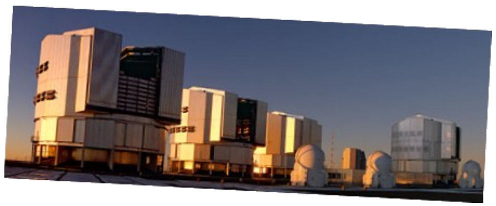
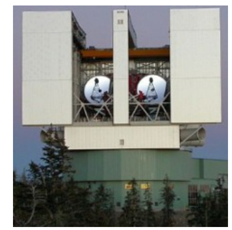
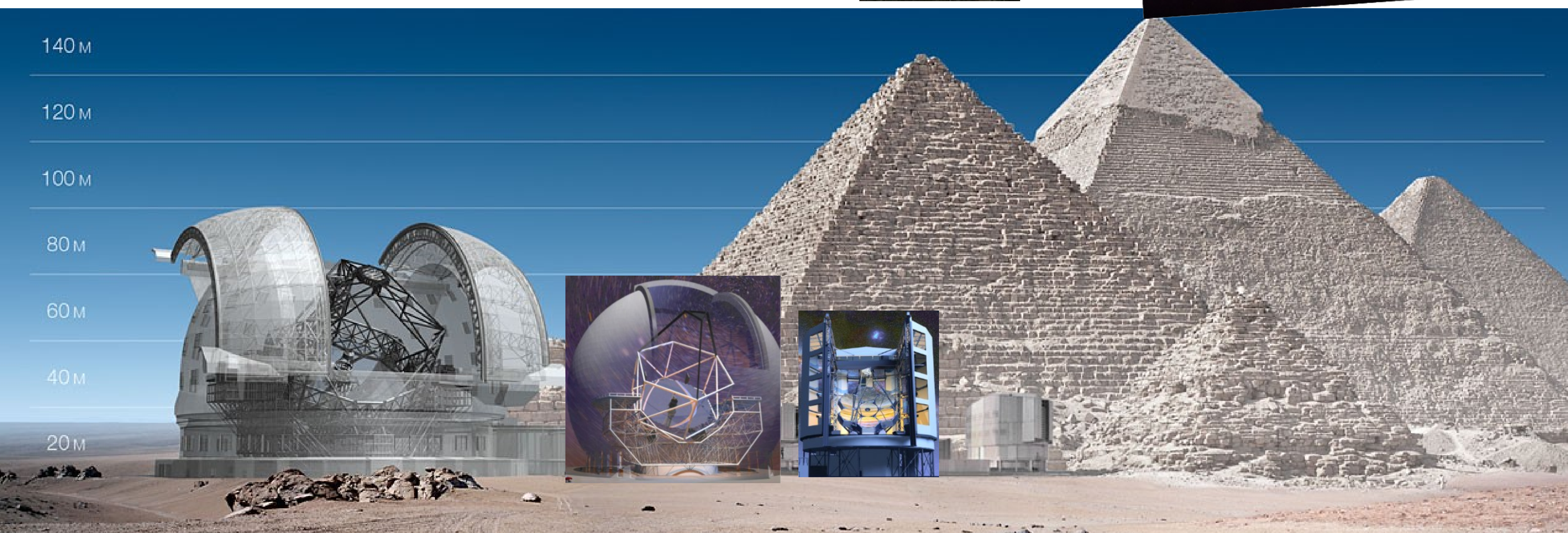
Giant Telescopes

From ESO NTT (3.6 m, 1989) & Keck (1995?) to the GMT, TMT & ESO Extremely Large Telescope (39 m, 2027)



Prof. Jorge Melendez, AGA5802

Atualização: 27/05/23

Giant telescopes

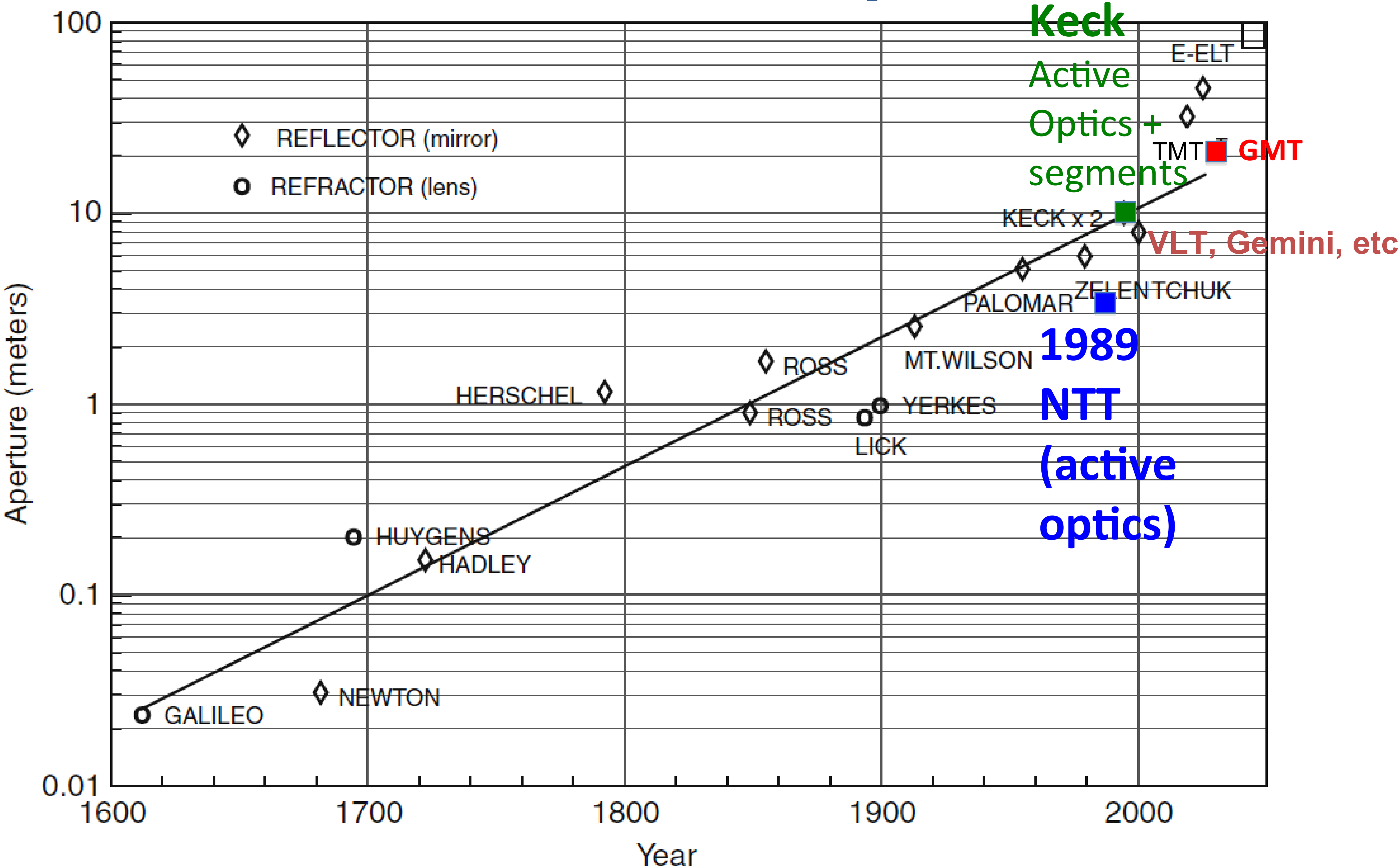
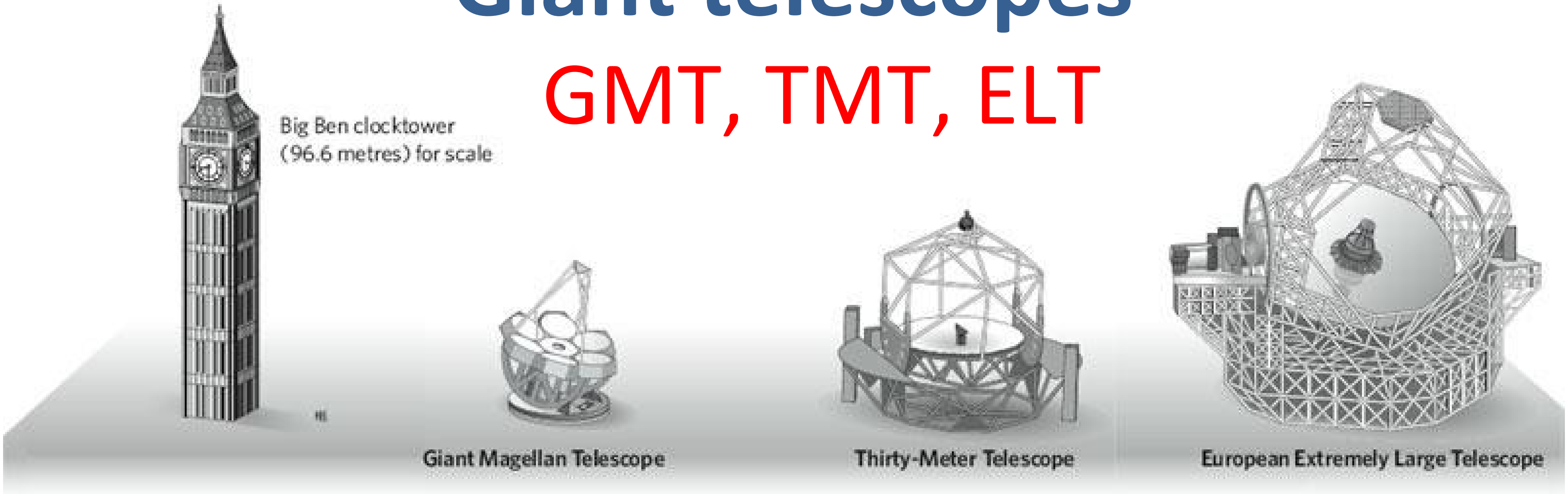


Fig. 1.8, Lena, 3rd Ed.

Giant telescopes

GMT, TMT, ELT



	Giant Magellan Telescope	Thirty-Meter Telescope	European Extremely Large Telescope
Telescope diameter	25.2 metres	30 metres	42 metres **39 m**
Component mirror segments	7 (8.4-metre segments)	492 (1.44-metre segments)	984 (1.45-metre segments)
Cost	US$600 million 2018: US$1 bi 2022: US$2 bi	US$754 million 2016: US$1,4bi 2022: US$2,4bi	€900 million (US$1.37 billion) 2018 €1,4 bi 2022: €1,4bi
Planned location	Chile	Candidates: Hawaii; Mexico; three sites in Chile	Candidates: Canary Islands; Morocco; Argentina; two sites in Chile
Planned construction period	2010-2017 (First mirror already cast)	2009-2016	2010-2017
Technical advantages	Adaptive optics integrated within secondary mirror Shortest focal length means it has the smallest and cheapest structure	Mirror segments are comparatively cheap and more easily replaced Similar scaled-up version of the existing Keck telescopes	Five-mirror design results in a flat focal plane and better images Similar mirror-segment size to the TMT, so greater vendor choice
Financial advantages	Potential support from $34-billion Harvard endowment or Texas billionaire George Mitchell	$200-million gift from Intel founder Gordon Moore	Steady European funding stream
Disadvantages	Only one place can make the mirrors Gaps in mirror limit the effective aperture to 21.5 metres	Adaptive optics performed after the light leaves the telescope, so the 'natural seeing' mode cannot benefit from adaptive corrections to wind effects	Biggest and most expensive design No similar design experience Reflections through five mirrors reduce light levels

Nature 452, 142-145 (2008)

The road to Giant telescopes: NTT @ESO

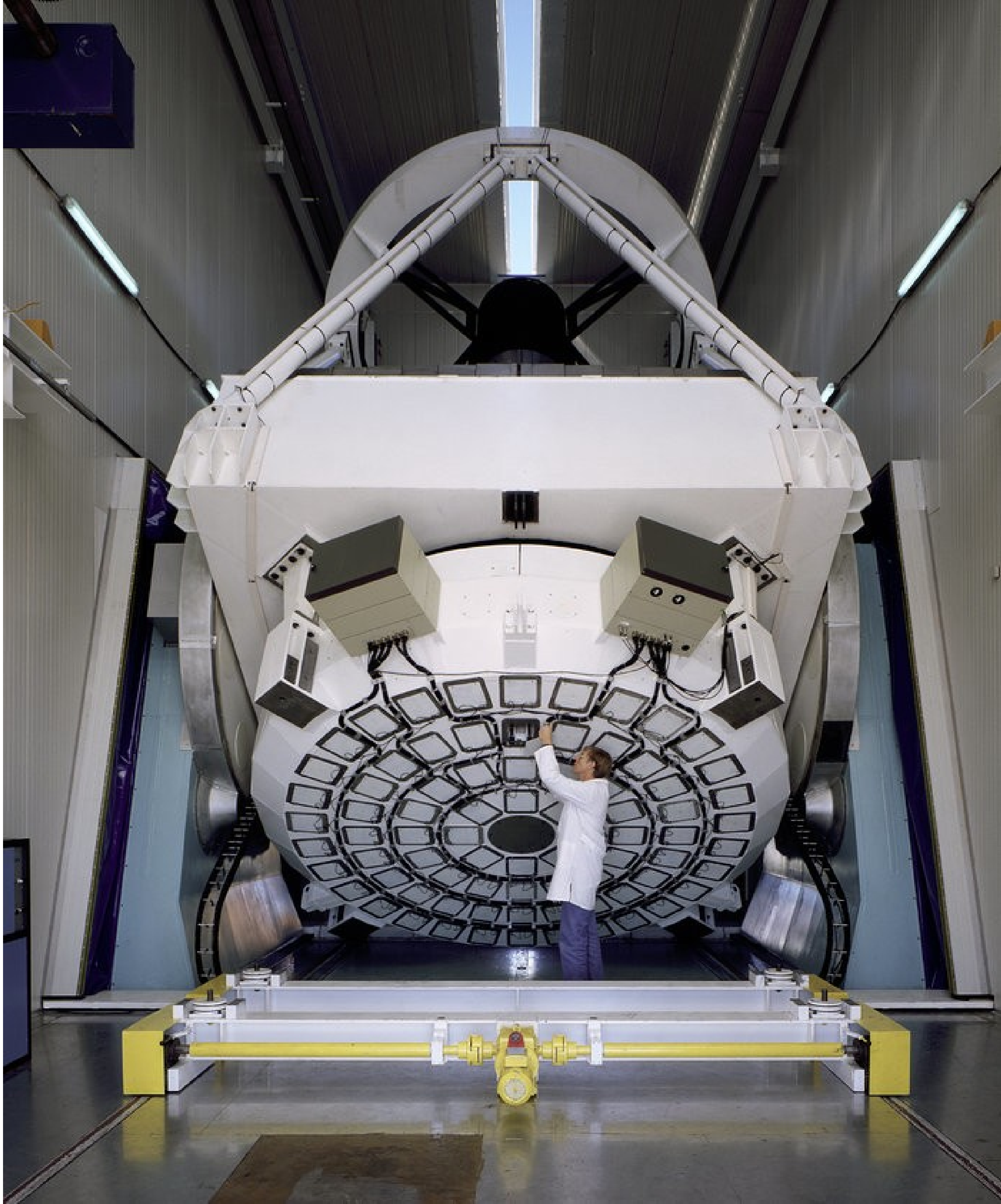
- The construction of telescopes with large mirror faces difficulties, as mirror deformation is more severe

- Solutions: (1) Make thin mirror; (2) Control its shape by computer-controlled actuators (Active Optics)

→ New Technology Telescope (3.6 meters). First light 1989. Control on both primary & secondary mirrors

The New Technology Telescope (NTT) pioneered Active Optics: its 3.56m diameter mirror is thin (24 cm) and flexible, its shape is kept perfect thanks to 75 actuators supporting it.

First light March 1989: sharpest image obtained at that time: 0.33 arcsec



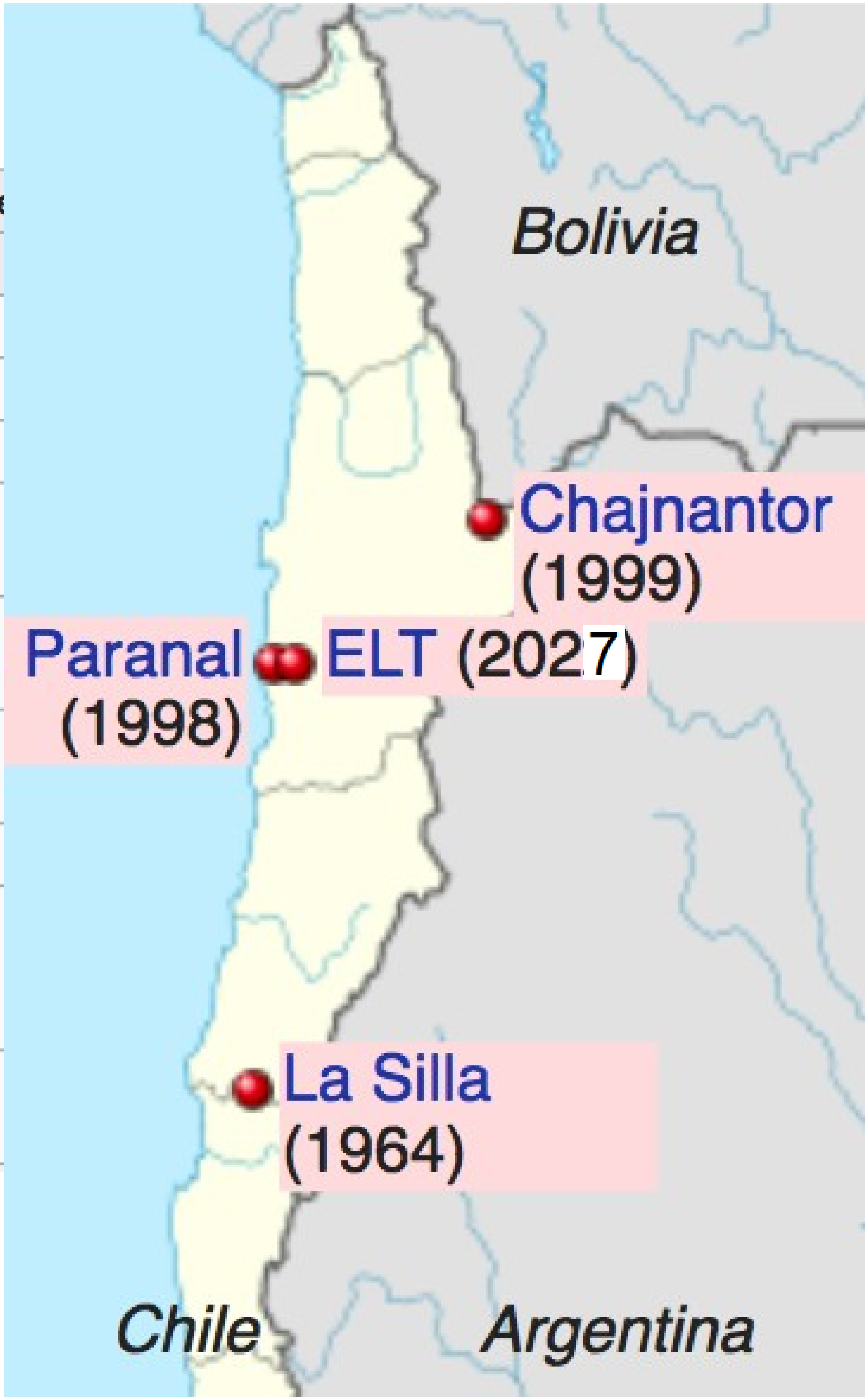
ESO telescopes

ESO telescopes					
Name	Short	Size	Type	Location	Year
ESO 3.6 m telescope – *hosting HARPS*	ESO 3.6m	3.57 m	optical and infrared	La Silla	1977
MPG/ESO 2.2 m telescope	MPG	2.20 m	optical and infrared	La Silla	1984
New Technology Telescope	NTT	3.58 m	optical and infrared	La Silla	1989
Very Large Telescope	VLT	4 × 8.2 m 4 × 1.8 m	optical to mid-infrared, array	Paranal	1998
Atacama Pathfinder Experiment	APEX	12 m	millimetre-/submillimetre-wavelength	Chajnantor	2005
Visible and Infrared Survey Telescope for Astronomy	VISTA	4.1 m	near-infrared, survey	Paranal	2009
VLT Survey Telescope	VST	2.6 m	optical, survey	Paranal	2011
Atacama Large Millimeter/submillimeter Array[A]	ALMA	50 × 12 m 12 × 7 m 4 × 12 m[30]	millimetre-/submillimetre-wavelength interferometer array	Chajnantor	2011
Extremely Large Telescope	ELT	39.3 m	optical to mid-infrared	Cerro Armazones[24]	~~2024~~

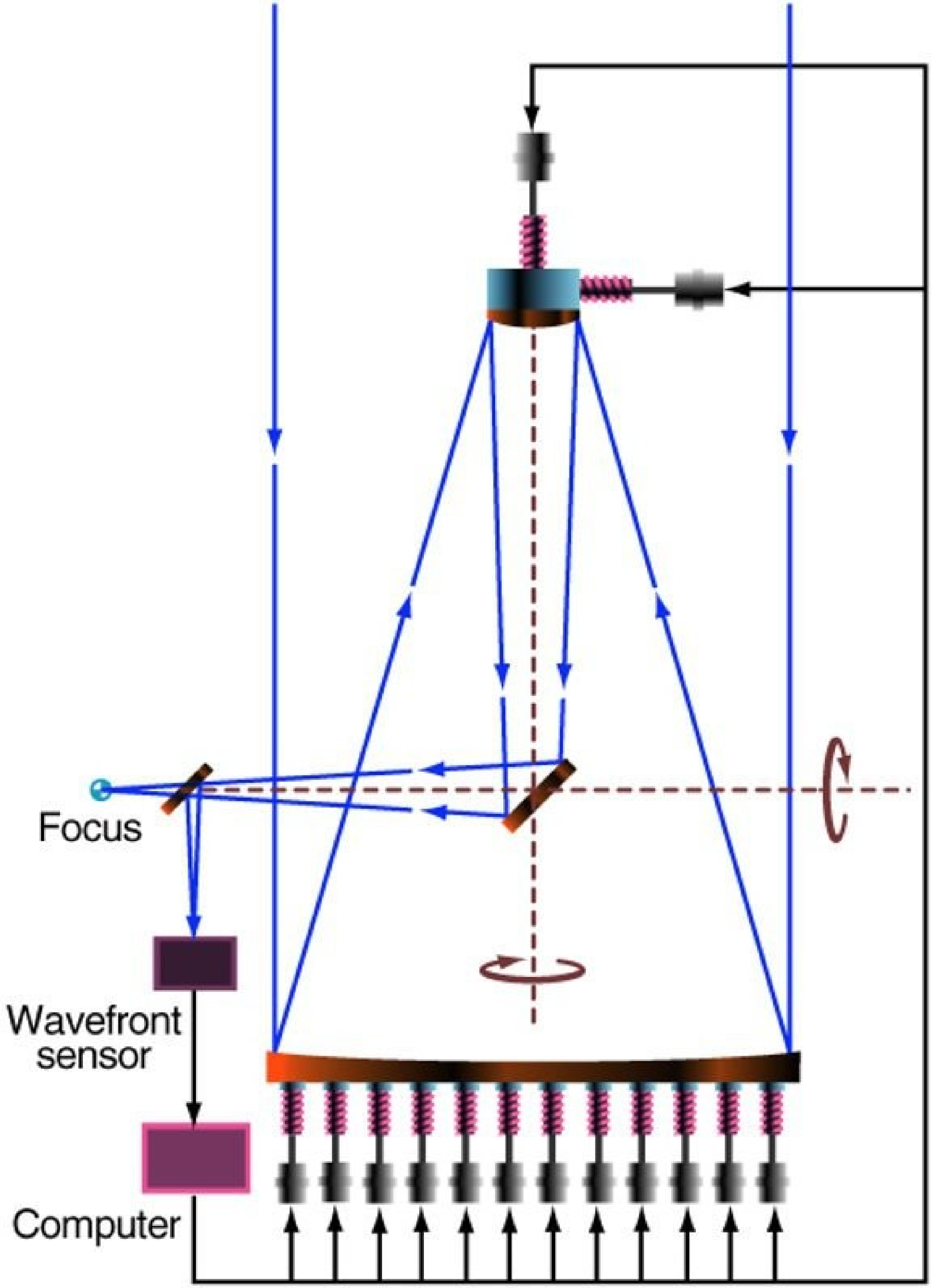
2027

ESO telescopes

ESO telescope		
Name	**Short**	**Size**
ESO 3.6 m telescope – *hosting HARPS*	ESO 3.6m	3.57 m
MPG/ESO 2.2 m telescope	MPG	2.20 m
New Technology Telescope	NTT	3.58 m
Very Large Telescope	VLT	4 × 8.2 m 4 × 1.8 m
Atacama Pathfinder Experiment	APEX	12 m
Visible and Infrared Survey Telescope for Astronomy	VISTA	4.1 m
VLT Survey Telescope	VST	2.6 m
Atacama Large Millimeter/submillimeter Array[A]	ALMA	50 × 12 m 12 × 7 m 4 × 12 m[30]
Extremely Large Telescope	ELT	39.3 m



Cerro Paranal: ESO/VLT telescopes



The VLT Active Optics System provides control of the optics and optimizes its performance in all telescope positions. This is achieved by changing the shape of the primary 8.2-m Zerodur mirror and also shifting the position of the secondary 1.1-m beryllium mirror. A stellar image is registered by the "wavefront sensor" and analysed, and corresponding corrections are generated to move the 150 actuators.

Mirror: 8.2 m
Thickness: only 17 cm
Weight: 22 tons

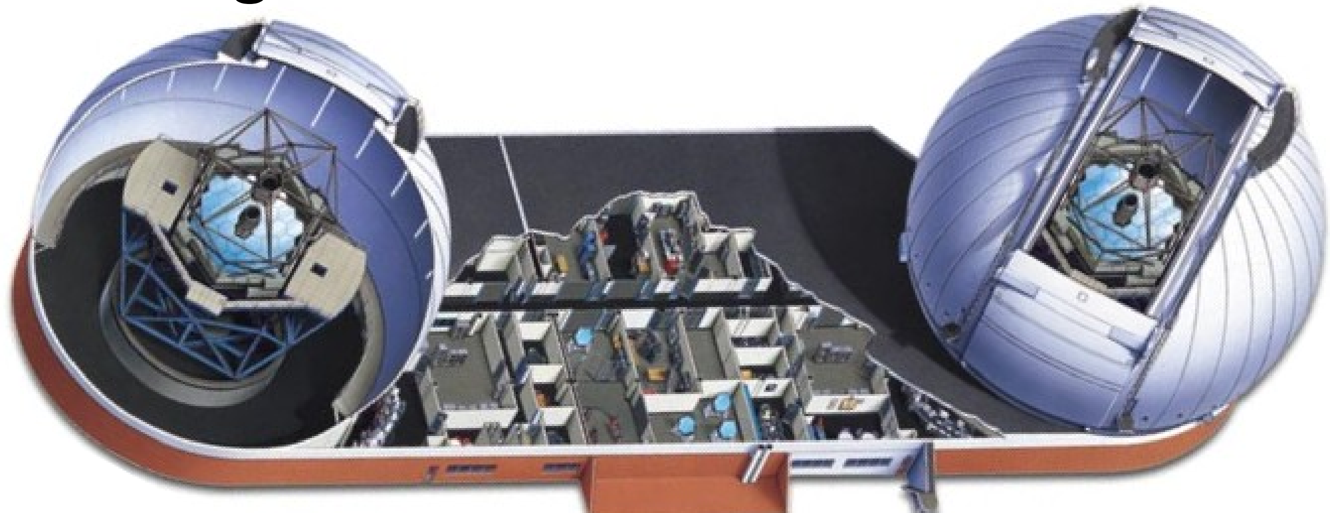
The road to Giant telescopes: Keck

- Building telescopes with large mirror faces difficulties

- Solutions

  ⇨ very thin mirrors

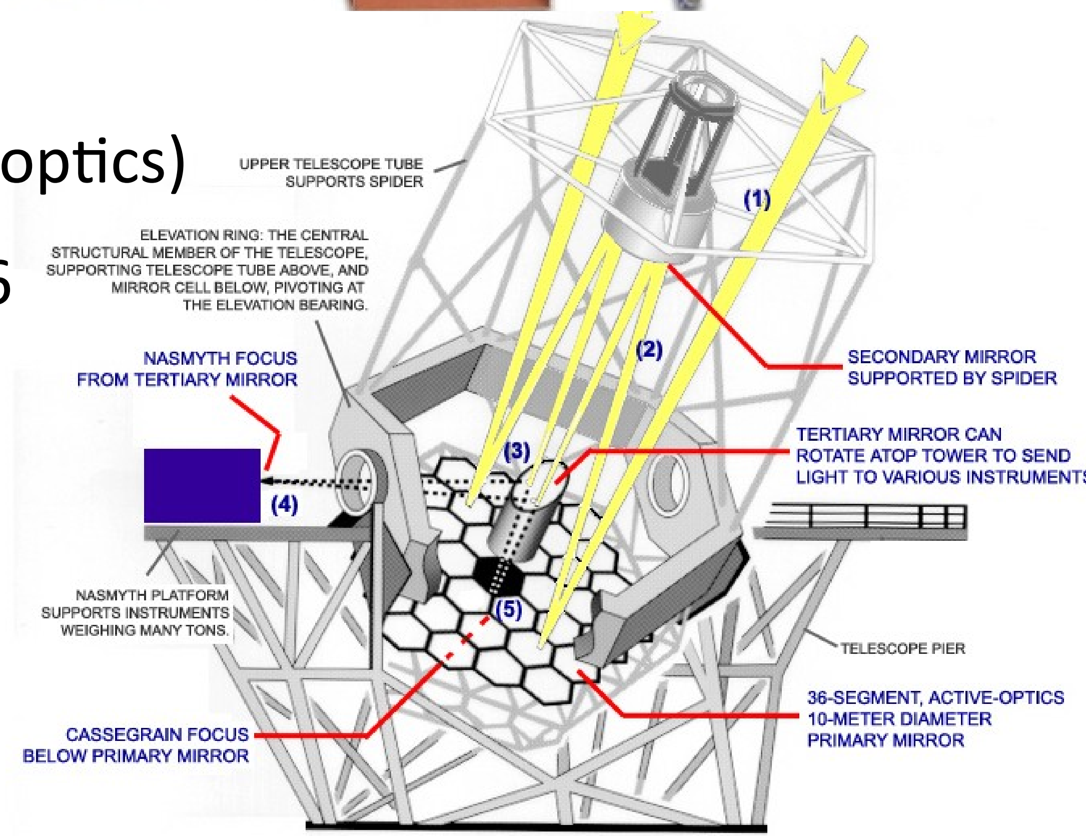
  ⇨ mosaic of mirrors



→ **Keck: 10m = 36 x 1,8m**

→ Support for each mirror (active optics)

→ Full first light 5/1993 & 10/1996



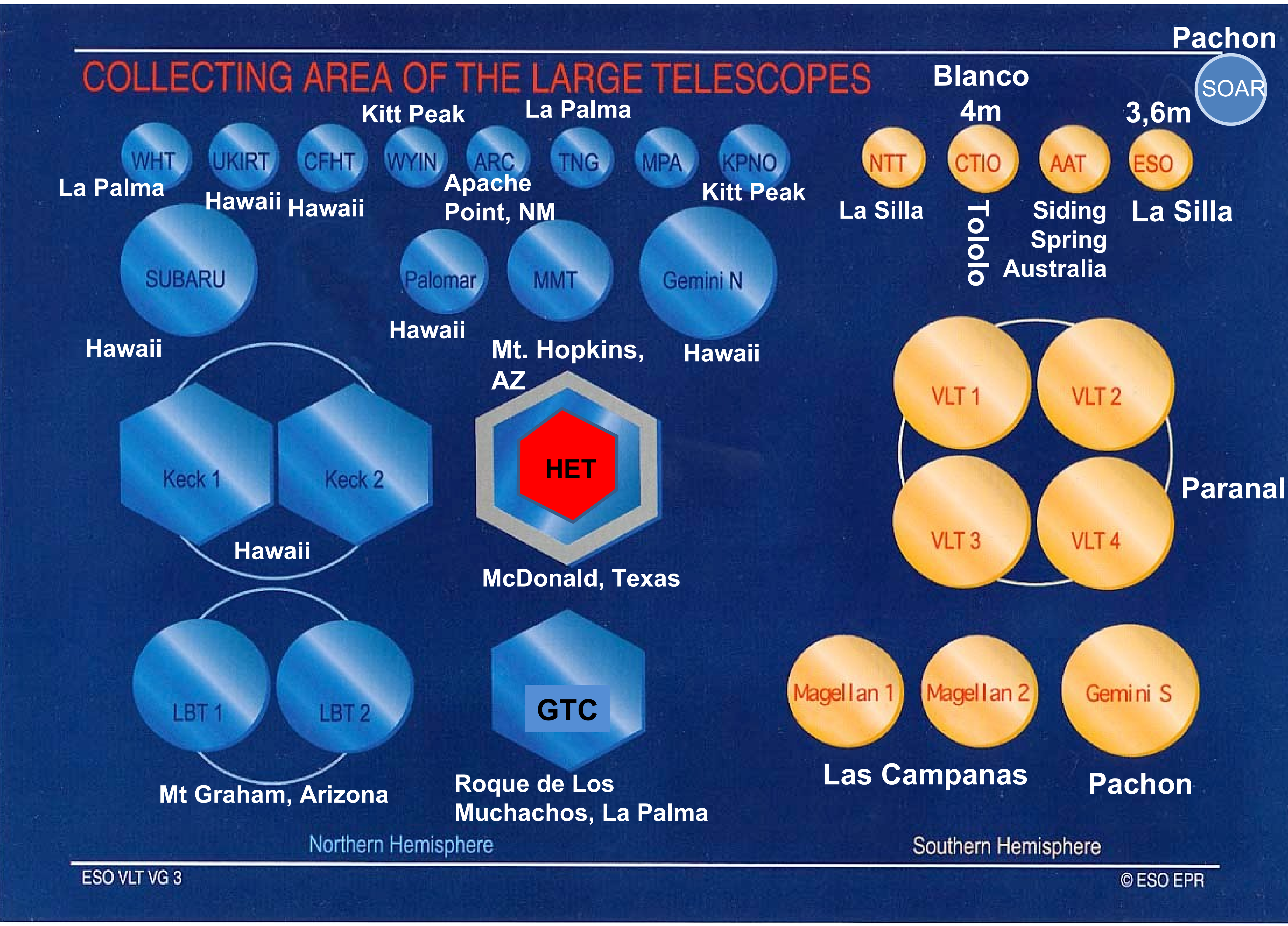
The 10 meter Keck telescopes were developed and built by Caltech & Univ. California.

Keck Observatory Call for Community Instrument Development White Papers (22/jun/2022)

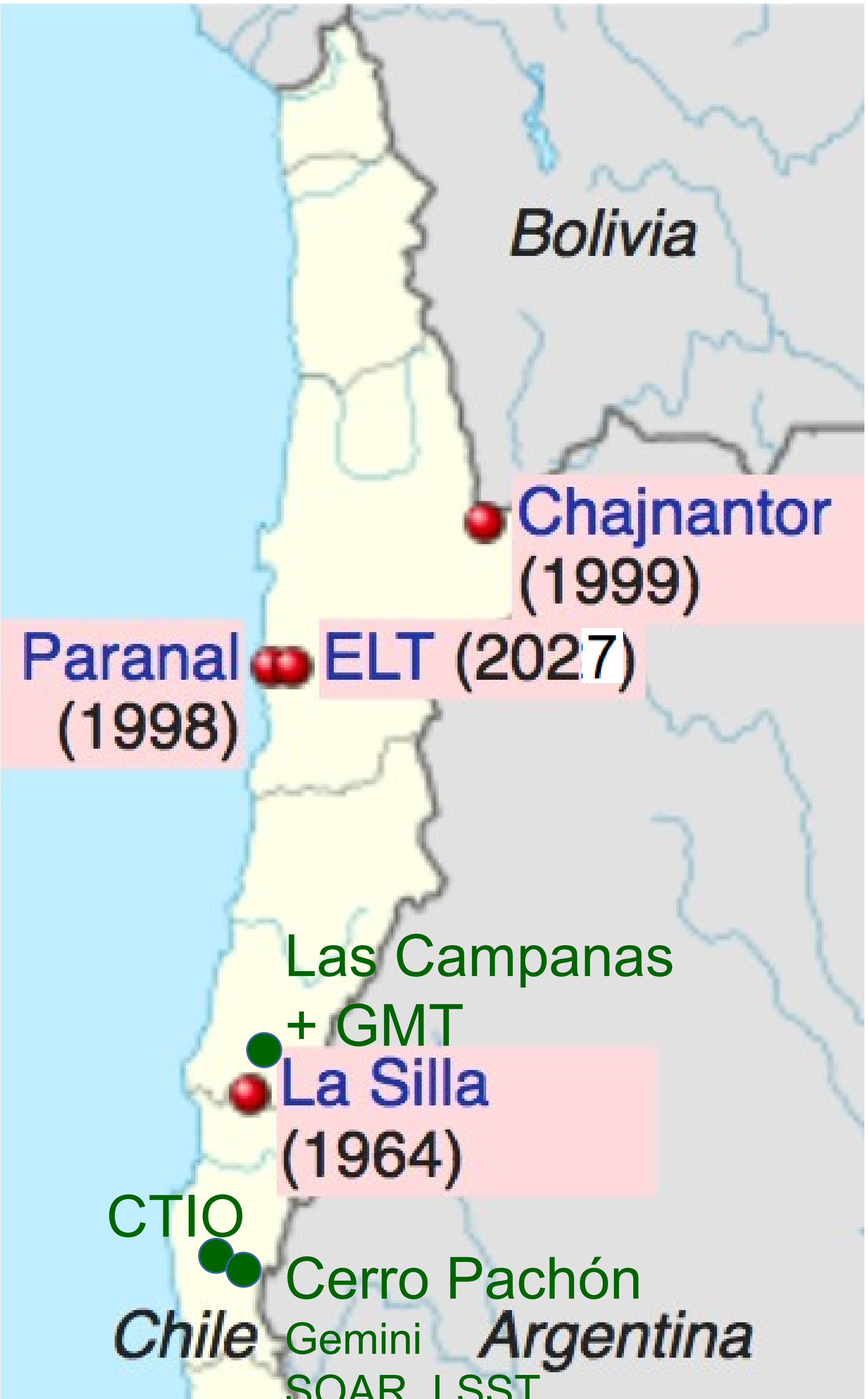
W. M. Keck Observatory (WMKO), in concert with its Science Steering Committee (SSC), announces an instrument development call soliciting requests to fund:

- Instrument **concept studies** to take ideas for upgrades and instruments and determine feasibility
- **Phase A design** studies that mature initial concepts for assessing cost and schedule in advance of proposal development
- **Proposal development** efforts to draft and submit proposals to funding agencies
- **Mini grants** for efforts and equipment costs for either new tools and techniques to improve the observatory scientific productivity or minor hardware capability enhancements

All requests should be submitted in pdf format by 22 June 2022 to whitepapers@keck.hawaii.edu, and all requests will be reviewed by the SSC in early July. All members of the WMKO community are encouraged to participate. All major instrumentation concepts suitable for a large telescope as well as upgrades to our existing instrument suite are encouraged.

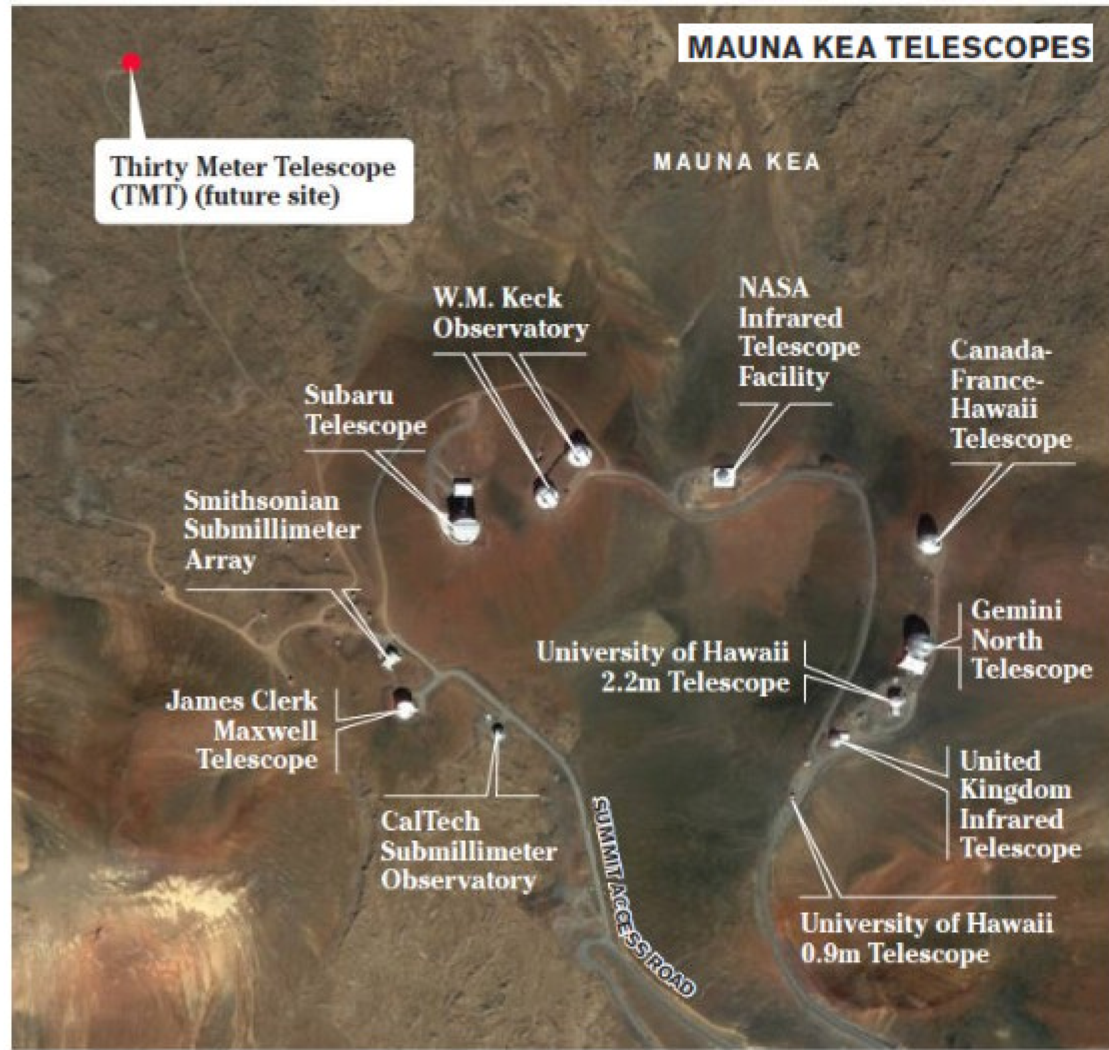


Updated by J.M. on May 2nd, 2012



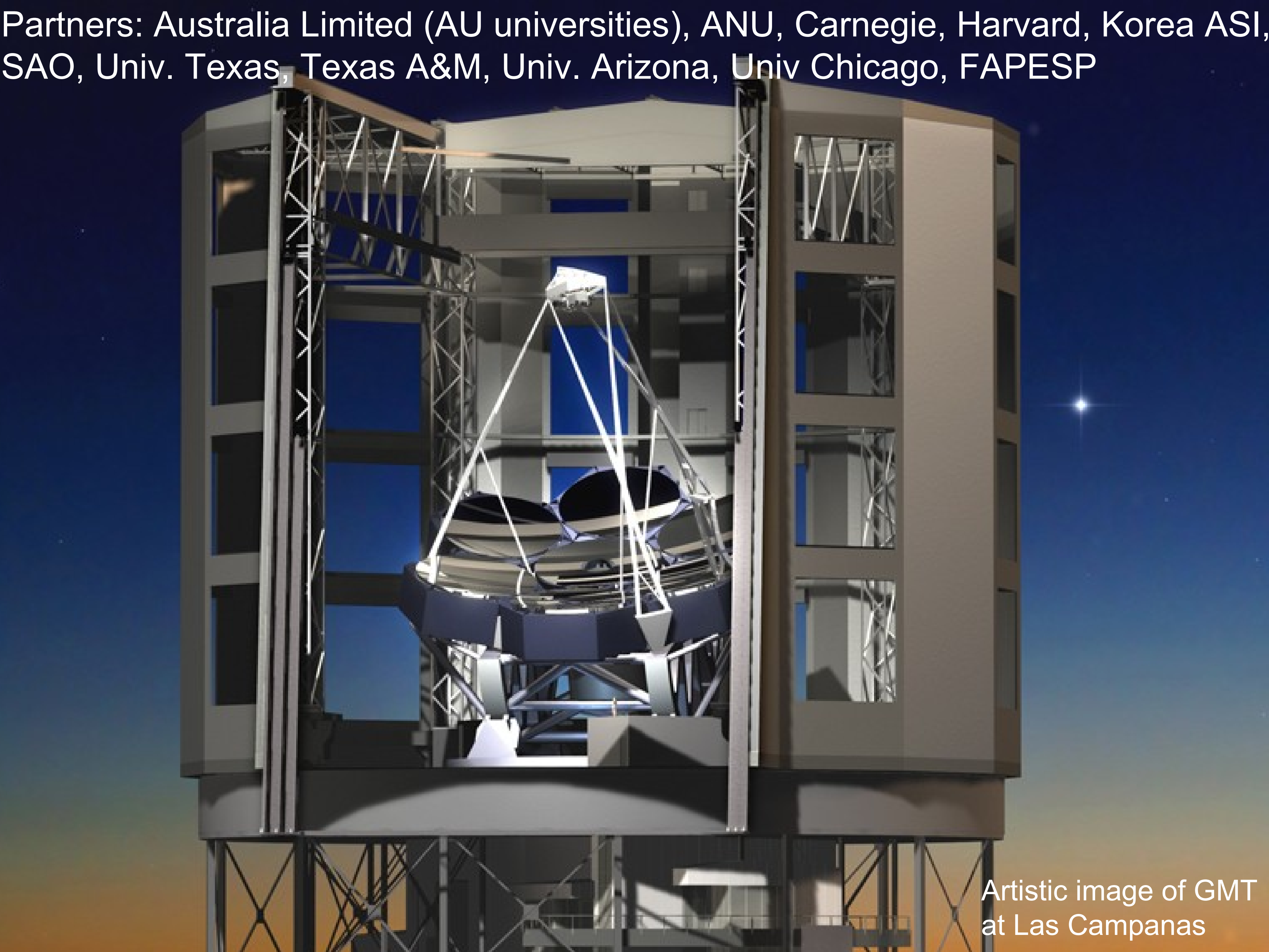
Bolivia
Chajnantor
(1999)
Paranal
(1998)
ELT (2027)
Las Campanas
+ GMT
La Silla
(1964)
CTIO
Cerro Pachón
Chile
Gemini
SOAR, LSST
Argentina

Kawaikini
5241 ft / 1598 m
Hawaiian Islands
4959 ft / 1512 m
Kamakou
5786 ft / 1764 m
Puu Kukui
Mauna Kea
13792 ft / 4205 m
Mauna Loa
13674 ft / 4169 m



MAUNA KEA TELESCOPES
Thirty Meter Telescope
(TMT) (future site)
MAUNA KEA
W.M. Keck
Observatory
NASA
Infrared
Telescope
Facility
Canada-
France-
Hawaii
Telescope
Subaru
Telescope
Smithsonian
Submillimeter
Array
Gemini
North
Telescope
University of Hawaii
2.2m Telescope
James Clerk
Maxwell
Telescope
United
Kingdom
Infrared
Telescope
CalTech
Submillimeter
Observatory
SUMMIT ACCESS ROAD
University of Hawaii
0.9m Telescope

Partners: Australia Limited (AU universities), ANU, Carnegie, Harvard, Korea ASI, SAO, Univ. Texas, Texas A&M, Univ. Arizona, Univ Chicago, FAPESP



Artistic image of GMT at Las Campanas

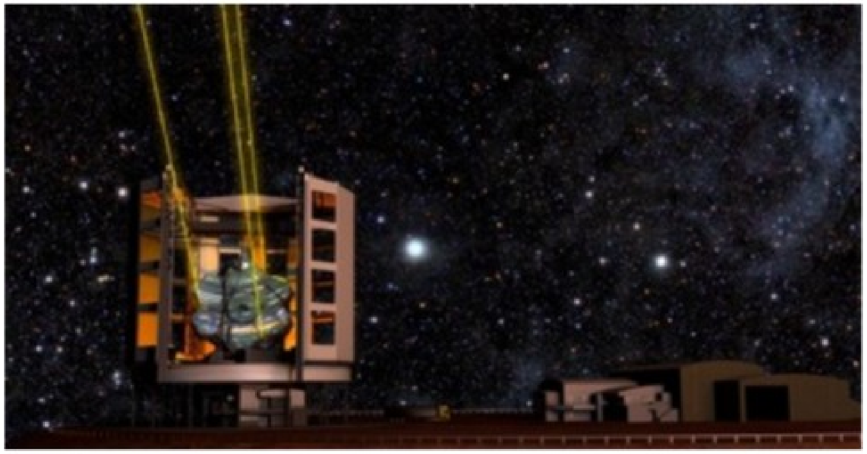
FAPESP no GMT, 4% cost (14 nights?)

São Paulo integra projeto internacional de megatelescópio

24 de julho de 2014

FAPESP:
Inicialmente US$ 40 mi.
Em 2022: mais US$5 mi

Por Diego Freire



FAPESP anuncia entrada no consórcio internacional do Giant Magellan Telescope com investimento de US$ 40 milhões (*GMT*)

Agência FAPESP – Um dos principais telescópios do mundo terá a participação de pesquisadores do Estado de São Paulo em suas operações, resultado da integração da FAPESP no consórcio internacional do Giant Magellan Telescope (GMT), que começará a ser construído em 2015, nos Andes chilenos.

O GMT, que deverá funcionar plenamente em 2021, ampliará em cerca de 30 vezes o volume de informações acessíveis aos telescópios atualmente em operação.

A FAPESP investirá US$ 40 milhões no projeto, o que equivale a cerca de 4% do custo total estimado. O investimento garantirá 4% do tempo de operação do GMT para trabalhos realizados por pesquisadores de São Paulo, além de assento no conselho do consórcio.

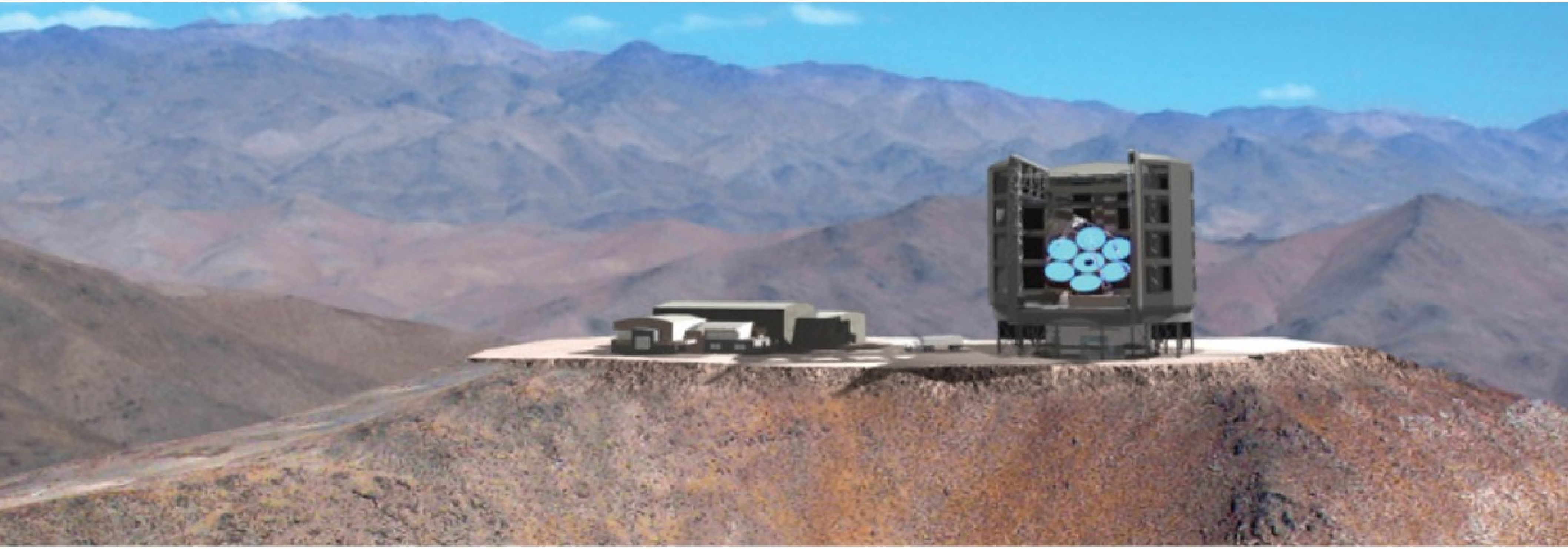
https://agencia.fapesp.br/telescopio-gigante-de-magalhaes-tera-novo-investimento-de-us-205-milhoes/39262/

Telescópio Gigante de Magalhães terá novo investimento de US$ 205 milhões

A FAPESP aportará US$ 45 milhões para a construção do GMT

03 de agosto de 2022

Cerro Las Campanas, 2550 m above sea level



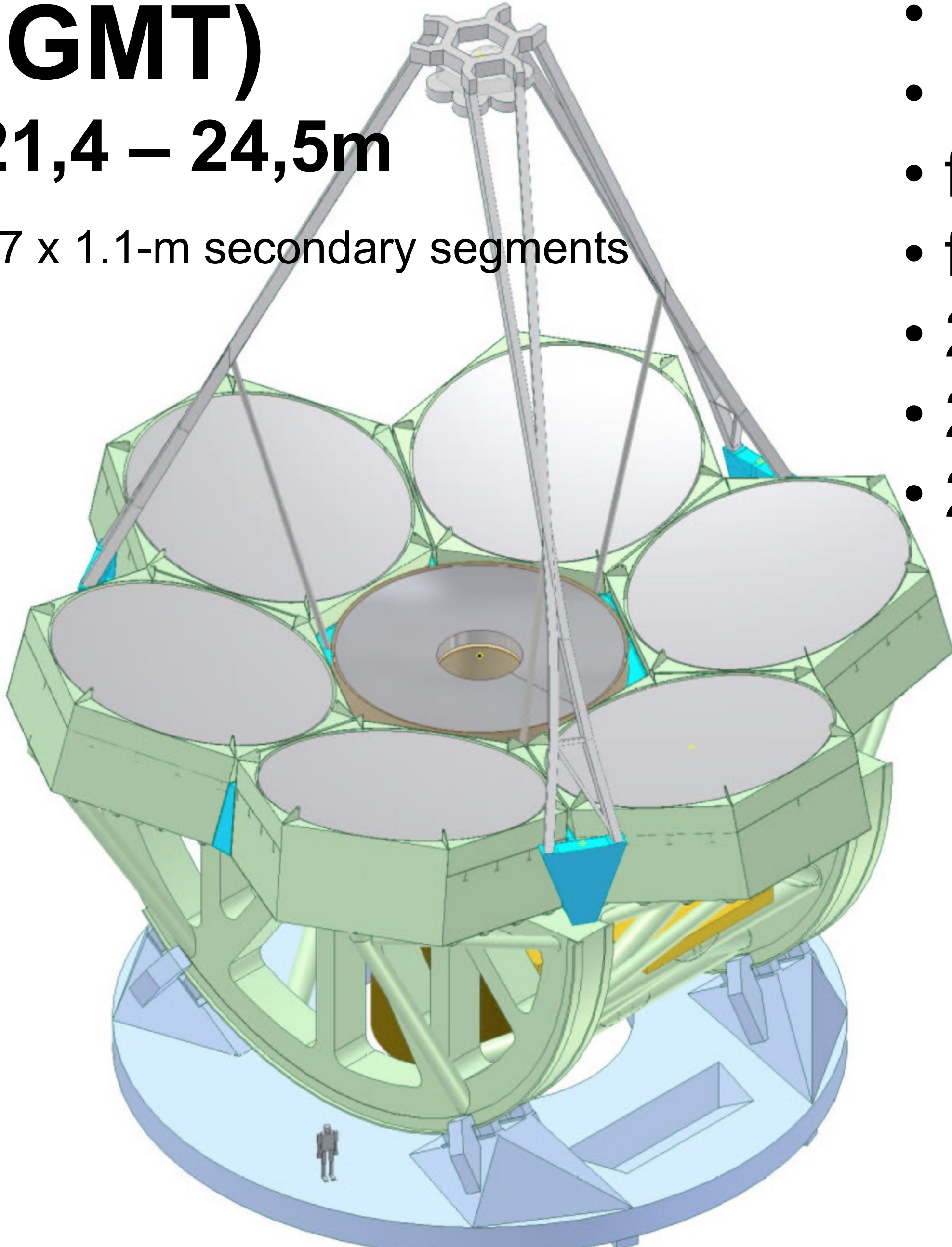
The location of the GMT also offers a key advantage in terms of seeing through the atmosphere. Located in one of the highest and driest locations on earth, Chile's Atacama Desert, the GMT will have spectacular conditions for more than 300 nights a year. Las Campanas Peak ("Cerro Las Campanas"), where the GMT will be located, has an altitude of over 2,550 meters or approximately 8,500 feet. The site is almost completely barren of vegetation due to lack of rainfall. The combination of seeing, number of clear nights, altitude, weather and vegetation make Las Campanas Peak an ideal location for the GMT.

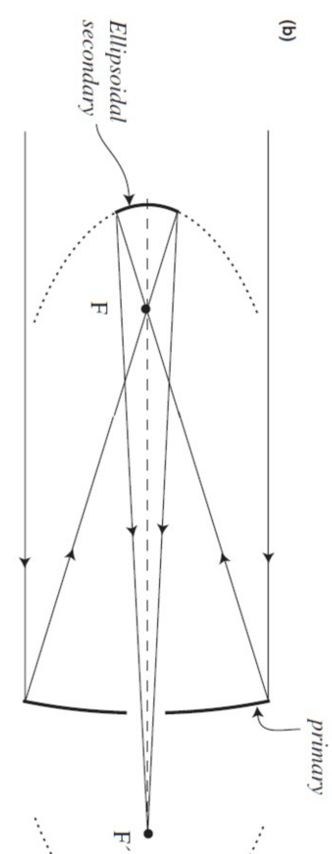
The Giant Magellan Telescope (GMT)

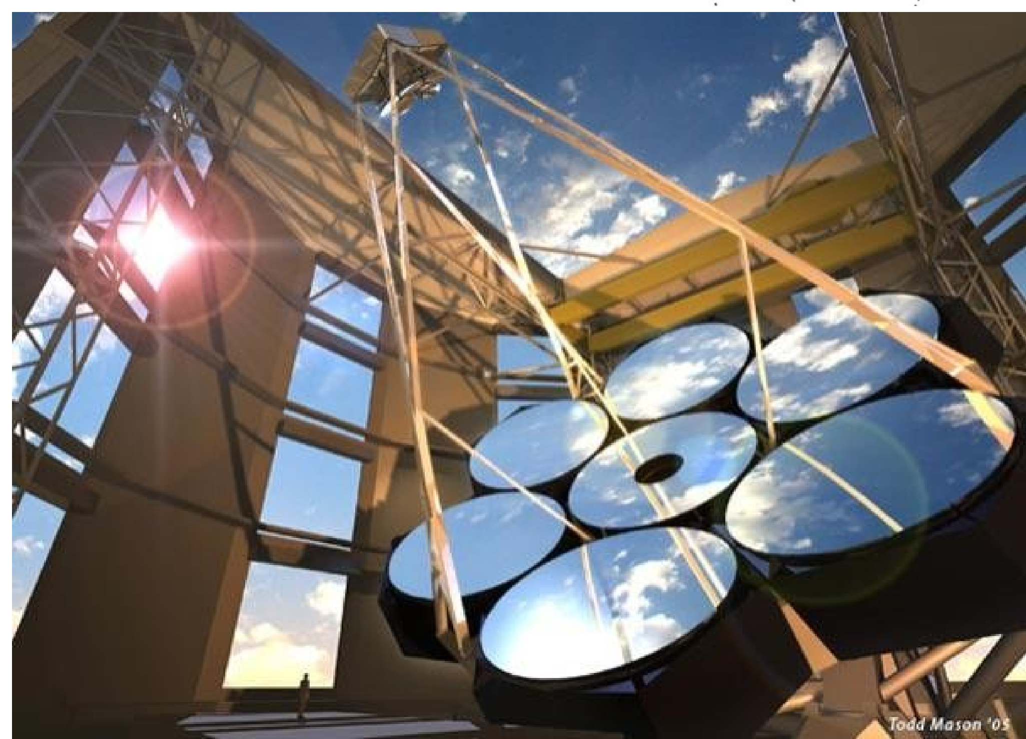
21,4 – 24,5m

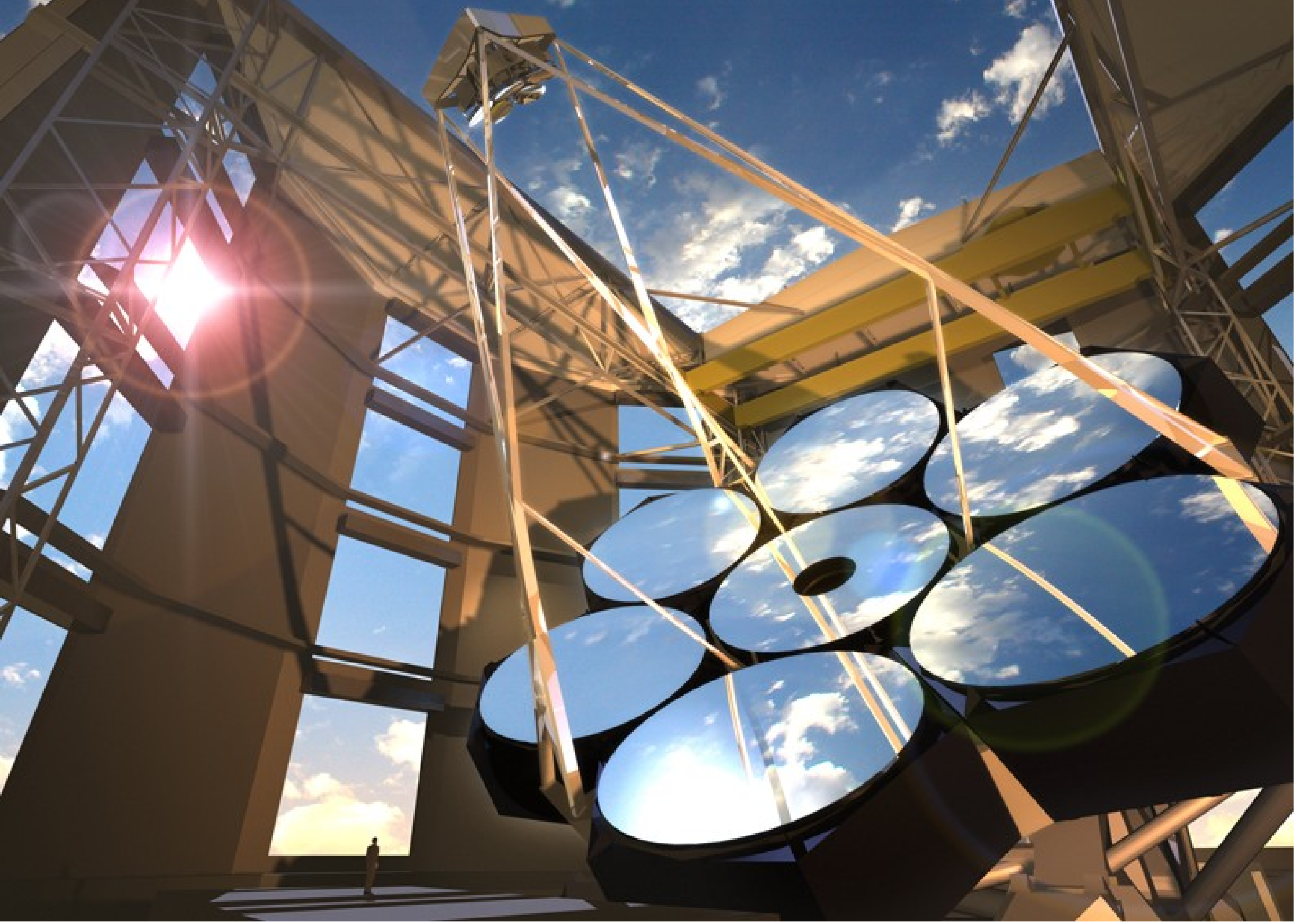
7 x 1.1-m secondary segments

- 7 X 8.4m Segments
- 18m focal length
- f/0.7 primary
- f/8 Gregorian focus
- 21.4m equiv. area
- 24.5m equiv. ang. res.
- 20-25’ FOV









- Cost in 2008, US$600 million, cost as of May 2012, US$700 million. Cost as of April 2016: 1 billion US$
- Completion target in 2008 → 2017; in 2016 → 2021; in 2017 → 2022, in 2018 → 2023; 2019 → 2029 (first light) and 2030 (all 7 mirrors)
- Location - Las Campanas Observatory, Chile (2,516 meters)
- Height of telescope housing - 200 feet (61 meters)

The GMT Plan Today

Instrument	Function	λ Range, μm	Resolution	Field of View
G-CLEF*	Optical High Resolution Spectrometer / PRV	0.35 – 0.95	20 – 100K	Single Object
GMACS*	Optical Multi-Object Spectrometer	0.36 – 1.0	1500 – 4000, 10,000	40-50 $arcmin^2$
GMTIFS	NIR **AO**-fed IFU / Imager	0.9 – 2.5	4000 – 10,000	10 / 400 $arcsec^2$
GMTNIRS†	JHKLM **AO**-fed High Resolution Spectrometer	1.2 – 5.0	50 – 100K	Single Object
NIRMOS*	Near-IR Multi-Object Spectrometer / imager	0.9 – 2.5	2700 – 5000	42 $arcmin^2$
TIGER	Mid-IR **AO**-fed Imager and Spectrometer	1.5 – 14	300	0.25 $arcmin^2$
MANIFEST*	Facility Robotic Fiber Feed	0.36 – 1.0		300 $arcmin^2$

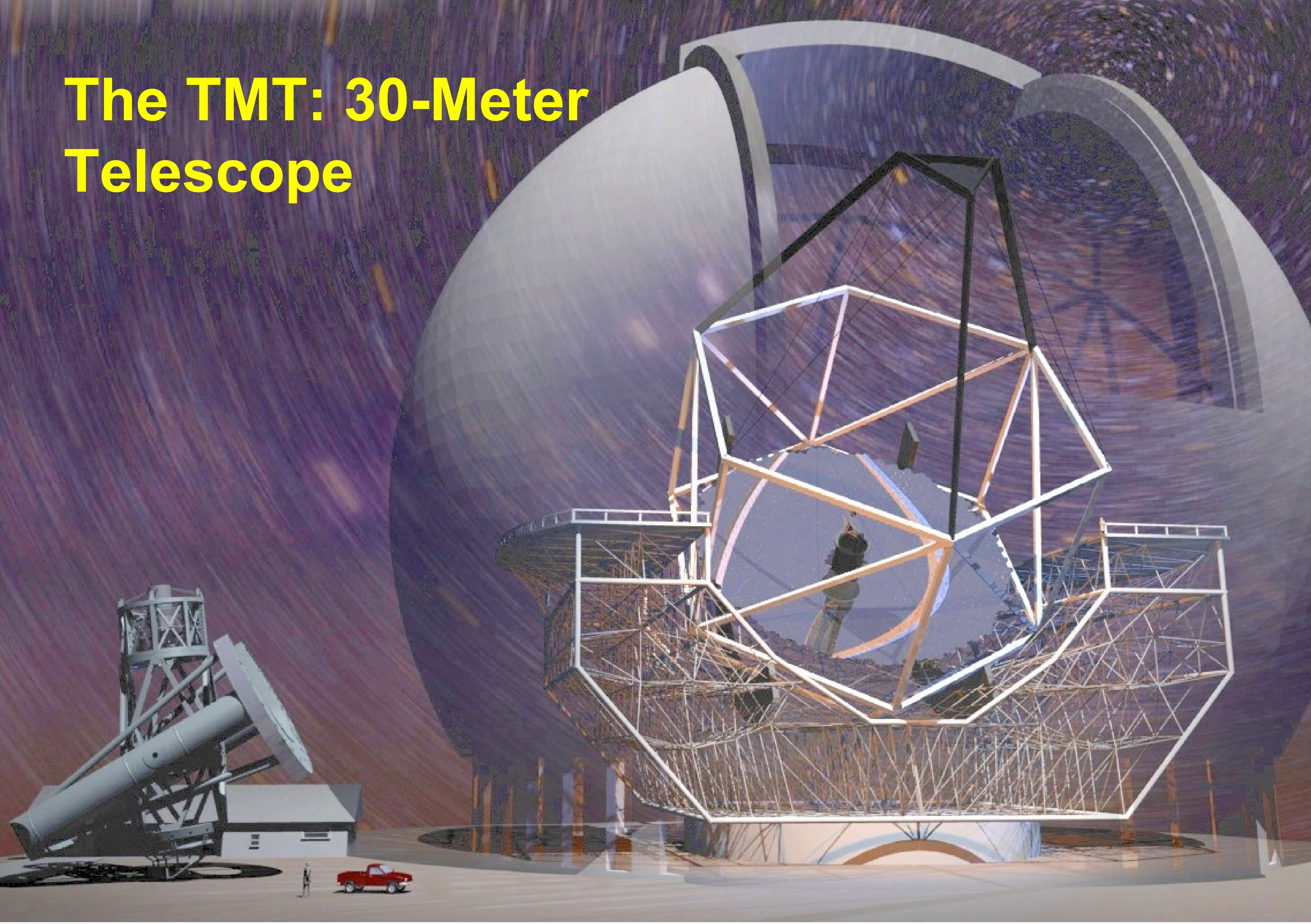
Optical | 1-2.5 μm | Mid-IR

- Proceed to Next Design Phase
- Develop Grating Technology
- Develop Prototype
- Include in Second Generation Call

★ GMACS, NIRMOS, and G-CLEF can be fed by MANIFEST (20 arcmin FoV, multi-IFUs, image slicers)

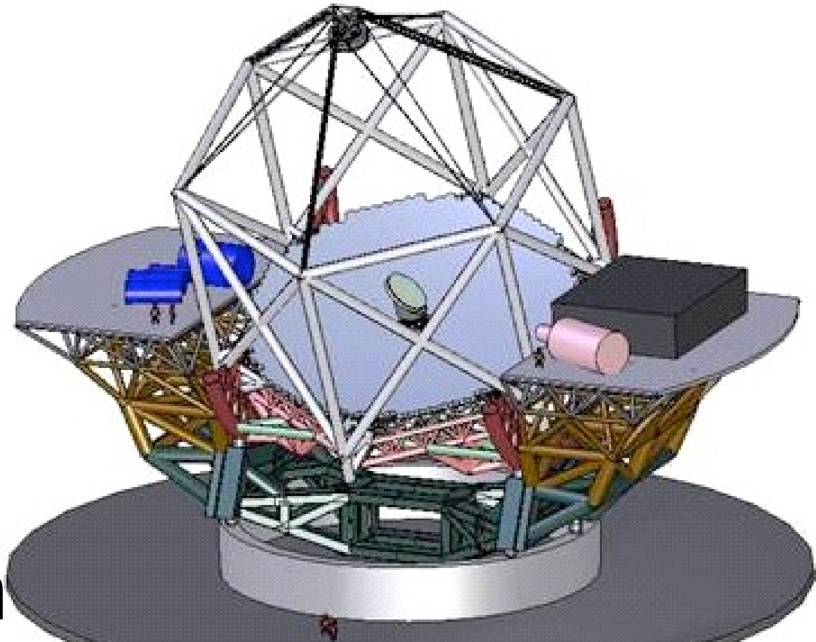
† GMTNIRS now includes Y-Z coverage @ R ~8000

The TMT: 30-Meter Telescope



The TMT Conceptual Design

- 30-meter filled aperture mirror
- 492 segments of 1.4m diameter
- Alt-azimuth mount
- Ritchey-Chrétien design
- f/1 primary, f/15 final focus
- Very AO-intensive
- Field of View = 20 arcmin
- Instruments located at Nasmyth foci, multiple instruments on each Nasmyth platform addressable by agile tertiary mirror



First light: 2008 estimate → 2016; 2012→ 2018; 2013→ 2021; 2015 → 2022; 2018→ 2026, 2019→ 2027, 2023 → 2035?

The TMT project is an international partnership among **Caltech**, the **University of California**, and the **Association of Canadian Universities for Research in Astronomy**. The National Astronomical Observatory of **Japan (NAOJ) joined TMT as a Collaborating Institution in 2008.** The National Astronomical Observatories of the **Chinese Academy of Sciences joined TMT as an Observer in 2009**. **India joined as an observer in 2010.** **China and India became TMT partners in 2012**

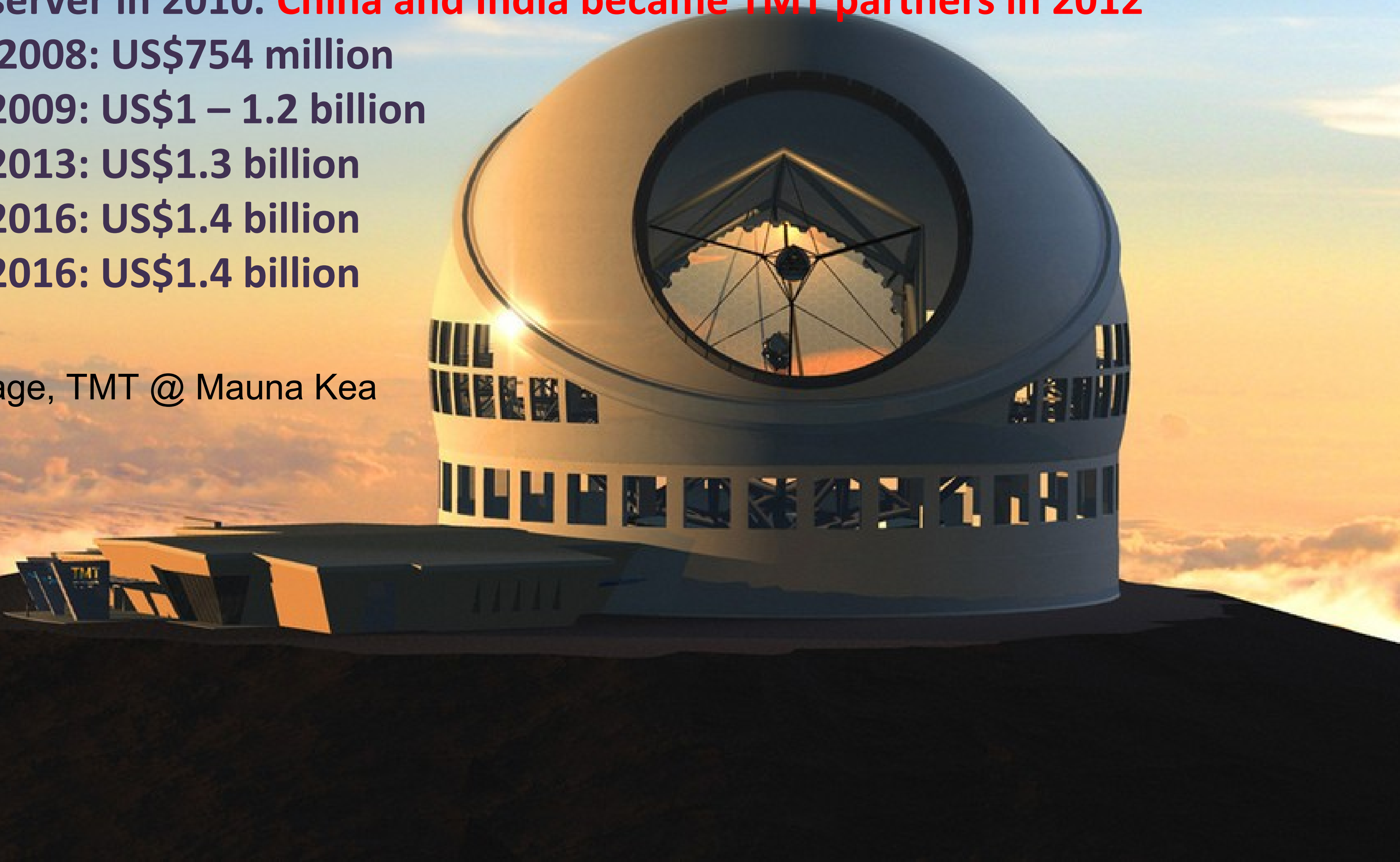
COST in 2008: US$754 million

COST in 2009: US$1 – 1.2 billion

COST in 2013: US$1.3 billion

COST in 2016: US$1.4 billion

COST in 2016: US$1.4 billion



Artistic image, TMT @ Mauna Kea

Cultural practitioner Joshua Lanakila Mangauil, along with Kahoʻokahi Kanuha and Hawaiian sovereignty supporters block the access road to Mauna Kea in October 2014, demonstrating against the building of the Thirty Meter Telescope.
https://www.flickr.com/photos/occupyhilo/15489459316/in/photostream/

https://pubs.aip.org/physicstoday/article/75/12/22/2848608/Giant-telescopes-take-small-but-significant-steps

Physics Today, 12/2022:

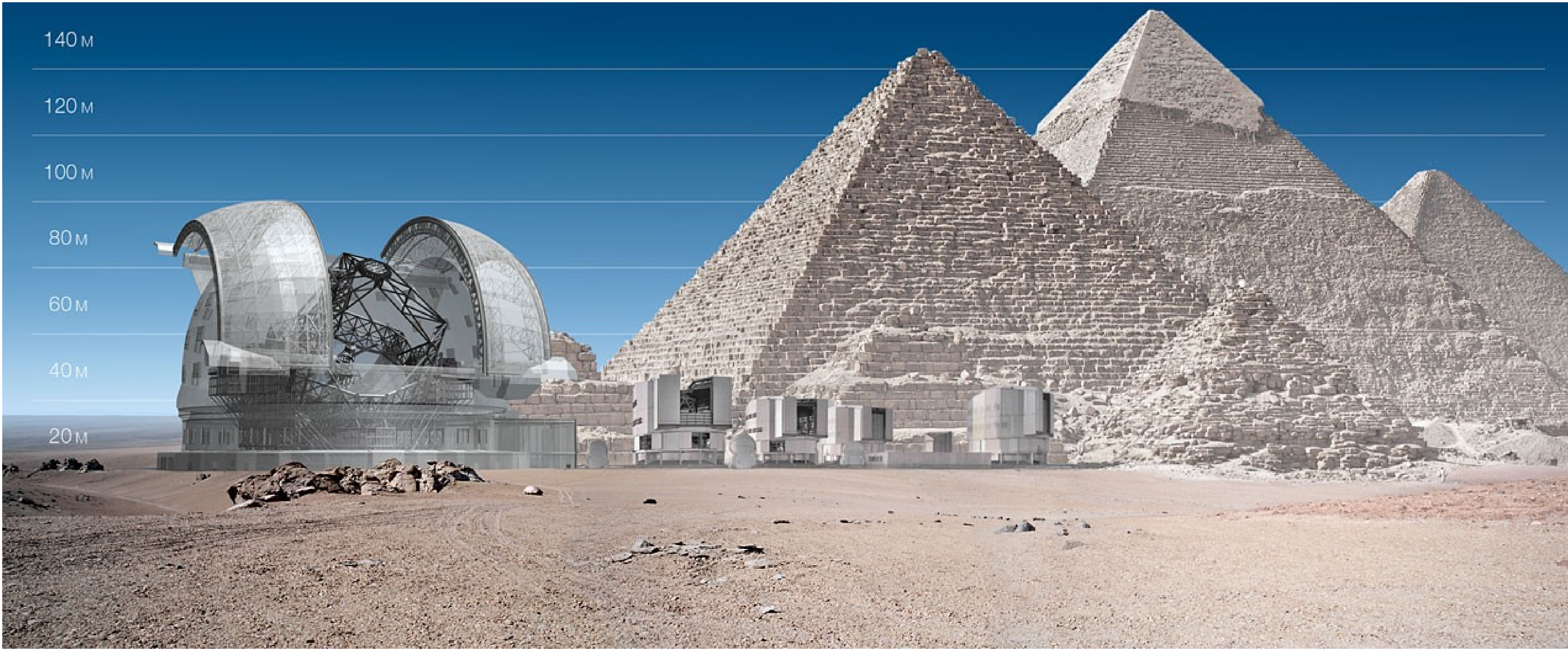
A year ago, I would have been pessimistic about building the Thirty Meter Telescope on Mauna Kea," says John O'Meara, deputy director and chief scientist for the W. M. Keck Observatory, one of 13 observatories on Mauna Kea, the Northern Hemisphere's premier site for optical and IR astronomy. Opposition to the Thirty Meter Telescope (TMT) has long been strong, and in 2019, hundreds of Native Hawaiians and others blocked the road to prevent its construction on the mountain. (See "Thirty Meter Telescope faces continued opposition in Hawaii," Physics Today online, 5 August 2019.)

European Extremely Large Telescope (E-ELT)

Aperture:	~~42 m~~ **39,3 m (798 hexagonal 1.4 m mirror segments)**
Field of view:	10 arcminute diameter
Mounting:	Nasmyth mount
Location:	**Cerro Armazones,** Chile @ 3060 m
Housing:	Dome
Start of operations:	~~2018~~ (planned) **Late 2027 or in 2028**
Wavelength range:	blue atmospheric cut-off (300 nm) to mid-infrared (24 microns)
Instrumentation:	9 stations for fixed instruments
Pixel scale:	at Nasmyth focus (F/17.7), 1 arcsecond on sky corresponds to 3.6 mm in the focal plane

Cost 1,4 billion euros

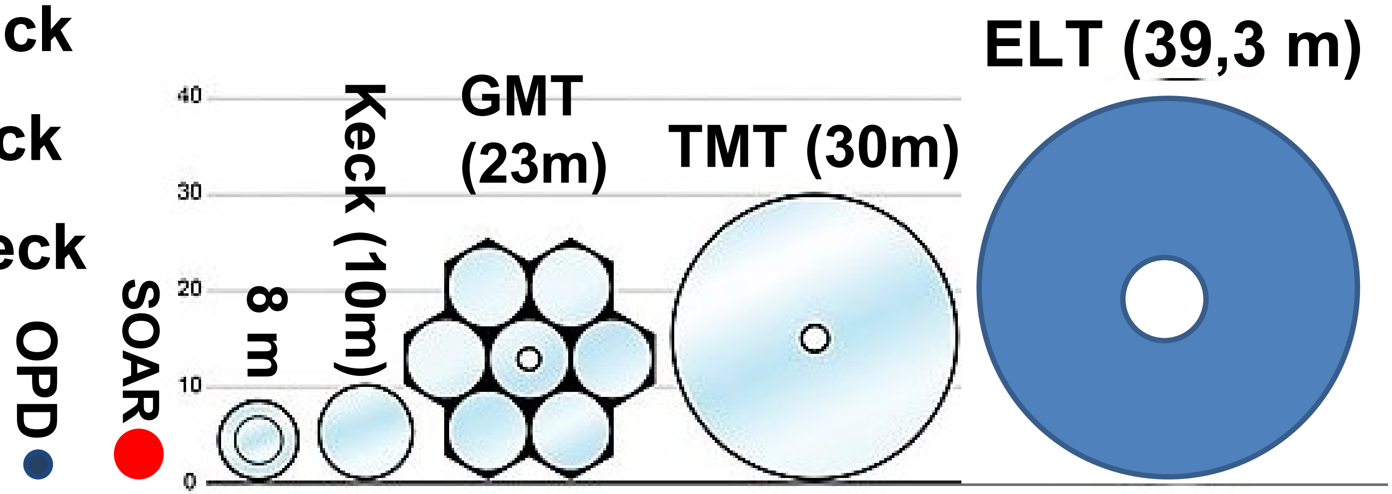
E-ELT and VLT vs Giza Pyramids

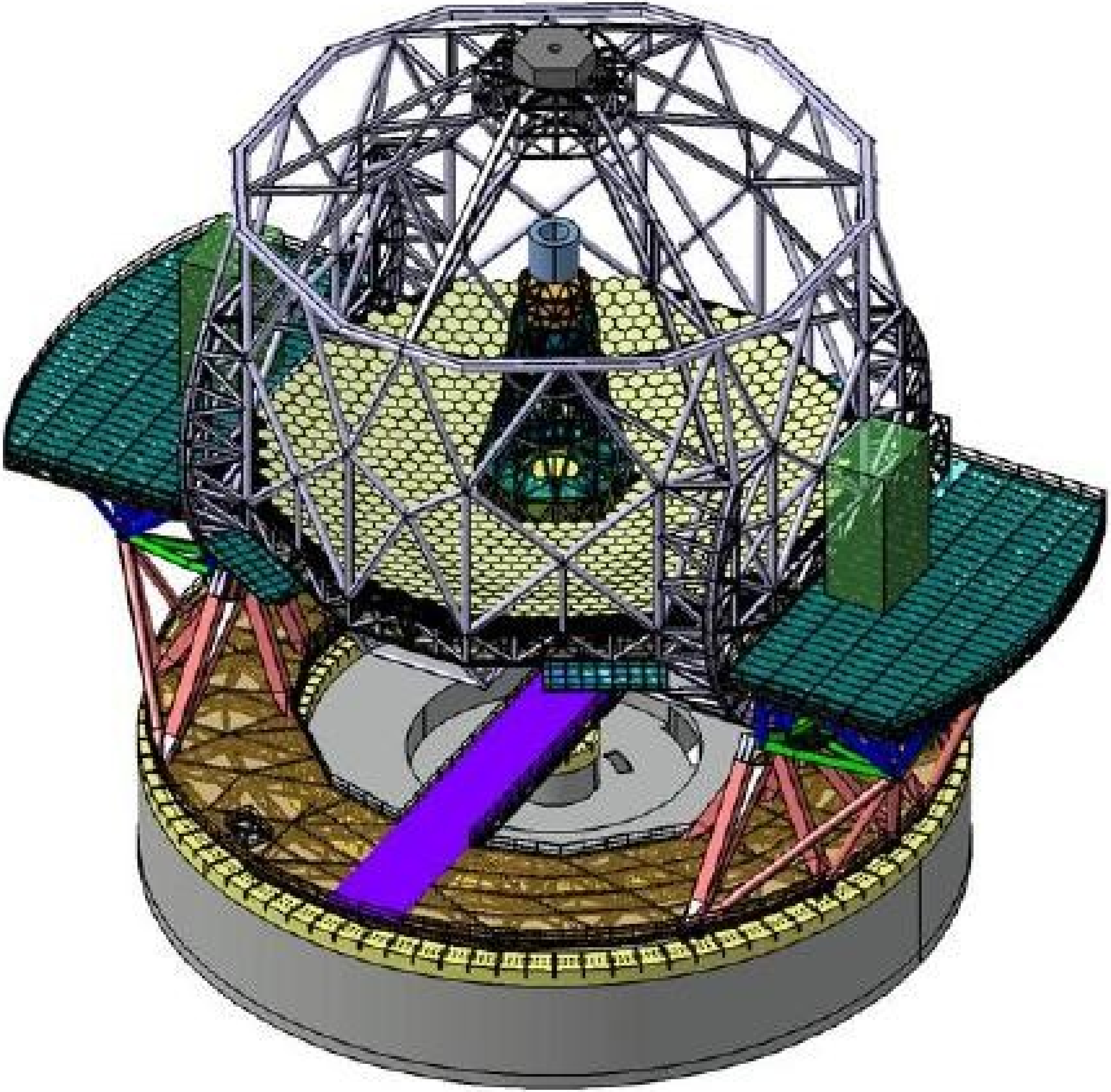


GMT = 5 Keck

TMT = 9 Keck

ELT = 15 Keck



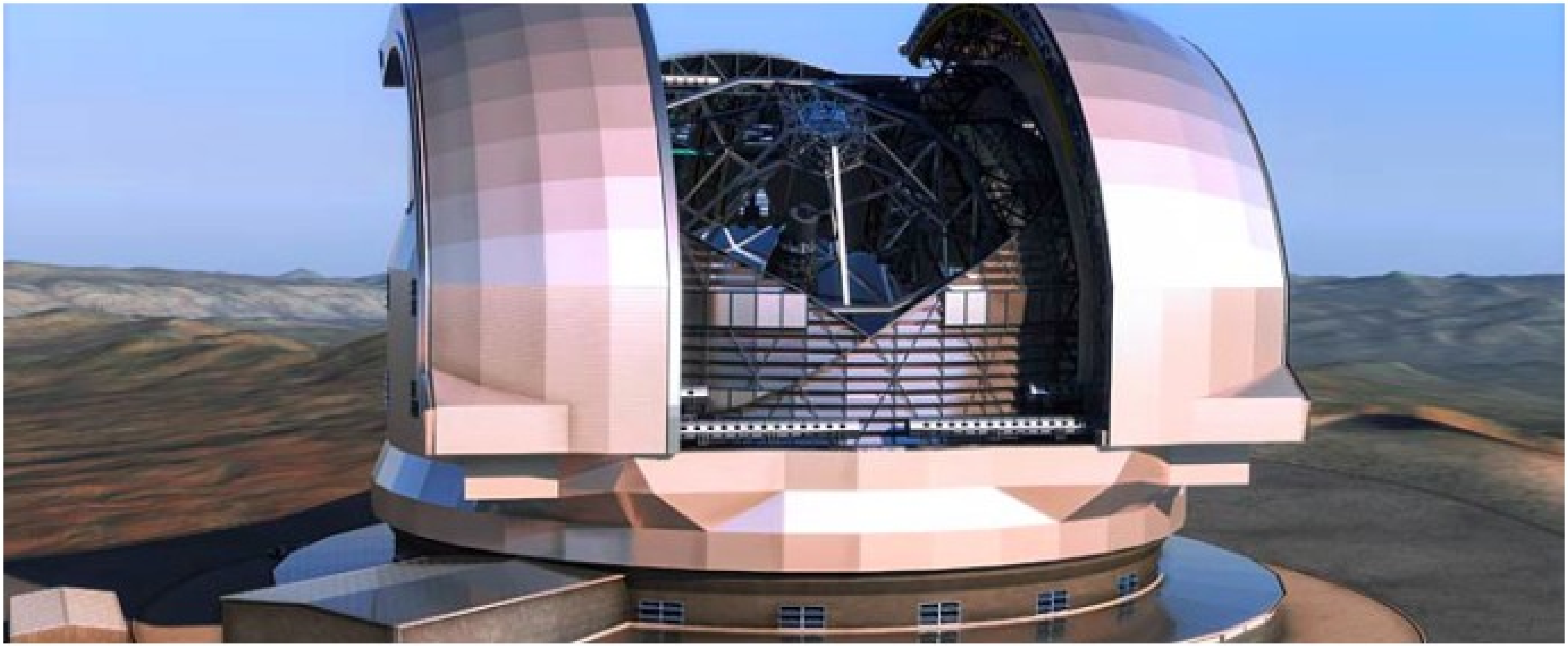


http://www.eso.org/public/brazil/news/eso1440/

December 2014: Green light to construct the ELT

Sinal verde para a construção do E-ELT

4 de Dezembro de 2014



Numa reunião recente o órgão dirigente do ESO, o Conselho, deu [1] sinal verde para a construção do European Extremely Large Telescope (E-ELT) em duas fases. Foi autorizada a atribuição de cerca de um bilhão de euros para a primeira fase, o que cobrirá os custos de construção de um telescópio completamente operacional com uma série de poderosos instrumentos e com a primeira luz prevista para daqui a dez anos. O telescópio permitirá fazer enormes descobertas científicas em áreas tão variadas como exoplanetas, composição estelar de galáxias próximas e Universo profundo. O maior contrato ESO, para a construção da cúpula do telescópio e da estrutura principal, será atribuído durante o próximo ano.