The Status of the Thirty Meter Telescope Project

Gary Sanders and Jerry Nelson
SPIE 7733-69 San Diego
July 1, 2010
Where We Are
TMT Schedule by Program Phase

TMT Project Schedule by Programmatic Phase
(by calendar year)

- DDP
- ECP
- Construction
- EOPS/Operations

SPIE 2008
Where we are

- $85 million DDP completed April 2004 – March 2009
- $42 million ECP underway April 2009 – September 2011
- Hawaii site selected and Hawaii EIS approved
- Major and critical systems in Preliminary Design except
  - Enclosure, Mirror Blanks, Segment Polishing, Segment Supports are in Final Design
  - Summit Facilities in Schematic Design
  - Early Light Instruments, Observatory Software in Conceptual Design
- Vigorous partnership formation effort in progress with Caltech/UC, Canada, Japan, China, India, … to define
  - Multi-partner technical responsibility and
  - Resource implementation planning
  - 2010 – 2011 to complete this process
India joins as observer in Thirty Meter Telescope project

India joined as an observer in the ambitious astronomical observatory - Thirty Meter Telescope (TMT) - on Friday in Hawaii. The observatory will help in unravelling mysteries of black hole, origin of galaxies and formation of planets among others.

The status of an observer is first step by India in becoming a full partner in TMT which will be fully operational in the year 2018. A statement of the project said that it will be world's most advanced astronomical observatory.

Minister of Science and Technology Prithviraj Chavan announced the decision to join the project in Washington.
TMT Site Decision and Mauna Kea Process

Chile Campaign
Mauna Kea Selection
Public Release of All Site Data
Hawaii Permitting Process
Facilities Design Status
It could have been Chile!...

Congratulations to ESO on selecting Cerro Armazones for the E-ELT!
Corporación norteamericana solicita concesión a Bienes Nacionales para instalar observatorio

La Ministra de Bienes Nacionales, Romy Schmidt, recibió en audiencia a representantes de TMT Observatory Corporation quienes están solicitando una concesión fiscal para instalar un nuevo observatorio astronómico en la Región de Antofagasta. En esta reunión participaron Gary Sanders, representante oficial de TMT, Angel Otárola, asistente de TMT, Pablo Mecklenburg, jefe de la División de Bienes, y Angelica Palacios, jefa del Departamento de Enajenaciones del Ministerio.
Thirty Meter Telescope Selects Mauna Kea

July 21, 2009

PASADENA, Calif. — After careful evaluation and comparison between two outstanding candidate sites—Mauna Kea in Hawaii and Cerro Armazones in Chile—the board of directors of the TMT Observatory Corporation has selected Mauna Kea as the preferred site for the Thirty Meter Telescope. The TMT will be the most capable and advanced telescope ever constructed.

When completed in 2018, the TMT will enable astronomers to detect and study light from the earliest stars and galaxies, analyze the formation of planets around nearby stars, and test many of the fundamental laws of physics.

To achieve these outstanding results, the TMT will integrate the latest innovations in precision control, segmented mirror design, and adaptive optics to correct for the blurring effect of Earth’s atmosphere, enabling the TMT to study the Universe as clearly as if the telescope were in space. Building on the success of the twin Keck telescopes, the core technology of TMT will be a 30-meter primary mirror composed of 492 segments. This will give TMT nine times the collecting area of today’s largest optical telescopes.
Press Release

TMT Releases Public Database of its Site Testing Campaign

01.05.2010

Pasadena, Calif. — The Thirty Meter Telescope Project (TMT) is launching a new database containing 5 years of atmospheric data from the telescope’s initial five candidates sites: Cerro Tololo, Cerro Armazones, and Cerro Tolonchar, Chile; San Pedro Martir, Mexico; and Mauna Kea, Hawaii, the site selected for TMT. A website containing the entire dataset, the largest of its kind, will be released free of charge to the public today.

“TMT believes that this dataset will be of great interest to the site testing community and astronomers in general,” said Matthias Schoock, TMT’s Image Quality Scientist. “Whether it is because they are interested in the sites themselves or as input for simulations or data analysis, the data will be available to any team looking to build or operate an observatory.”

The breadth and consistency of the dataset will also make it of value to researchers in climatology, boundary layer physics, aeronautics, and satellite studies, explained Schoock.

The new database includes accurate and long-term measurements of virtually every atmospheric feature that might affect the performance of the telescope, including turbulence strength, temperature, barometric pressure, wind speed and direction, humidity, atmospheric water vapor content, solar irradiance, ground heat transfer, dust levels, and cloud cover.

An essential element of the TMT site testing campaign was the deployment of identical...
Press Release

EL Proyecto Astronómico TMT Libera Para Uso Público Su Base De Datos De Estudio De Sitio

01.05.2010

Pasadena, Calif. - El Telescopio de Treinta Metros ha colocado a disposición del público en general su base de datos consistente en los parámetros atmosféricos observados en el transcurso de cinco años y para los cinco sitios candidatos para la instalación de este telescopio. Los sitios incluidos son: tres en el norte grande de Chile, Cerro Tololo, Cerro Armazones y Cerro Tolonchar, y los sitios San Pedro Mártir en Baja California, México y el sitio denominado 13N en el volcán Mauna Kea en Hawái, respectivamente. Este último resultado es el sitio seleccionado para el TMT.

Esta base de datos de variables atmosféricas esta disponible en forma gratuita al público en general. El Dr. Matthias Schöck, científico de TMT y quien dirigió los estudios atmosféricos ha dicho: "TMT espera que esta base de datos resulte de interés a la comunidad astronómica en general. Pero especialmente a los investigadores interesados en las ciencias atmosféricas, climatología, aeronáutica, a aquellos interesados en el uso de energías renovables para quienes variables tales como velocidad y dirección del viento, así como radiación solar, son especialmente relevantes, y también a los investigadores interesados en el estudio de las condiciones atmosféricas en relación a la instalación y operación de proyectos astronómicos."


Thirty Meter Telescope Site Testing -- Public Database Server

These pages provide access to the database of the Thirty Meter Telescope (TMT) site testing effort. It is our hope that they will become a useful tool for site testers, astronomers and other interested users around the world. The data are provided free to anybody with minimal usage and publication restrictions.

This data set represents a multi-year campaign at the five TMT candidates sites. The data have been gathered for, depending on the site and the type of data, periods between two and five years. Data were taken using identical sets of instruments on all five sites.

Site Content:

- **Overview**: Descriptions of the TMT candidate sites, the site testing instrument suite, the data in the database, known problems with the data, and the date ranges for which data are available
- **Change Log**: Changes made to the database or website are reported here
- **Create Account**: Create a log-in account
- **Download Data**: Download data from the database, provided as ASCII tables (log-in required)
- **Plot Data**: Online plotting tools (log-in required)
- **Usage Conditions**: Conditions for use and publication of results obtained with the data
- **References**: List of references describing the TMT site testing work, candidate sites, instruments and results
- **Acknowledgements**: List of contributors to the TMT site testing effort and TMT funding sources
- **Disclaimers**
- **Contact Us**: For questions or comments concerning the data or this website

**Important**: Please note that the data are not filtered for potentially invalid or corrupted points, as this would alter some of the statistics of the data set. Data that are invalid for one analysis might have to be included for another, so as not to arrive at misleading or incorrect results. We have therefore not excluded data from the database even if there are known problems with them. Please check out the Known Issues page for more information.

The TMT Project gratefully acknowledges the support of the TMT partner institutions. They are the Association of Canadian Universities for Research in Astronomy 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 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, Inc. (AURA), and the U.S. National Science Foundation.
Two processes are required to build on Mauna Kea
- Chapter 343 (Environmental Impact Statement) (EIS)
- Conservation District Use Permit (CDUP)
- These are done partially in parallel

State of Hawaii also developed and approved a prerequisite Comprehensive Management Plan for Mauna Kea

The TMT Final EIS was approved by Hawaii Governor Lingle on May 20

University of Hawaii Board of Regents unanimously approved TMT and the submission of our Conservation District Use Application on June 28
June 23, 2010 – Hawaii Island

Video by David Corrigan, voice of Tim Bryan

Governor Linda Lingle made a trip to the Big Island of Hawaii on Tuesday to tour the leaders in innovation and technology on all sides of the county.
OMKM Design Process
Design Development Review Meeting

Thirty Meter Telescope
Summit Facilities

José Terán U., AIA
Eric Grigel, AIA

April 5, 2010

TMT.SUM.PRE.10.006.REL01
Site Plan – 13 North

Area of Disturbance:
4.85 Acres
(Previously 4.4 acres)

Contour Intervals: 1 Ft.

Prevailing Wind

north
Floor Plan: FFE=13,130'
Construction Sequence
Summit (Pre-Construction)
Construction Sequence
Rough Grading
Construction Sequence
Pier / Foundation Excavation & Utilities
Construction Sequence
Pier and Tunnel Concrete
# Construction Sequence

**Fixed Enclosure Foundation & Slab**

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Construction Sequence
Fixed Enclosure Structural Steel
Construction Sequence
Rotating Enclosure Erection
Construction Sequence
Foundation & Tunnel
Construction Sequence
Concrete Slab & Backfill
Construction Sequence
Summit Facility Steel
Construction Sequence
Fixed Enclosure Wall Panels
Construction Sequence
Shell, Utilities, & Site Work
Construction Sequence Completion
- 30m filled aperture, finely segmented
- Three mirror telescope
- f/1 primary
- Field of view 20 arcmin
- Elevation axis in front of the primary
- Wavelength 0.31 – 28 µm
- Operational 1° thru 65°
- Seeing-limited
- Adaptive optics
The Primary Mirror System
Full Scale Segment on Segment Support Assembly
Segment #1 Sub-aperture Optical Test
Room Temperature

1.2m Test Plate

P2 Segment
Segment Development Across TMT

- Tinsley and ITT are carrying out a mature polishing development process.
- E-ELT efforts with SAGEM and Optic Glyndwr are also relevant to TMT and both projects are cooperating to provide robust and competitive options in glass varieties and fabrication.
- In addition, as TMT has broadened to become a global project, polishing trials are being initiated in Japan, China and India.
- Selection of the fabrication firms is scheduled at the end of 2011.
LAMOST → ELT technology
NIAOT annular polishing
Stressed Mirror Polishing at NIAOT
1.5 meter ion beam figuring
Vertical Testing Tower at NIAOT

Polishing Machine with 4-m diameter capacity
India
Canon polishing trials for TMT M1 segments are based upon experience with the Subaru HSC instrument and the G1 asphere.

Canon has extensive serial production capacity.

Specs. of G1 lens:
- 0.86m in Diameter
- Asphere at concave
- Sphere at convex
Secondary Mirror (M2) Design Studies by NOAO, CSA, Quartus, SAGEM, ADS
Tertiary Mirror (M3) Design Studies by NOAO, GDST, IMTEC, Brashear, Melco
Mitsubishi Electric Corporation (MELCO) built SUBARU 8m telescope. MELCO is working on R&D activities for TMT including:
- Preliminary study for M2, M3 active support system based on the successful experience of M1 active support of SUBARU.
- Performance prediction for M3 support system.

Photos are courtesy of NAOJ
Actuator Development and Selection

TPG P1
Hard Actuator

JPL P1
Hard Actuator

Keck
Hard Actuator

Marjan P0
Soft Actuator

Marjan P1
Soft Actuator

TMT Actuator
(Marjan P1+ Soft Actuator)

TMT P2
Actuator
(JPL/Marjan)
Sensor Development and Selection

- Micro-Epsilon Inductive Sensor
- Keck Capacitive Sensor
- Heidenhain Optical Sensor
- Fogale Inductive Sensor (Direct deposition onto glass)
- TMT Capacitive Sensor (Flexible winding bonded to glass)
AO System Architecture

- **Narrow Field IR AO System (NFIRAOS)**
  - Mounted on Nasmyth Platform
  - Interfaces for 3 instruments
  - 4-OAP, distortion free design

- **Laser Guide Star Facility (LGSF)**
  - Laser launch telescope mounted behind M2
  - Lasers mounted on TMT elevation journal
Wavefront Correctors: Prototyping Results

Subscale DM with 9x9 actuators and 5 mm spacing

Prototype Tip/Tilt Stage

Simulated DM Wiring included in bandwidth demonstration

Low hysteresis of only 5-6% from -40° to 20° C

-3dB TTS bandwidth of 107 Hz at -35C

20 Hz Req’t
Highlights Since 2008 SPIE

- Improved distortion-free NFIRAOS optical design
- Improved LGSF architecture matched to progress in lasers
- Component development progress
  - Tip/tilt stage prototype
  - HgCdTe Teledyne H2RG detector noise tests
  - Visible WFS polar coordinate CCD prototyping
  - RTC Conceptual Design Studies [7736-38; Tue 1550]
  - Laser System Preliminary Designs/prototypes (ESO/AURA) [7736-64; Thu 1400]
- Performance estimates updated and refined
  - Updated turbulence/telescope models [7736-31, Mon 1630; 7736-70; Thu 1640]
  - Sky coverage modeling; side- vs. center launch LGSF study; fratricide… [7736-16, Sun 1610; 7736-167, Wed 1800 ; 7736-178, Wed 1800]
- Lab demonstration of LGS wavefront sensing architecture with time varying, unknown sodium layer profiles [7736-77; Fri 1050]
- High resolution sodium layer LIDAR measurements [7736-71; Thu 1710]
Guidestar Laser at TIPC, Beijing
Field experiment for LGS system

589 nm laser system for LGS

Laser setup: 12.7W, $M^2=1.2$, 0.4GHz, 589nm

Launch telescope
made in IOE, CAS

Sodium beacon image

Recorded with a CCD
“Polar Coordinate” CCD Array Concept for Wavefront Sensing with Elongated Laser Guidestars

Fewer illuminated pixels reduces pixel read rates and readout noise

D = 30m

\( \Delta H = 10 \text{km} \)

H = 100 km

Elongation \( \approx 3-4'' \)

sodium layer

TMT

LLT

AODP Design
Polar Coordinate CCD Masks
Serial Register Routing
Mauna Kea, Hawaii

10m horizontal resolution

View from the NW
Aero/thermal modeling on Mauna Kea (benchmarked with Keck, CFHT data)
Segment Support Assembly (SSA) Manufacturing Error

- Prototype measurement:
  - 1 g axial load - \( \sim 25 \text{ nm}_{\text{RMS}} \) (mostly astigmatism and focus)
  - 1 g lateral load - \( \sim 18 \text{ nm}_{\text{RMS}} \) (mostly astigmatism)
- Corrected by Warping Harness and APS (Segment-Wise Controller) at 30° zenith
  - During initial shape correction
  - After segment exchanges (together with the rest of the figure errors)
  - Springs back towards 0° and 65°
- No maintenance between APS runs – WH is “set-and-leave”

Prototype measurement:
- 1 g axial load - \( \sim 25 \text{ nm}_{\text{RMS}} \) (mostly astigmatism and focus)
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Segment Support Assembly (SSA) Manufacturing Errors

- Prototype measurement:
  - 1 g axial load - ~25 nmRMS (mostly astigmatism and focus)
  - 1 g lateral load - ~18 nmRMS (mostly astigmatism)

Corrected by Warping Harness and APS (Segment-Wise Controller)
- During initial shape correction
- After segment exchanges (together with the rest of the figure errors)
- Springs back towards 0° and 65°

No maintenance between APS runs – WH is "set-and-leave"

Modeled performance contribution: 0.9967
Project Management Control System

INTEGRATED SYSTEM

- Cost Estimating (Proprietary)
- Integrated Project Schedule (IPS) (Open Plan)
- Earned Value Management System (EVMS) (Cobra)
- Enterprise Reporting (Proprietary)
- Change Control (Proprietary)
Feasibility studies 2005-6
(concepts, requirements, performance,...)
Define instrument capabilities
Parameters: $\lambda$, $\Delta \lambda$, $R$, $d\Omega$, $\theta$

"Package" capabilities into desired instrument suite

Science Requirements Document (SRD)

Feasibility Studies (~200 scientists+engineers @ 46 institutions)

TMT Science Flowdown

TMT Foundation Documents

Observatory Requirements Document (ORD)
Observatory Architecture Document (OAD)
Operations Concepts Document (OCD)

Revised SRD

TMT Detailed Science Case

More Detailed Science Cases

Operational concepts (calibrations, etc.)
TMT Early Light Science Instruments

- IRIS
  - [7735-208, 212, 214, 284, 285, 79, 87]

- IRMS
  - [7735-211]

- WFOS
  - [7735-215, 77]

- MOSFIRE
  - [7735-49]
Early light instruments are expected to be available at the start of TMT science operations. This category includes the following instruments:

- Wide-Field Optical Spectrometer (WFOS)
- InfraRed Imaging Spectrometer (IRIS)
- InfraRed Multi-slit Spectrometer (IRMS)

First decade instruments are expected to be commissioned during the first decade of TMT operations. They include:

- Planet Formation Instrument (PFI)
- High-Resolution Optical Spectrometer (HROS)
- Mid-InfraRed Echelle Spectrometer (MIRES)
- InfraRed Multi-Object Spectrometer (IRMOS)
- Near-InfraRed Echelle Spectrometer (NIRES)
First version of Handbook prepared for 2007 TMT science workshop in Irvine:

In 2010 version:

- 160 pages covering Early-Light and First Decade instrumentation (requirements and designs), instrument synergies, and instrument development
- Updated information on WFOS and IRIS
- All 2006 instrument feasibility studies were combed systematically to extract all available science simulations, and tables of sensitivities/limiting magnitudes/integration times

Available at http://www.tmt.org/documents.html
TMT “Kickoff” Instrument Meeting just before SPIE 2010

“An introduction to TMT instrumentation”

Goals:

- Update teams on project status, design and performance expectations
- Discuss early-light instrument status
- Discuss partner capabilities and interests (both scientific and technical)
- Provide introduction to current plans for future instruments
- Provide opportunities for partners to meet, exchange ideas and share technical expertise
- Solicit community feedback
- Initiate an open interchange and work towards soliciting proposals for a new look at TMT science instruments and AO upgrades
Summary

- Access to Mauna Kea, and site specific design and planning are advancing
- Major TMT systems are in vigorous Preliminary Design
- Most critical hardware items have been prototyped and tested
- Key technology choices have been made
- All the major management processes of a major project are in use or nearing readiness
- Designing TMT to cost is underway
- The industrial base for TMT is being demonstrated
- Forming a global TMT team is underway, towards an observatory that will support our full set of science requirements, with first light in 2018.
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.