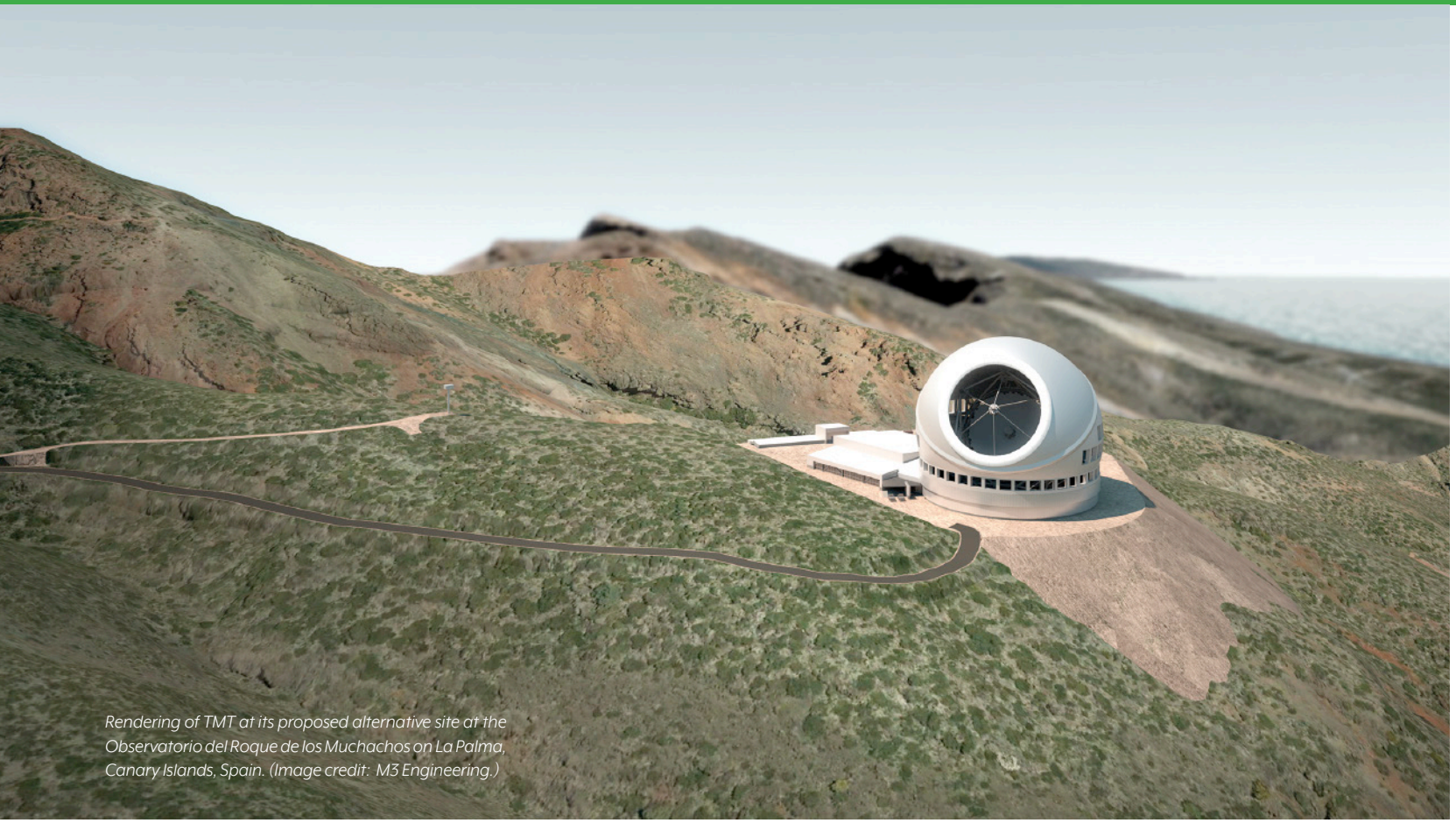

*Rendering of TMT at its proposed alternative site at the Observatorio del Roque de los Muchachos on La Palma, Canary Islands, Spain. (Image credit: M3 Engineering.)*

# An Update on the Thirty Meter Telescope Site

Mark Dickinson (NOAO), Christophe Dumas (TMT International Observatory), and Michael Bolte (UC Santa Cruz)

Maunakea was selected in 2009 as the preferred site for building the Thirty Meter Telescope (TMT). An Environmental Impact Statement (EIS) was completed and approved by the Governor of Hawai'i in 2010. Because of the well-known cultural sensitivities associated with Maunakea, the EIS development included 14 community meetings and multiple consultations with Native Hawaiian cultural practitioners. After a long process that included additional public meetings and a seven-day contested case hearing, the Hawai'i Board of Land and Natural Resources granted the permit to build and operate TMT at Maunakea in April 2013. Following this, the TMT International Observatory (TIO) and the University of Hawai'i agreed to terms for a sublease, which was approved (officially, "given consent") by the Land Board in July 2014. Work at the site was set to begin in the spring of 2015. However, the construction project is opposed by some members of the Hawaiian community, and protests stopped construction vehicles on several occasions. In December 2015, the Supreme Court of the State of Hawai'i vacated TMT's conservation district use permit on procedural grounds. Through the courts, a new contested case hearing was ordered and that hearing is now underway. If the hearing officer rules in favor of TMT, there will be a second vote of the Land Board on whether to issue a new permit. There may also be an additional hearing specifically on the terms of the sublease. If a new permit is issued, it is quite likely that it will be challenged and that the case will go directly back to the state's Supreme Court.

While Maunakea remains the preferred site for TMT, and TIO is fully engaged in the activities in Hawai'i, the TIO Governing Board has now selected an alternative site in case construction on Maunakea cannot be approved in a timely manner. The TIO Board has stated that its firm goal is to start TMT construction in April 2018. To make this possible, "reasonably assured access" to a site is required by the fall of 2017, in order that budget proposals can be submitted to the financial authorities of the various TIO partners.

In 2016, the TMT project, its Scientific Advisory Committee (SAC), and the Governing Board considered several alternative sites in both hemispheres. Some of these sites had been previously considered by TMT before the selection of Maunakea in 2009, while others were being reviewed for the first time. In the north, the sites that were studied were the Observatorio del Roque de los Muchachos (ORM) in La Palma, Canary Islands, Spain; San Pedro Mártir in Baja, Mexico; Ali in China; and Hanle in India. Two Chilean sites were also considered: Cerro Vicuña Mackenna, which is nearby to Cerro Armazones (now the site of the European Extremely Large Telescope, E-ELT) and with similar altitude, and Cerro Honar, a high-altitude (5400m) site above the Chajnantor plateau, where ALMA is located.

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***Update on the TMT Site continued***

Many criteria were considered for these alternative sites, including the astronomical characteristics of the sites and their suitability for carrying out the TMT science mission, construction feasibility, the cost of construction and operations, the schedule for initiating and completing construction, the degree of risk for obtaining the required permits, and the legal status of TIO to carry out construction and operations in the host country of each site. All of the alternative sites were considered to be excellent for carrying out the core science of TMT, and the potential host countries and organizations all welcomed TMT's interest. During the course of these studies, the interests of the US astronomical community as a whole were represented by AURA's representatives on the TMT SAC, informed by discussions within the US TMT Science Working Group (SWG), which was convened by NOAO as part of the ongoing cooperative agreement between the National Science Foundation and TMT to develop a plan for potential US national partnership in the observatory. AURA representatives also participated as non-voting observers in TIO Board discussions.

After many months of intense site-study activity, the TIO Board announced on 31 October 2016 that it had selected ORM on La Palma as the primary alternative to Maunakea, based on the excellent observing conditions to support TMT core science programs; on considerations of cost, risk, and timeline; and on the importance of ensuring giant telescope access to Northern Hemisphere skies. The European Extremely Large Telescope (E-ELT) and the Giant Magellan Telescope (GMT) will both be situated in Chile, leading TIO to favor a Northern Hemisphere site to ensure full-sky coverage by the new generation of giant optical/infrared international observatories. Detailed information about ORM and its selection as the TMT alternate site is available at *www.tmt.org/observatory/site-information/alternate-site-studies*.

ORM is operated by the Instituto de Astrofísica de Canarias and is the home to nine telescopes, including the 10.2-meter Gran Telescopio de Canarias. It was recently selected as one of the sites for the Cherenkov Telescope Array. Among the alternate sites considered for TMT, ORM is that for which it is most practical to undertake a quick start in the case that Hawai'i is not feasible, and it has the shortest projected construction schedule. This is due in large part to the accessibility of ORM and the existing infrastructure in Tenerife and Santa Cruz de La Palma.

ORM has excellent astronomical observing conditions, particularly regarding seeing and adaptive optics (AO) metrics. The table summarizes a variety of site characteristics for ORM and for TMT's planned Maunakea Observatories (MKO) site. AO is central to many aspects of TMT science, and diffraction-limited performance enables sensitivity gains proportional to the fourth power of primary mirror diameter, or even more for crowded-field conditions. TIO's study shows that the atmospheric turbulence profile above ORM is similar in character to that of Maunakea and that the median seeing, isoplanatic angle, and atmospheric coherence time at ORM are nearly as good as those at MKO. The fraction of usable nights is the same for both sites (72%).

Dust from the Sahara Desert can reach the Canary Islands, particularly at sea level, and there is a perception in the astronomical community that it can significantly impact observations at ORM. TIO's study examined many sources of data about dust at La Palma and other sites, including 25 years of measurements from the Carlsberg Meridian Telescope at ORM, as well as observatory logs. It found that the average dust levels at the altitude of ORM are comparable to those at MKO. There is an increased likelihood of enhanced extinction events at ORM in July and August, but overall extinction statistics at ORM are similar to those at MKO, as well as to other sites such as Cerro Paranal. There is no evidence that observatory-level dust causes significant loss of observing time, and the effect of dust on telescope optics was found to be similar for both ORM and MKO. In fact, fractions of time with dust masses exceeding 100 µg/m3, which typically requires dome closure, are several times more frequent at Maunakea than at ORM.

La Palma's elevation is substantially lower than that of Maunakea. This leads to a warmer mean temperature, hence increased thermal background affecting observations at wavelengths longer than about 2.2 microns. Precipitable water vapor is significantly higher at this lower altitude, and higher atmospheric pressure leads to broader telluric absorption and emission lines. Together, these effects can compromise performance at mid-infrared wavelengths at ORM compared to MKO, particularly at wavelengths longer than 14 microns.[1] Extinction at UV wavelengths close to the atmospheric cutoff is also

| **Site Characteristics** *(median values, unless otherwise stated)* | **MKO (USA)** | **ORM (Spain)** |
|---|---|---|
| Altitude of site (m) | 4050 | 2250 |
| Fraction of yearly useable time (%) | 72 | 72 |
| Seeing at 60m above ground (arcsecond at 500 nm) | 0.50 | 0.55 |
| Isoplanatic angle (arcsecond) | 2.55 | 2.33 |
| Atmospheric coherence time (ms) | 7.3 | 6.0 |
| Adaptive Optics Strehl merit function | 1.0 | 0.93 |
| Precipitable water vapor (% time < 2mm) | 54 | ≥20 |
| Mean nighttime temperature (oC) | 2.3 | 7.6 |
| Extinction ($V_{mag}$/airmass) | 0.111 | 0.137 |

*Main site characteristics for MKO and ORM. The AO merit function is an updated version of the one described by Schöck et al. 2011, RevMexAA, 41, 32 and is designed to scale inversely with the observing time required to achieve a specified sensitivity or science goal.*

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[1] TMT does not presently have a thermal infrared instrument planned as a first-light capability, although there is an active development effort for a possible future-generation instrument. The current design for this instrument, known as bMICHI, is focused on the 3 to 13 micron wavelength range.

***Update on the TMT Site continued***

higher. The Thirty Meter Telescope Detailed Science Case (Skidmore et al. 2015, RAA, 15, 1945) features important examples of thermal infrared science in the areas of star formation, exoplanets, our solar system, and AGN and near-UV spectroscopy for studying the intergalactic medium and stellar physicts. To some degree, particularly in the mid-infrared, ORM's disadvantages can be mitigated by implementing an operations model that includes flexible scheduling to take advantage of the best conditions for high-priority observations. ORM is also farther north than Maunakea (28.9° vs. 19.8° latitude), which is disadvantageous for observing some important southern targets such as the Galactic Center but helpful for AO observations at high northern declinations such as M31, M33, M82, the Coma Cluster, and the GOODS-North and Extended Groth Strip deep-survey fields.

TIO will now work to complete a hosting agreement for ORM and to carry out the permitting process for that site. Detailed replanning for construction at ORM is also underway. The TMT SAC will further consider impacts of the possible change of site on TMT's planned instrumentation and its operations model. In the meanwhile, TIO intends to continue its full participation in the Hawai'i contested case hearings and in any legal proceedings that follow. The US TMT SWG agrees that Maunakea remains the preferred site on scientific grounds but that most aspects of the case for US national participation in TMT would be unchanged if the observatory were built on La Palma instead. Even before the current effort to identify an alternate site, the US TMT SWG has stressed the benefits of adaptive, flexible scheduling to make use of the best observing conditions for certain programs, and this may become even more relevant at ORM, particularly for mid-infrared science. The SWG feels that an expedient path to construction and first light is essential. While SWG members had mixed opinions about priorities for northern vs. southern sites, they clearly recognize the value of hemispheric complementarity with E-ELT and GMT and the net benefit for astronomy of full-sky coverage by the new giant telescopes.

# US National Gemini Office Mini-workshop: "Mining Observatory Archives"

Ken Hinkle

The US National Gemini Office (US NGO) sponsored the third in a series of winter AAS mini-workshops at the January 2017 AAS meeting in Grapevine, Texas. The mini-workshops focus on topics of interest to the US and Gemini user communities. The topic for the January 2017 workshop was "Mining Observatory Archives."

Publication statistics from Gemini and other major public observatories show that less than half of the programs scheduled result in a publication. Statistics at Gemini show this to be independent of instrument or mode of observation and whether or not raw or pipeline-reduced data are delivered. Even the percentage of the program completed does not have a strong impact for programs over 50 percent complete. The average time between observation and publication is two years, with the number of publications after two years declining roughly exponentially.

All data taken at public observatories enter the public record after the proprietary period expires. Observatories and their funding agencies are anxious for the data to be used. With observational astronomy transitioning from a strong dependence on principal investigator (PI)–driven research to survey science, the discovery and use of archival and survey data is becoming increasingly important. Furthermore, the archived data results from highly ranked peer-reviewed proposals.

The workshop began with a discussion of observatory metrics by Andy Adamson (Gemini). André-Nicolas Chené (Gemini) then discussed the Gemini Archive. The next two speakers were Harry Teplitz (Caltech; IPAC) and Scott Fleming (STSci; MAST). The IPAC and MAST databases are largely funded by NASA and aggressively promote the use of archived survey and PI data. Access to this data has become a fundamental part of many research programs. The session concluded with a presentation by Knut Olsen (NOAO) on the Data Lab project. Data Lab is an ambitious project at NOAO to provide access to the large imaging surveys currently taking place with NOAO telescopes. Data Lab includes tools well-suited to mining both survey and archival data.


*From left to right are workshop speakers Knut Olsen (NOAO), Scott Fleming (STSci), Ken Hinkle (US NGO, NOAO), Andy Adamson (Gemini), Harry Teplitz (Caltech), and André-Nicolas Chené (Gemini). (Image credit: B. Miller/Gemini.)*

Each Gemini partner country hosts a national office. The US office is part of the Community Science and Data Center division of NOAO.

The workshop abstracts and PowerPoint presentations are available on the US NGO website at *http://ast.noao.edu/csdc/usngo/mini-workshops*. We welcome suggestions for future topics of broad interest to the NOAO and Gemini communities.