

# THE HISTORY OF ASTRONOMY ON MAUNAKEA & THE THIRTY METER TELESCOPE



MAUNAKEA OBSERVATORIES

Roy Gal  
UH Institute for Astronomy



5 September 2019



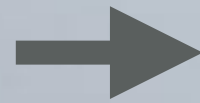




# Maunakea Astronomy Origins



May 23, 1960: a massive tsunami devastates Hilo.



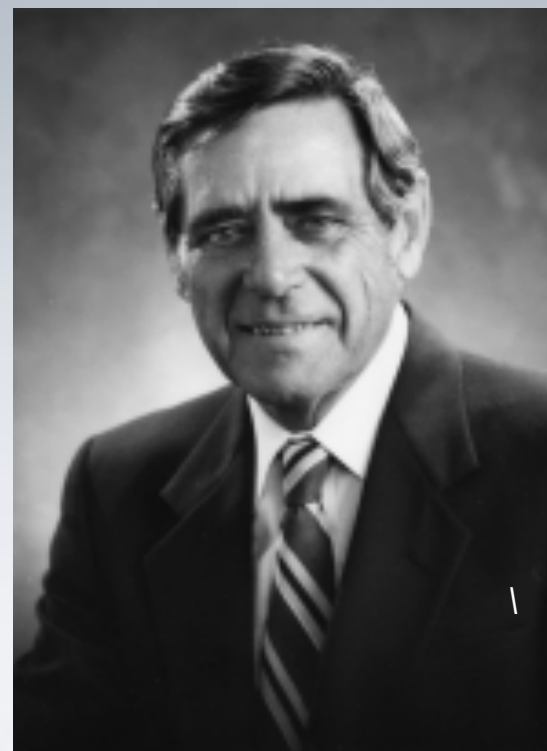
In 1964, Mitsuo Akiyama, HICC Executive Secretary, invites astronomers to check out Maunakea as an observatory site, to boost the economy.



The only response was from Gerard Kuiper, from the UA Lunar and Planetary Lab



Site testing proves Maunakea has superior conditions to Haleakalā



John Jefferies, just arrived at UH, competes for a NASA-funded telescope.





# Site Testing



Kuiper & Gov. Burns in 1964

Kuiper had tested Haleakalā in 1963, and returned to examine Maunakea. Gov. Burns offered state funds to build a road from HP to summit



Alika Herring  
Native Hawaiian, telescope maker,  
site tester



Mitsuo Akiyama, his wife, and Howard Ellis, head of Mauna Loa Weather Station



Alika Herring and his  
12" telescope on Maunakea

Maunakea is best site he has ever tested



# The First Telescopes

Two 24" telescopes open in 1968

Air Force telescope at Hoku Kea location

Lowell Observatory telescope where Gemini-N is now located



Mauna Kea Observatory, dedication of UH 88-inch telescope, June 26, 1970



The UH 88" opens in 1970 and establishes Maunakea as the best site for ground based astronomy



# Development in the 1970s

1973: CFH agreement signed, UKIRT designed

1974: IRTF contract awarded (against UA/Mt. Lemmon)

1975: UK plans sub-mm telescope but stops due to environmental opposition

1979: CFHT, IRTF, UKIRT go online

Maunakea is first site considered for sub-mm astronomy due to its dryness



CFHT



IRTF



# 1983 Development Plan

- Envisioned 13 telescopes (11 major + 2 minor) by year 2000
  - 1983 existing (6): 2x24" UH 2.2m CFHT UKIRT IRTF
  - Foreseen (3): CSO JCMT Keck I
  - Predicted (4): 3 O/IR (Keck 2, Subaru, Gemini) + 1 Radio (SMA)
  - 1994: One 24" removed for Gemini



# Development in the 1980s

1982: UK+Netherlands agree to build JCMT

1984: Keck Foundation \$70m donation to build a 10-m telescope; Maunakea selected from 13 sites

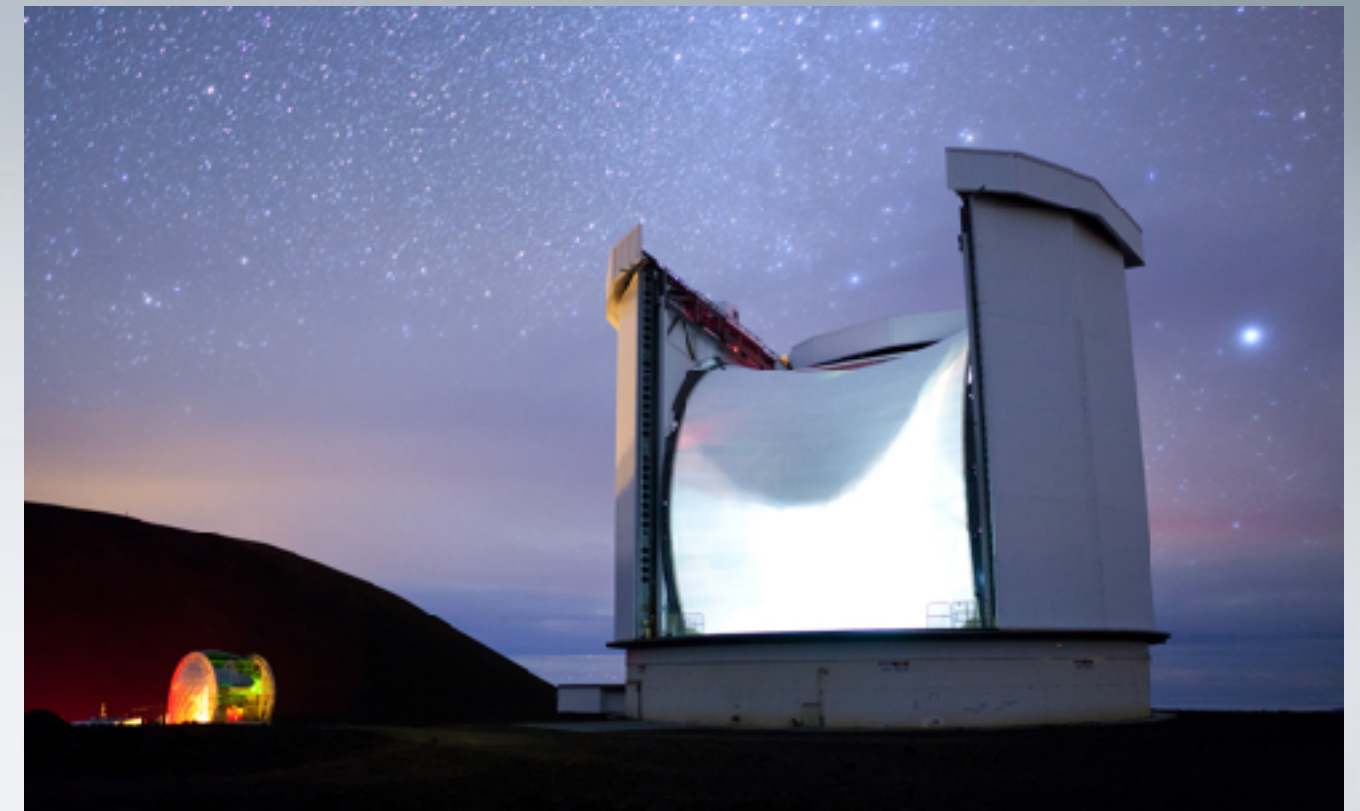
1986: CSO opens

1987: JCMT opens

1989: Gemini N+S proposed



CSO



JCMT



# Development in the 1990s

1993: Keck I opens

1992: VLBA antenna, far below summit

1992: Work begins on Subaru

1996: Keck II opens

1998: NASA plans Keck outriggers

1999: Subaru and Gemini-N open

1998: Audit of UH Management



Keck I + II



Subaru



Gemini N



# The 1998 Audit

We found that the University of Hawaii's management of the Mauna Kea Science Reserve is inadequate to ensure the protection of natural resources. The university focused primarily on the development of Mauna Kea and tied the benefits gained to its research program. Controls were outlined in the management plans that were often late and weakly implemented. The university's control over public access was weak and its efforts to protect natural resources were piecemeal. The university neglected historic preservation, and the cultural value of Mauna Kea was largely unrecognized. Efforts to gather information on the Weiku bug came after damage had already been done. Trash from construction was cleaned up only after concerns were raised by the public. Old testing equipment constructed in the early years of development has not been removed as required by the lease agreement.

This was 21 years ago, but it is still often referenced for  
UH management issues

<http://files.hawaii.gov/auditor/Reports/1998/98-6.pdf>



# 2000 Mauna Kea Science Reserve Master Plan

- Created Office of Maunakea Management (OMKM)
- Defined Astronomy Precinct (525 acres)
- Kahu Ku Mauna Council
- Project review process outlined
- Keck Outriggers & Pan-STARRS4 (did not happen)
- TMT at its current location
- Other future development limited to existing sites
  - CFHT → Maunakea Spectroscopic Explorer (MSE)

<http://www.malamamaunakea.org/management/master-plan>

# Development - and not - in the 2000s

2000: Mauna Kea Science Reserve  
Master Plan adopted

2000: OMKM created

2002: OHA files suit to require EIS  
for outriggers

2006: NASA pulls outrigger funding,  
permit overturned  
Judge requires Comprehensive  
Management Plan (CMP)

2003: SMA opens



Smithsonian Millimeter Array



# 2010 Comprehensive Management Plan

- Incorporates the 2000 Master Plan for future projects
- Four sub-plans
  - Cultural Resources
  - Natural Resources
  - Public Access
  - Decommissioning

[http://www.malamamaunakea.org/management/  
comprehensive-management-plan](http://www.malamamaunakea.org/management/comprehensive-management-plan)

# 2014 Follow-up Audit

- “In our follow-up, we found that UH has developed several management plans that provide a comprehensive framework for managing and protecting Mauna Kea while balancing the competing interests of culture, conservation, scientific research, and recreation. We also found that contractual terms and other requirements currently preclude UH and DLNR from updating general leases, subleases, and permits; however, they have taken steps to ensure future agreements provide for adequate stewardship of the mountain and reflect current land management .”
- Rulemaking is still lagging, mostly due to unavoidable delays (such as the TMT contested case hearings)

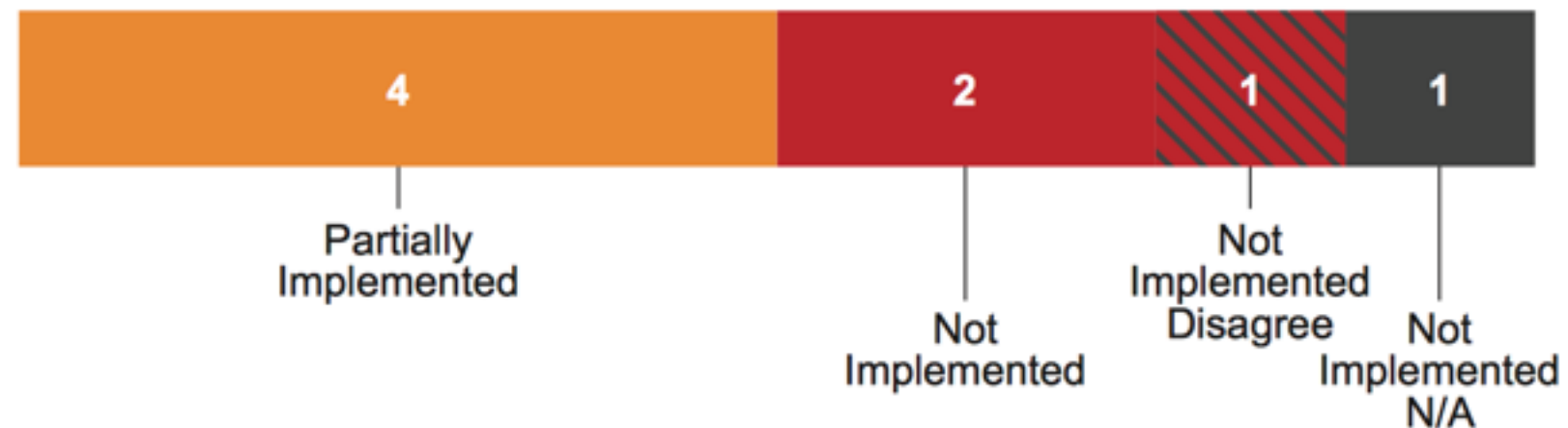
[http://www.malamamaunakea.org/uploads/management/  
Audit\\_14-07.pdf](http://www.malamamaunakea.org/uploads/management/Audit_14-07.pdf)



# 2017 Follow-up of 2014 Audit

- Progress made on some recommendations, but delays due to legal and government actions continue
- Note: BoR set to vote on Maunakea administrative rules in Nov. 2019

**Exhibit 1: Audit Recommendations by Status**

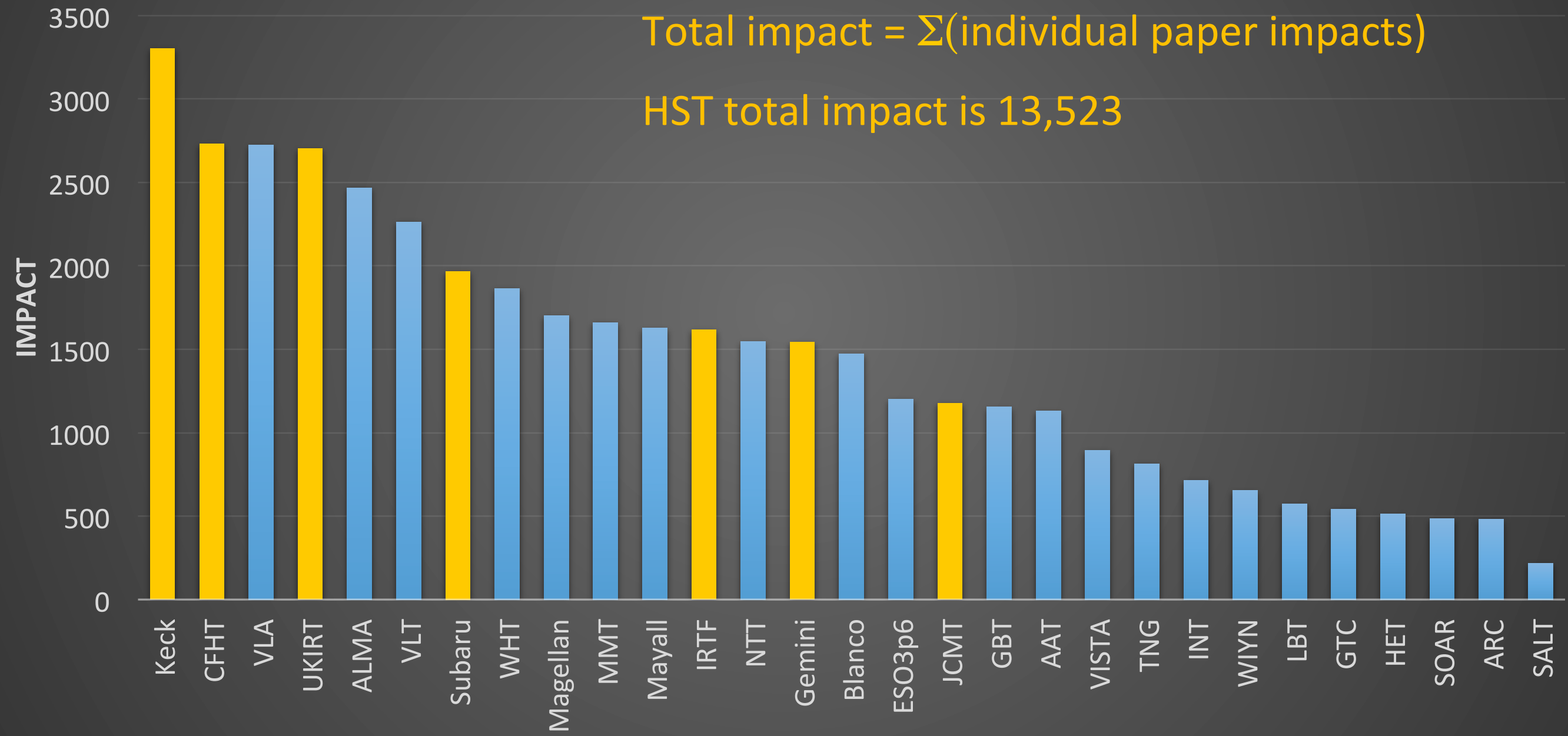


Source: Office of the Auditor

<http://files.hawaii.gov/auditor/Reports/2017/17-06.pdf>

# Impact

## Total Impact 2012 – 2016 Per Telescope Basis



OBSERVATORY

Crabtree, 2018



# The TMT Timeline

- 2003: TMT Observatory Corp. founded (Canada, UC, Caltech)
- 2005: Project Office opens
- 2008: Japan comes on board
- 2009: Seven draft EIS meetings held, 6 on Hawai'i Island; Maunakea selected as preferred site
- 2009: China and India join project
- 2010: MKMB, UH BoR approve TMT, EIS completed
- 2011: CDUP granted, five Contested Case hearings
- 2012: Hearing Officer upholds CDUP

# The TMT Timeline

- 2013: BLNR grants permit after oral hearings; CDUP upheld by Judge Nakamura
- 2014: Sublease granted, TIO formed
- 2015: Notice to proceed issued, first protests at groundbreaking
- May 2015: Gov. Ige orders stand-down and issues 10-point plan
- Dec. 2015: HSC revokes permit, ruling that CCH should have been held before permit issued by BLNR
- Mar. 2016: La Palma selected as alternate site
- Oct. 2016: Second CCH begins; ends Mar. 2017
- July 2017: Hearing Officer Amano recommends CDUP



# The TMT Timeline

- Oct. 2017: CDUP appealed to HSC
- Oct. 2018: HSC upholds CDUP
- June 20: Notice to Proceed issued
- July 10: Gov. Ige announces construction start
- July 15: Access road closed, protester blockade begins



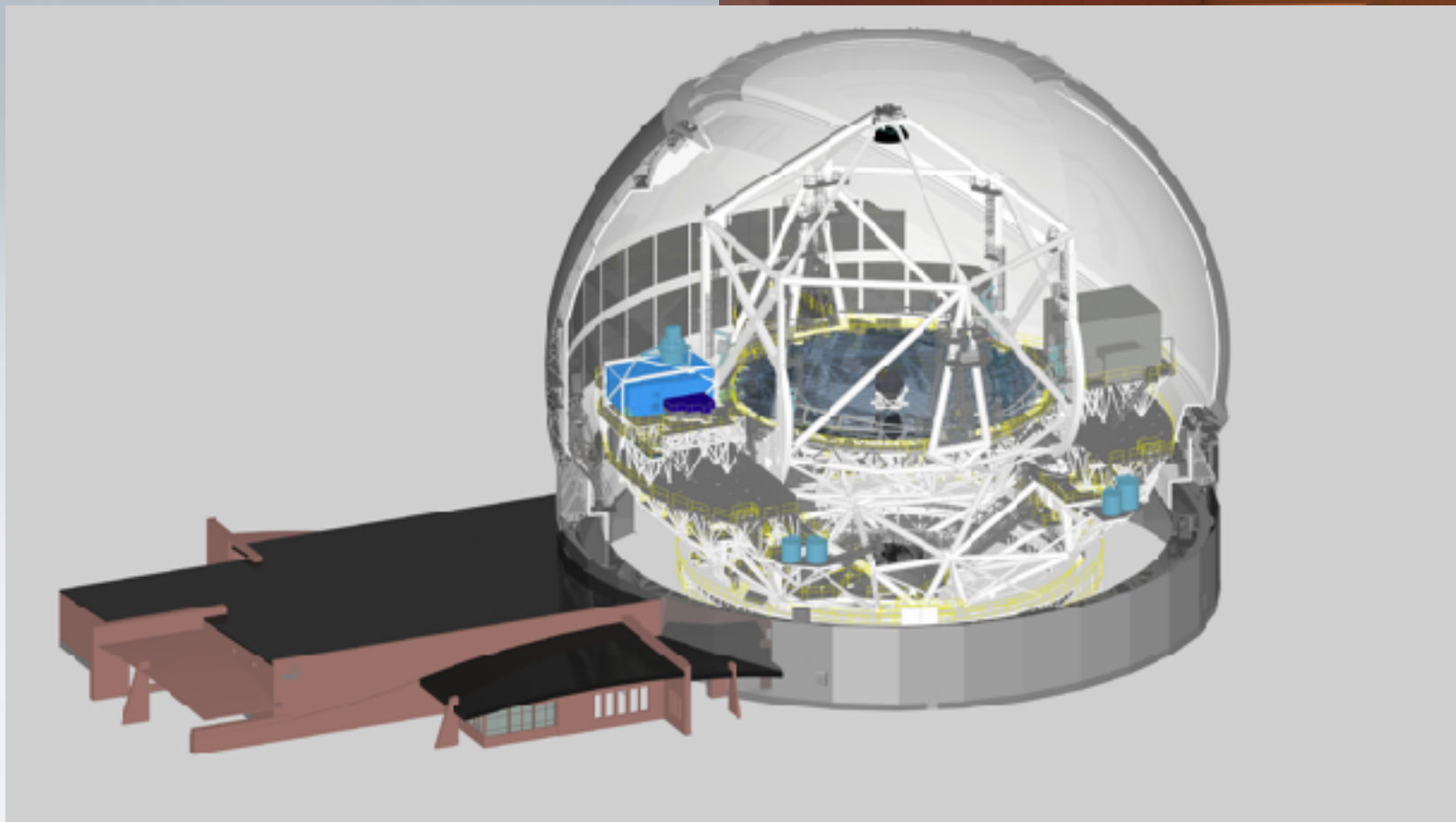
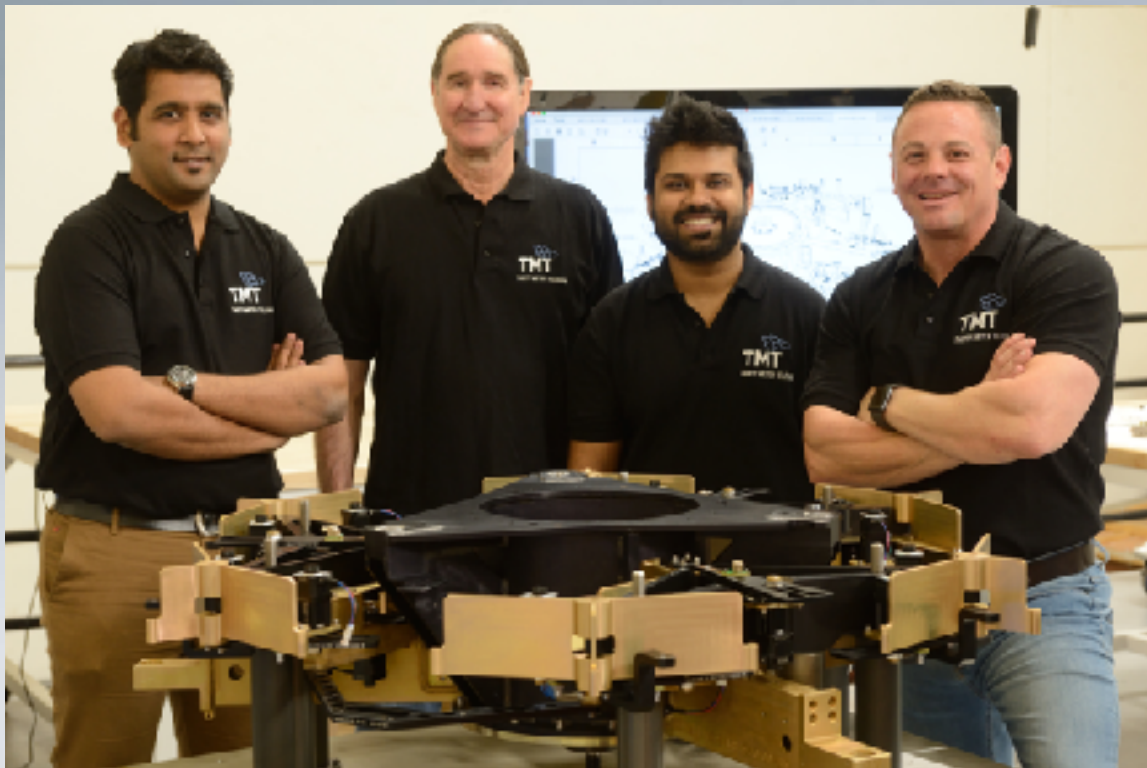


# The TMT

30-meter diameter

492 1.4m hexagonal segments  
half of segment blanks fabricated!  
segment supports being made

Primary is  $f/1$  to minimize size





# TMT Science

Exoplanets: Do Earth-like planets around other stars have atmospheres like ours? Could they host life?

The Early Universe: study the earliest galaxies that formed, containing stars comprised of raw materials from the Big Bang

How Do Stars & Planets Form: Do the properties of stars and planets depend on where they were born?

The Unknown: Every new observational capability has revealed completely new and unexpected types of objects and physical processes in the universe

# TMT Instruments

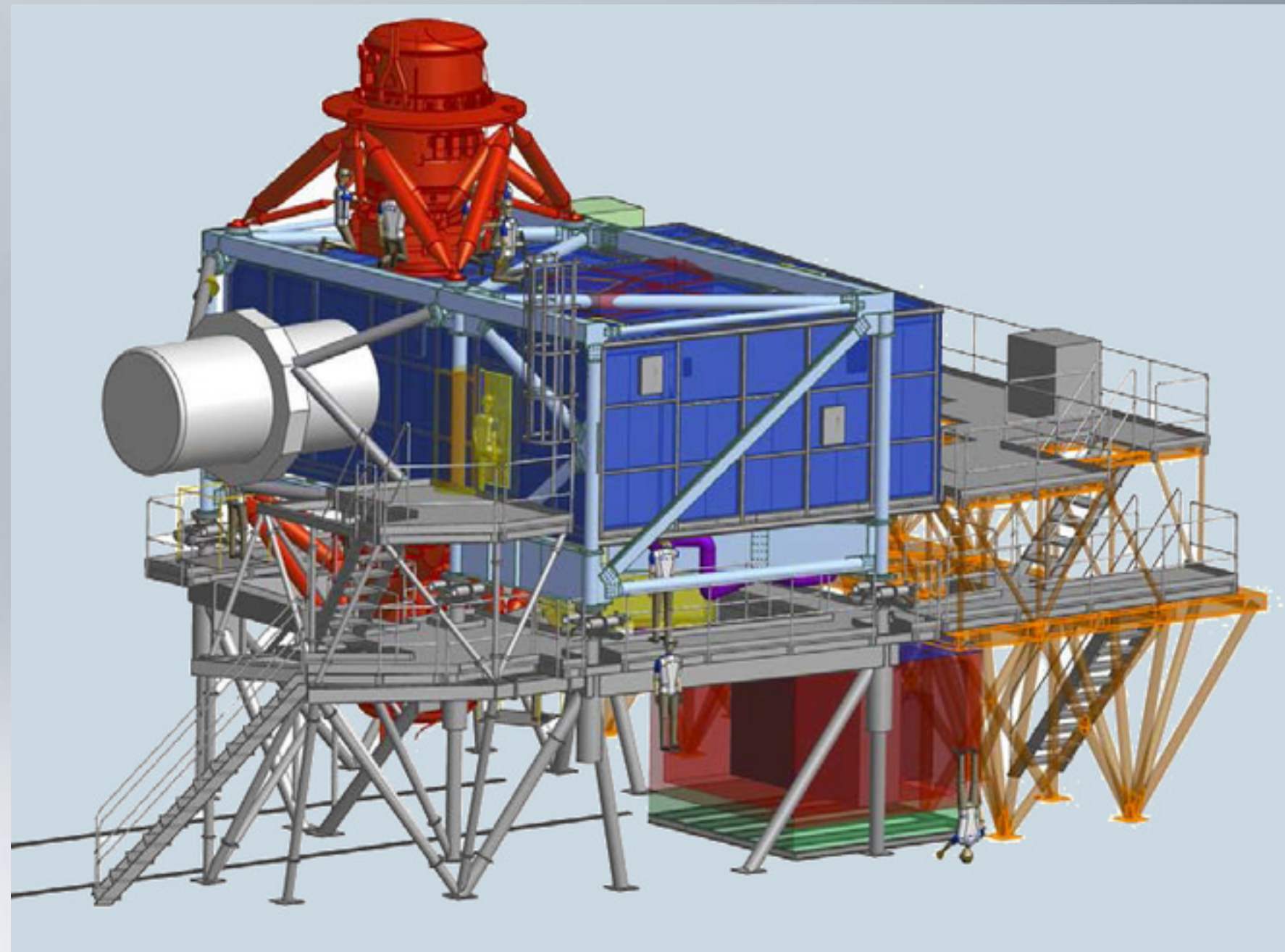
NFIRAOS: Narrow Field InfraRed Adaptive Optics System

~60 x 60 laser guide star (LGS)  
multi-conjugate AO (MCAO) system

Uniform, diffraction-limited  
performance in the J, H, and K bands

34" x 34" FOV with 50% sky  
coverage at the galactic pole

Feeds IRIS and IRMS instruments





# TMT Instruments

IRIS: InfraRed Imager and Spectrometer

R=4000-8000 IfU spectrograph

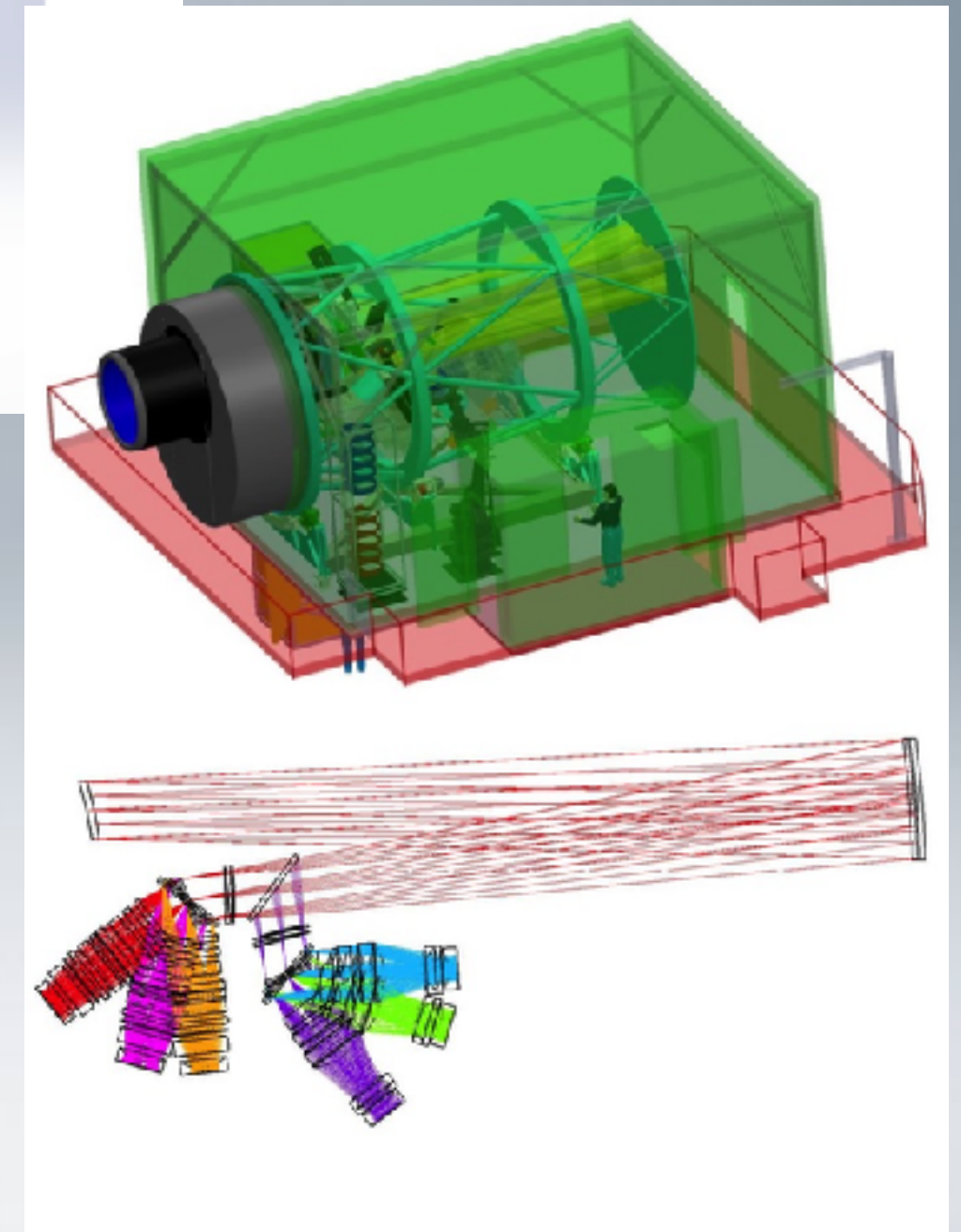
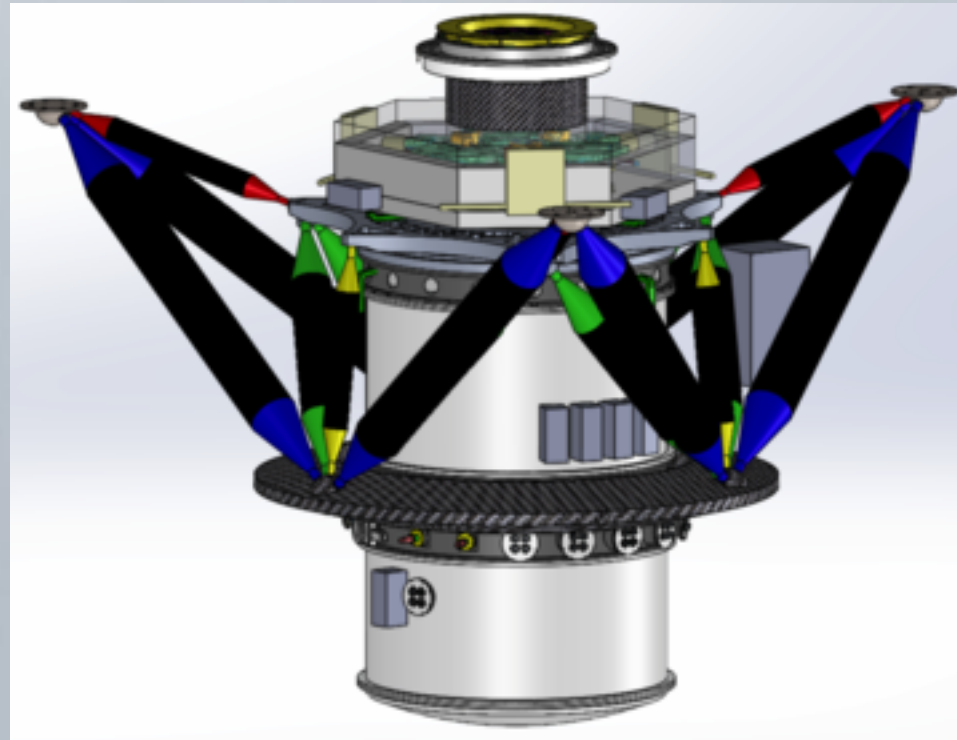
Imager

IRMS: InfraRed Multi-slit Spectrometer

40+ slits over 2' FOV

WFOS: Wide Field Optical Spectrometer

8.3' x 3' FOV, ~60 targets





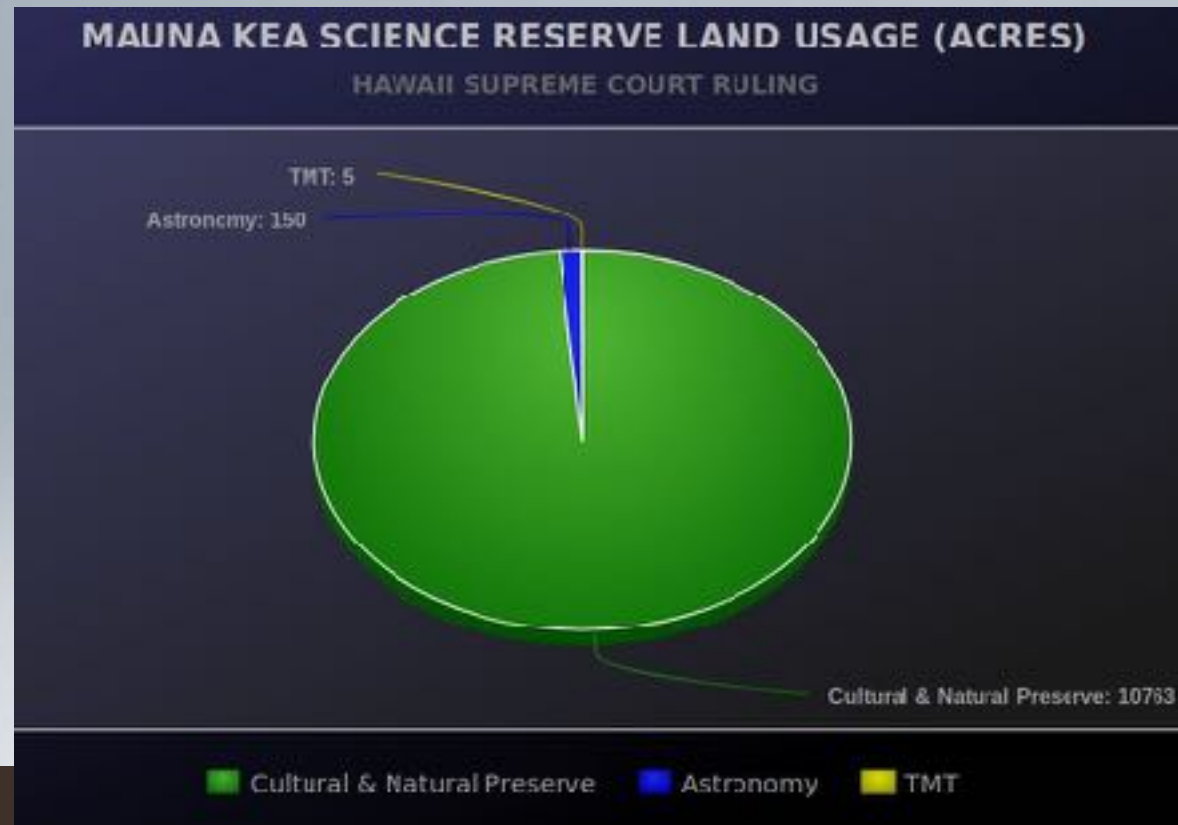
# Where are we now?



law enforcement roadblock  
kupuna tent

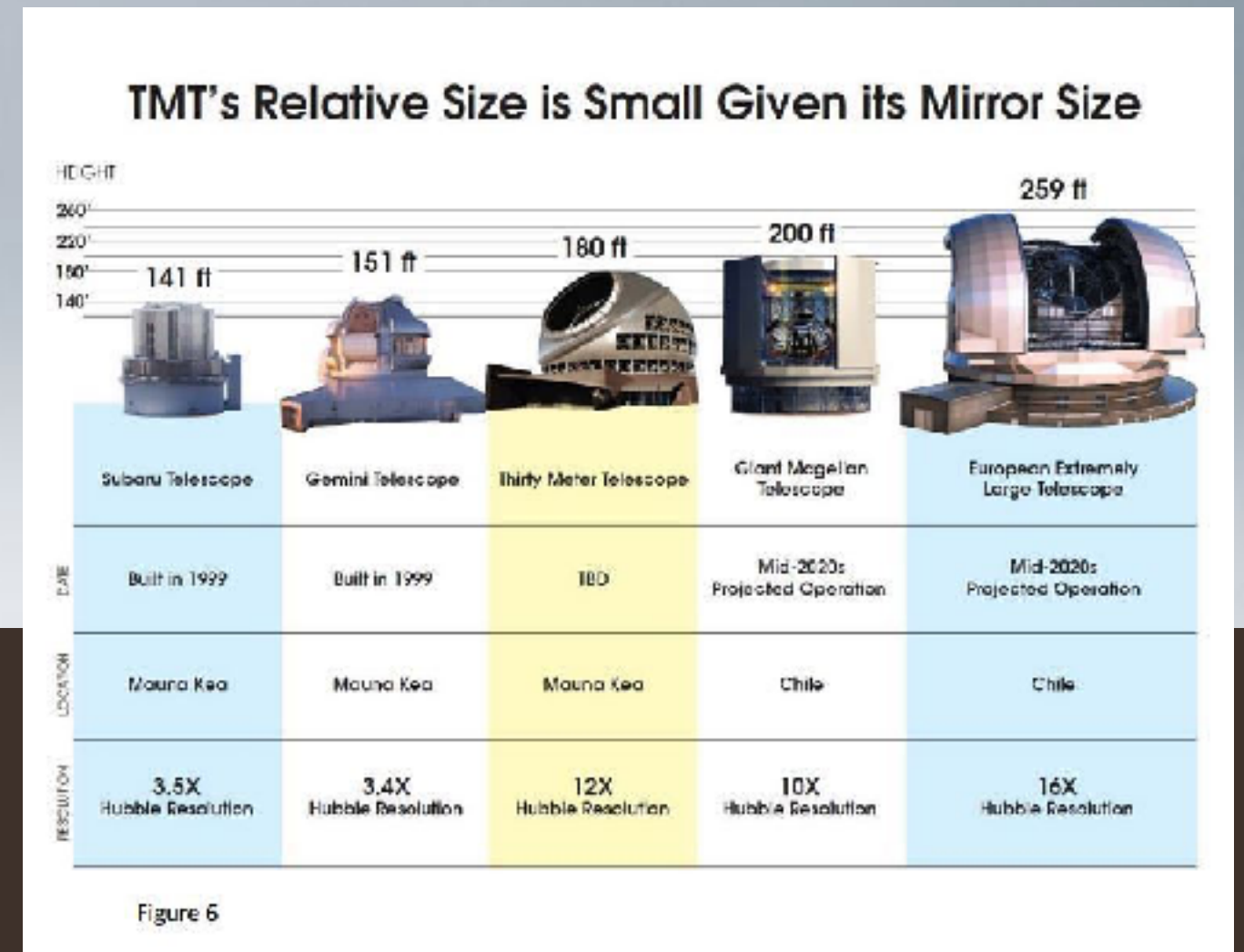
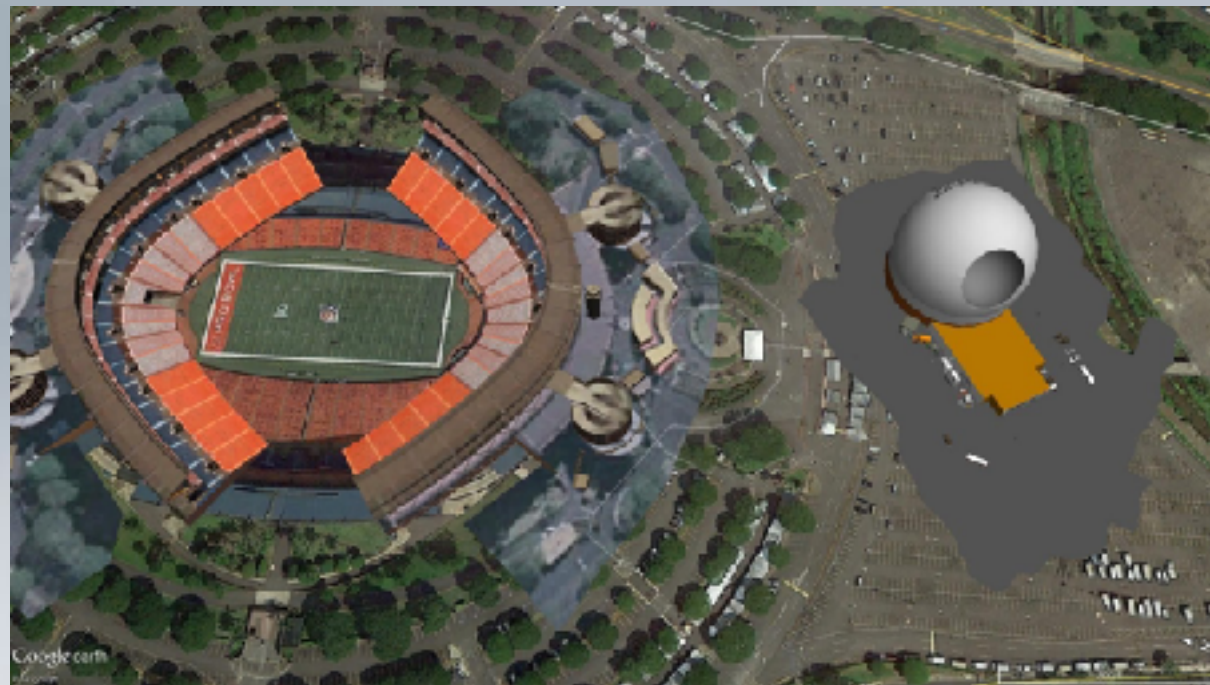


- TMT footprint is 5 acres
  - Maunakea is 588,000 acres
  - Science reserve 11,288 acres (2% of MK)
  - Observatories & roads 150 acres (0.02%)
  - TMT is 0.001% of Maunakea



# Maunakea Land Usage

- The TMT is neither the tallest nor the largest building on Hawai‘i Island
  - Large stores like Costco have 2-3x as much floor space; PKP mall in Hilo ~10x bigger
  - Ka Lae wind turbines are 330 feet tall to top of rotor
  - TMT would fit on a standard football field; two could fit in Aloha Stadium



# TMT size

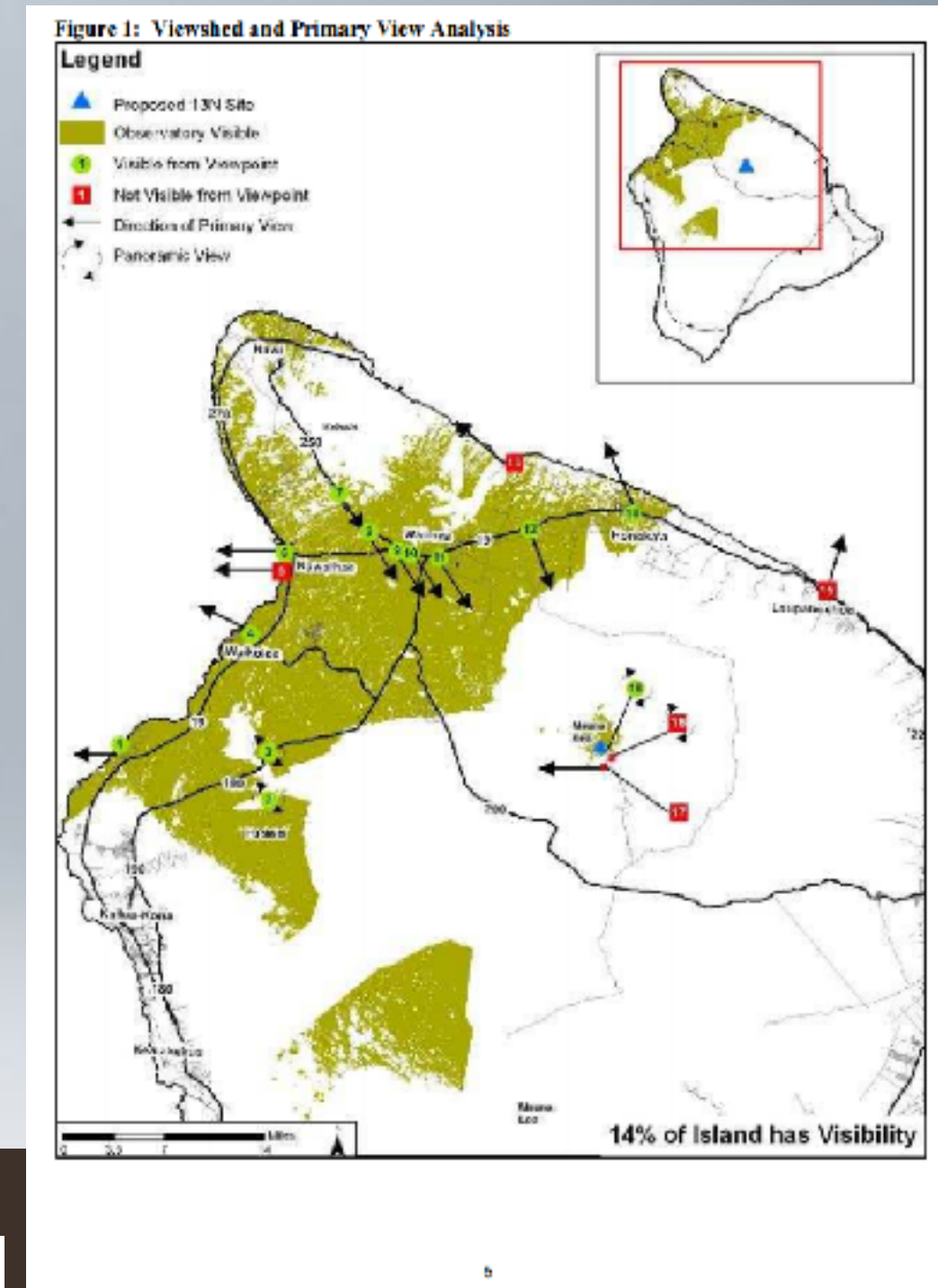


- Cultural practitioners have access to the summit 24/7

- except when road closed due to hazards (snow, ice)

- TMT is low visibility

- TMT will not be visible from the summit of Kukahauula, Lake Waiau, or Puu Lilinoe.
- Only visible from 14% of the island.
- TMT will not block the view of Haleakalā



# Cultural Resources I.

- Mandatory cultural and natural resources orientation for everyone who works or does business on Maunakea

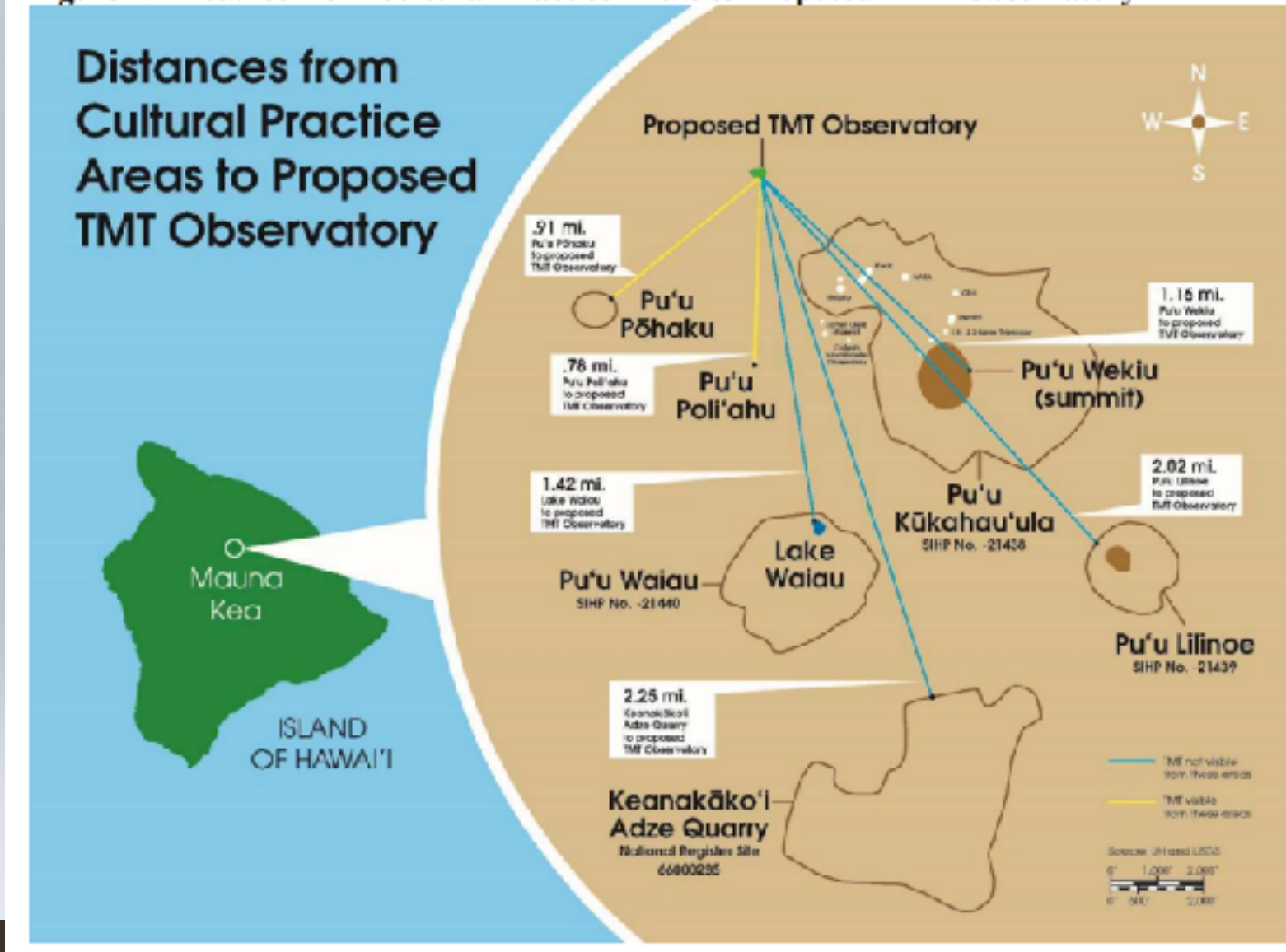
- Required annually for TMT employees

- No burials or archaeological sites on TMT property

- Cultural monitors and archaeologists during all excavation activities

- No dynamite will be used

Figure 2: Distance from Cultural Practice Areas to Proposed TMT Observatory



# Cultural Resources II.

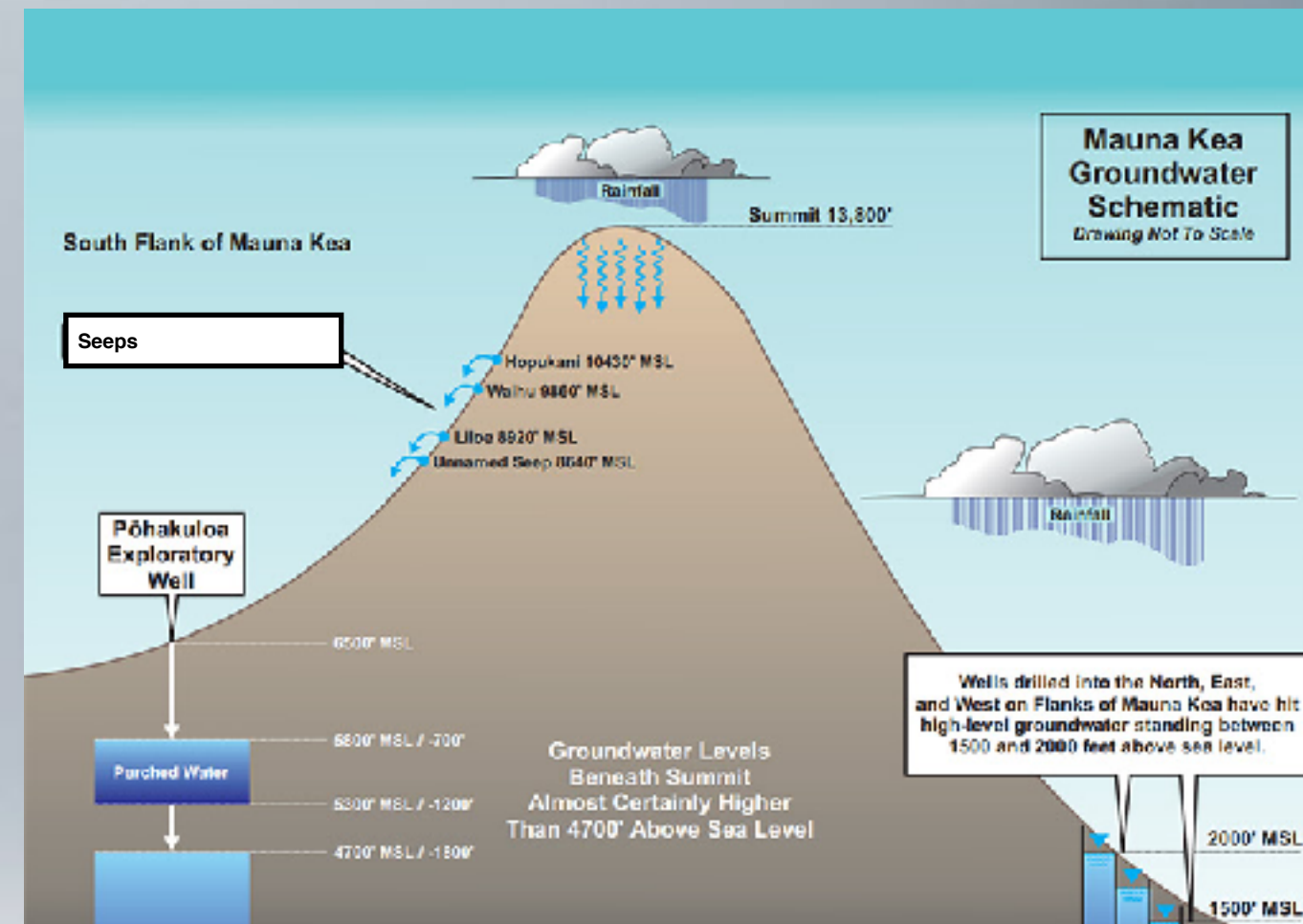


- There are no wells near the summit

- Closest is 12 miles away
- TMT will be zero-waste
- Water in high-elevation (7000') wells is 1000s of years old and highly filtered naturally

- The summit area is extremely dry

- Equivalent of 7" of rain annually
- Clouds typically around 10,000 feet elevation
- Near-shore groundwater comes from ~7,000' elevation



# The Aquifer

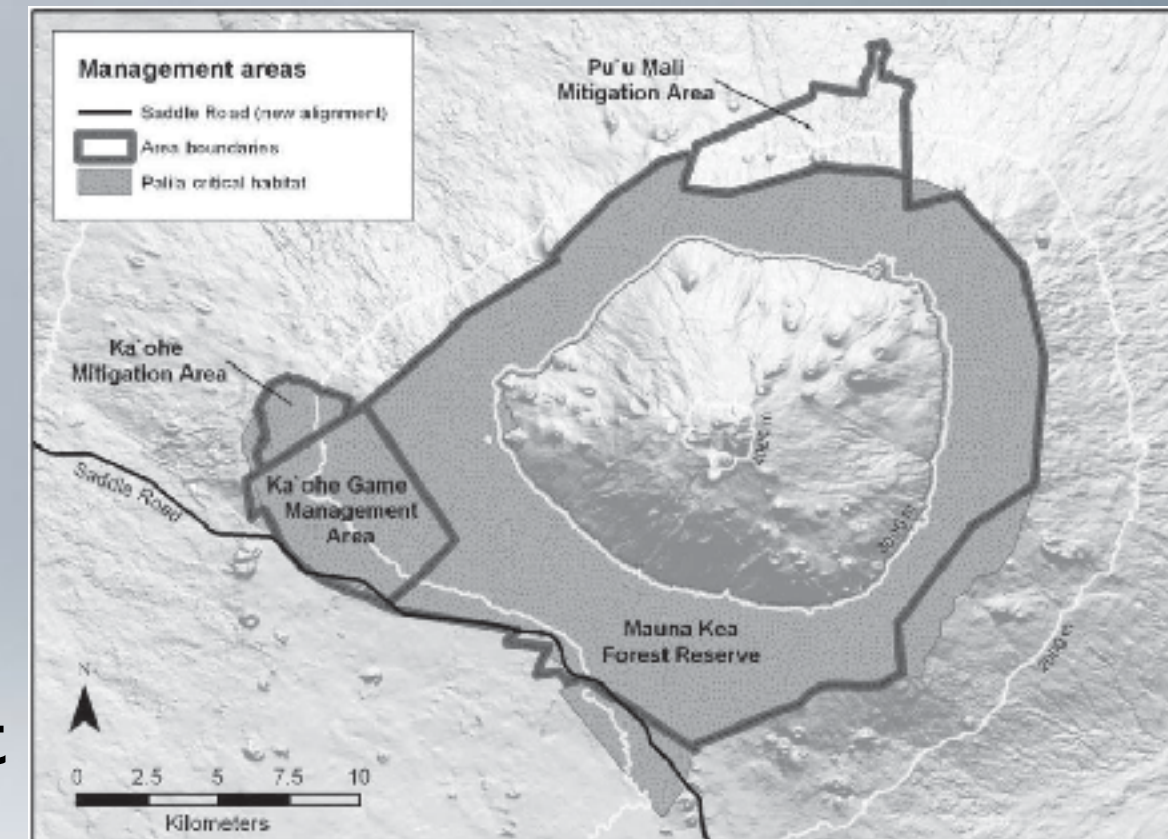
See Judge Amano's 2017 Report and Recommendations on page 94, item 506.

- No rare, threatened, or endangered plant species are found in the Astronomy Precinct.

- Core Palila habit is on western slopes of Maunakea in māmane forest. Palila live below 10,000 feet.

- Endangered Silversword habitat is primarily the eastern slopes of Maunakea, at approximately 9,000 feet. The highest elevation silverswords have been planted, at ~12,300 feet.

- Wēkiu bug is neither endangered nor threatened. Its habitat is limited to cinder cones above ~12,000 feet



# Endangered Species

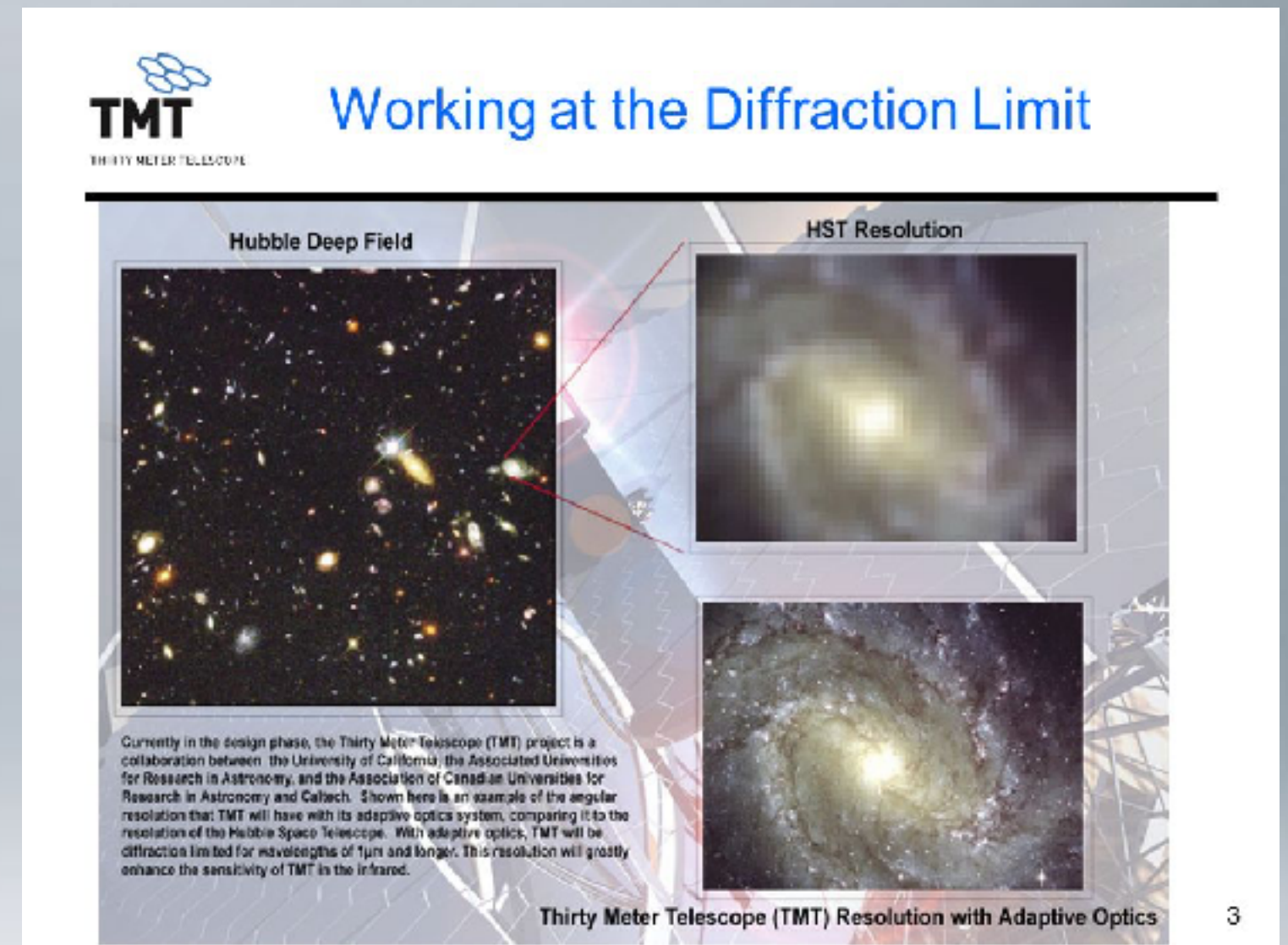


- CSO and Hoku Kea are in decommissioning process
  - UKIRT is very productive but will be decommissioned prior to TMT operations.
  - Any visitor to the observatories can see they are operational
  - None are rusting or abandoned



# Abandoned Telescopes

- TMT has 155x the light-gathering power of HST, and 12x better resolution
- 21x light-gathering power of JWST, almost 5x better resolution
- TMT is upgradeable with new instruments and technology
- Impossible to launch 30m telescope into space



# Space Telescopes are Better



- This is a recent (2019) rumor that is entirely made up.
  - State law: No nuclear fission power plant shall be constructed or radioactive material disposed of in the State without the prior approval by a two-thirds vote in each house of the legislature.
  - TMT will draw power from HELCO grid
  - Cooling done by standard A/C
  - There is no aquifer anywhere near summit



# Nuclear Power/Water Cooled

- Observatories are non-profits. They produce science.
  - TMT partners are UC, Caltech, India, Japan, China, Canada
  - Partners put in funds or in-kind contributions to cover cost of construction and operation
  - Partners get fraction of telescope time based on fraction of total cost
  - Telescope time is not bought or sold, and all data is available to public
  - Hawai'i will get 7.5% of time
  - TMT field-of-view, tracking speed, etc. totally useless for satellite tracking



**TMT makes profit, or is military**



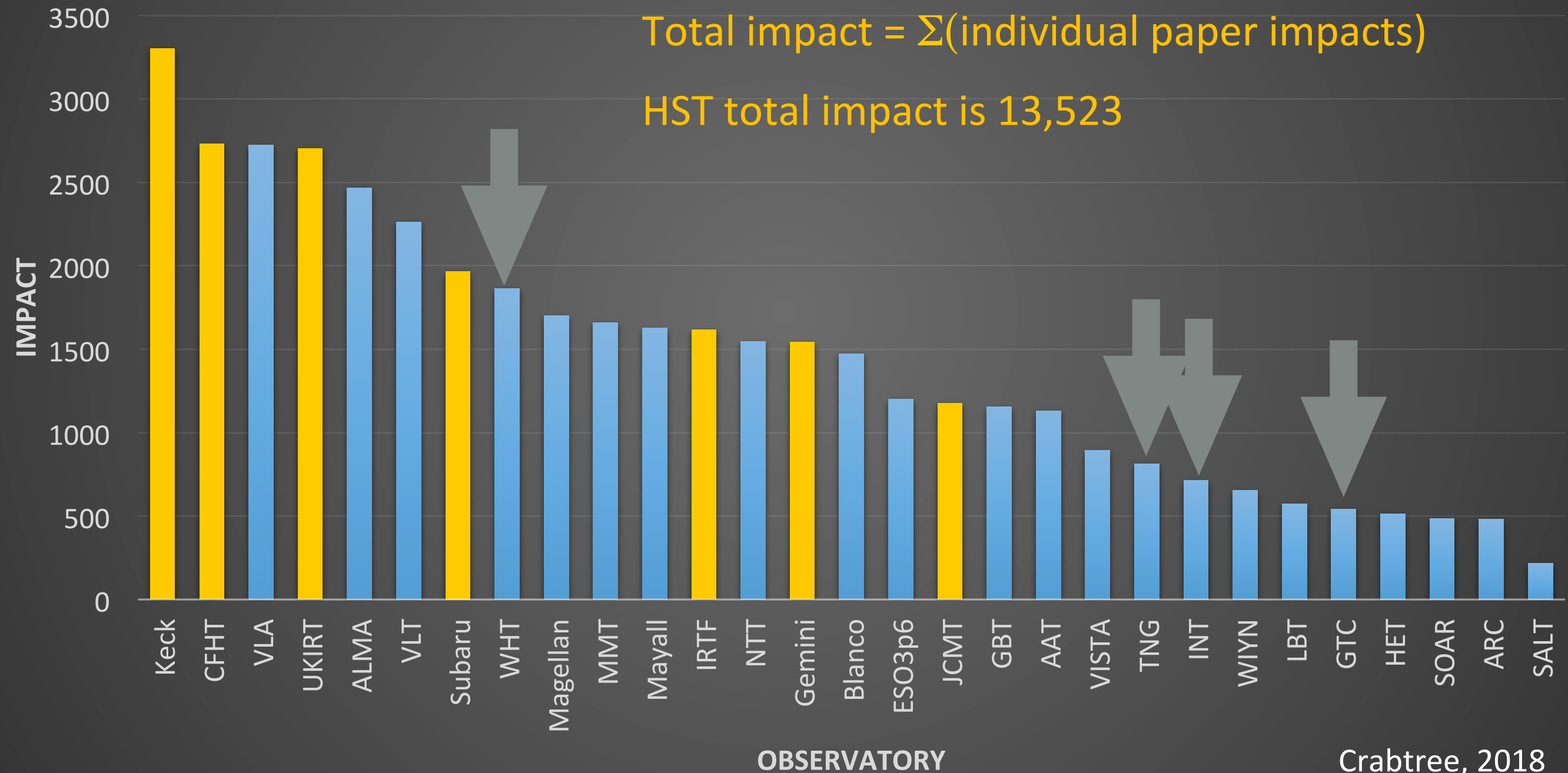
- Observatorio del Roque de los Muchachos is inferior
  - 7861 feet elevation vs. 13796 for Maunakea - MUCH more atmosphere
  - Maunakea is 15% better in visible, 30% in near-IR, **300% better in mid-IR**
  - Some science, like exoplanet atmospheres, probably impossible at Canaries site
  - Maunakea has much less impact from jet stream - higher contrast imaging for planets around other stars
  - Canaries impacted by dust blown from Sahara desert
  - Ongoing lawsuits by Ben Magec, an environmental action group, delaying TMT process at ORM



Canary Islands site is equally good

# Impact

## Total Impact 2012 – 2016 Per Telescope Basis





- **Maunakea as a culturally significant site**

- Earth Mother, Papahānaumoku, and the Sky Father, Wākea, created the Islands
- Mauna a Wākea - mountain of the sky father
- Home of Poli‘ahu, the snow goddess
- Summit was kapu; only royalty and priests could go up
- Many burial sites and smaller ahu/shrines, but not at TMT site



# Cultural Significance

# ● Unclear historically

- Peter Apo: “I found no documentation indicating that Mauna Kea, as a whole, is sacred. I could not find any reference to any blanket of sacredness over the entire mountain and the air column in any of the usual sources of validation — not even in the Kumulipo Hawaiian creation-origin chant, or in the writings of Native Hawaiian historians of the 19th century like Samuel Kamakau, David Malo, John Papa ‘I‘i and Kepelino.”
- Validated sacred places include the peaks of Pu‘u o Kūkahau‘ula, Pu‘u Poli‘ahu and Pu‘u Lilinoe, Lake Waiau, and various heiau (temples), ‘ahu (altars), ana (caves), lua kā ko‘i (quarries), and ilina (burials).
- Adz quarry suggests “industrial” use of mauna was acceptable



## Implications & complications

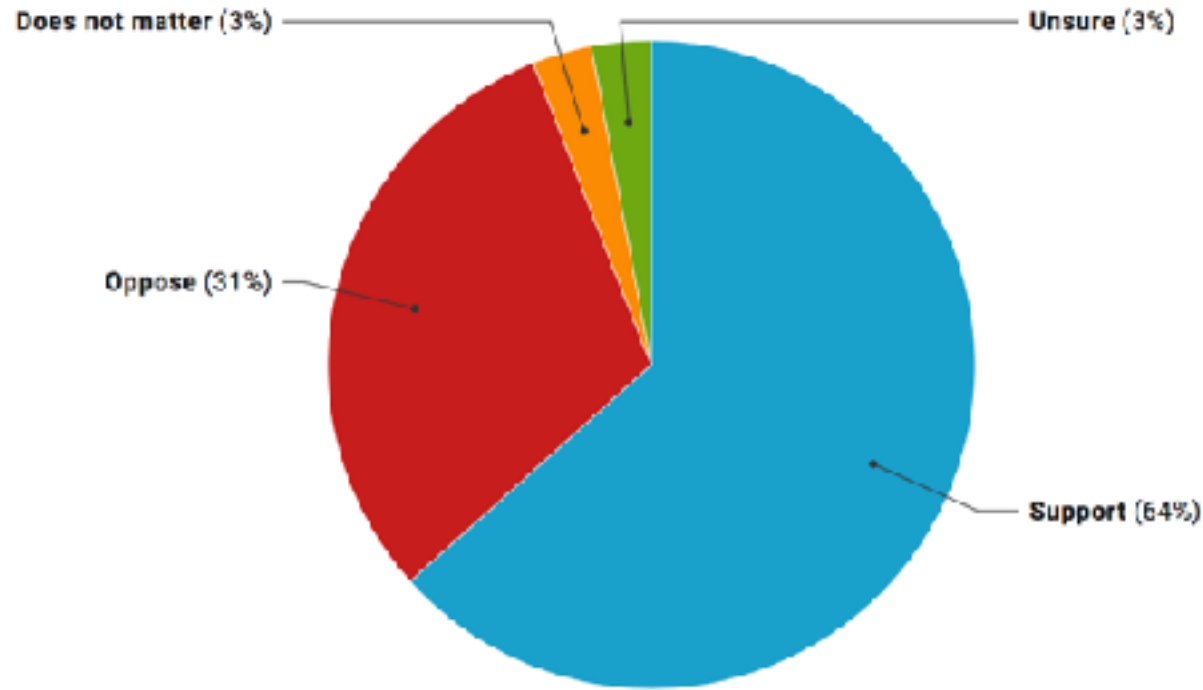


- “I wouldn’t characterize it as sacred. Sacred has to do with gods or gods and worship. I would characterize the mountain as being spiritual — about being a connection or building a relationship to the environment or to the place.”
- “our esteemed ali‘i” advocated for the abolishment of the Hawaiian religious order — the kapu system — in 1819.
- “I also want to be on right side of humanity. I want to be on the right side of enlightenment and knowledge. And I also want to be on the right side of education that inspires a whole new generation of explorers.”
- “That mountain is plenty big. It can accommodate everybody’s practice.”

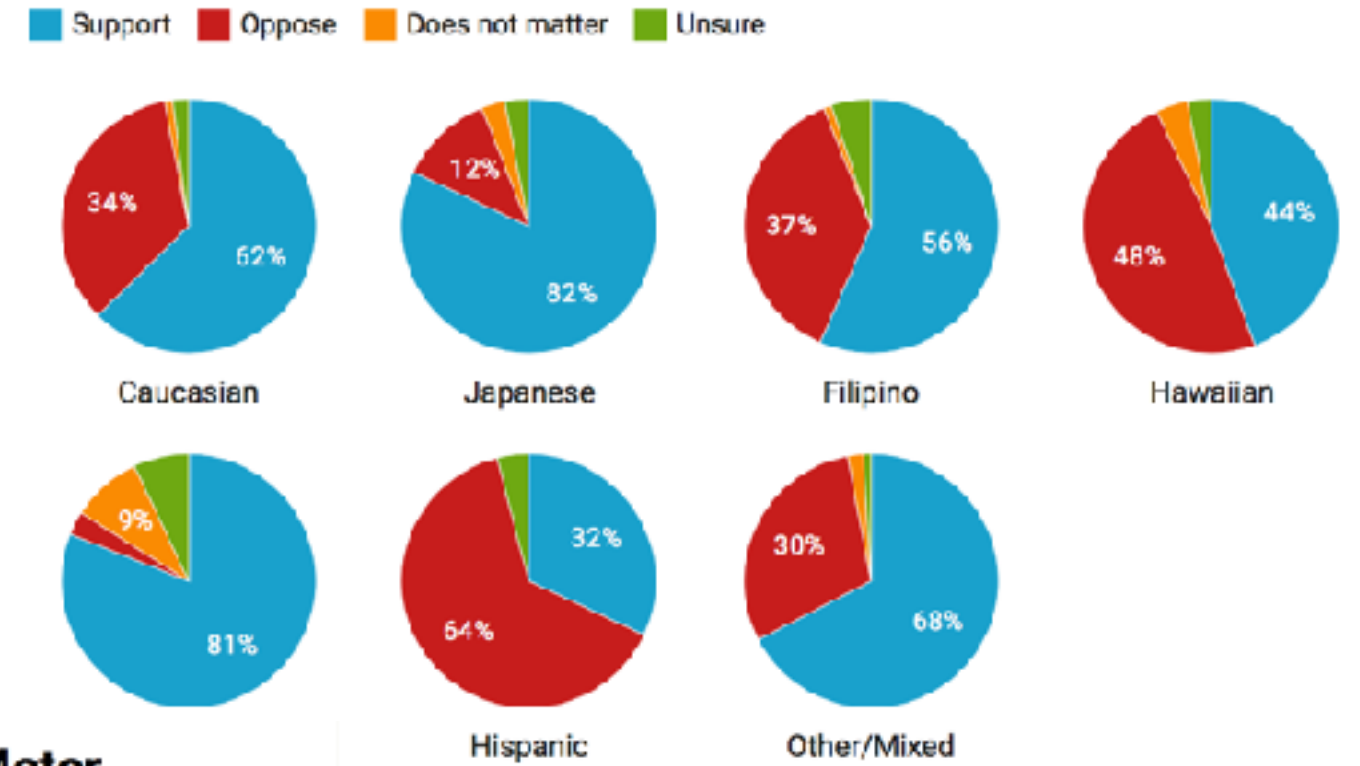


Kālepa Baybayan, Navigator in Residence at the  
‘Imiloa Astronomy Center of Hawai‘i

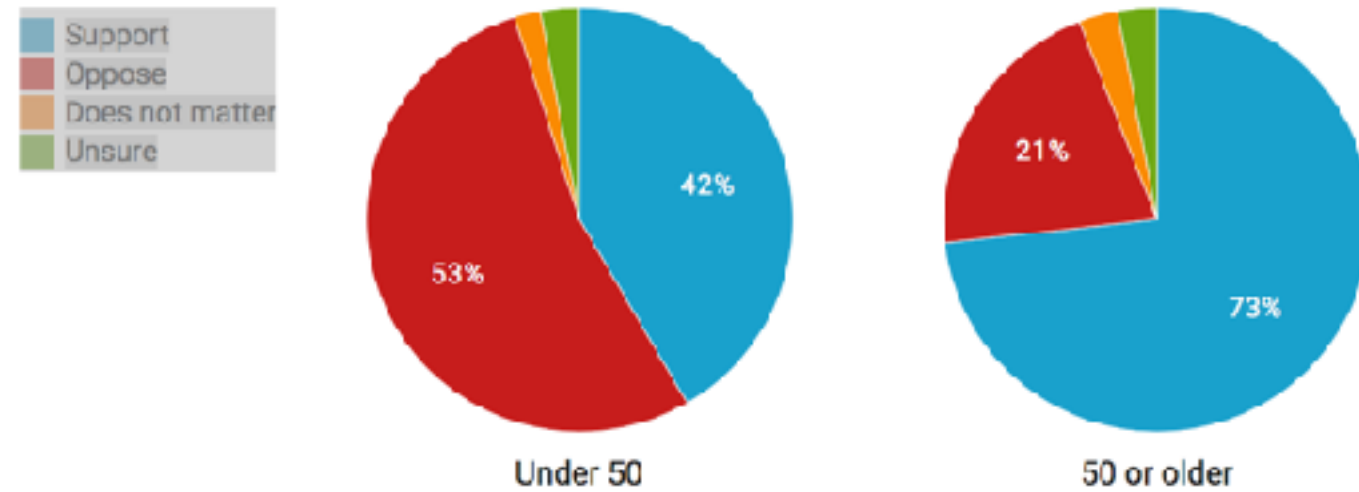
### Overall: How do you feel about building the Thirty Meter Telescope on Mauna Kea?



### By Race/Ethnicity: How do you feel about building the Thirty Meter Telescope on Mauna Kea?



### By Age: How do you feel about building the Thirty Meter Telescope on Mauna Kea?



# Polling



- Sovereignty
- Statehood
- Hawaiian Renaissance
- Land use
- Priorities
- State governance
- DHHL, OHA
- Self-determination
- Economy
- Multiple voices



So many issues

- **Contested Case Findings of Fact/Conclusions of Law**
  - <https://dlnr.hawaii.gov/mk/files/2017/09/882-BLNR-FOFCOLDO.pdf>
- **HSC Decision**
  - <https://www.tmt.org/download/Document/53/original>
- **TMT Myths**
  - <http://darkerview.com/wordpress/?p=26446>
- **TMT sites**
  - <http://www.maunakeaandtmt.org> and <http://www.tmt.org>



# RESOURCES