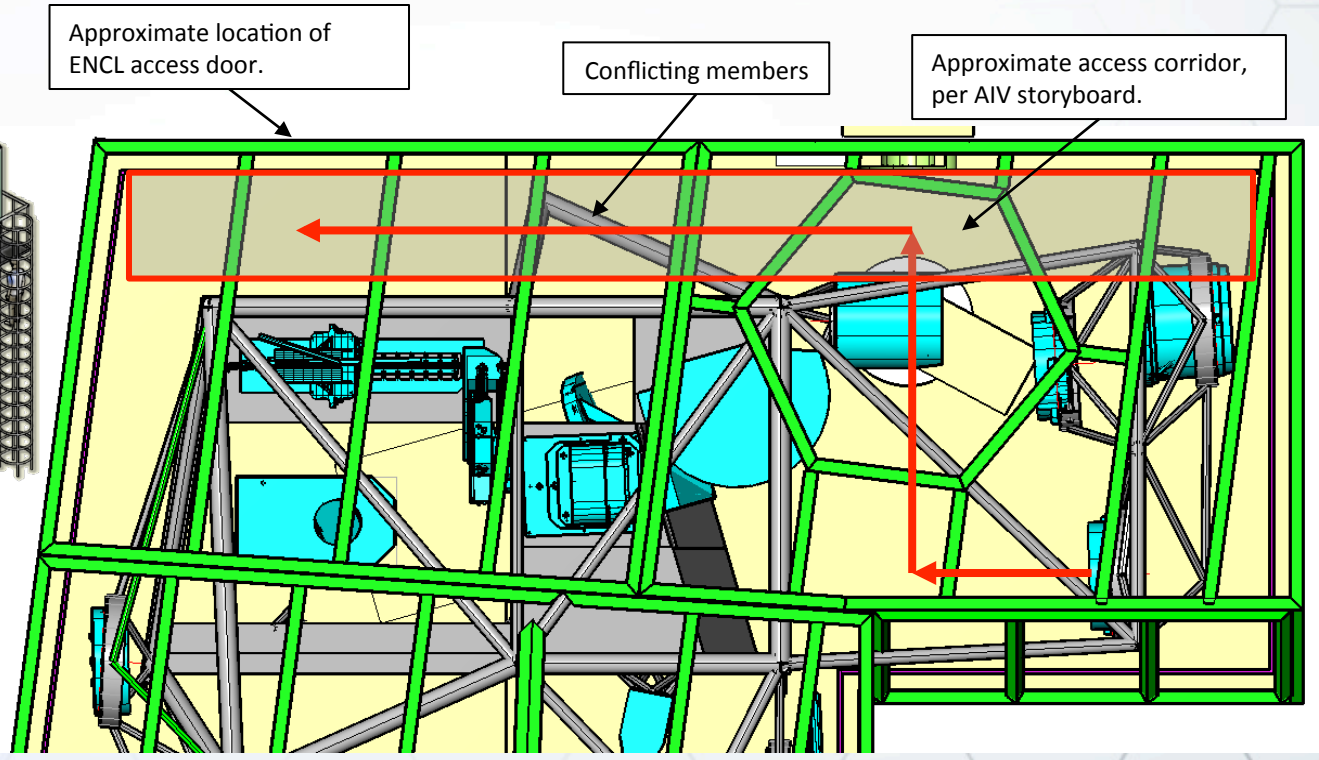
- NFIRAOS Final Design is progressing
  - Additional system engineer on board to support NFIRAOS
- Laser Guide Star Facility Preliminary Design is progressing
  - Successful Interim Review
  - Refractive design for Laser Launch Telescope selected to relax manufacturing tolerances
  - New TMT AO mechanical engineer on board to review IOE mechanical design
- DM Final Design and Prototyping at AOX is progressing well
- CILAS DM Final Design is converging
- Successful PDR for NFIRAOS Visible WFS Cameras (March 21, 2016)
- RTC Final Design is progressing with first interim review end of May

AO: NFIRAOS AIV Planning

- With IST/TABL subcontractor (Sightline), NRC is developing AIV plans for placing and removing optics



Component and Personnel Access Vestibules



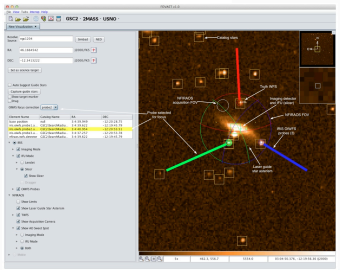
Science Instruments

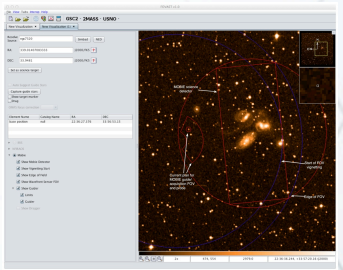
→ *(see Luc Simard talk after lunch!)*

Observatory Software

TMT Observatory Software

- Software development is shared between India and US
- Observatory Common Software Preliminary Design completed December 2015





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

- CSW procurement process on schedule
- CSW final design phase well underway
  - additional prototyping activities to finalize design and lower risk

Plan

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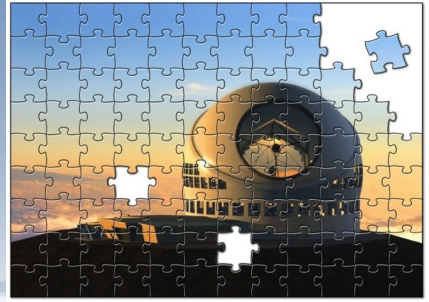
- Status of progress made wrt (sub-)systems design, instrumentation, etc
- **Alternate sites**

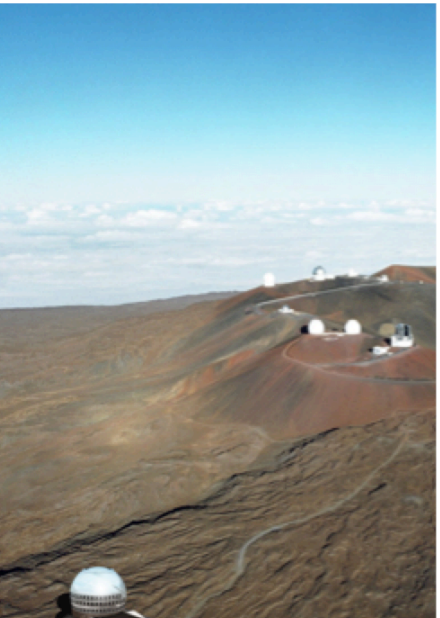
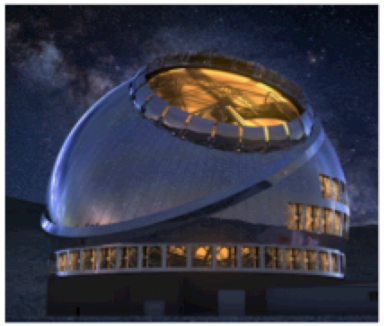
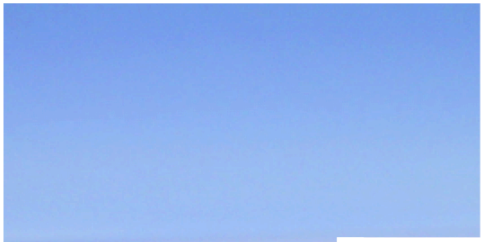
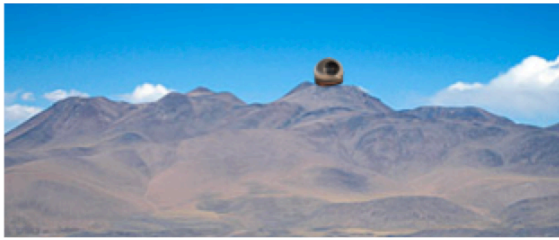
Construction site



Related activities

- Site-visit campaigns
- Comparison of site (sky-condition) characteristics
  - Access/processing data obtained by other groups whenever needed
- Understanding impact on TMT science cases
  - E.g. MICHI science cases

- TMT will be built!
- A plan is defined to:
  - Re-start construction early 2018
  - Have ‘first-light’ in 2027

Acknowledgments

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