

Testimony of Gary H. Sanders

I am Gary H. Sanders, Project Manager for the Thirty Meter Telescope (TMT) Project.

I received a B.A. degree from Columbia University in 1967 in physics and a Ph.D. from M.I.T in 1971 in high-energy physics. I then spent two years as Postdoctoral fellow in the Princeton University Physics Department before becoming an Assistant Professor at Princeton from 1972 to 1978. I worked at Los Alamos National Laboratory from 1978-1994 in several positions, serving as Principal Investigator and Program Manager for High Energy Physics, 1990-1994. I was the Project Manager and Deputy Director, Laser Interferometer Gravitational Wave Observatory at the California Institute of Technology from 1994 – 2004. In 2004, I became the Project Manager for the Thirty Meter Telescope for the California Institute of Technology and the University of California, which formed the TMT Observatory Corporation (TMT Corporation).

I have been with the TMT Corporation since 2004 and since May 2014 with the TIO. I am responsible for managing the design and construction of the Thirty Meter Telescope. The TMT International Observatory (TIO) was formed on May 6, 2014 and I report to its board of directors.

The TMT International Observatory, LLC

TIO builds on the prior and ongoing efforts of TMT Observatory Corporation, a California non-profit public benefit corporation formed by the University of California and the California Institute of Technology for the purpose of fostering astronomy. TIO is comprised of the University of California, California Institute of Technology and governmental institutions from China, Japan, India and Canada.

I. TMT Project Components

An astronomical observatory encompasses a number of components. This section outlines the various components of the TMT Project and provides explanation for certain terms. The TMT Project is the sum of the following proposed components:

- “TMT Observatory” refers to the components of the TMT Project located on the upper elevations of Maunakea, but below the summit. The TMT Observatory generally consists of the 30-meter telescope, instruments, dome, attached building, and parking.
- The “Access Way” refers to the road and other infrastructure improvements that will be provided to access and operate the TMT Observatory. Improvements in the Access Way will generally include a surface roadway and underground utilities.

- Hale Pohaku work refers to Hawaiian Electric and Light Company (HELCO) Upgrades. The new transformers will replace the existing ones on a 1:1 basis, and the fenced compound will not be expanded.
- “Headquarters” refers to the facility located in Hilo to manage activities at and support operation of the TMT Observatory. This includes an office building with a parking area.

A. TMT Observatory

The TMT Observatory will be located on Maunakea within the Mauna Kea Science Reserve (MKSR) on Hawai‘i Island in the State of Hawai‘i.

The entire 11,288-acre MKSR (TMK 4-4-15: 9) is designated as part of the State of Hawai‘i Conservation District resource subzone. It is managed by the State of Hawai‘i Department of Land and Natural Resources (DLNR), though certain responsibilities are delegated to the University of Hawaii (UH) through the Comprehensive Management Plan (CMP) (UH 2009a). The MKSR is leased by DLNR to the UH; the current lease expires in 2033. Eight optical and/or infrared observatories are currently present in the MKSR’s 525-acre Astronomy Precinct; the first Maunakea observatories were built in the 1960s. Optical/infrared telescopes use mirrors to collect and focus visible and infrared light. Each optical/infrared observatory consists of a single telescope, except the W. M. Keck Observatory which currently houses the two most powerful optical/infrared telescopes on Maunakea, each with a 10-meter diameter primary mirror. The MKSR also hosts three submillimeter observatories and a radio antenna¹ (Figure 1).

¹ The Very Large Baseline Array (VLBA) antenna is a telescope but does not individually meet the definition of an observatory because it is only one part of a larger array, which stretches from the U.S. Virgin Islands to Maunakea. All the various antenna, instrumentation, and support facilities make up the VLBA antenna.

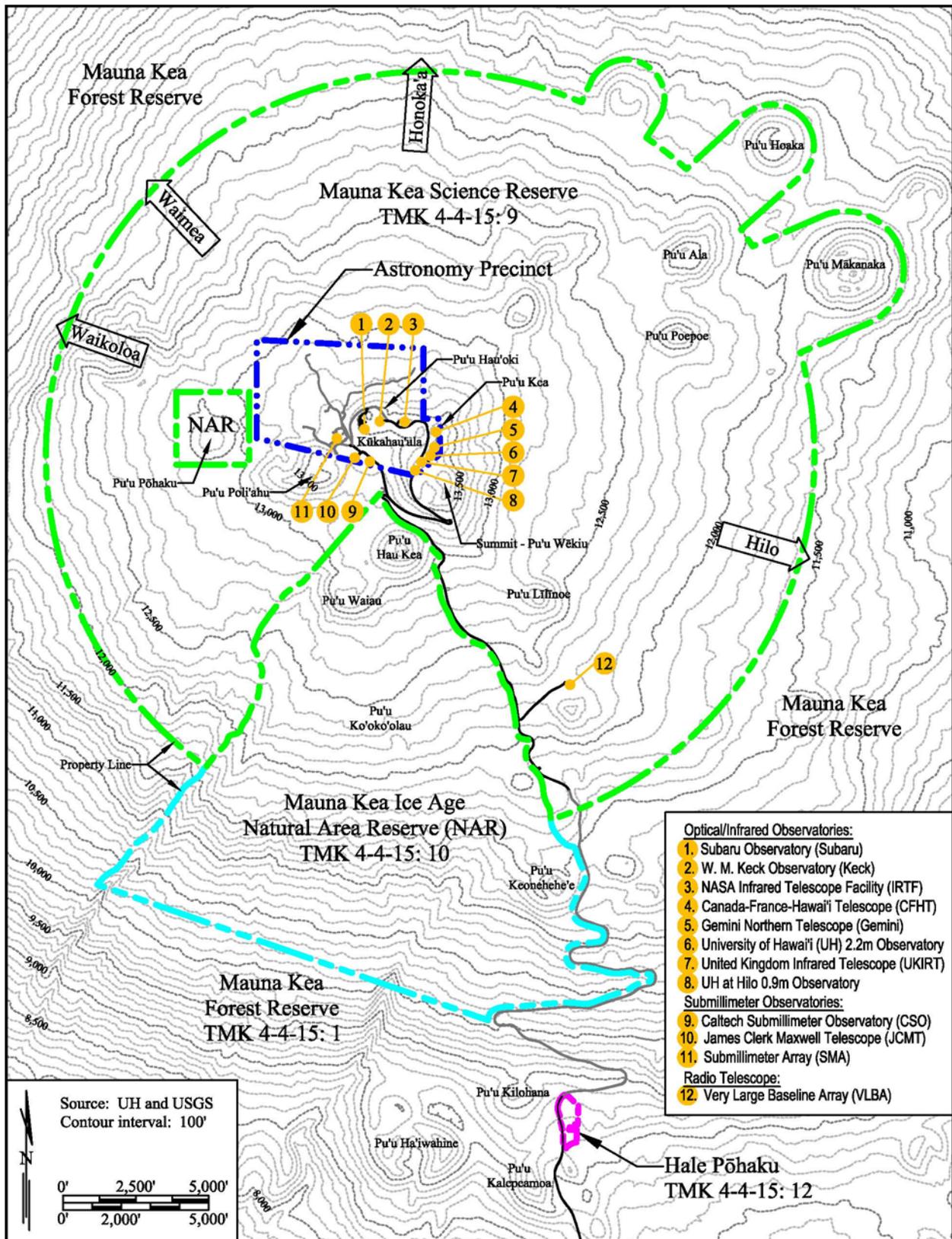


Figure 1: Maunakea Overview

The 2000 Master Plan specifies Area E as a preferred location for a NGLT. Area E was identified as a preferred location because it was anticipated to provide suitable observation seeing conditions with the minimum impact on existing facilities, wēkiu bug habitat, archaeological sites, and viewplanes. Area E ranges in elevation from 13,100 to 13,300 feet; the summit of Maunakea is at an elevation of 13,796 feet. Area E is located approximately 1/2-mile northwest of the eight existing optical/infrared observatories located near the summit. The elevations range from 13,600 to 13,775 feet. Thus, Area E is significantly lower in altitude than the summit region and the existing optical/infrared observatories.

Within Area E, the TMT Observatory will be located on a roughly 5-acre site near the end of the existing 4-wheel drive road, at an elevation of approximately 13,150 feet. This site is known as 13N in reference to its elevation and its location on the northern plateau.

B. TMT Observatory Design

The TMT Observatory design is being and will continue to be developed in consultation with the Office of Mauna Kea Management (OMKM) through their design review process. Whenever possible, the TMT Project will incorporate sustainable technologies and energy efficient technologies into facility design and operations, per CMP Management Action IM-11. The design details provided here represent the current design. The OMKM design review process has been in progress since 2008. No significant design changes, such as the TMT Project site or dome and support building size and height, are anticipated; however, adjustments to finer details could still take place. The TMT Observatory will include the following:

- The telescope, described above. The surface of the primary mirror will be located approximately 66 feet above the ground surface.
- The instruments mounted around the primary mirror used to see and analyze both the visible part of the spectrum and the infrared spectrum.
- The TMT Adaptive Optics (AO) system. The TMT Observatory will be the first optical/infrared observatory of its size to integrate AO into its original design. AO systems correct for the image distortion that is caused by the atmosphere. The TMT AO system will project up to eight laser beams into the atmosphere to create an asterism, or group, of “guide stars” that are used to determine the atmospheric distortion of the visible and infrared light from distant objects and thus correct for it. The TMT AO system will generate each of these eight beams using a 25-watt laser; the laser light will appear yellow (0.589 microns – the sodium D2 line).

- The dome housing the telescope will be a Calotte² type enclosure with the following characteristics (Figures 2 and 3).
 1. Total height of roughly 183.7 feet above the current ground surface, with an exterior radius of 108 feet.
 2. The dome shutter will be 102.5 feet in diameter and it will retract inside the dome when opened.
 3. The dome will rotate on two planes, one horizontal at the base structure 25 feet above the ground and the other at roughly 25 degrees as the cap structure, enabling the telescope to view from straight up into the sky to 65 degrees downwards toward the horizon.
 4. The Calotte dome base, cap, and shutter structures will appear rounded and smooth and have a reflective aluminum-like exterior coating.
 5. The fixed cylindrical structure below the rotating base will enclose 35,000 square feet, and extend to 25 feet above grade. The structure will be lava-colored.
 6. The dome base structure and dome fixed structure will have a combination of 88 vents that will be closed during the day and will open at night. The vents will be used to maintain temperature equilibrium between interior and exterior air at night and manage air flow through and around the dome.

² A Calotte type dome features a circular shutter and two planes of rotation. Standard observatory domes include a rectangular shutter and one plane of rotation. Benefits of a Calotte type dome include (a) overall smaller dome size, (b) improved air flow profile reducing air turbulence around the dome, (c) mechanically less complex, and (d) sheds snow better.

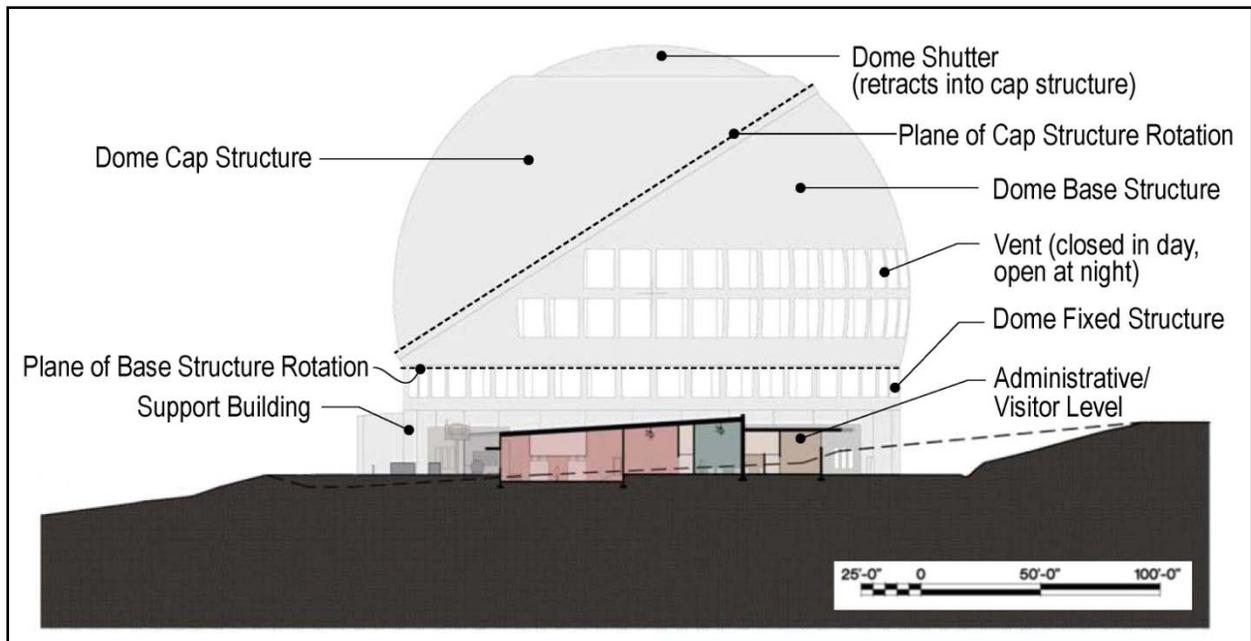


Figure 2: TMT Observatory Cross Section

- A support building will be attached to the dome (Figures 2 and 3). The building will have a roof area of approximately 21,000 square feet, a total interior floor area of roughly 18,000 square feet, a flat roof, and be lava-colored. The support building will include the following spaces:
 1. Mirror coating and staging area.
 2. Laboratory and shop spaces, including a computer room, engineering and electronics laboratories, and mechanical shop.
 3. Utility spaces – including electrical services, chillers, a generator, pumps for fire suppression and other non-potable water needs, restrooms, and fluid dynamic bearing pumps that control the movement of the telescope.
 4. Administration space, including offices and a kitchenette.
 5. Visitor and public spaces, consisting of a lobby, restroom, and viewing platform.

- A roughly 6,000 square foot exterior equipment area on the north side of the support building (Figure 3) will include two electrical transformers and electrical service switchboards; three 5,000-gallon underground storage tanks – one for water storage, one for domestic waste storage, and one double-walled for chemical waste storage; a 25,000-gallon underground storage tank for water storage as part of the fire suppression system; and one double-walled 2,000-gallon above-ground storage tank for diesel fuel to power the emergency generator.

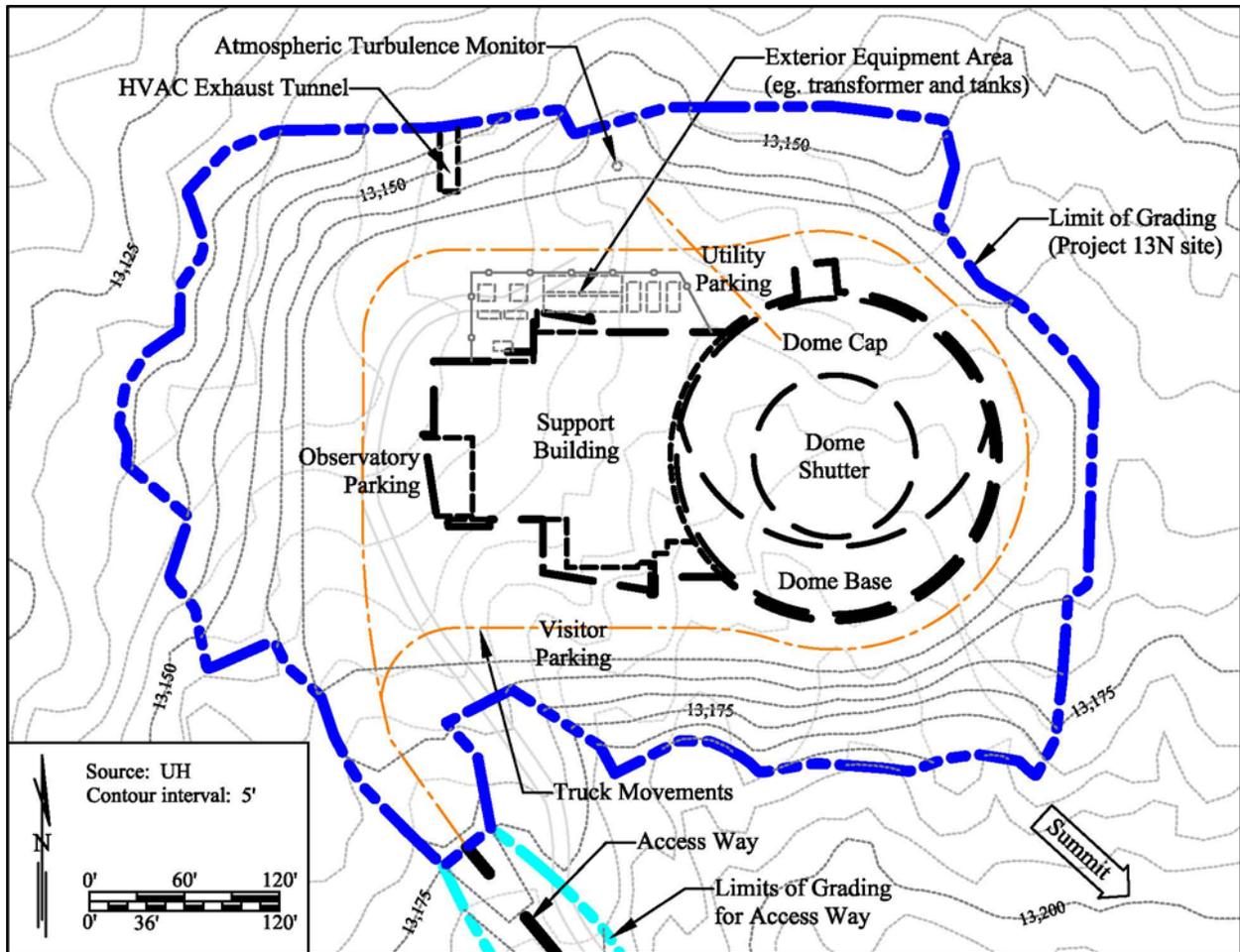


Figure 3: TMT Observatory Plan View and Grading Plan

- Parking area for observatory staff and delivery vehicles (Figure 3). Parking areas will be unpaved and located outside of the support facility. A guard rail will be placed along the top of the slope on the north and west sides of the graded area where there is a drop off.
- Weather instruments will be mounted on a roughly 30 foot tall tower. The atmospheric turbulence monitor will be on a 7-meter tower and located just outside the guardrail at the northwest corner of the level area (Figure 3).

The footprint of the TMT Observatory dome, support building, parking area, and area disturbed during construction will be roughly five acres. A 0.5-acre portion of this area has previously been disturbed by the existing 4-wheel drive road and site testing equipment; the original disturbance occurred during site testing in the 1960s, site testing was also performed in the 2000s, and geotechnical studies in 2013/14 within the five acre TMT site. Finally, some site preparation for the TMT groundbreaking was done in 2015 also within the TMT site boundaries.

C. Access Way

The Access Way will include a road and utility services to the TMT Observatory from existing services. Currently, utility services exist along the Mauna Kea Access Road to a point near the intersection of the Mauna Kea Loop Road and the Submillimeter Array (SMA) roadway. The proposed Access Way will start at that point and extend to the TMT Observatory; it will follow either existing 4-wheel drive roads or the wider roads that serve the SMA facility. The Access Way that the TMT Project has proposed is limited to a single lane over the southernmost portion of the Access Way (i.e., the portion that crosses Pu'u Hau'oki and through the SMA array); the remainder is two lanes. The vast majority of the Access Way route follows and goes over an existing single-lane, 4-wheel drive road that was previously developed for access and testing of the 13N site in the 1960s. A portion of the route was graded during construction of the SMA facility as well. Some work was done on the Access Way to facilitate the geotechnical studies and TMT groundbreaking.

The switch boxes needed to extend electrical power and communication service to the TMT Observatory will be placed above ground next to the existing ones across the road from the SMA building. To the extent possible, utilities from that point northward to the TMT Observatory site will be placed beneath the road to reduce the footprint of disturbance, with pull boxes located to the side of the road in already disturbed locations where possible. UH will ensure that any easement required for this utility is obtained.

D. Hale Pōhaku

Two transformers within the HELCO compound will be upgraded by the local electrical utility company. The HELCO compound is located across Mauna Kea Access Road from Hale Pōhaku. The new transformers will be placed in the same location as the existing transformers and the existing fenced compound will not be expanded.

In addition, electrical service from the transformer compound near Hale Pōhaku to the existing utility boxes across the road from the SMA building will be upgraded by the local electrical utility company to support the TMT Observatory's power requirements. This will be done by removing existing conducting wire and placing new electric conducting wire in existing underground conduits.

The existing conduit is located approximately 50 feet west of the Mauna Kea Access Road within UH Management Areas for portions of the distance to the summit area; however, in areas the electrical conduit is located along a former access road alignment that is now within the Ice Age NAR (Figure 4).

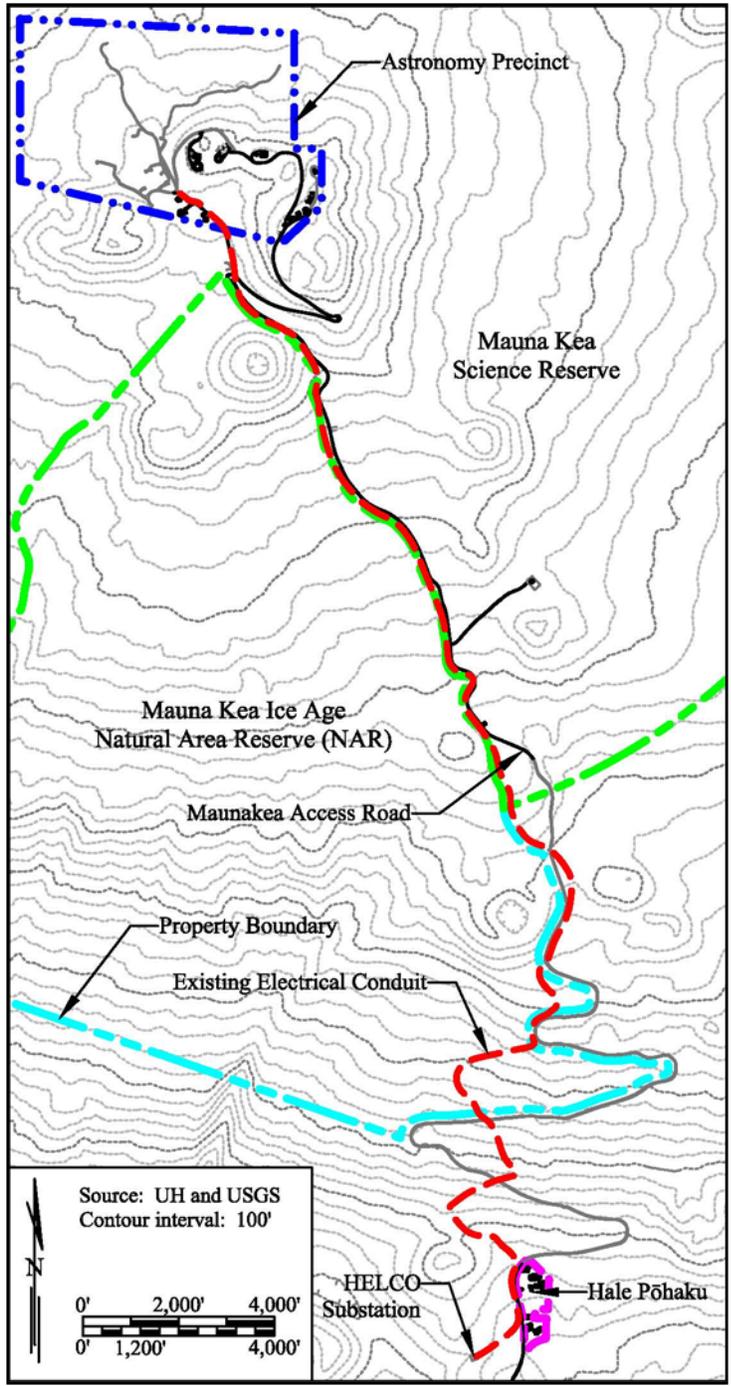


Figure 4: Route of Electrical Conduit

There are pull boxes located approximately every 300 feet along the conduit. Installing new wire in the conduit will not result in any new disturbance but the local utility company will need to access the pull boxes to install the new cable.

II. Construction Areas

During construction, additional areas will temporarily be utilized and/or disturbed. Construction baseyards required for the construction of the telescope and observatory will include:

- “Port Staging Area.” An existing warehouse and/or yard near the port where the TMT Project components are received. This area will be used for receiving materials and assembly of those materials to the extent possible prior to transport to either another staging area or the construction site.
- “Batch Plant Staging Area.” A roughly 4-acre area northwest of where the Mauna Kea Access Road forks near the summit. This area will primarily be used for storing bulk materials and a concrete batch plant, as it has been in the past during construction of other observatories.
- The area within the TMT Observatory and Headquarters sites not occupied by structures will also be utilized as staging areas during construction of those facilities. These areas will be utilized for materials needed in the short term and final pre-assembly of components prior to installation.

III. TMT Project Phases and Activities

The TMT Project involves four major phases: planning and design, construction and testing, operation, and decommissioning. The following sections discuss activities anticipated during the various phases of the TMT Project.

A. Planning and Design

The TMT Corporation conducted an extensive worldwide study to evaluate potential locations for the TMT Observatory. After narrowing the potential observatory sites to five, site testing was performed to evaluate observation conditions at each of the five sites. Based on testing results and other factors, Maunakea in the United States was identified by the TMT Corporation board as the preferred site.

The Hawaii Revised Statutes Chapter 343 environmental review process for the TMT Project at the Maunakea site is completed. The design of the TMT Observatory has been ongoing, and has included design of the telescope; instruments, including the AO system; and the dome and attached building.

B. Construction and Testing

Project pre-construction could begin in 2018, with construction to follow if a CDUP was approved. It would take approximately seven years to complete. Construction would begin with Access Way improvements. These improvements provide access to and support construction of the TMT Observatory.

It is anticipated that the construction crew at the TMT Observatory site will average 50 to 60 crew members through the life of construction; during certain phases, a crew of more than 100 will be working at the site. Construction is expected to take place six days a week, 10 hours a day; however, some operations or construction phases will require longer work hours. It is also expected that winter weather conditions at the TMT Observatory site will interrupt construction at times.

First light, or the time when the TMT Observatory is first used to take an astronomical image, is expected no earlier than 2024. Tests will then be conducted and adjustments to the telescope and instruments made for a period of time to gain optimum efficiency and seeing.

C. Operation

The first scientific results using the TMT Observatory are expected no earlier than 2024. During the life of the TMT Observatory, astronomical observations will be made by scientists from around the world. A staff of up to 140 people will be necessary to operate and maintain the observatory. It is expected that an average of 24 employees will work at the TMT Observatory during daytime operations, with a minimum of 15 and a maximum of 43 possible depending on activities. Each night a nighttime staff of up to 6, but typically 2 to 3 operators, will be present at the TMT Observatory, while observers and support astronomers will observe remotely from the Headquarters. All other members of the staff will work at the Headquarters.

D. Decommissioning

The TMT Observatory and the extent of the Access Way exclusively used to access the TMT Observatory will be dismantled and the site restored at the end of the TMT Observatory's life, in compliance with the Decommissioning Plan for the Mauna Kea Observatories, a Sub-Plan of the Mauna Kea Comprehensive Management Plan (Decommissioning Plan) (OMKM, 2010a). Deconstruction and site restoration efforts will be managed by the TMT Project staff with oversight by OMKM. A process similar to the Mauna Kea Management Board (MKMB) approved Project Review Process will be established to review, guide, and recommend the disposition of a site, including site restoration. Reviewers will include OMKM, Kahu Kū Mauna, and the MKMB Environment Committee, with MKMB approval required. Options include:

- Complete infrastructure removal – the entire facility, including all underground utilities, pilings, and foundation would be removed to the extent practicable; or

- Infrastructure capping – all or part of the underground portion of the facility would be left in place, capped with an impermeable material, and topped with materials similar to the surroundings.

1. Site Restoration Plan (SRP)

The SRP will present specific targets for site restoration and describe the methodology for restoring disturbed areas after the demolition/construction activities described in the SDRP are completed. The Decommissioning Plan (OMKM, 2010a) states that the two primary objectives of site restoration are (1) restoring the look and feel of the summit prior to construction of the observatories, and (2) providing habitat for the aeolian arthropod fauna.

The level of restoration to be performed and the potential impact of the restoration activities on natural and cultural resources during and post-activity must be carefully evaluated in the SRP. Specific factors that need to be considered during the development of the SRP include cultural sensitivity.

Three levels of site restoration have been set forth in the CMP (UH, 2009a) and the Decommissioning Plan (OMKM, 2010a). Establishing three levels recognizes that in addition to the potential benefits of site restoration, there are also potential impacts. The three levels of site restoration are:

1. Minimal – would include the removal of all man-made materials and the grading of the site.
2. Moderate – would include the removal of all man-made materials, grading of the site, and enhancing the structure of the physical habitat to benefit the arthropod (insect) community.
3. Full – would include return of the site to its original topography and restoration of the arthropod habitat.

The level of restoration to be performed by TMT will be negotiated between TMT, UH, and DLNR according to the sublease terms.

Site restoration activities may involve using stockpiled material or materials similar to the surroundings either to fill holes or to reconstruct topography. Consideration will be given to where fill material will come from, how excavation and removal of materials will impact the collection area and any habitat surrounding the restoration area, and what the cultural considerations are for bringing materials from a different place to Maunakea.

Upon the completion of site restoration, monitoring of the restoration activities will begin and continue for at least three years. Results of monitoring activities will be submitted to OMKM.

2. Management Actions

The CMP also lays out several decommissioning management actions, they are:

1. Consider future decommissioning during project planning and include provisions in subleases that require funding of full restoration (CMP Management Action SR-3).
2. Once the TMT Observatory's useful life has ended, develop a recycling and/or demolition plan (referred to as a SDRP and SRP in the Decommissioning Sub Plan) that considers items such as waste management and demolition best management practices (BMPs) (CMP Management Action SR-1).
3. CMP Management Action FLU-3 requires cataloguing the initial site conditions for use when conducting site restoration in the future.
4. Once the TMT Observatory's useful life has ended, develop a SRP in association with the SDRP, which will include an environmental cost-benefit analysis and a cultural assessment (CMP Management Action SR-2). The cost-benefit analysis of the three levels of restoration will consider restoration costs and related impacts, including the cultural assessment.

To address the first management action, the TMT Project has (a) included in the design of the TMT Observatory and Access Way the use of almost all excavated material on those sites so that it will be available for use again during site restoration, and (b) included in the planned TMT Project operation budget annually setting aside funds that will be used for decommissioning of the TMT Observatory. The TMT Project anticipates decommissioning and site restoration requirements will be included in the sublease.

The TMT Project is committed to preparing the necessary plans, such as the SDRP, and SRP, in accordance with the general timeline presented in the Decommissioning Plan and providing an opportunity for the public to comment on the plans.

IV. TMT Project's Educational and Employment Plans

A. Community Benefits Package

The TMT Project has committed to a **Community Benefits Package** (CBP). The CBP will be funded by the TIO and will be administered via The Hawaii Island New Knowledge (THINK) Fund Boards of Advisors. The THINK Fund Boards of Advisors will consist of local Hawaii Island community representatives. A portion of the CBP funding commenced in 2014 upon the start of the TMT Project construction and was committed to continue throughout the TMT

Observatory's presence, so long as the CDUP is not invalidated or construction is not stayed by court order. However, even though the TMT CDUP has been invalidated, TIO has continued the CBP. As part of the CBP, the TMT Corporation has provided \$1 million annually during such period to the THINK Fund; the dollar amount is adjusted annually using an appropriate inflation index. The funding is divided; \$750,000 distributed through the Hawaii Community Foundation and \$250,000 through the Pauahi Foundation. To date TIO has remitted \$630K to the Pauahi Foundation, and \$1.8 Million to the Hawaii Community Foundation, a total of approximately \$2.5 million.

The \$2.5 million remitted to date has funded over sixty scholarships and \$100,000 in small grants for classroom projects for twenty seven classrooms. The THINK Fund was the originator and initial contributor to the STEM Grant Learning Partnership program, giving \$400,000 in the first two years for this endeavor. Programs supported focus on key elements of building a strong STEM education system. Educational initiatives are focused on K-5, 6-8, 9-12, and college. The program includes support for students to visit 'Imiloa Astronomy Center and the Maunakea observatories.

B. Workforce Pipeline Program (WPP)

The TMT Project is committed to partner with UH Hilo, Hawai'i Community College (HawCC), and the Department of Education (DOE) to help develop, implement, and sustain a comprehensive, proactive, results-oriented WPP that will lead to a highly qualified pool of local workers who could be considered for hiring into most job classes and salary levels. Special emphasis will be given to those programs aimed at preparing local residents for science, engineering, and technical positions commanding higher wages. Therefore, there will be a significant component in the WPP for higher education on the Island of Hawai'i.

The TMT Project began to refine the WPP with a workforce roundtable in September 2009. The roundtable initiated information exchanges and close coordination with current and new programs on Hawai'i Island. A dedicated TMT Project WPP manager will coordinate the program.

In addition, the TMT Project is participating in a County of Hawai'i Workforce Investment Board initiative with the Mauna Kea Observatories to introduce focused programs within the Hawai'i Island community to provide the observatories with a broader and stronger qualified local labor pool for careers in the local astronomy enterprise

The program will continue focus on long term investments to strengthen the current STEM skills infrastructure, programs, and curricula at UH Hilo, HawCC, and Big Island K-12 education organizations, especially those serving lower income and first-generation college attending populations. Examples could be the development or support of astronomy, other sciences, and engineering education at UH Hilo as well as programs at HawCC that could provide well-qualified mechanical and electrical technicians. The scope of these investments will include

strengthening language and culture programs and their integration with science and engineering to broaden the appeal of STEM disciplines to Hawai'i Island college students while earning and retaining community support.

Initial efforts for the WPP began in 2008, and will ramp up during the early construction phase so that local youth of today have the qualifications and could be considered for hiring into most job classes and salary levels with the TMT Project when the operational phase begins.

VI. TMT Project Mitigation Measures

A. TMT Observatory Location

The TMT Observatory has been sited at the 13N site, within Area E, north of and below the summit. Therefore the TMT Observatory:

- Will not be visible from culturally sensitive locations, such as the summit of Kūkahau'ula, Lake Waiau, and Pu'u Līlinoe;
- Will not block the view of Haleakala from Pu'u Poli'ahu, is approximately 0.78 miles from the summit of Pu'u Poli'ahu, and is several hundred feet below it;
- Is more than 200 feet from known historic properties;
- Is not visible from Pu'u Wekiu, the very summit of Maunakea;
- Will not be visible from Hilo and the southern portion of the island; and
- Is outside of the wēkiu bug's preferred habitat.

B. TMT Access Way Design

The Access Way's physical and visual impacts have been mitigated by:

- Designing the Access Way to minimize the disturbed area and to reduce the potential for both physical and visual impacts to the historic properties and potential impacts to natural resources known to be in the vicinity.
- Limiting the southern 750 foot long portion of the Access Way to a single-lane even though such a configuration is not desirable from an operational standpoint.

- Aligning the bulk of the Access Way to follow an existing single-lane, 4-wheel drive road that was built in the 1960s for access and testing of the 13N site.
- Paving the portion of the Access Way within the boundaries of Kūkahau‘ula on the flank of Pu‘u Hau‘oki, and, therefore, within the alpine cinder cone habitat, in order to reduce dust.
- Coloring the pavement and guardrail a reddish color that blends with the surrounding area.
- Placing the utilities to the TMT Observatory within the Access Way and beneath the paved roadway instead of on a different or parallel alignment that would cause more ground disturbance.

C. Cultural and Natural Resources Training Program

Institute a Cultural and Natural Resources Training Program. The content of the training program will be determined by OMKM. All TMT Project staff and all construction workers have been and will continue to be trained annually regarding:

- Potential impact to cultural practices and archaeological/historic resources and the measures to prevent such impacts.
- Potential impacts to natural resources and the measures to prevent such impacts.

D. Development of Exhibits

The TMT Project will support, through financial contributions and utilization of its outreach office, the development of educational exhibits related to Mauna Kea. The exhibits will be:

- Developed in coordination with OMKM and ‘Imiloa.
- Address the following subjects: cultural, natural, and historic resources.
- Developed for use at the Visitor Information Station (VIS), ‘Imiloa, TMT facilities, and other appropriate locations.
- Include informational materials that explore the connection between Hawaiian culture and astronomy.

E. Restoration of Pu‘u Poli‘ahu

The TMT Project will fund the restoration of the closed access road on Pu‘u Poli‘ahu per a plan submitted by the Institute for Astronomy and approved by DLNR (SPA HA-10-04).

F. Camouflage Utility Boxes

The TMT Project will camouflage utility boxes that are visually distracting or intrusive at the summit of Mauna Kea and other key locations visible from other portions of Kūkahau‘ula. The method of camouflage will be determined through consultation with Kahu Kū Mauna and may include one of the following options:

- Painting the lids to match the surrounding natural colors.
- Affixing stones and cinders from nearby to the exposed utility box.

G. Sense of Place

- The TMT Project facilities will be furnished with items to provide a sense of place and acknowledge the cultural sensitivity and spiritual attributes of Mauna Kea.
- Will be a constant reminder of the lessons learned during the required annual cultural training to respect, honor, and not restrict or interfere with cultural or religious practices.

H. Cultural History

The TMT Project will support, through financial contributions and utilization of its outreach office:

- The translation of chants and mele and use their teachings; the focus here will include both (a) translation, and (b) developing programs that go to schools to spread what is learned about Hawaiian science and genealogy.
- The hosting of an annual cultural event or training. Examples of how this measure will be implemented include activities such as a star-gazing program at the annual Makahiki festival, workshops of stone adze-making, and workshops on how to recognize archaeological sites and to assess their importance.
- The translation of modern astronomy lessons into Hawaiian language for use at Hawaiian language charter schools.

I. Cultural Outreach

The TMT Project will:

- Have an open door policy so that the TMT Project’s outreach management can be contacted by the Native Hawaiian community to discuss various issues.
- Provide initial and then annual or as-needed tours of the TMT Observatory, with the Native Hawaiian community invited at least two weeks prior to the tour. Insofar as practicable, these tours will be scheduled on the days (up to four each year) on which cultural events are scheduled.
- Request permission to attend meetings of the Kahu Kū Mauna council on a quarterly basis. A TMT Project representative will be available on an ongoing basis to review cultural impact issues, should there be any related to the TMT Project. By attending the meetings the TMT Project representative would become aware of other cultural resource issues on the mountain and then implement any necessary changes in TMT Project policies to address potential similar issues at the TMT Observatory.
- Work with ‘Imiloa and Native Hawaiian groups to support/fund programs specific to Hawaiian culture and archaeological resources.

J. Cultural Observance

On up to four days per year, to be identified by Kahu Kū Mauna, the TMT Project will minimize daytime activities in observance of Native Hawaiian cultural practices. While the observatory will be operated during these periods, this measure will involve having only a skeleton crew at the observatory, minimizing vehicle traffic reducing noise, and prohibiting visitors to the TMT Observatory.

K. Cultural Protocols

Continue consultation with the State Historic Preservation Division and Kahu Kū Mauna Council regarding the appropriate protocols for the relocation of the modern shrine at the 13N site.

L. Arthropod Monitoring

Arthropod monitoring will be performed prior to, during, and for two years following construction in the area of the Access Way on the alpine cinder cone habitat (the flank of Pu‘u Hau‘oki).

M. Wēkiu Bug

The TMT Project will work closely with OMKM to develop and implement a wēkiu bug habitat restoration study.

N. Invasive Species Prevention and Control

Develop and implement invasive species prevention and control program that will include:

- Materials control and reduction.
- Washing/cleaning.
- Inspections.
- Monitoring.
- Species control and education/training.

O. Visual Impact

The TMT Observatory has been designed to mitigate its visual impact by:

- Reducing the size of the dome through the use of a Calotte type dome.
- Designing the telescope to be much shorter than usual using a focal ration of $f/1.0$ to allow for the smallest dome possible, minimizing the height, and thus the visual impact.
- Designing the dome to fit very tightly around the telescope, leaving just enough room for a person, only about 20 inches, between the telescope and the dome. In comparison, the Keck Observatory consists of two telescopes with mirrors 33 feet in diameter with a focal ration of $f/1.75$; the diameter of each Keck dome is 121. If the TMT were to use the same ratio of mirror to dome size it would result in a dome with a diameter of 364 feet.
- Finishing the dome with a reflective aluminum-like surface similar to that on the Subaru Observatory, which during the day reflects the sky and reduces the visibility of the structure.
- Finishing the support building and fixed structure exterior with a lava color.
- Figure 5 shows visual impact mitigations, Figure 6 shows mirror and dome size comparisons with current and planned observatories. Note that TMT is ~30 feet taller than Gemini.

Mitigation Measures Reduce the Size and Visibility of TMT

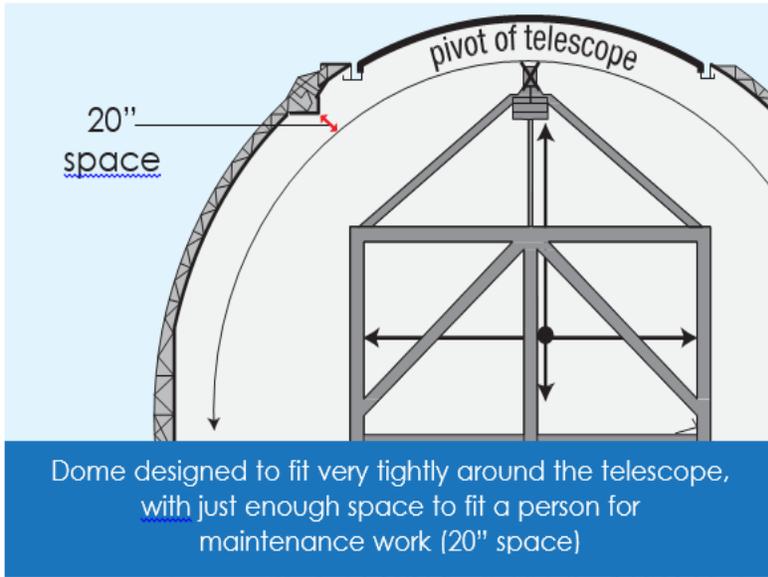
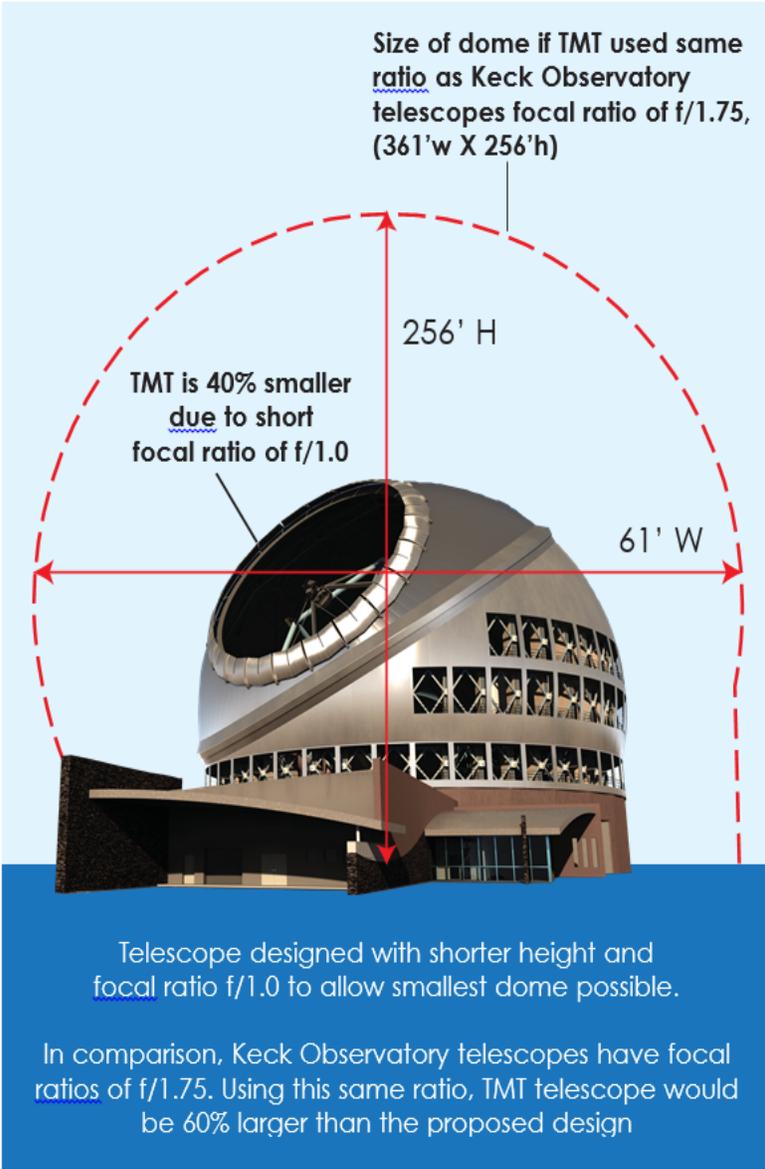


Figure 5: Visual Impact Mitigation

TMT's Relative Size is Small Given its Mirror Size

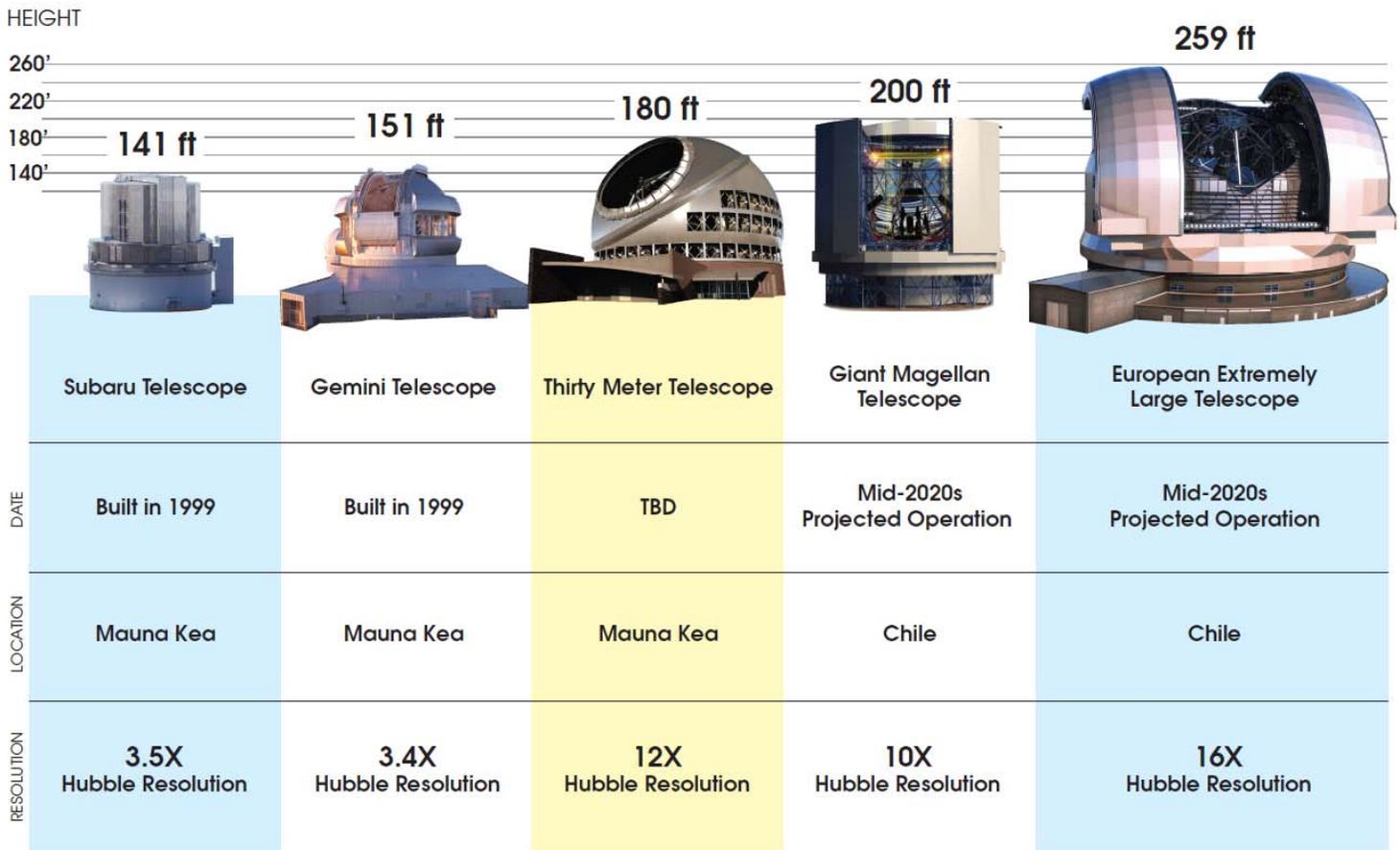


Figure 6

P. Wastewater Treatment

A zero-discharge wastewater system will be installed at the TMT Observatory. All wastewater generated at the TMT Observatory will be transported to an approved treatment facility for treatment and disposal. The discharge of wastewater within the summit region has been identified as an impact on cultural resources and is one of the reasons for this measure.

Q. Water Saving

The TMT Project will install water efficient fixtures and implement water saving practices to reduce the demand for freshwater resources.

R. Waste Minimization and Recycling

The TMT Project will implement a Waste Minimization Plan (WMP) and institute an annual WMP audit, which will include an examination of:

- Waste produced by the TMT Project and how that waste could be reduced, reused, or recycled.
- Water use by the TMT Project and how that use could be reduced.
- Energy use by the TMT Project and how that could be reduced.
- The TMT Project will recycle solid and non-hazardous waste material and reuse them to the extent possible.

S. Materials Storage/Waste Management and Spill Prevention and Response Plan

The TMT Project will implement a Materials Storage/Waste Management Plan, including a Spill Prevention and Response Plan. The plan will require:

- Daily inspections of equipment handling hazardous materials.
- Mandatory training of all personnel handling hazardous materials and wastes.
- Regular inspections by a Safety and Health Officer.
- That all solid waste be collected in secured and covered storage containers.
- That all wastes be transported down the mountain for proper disposal at an off-site disposal facility.