Overview of Thirty Meter Telescope Project

L. Stepp
November 16, 2010
Outline

- Introduction to TMT
- TMT site selection
- TMT partners
- Summary of TMT design
- TMT requirements for segments
- Plans for segment production
- Project status and schedule
- Summary
Introduction to TMT

- The Thirty Meter Telescope project was established in 2003 to build a facility to fulfill the scientific potential envisioned by the 2000 astronomy decadal review committee for a giant segmented mirror telescope.

- Observations made with TMT will help answer some of the key questions in astronomy:
  - What is the nature and composition of the universe?
  - When did the first galaxies form and how did they evolve?
  - What is the relationship between black holes and galaxies?
  - How do stars and planets form?
  - What is the nature of extra-solar planets?
  - Is there life elsewhere in the universe?
Consolidation of ELT Projects

GMT  |  Euro50  |  OWL  |  CELT  |  GSMT  |  VLOT  |  CFGT

GMT   |  E-ELT   |  TMT  

TMT.TEL.PRE.10.016.REL02
TMT Conducted a Multi-year Site Testing Program at Five Sites

- Tolar – 2290m
- Armazones – 3064m
- Tolonchar – 4475m
- Mauna Kea – 4210 m
- San Pedro Martir – 2830m
TMT Board Selected Mauna Kea as the TMT Site

- TMT Site
  - 4000m Elevation

TMT Environmental Impact Statement has been approved
  – signed by Governor of Hawai’i

Application for a Conservation District Use Permit is moving through the approval process
TMT Partners

United States

Canada

Japan

China

India
**Design Heritage**

- W. M. Keck Observatory pioneered segmented mirror technology for ground-based telescopes
  - First large telescopes to be built with segmented primary mirrors
  - They’ve been the archetypes for other large segmented-mirror telescopes
  - Many of the key Keck design team members are working on TMT
  - Keck staff are collaborating with TMT on many technical issues
TMT is also Building on the Lessons Learned on Other Large Telescopes

The TMT team includes members who worked on:

- Gemini
- CFHT
- LBT
- VLT
- LAMOST
- Keck
- Subaru
Telescope Design Architecture

28.5 m R
Stay-in Radius

EL AXIS

27.6 m R
28 m

56 m

51 m

23 m

16 m
Optical Design Summary

Ritchey-Chrétien optical design

30m hyperboloidal f/1 primary mirror w/ 492 segments

3.1m convex hyperboloidal secondary mirror

f/15 final focal ratio

Flat 2.5m x 3.5m tertiary mirror

20 arcmin field of view 2.62 m diameter
Telescope Architecture

- Hydrostatic bearings
- Direct drive motors
- Tape encoders

Instruments on Nasmyth platforms

Central pintle bearing
Mauna Kea-Specific Facility Design

Calotte enclosure design
TMT Incorporates Adaptive Optics as Integral Part of Telescope Design

- TMT will take advantage of best current AO capabilities
  - TMT first light AO system will have 60 x 60 correction over the aperture
  - Next generation systems planned to have > 120 x 120 correction
- 60 x 60 correction allows diffraction-limited images at $\lambda > 2 \mu m$
  - Partial wavefront correction down to $1 \mu m$
  - At $2 \mu m$, TMT will produce images of 0.006 arc seconds FWHM
- At shorter wavelengths, TMT will be used in seeing-limited mode
- TMT maintains error budgets for both of these modes
Adaptive Optics-Corrected Mode

- TMT first-light AO system corrects spatial frequencies up to
  ~ 30 cycles per aperture
  - 1 meter spatial period on M1
  - 100 mm spatial period on M2
  - 45 mm spatial period on M3
- Any higher spatial frequency errors must be kept very small
  - < 35 nm RMS residual wavefront error from telescope optical surfaces and alignment errors, after AO correction
Seeing-Limited Mode

- Image size will be limited by the atmosphere
  - 0.6 arc sec FWHM median seeing at $\lambda = 500$ nm
  - Telescope wavefront errors must be << than atmosphere
- TMT uses Point Source Sensitivity (normalized) as the SL metric

\[
PSS_N = \frac{\iint PSF_{\text{total}}^2 \, d\alpha}{\iint PSF_{\text{atm}}^2 \, d\alpha}
\]

- For many observations, scientific productivity $\propto PSS_N$
- Loss of $PSS_N$ varies as spatial frequency squared:
  - For spatial periods longer than $\sim 0.5 \, r_0$:
    \[
    (1 - PSS_N) \propto \sigma^2 f^2
    \]
    where: $\sigma = \text{amplitude of wavefront error}$
    $f = \text{spatial frequency of surface error}$
    $r_0 = \text{Fried parameter, median value} \sim 15$ cm
Effect of Zernike Error Modes on PSS

At same RMS wavefront level, higher frequency modes have greater effect on PSS
TMT uses structure functions to define the required surface accuracy of the optics

- SF relates amplitudes of errors to their spatial frequency
- Based on tilt-removed atmospheric structure function
  - But with larger $r_0$, to ensure telescope errors aren’t limiting

Structure functions address needs of both AO & SL error budgets

![Segment Structure Function Specification](image-url)
Segment Edges

- Gaps between segments scatter light
  - Scattered light $\propto$ area of gaps
- TMT specification allows:
  - 2.5 mm nominal gap width
  - 0.5 mm edge bevel on segments
- Total area of gaps and bevels
  $< 0.6\%$ of aperture

- Any optical surface edge roll-off
  - Increases effective gap width
  - Increases scattered light
  - Reduces contrast
- Clear aperture extends to the bevels
- Structure function applies over clear aperture

**No extra allowance for edge roll-off**
TMT and TMT partners are exploring segment polishing development

- Segment polishing studies ongoing in US, China, Japan and India
- ITT has hex cut the first (spherical) segment and mounted it on its segment support
Evaluation of Segment Surface with Spherical Test Plate after Ion Figuring and Edge Cutting Shows No Edge Roll-off

Edge of test plate

Edges of segment
Tinsley Currently Working on Stressed-Mirror Polishing of Two More Segments

P3: Segment Type-2
Least aspheric: ~6um PV OHARA Glass

P4: Segment Type-82
Most aspheric: ~226um PV LZOS Glass
Acceptance Test Requirements

- Must accommodate all 82 types of segments, with asphericity up to 226 microns P-V surface
- Must be performed with segment:
  - mounted on its segment support assembly
  - zenith pointing
  - at mountain-top temperature: 2°C
- Must accurately measure the low-order figure errors, including control of radius of curvature
- Interferometric resolution of at least 500 x 500 coverage over entire segment (< 3 mm pixels) with 1 mm resolution along the edges
- Metrology methods are under development at multiple suppliers in TMT partner countries
  - TMT supporting development of Fizeau-CGH test method by Jim Burge at Univ. of Arizona (illustration adapted from Burge et al, 2010)
Segment Production Plans

- TMT Segment production plans must be solid and credible
  - Reviewers & competitors see this as a key challenge the Project must address:
    - Technical risk: optical performance (edges, high spatial freq.)
    - Total production cost:
      - A variety of production methods are being proposed (some unproven)
      - Facilitation expenses may be large
    - Production schedule:
      - segments will be on the project critical path
- TMT Partnership must decide on best path forward in the next year
  - Consideration being given to both 1-supplier and 2-supplier plans
  - Options include possibly dividing the production between an aspiring supplier in a partner country and a more experienced one – inside or outside the partnership
Current Project Status

- TMT is currently in the Early Construction Phase
- Highest priorities:
  - Detailed design & prototyping
  - Manufacturing development
  - Project-wide planning and cost estimating
    - Project is currently engaged in a comprehensive update of our construction plans and cost estimate
    - External panel review of Construction Cost Estimate: January 2011
  - Partnership development:
    - Definition of partner roles
    - Industrial demonstrations and cost estimates
    - Support of partner funding proposals
    - October TMT Board meeting was an important step forward in this process
TMT Schedule by Program Phase

TMT Project Schedule by Programmatic Phase
(by calendar year)

DDP
ECP
Construction
EOPS/Operations

Planning date, paced by partner funding
More Information About TMT is Available at:  http://www.tmt.org
Summary

- TMT is in its Early Construction Phase,
  - aiming for the start of on-site construction in 2012
- The TMT international partnership is coalescing
  - partner roles will be firmed up in the next year
- TMT segment production requirements are demanding
  - good, quick and cheap
- TMT is currently on schedule to complete construction and have “first light” by the end of 2019
Acknowledgments

The TMT Project gratefully acknowledges the support of the TMT partner institutions. They are the Association of Canadian Universities for Research in Astronomy (ACURA), the California Institute of Technology and the University of California. This work was supported as well by the Gordon and Betty Moore Foundation, the Canada Foundation for Innovation, the Ontario Ministry of Research and Innovation, the National Research Council of Canada, the Natural Sciences and Engineering Research Council of Canada, the British Columbia Knowledge Development Fund, the Association of Universities for Research in Astronomy (AURA) and the U.S. National Science Foundation.