Plan

- Introduction to TMT & project update
- Capabilities for studying the Small Bodies of our Solar System
International Partnership and construction site(s)

Canada
Univ. California & CalTech

China

Japan

India

Hawai‘i (prime site)

Canary Islands (alternate site)
US-ELT Program

U.S. EXTREMELY LARGE TELESCOPE PROGRAM
Under Development by NOAO, TIO, GMTO

NSF’s National Optical Astronomy Observatory (NOAO)
Giant Magellan Telescope Organization (GMTO)
Thirty Meter Telescope International Observatory (TIO)

2 telescopes, 2 hemispheres, 1 system
All-sky coverage
Broad instrument suite
US-led Key Science Programs

Overlap area → Airmass < 2 for 2 hours or more
TMT in a nutshell

- Wide-field, Alt-Az Ritchey-Chretien telescope
- 30 meter diameter primary mirror (492 hexagonal segments, 1.44m across corners)
- Can swap instrument/targets in ~ 10 minutes
- Can track fast non-sidereal targets (e.g. NEOs)
- Up to 8 instruments on two Nasmyth platforms

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.

Expected (re-)start of construction: 2019. First-light: 2027/28
TMT’s science operations model
(work in progress . . .)

- TMT will support **visitor** (PI-mode) & **service** (queue) observing modes (inc. ToOs, eavesdropping)
  - Visitor mode: All observations done remotely from HQs

- TMT operations staff will support all science operations activities
  - Proposal submission, observing preparation/execution, instrument performance-monitoring/upgrades, quality control, data-reduction

- Proposal cycle of 12 months with **fast-turnaround**

- **All data archived**: Raw, calibrations, metadata, possibly reduced-data (proprietary period ~ 18 months)
Current construction timeline

- **Today:** Access granted in Hawaii and La Palma (*only a few admin steps away in Hawaii*)
- **2019:** Start of construction in Hawaii (*La Palma is backup site*)
- **2020-2022:** Enclosure assembly
  - End 2023: End construction of all summit buildings
- **2022-2024:** Telescope structure integration
- **2024-2027:** AIV, commissioning
- **2028:** “First-light”
Science / instruments capabilities

- Dynamical and compositional monitoring & mapping of planetary surfaces & atmospheres
  - Support of space missions
- Study of the most primitive bodies in our solar system
  - Transport of volatiles across solar-system, search for organics
- Observing time-variable events (quick operational response-time)
**Expected boost in performance**

- **SENSITIVITY:** $S \sim D^2$
  - ~10 times the collecting area of Keck, or ~150 times that of the HST
  - For AO on point sources: $S \sim D^4$, i.e. ~200 times better than current VLTs

- **ANGULAR RESOLUTION:**
  - 12 times better HST
  - 3-4 times better than current VLTs
TMT spatial resolution at 1μm and at opposition for selected solar system bodies

<table>
<thead>
<tr>
<th>Target</th>
<th>Diameter (km)</th>
<th>Distance (in AU)</th>
<th>Angular diam. (&quot;)</th>
<th>Nb resolution elements across apparent diam.</th>
<th>Nb resolution elements across apparent surf.</th>
<th>Spatial resolution (km)</th>
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<td>Ceres</td>
<td>952</td>
<td>1.63</td>
<td>0.81</td>
<td>130 (~30 with VLT)</td>
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Ceres

Sphere, VLT

Dawn, S/C
TMT instruments
Discovery space

First-light + next-generation instruments capabilities

- **HROS (India & China)**
  - (comets, IGM z<6, ISM/stellar abundances, kinematics, RV/exoplanet, cosmology)

- **MODHIS**
  - (planetary surface & atmosphere, IGM z>7, chemistry of star formation, low-mass stars RV, stellar abundances, SN/Gamma-Ray burst)

- **IRMOS**
  - (resolved imaging of small bodies, exoplanets, star formation, AGN)
  - (small bodies composition, AGN, SMBH, high-z galaxies, dark matter, dark energy, exoplanets, star formation, stellar population)

- **WFOS**
  - (small body surfaces, comets, IGM structure, dark matter, galaxy chemistry z>1.5, SN/gamma-ray burst)

- **IRIS**
  - (planet atmospheres and small bodies, star formation, disks, exoplanets, AGN)

- **b-MICH**
  - (IFU spectroscopy of small bodies, early universe, JWST follow-up)
TMT instruments
Discovery space

- Instrument science teams being formed (time to join!)
- Conceptual studies to start this year
- Perfect time to discuss science requirements to secure that your science can be done
Possible timeline of instrument deployment

1st light and “next-generation”

- **1st light**
  - WFOS
  - IRIS
  - Adaptive Optics
  - MODHIS

- Deployment of PSI (blue), HROS, IRMOS

- Deployment of future instrument capabilities (still tbd)

TMT in operations until 2080+

**Recommendation:** The National Science Foundation (NSF) should invest in both the GMT and TMT and their exoplanet instrumentation to provide all-sky access to the U.S. community. (Chapter 4)

**Recommendation:** NASA should implement high-contrast starlight suppression technologies in near-term space- and ground-based direct imaging missions. (Chapter 5)

From “Exoplanet science strategy”, 2018, National Academy Press

From “Astrobiology strategy to search for life in the universe”, 2018, National Academy Press
Small bodies

- Asteroids (dry, “wet”, main-belt comets)
  - Satellites/rings: Search and characterization
  - 3-D shape and collision history
  - Surface composition (search for ices, organics)

- Comets
  - Near-IR and infrared regions are fundamental to study properties of released molecules
    - D/H ratio, nuclear spin temperatures of some species (e.g. NH$_3$, H$_2$O and dissociated products). Organic and prebiotic chemistry
  - Spectroscopy in the blue/UV ($\lambda<0.4\mu$m)

- Centaurs & Trans-Neptunians are faint, BUT brightest can be observed with AO/LGS (directly or w/ star appulse)
  - cryo-volcanism activity, ring structures, satellites
    - e.g. Chariklo, Chiron?, Haumea
Moons and rings observations to study solar system dynamics and collisions (via direct imaging or occultations)

- Aristide Vokrouhin, et. al. 2013
- K. Meech et. al. 2013
- T. Spence et. al. 2017
- M. Marsset et. al. 2017

Neptune’s ring arcs. Voyager and HST/Nicmos

- AO imaging (PSI)
- Fast photometry (WFOS, IRIS)
- near-IR low-res spectroscopy (PSI, IRIS)
Terrestrial planets got their water via transport of small, hydrated, solar system bodies such as asteroids, comets, trans-Neptunian objects.

A compositional of the most primitive/icy objects of our solar system (comets, asteroids) will help better constrain the origin of Earth’s water.

- AO imaging (PSI, IRIS)
- UV/near-IR low/high-res spectroscopy (WFOS, IRIS, MODHIS)
Giant planets and satellites

- Atmosphere composition, circulation/dynamics
- Energy budget
- Isotopic ratios and abundances
- Satellites
  - (cryo-)volcanism (e.g. Enceladus, Triton, Pluto)
  - surface/atmosphere composition and boundary conditions
    - Titan: Lake formation and surface/atmosphere interaction
    - Monitoring of Io’s volcanoes and Europa’s surface
    - Mapping of Europa and search for bio-signatures of organic material

AO imaging (IRIS, PSI) near-IR low/high-res spectroscopy (IRIS, MODHIS, MICHII)
International Science Development Teams - ISDT

ISDTs provide a unique opportunity to:

- Build bridges between the TMT project and the international science community
- **Shape the future science capabilities of TMT**
  - Definition of science cases and science/instrument requirements
  - Definition of ‘Key-programs’ (large, long-term observing programs)
- **Get involved in defining TMT’s operations capabilities to maximize science outputs of TMT**
  - Telescope time proposal process, data need, data-reduction pipelines, etc
- **Organize topical meeting** on specific science domains
  - E.g. Annual TMT Forum, TownHall meetings at AAS/DPS, science workshops, etc
ISDT membership renewed yearly

- Ongoing open call for 2019 (isdt@tmt.org). Deadline: Feb. 08

More than 200 scientists worldwide for 9 ISDTs:

- Early universe/galaxy formation, Exoplanets, Star-Planet formation, Solar system, Physics and cosmology, Milky-way & nearby galaxies, Stellar physics & the ISM, Supermassive black-holes, Time domain science
… while waiting for real construction images

Thank you!