THE EXTREMELY LARGE TELESCOPE (ELT)

Credit: E. Garcés/ESO. Ack.: N. Dubost

Building the biggest optical telescope on earth

37C3, 2023-12-27

ABOUT US

- We work as software engineers at European Southern Observatory (ESO)
- Nicolas works on observatory control software
- Linus works on adaptive optics control software

EUROPEAN SOUTHERN OBSERVATORY (ESO)

European Organization for Astronomical Research in the Southern Hemisphere

- Formation: 1962
- Intergovernmental Organization, 16 Member States

  - Chile: Host State
  - Australia: Strategic Partner
- *ESO's Mission is to design, build and operate advanced ground-based observatories, and to foster international collaboration for astronomy*

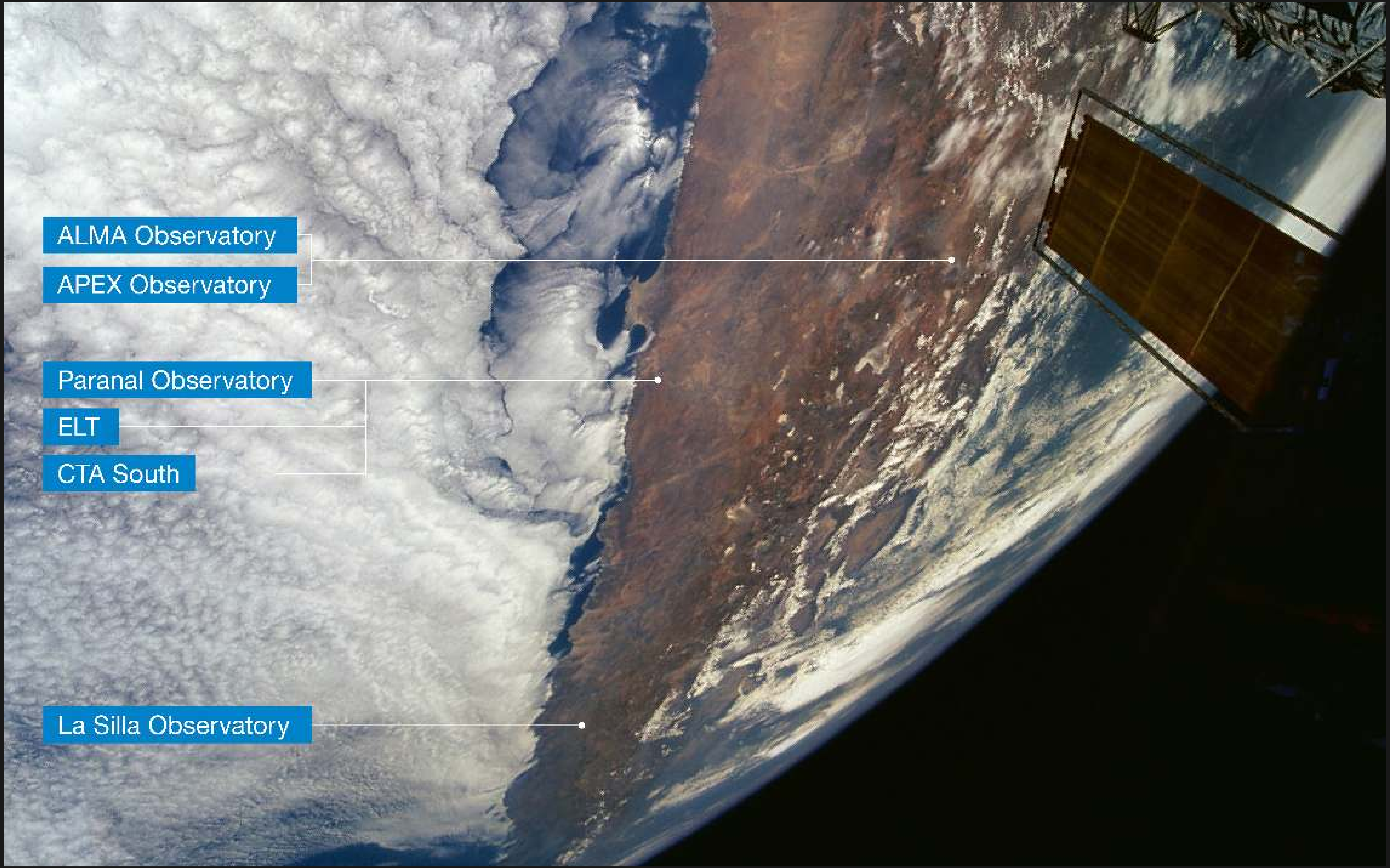
EUROPEAN SOUTHERN OBSERVATORY (ESO)

- Headquarters: Garching bei München, Germany (since 1981)
- Telescope sites: Atacama Desert, Chile
- Staff: ≈750 (HQ: 500, Chile: 250)
- Contributions in 2021: 192 M€

ESO HQ, Credit: E. Graf (graf-flugplatz.de)/ESO


Venezuela
Guyana
Suriname
French Guyana
Colombia
Ecuador
Brazil
Peru
Bolivia
Paraguay
Uruguay
Chile
Argentina
San Pedro de Atacama
Chajnantor
Antofagasta
Paranal
Armazones
Taltal
Chile
La Silla
La Serena
Argentina
Valparaiso
Santiago

Credit: ESO

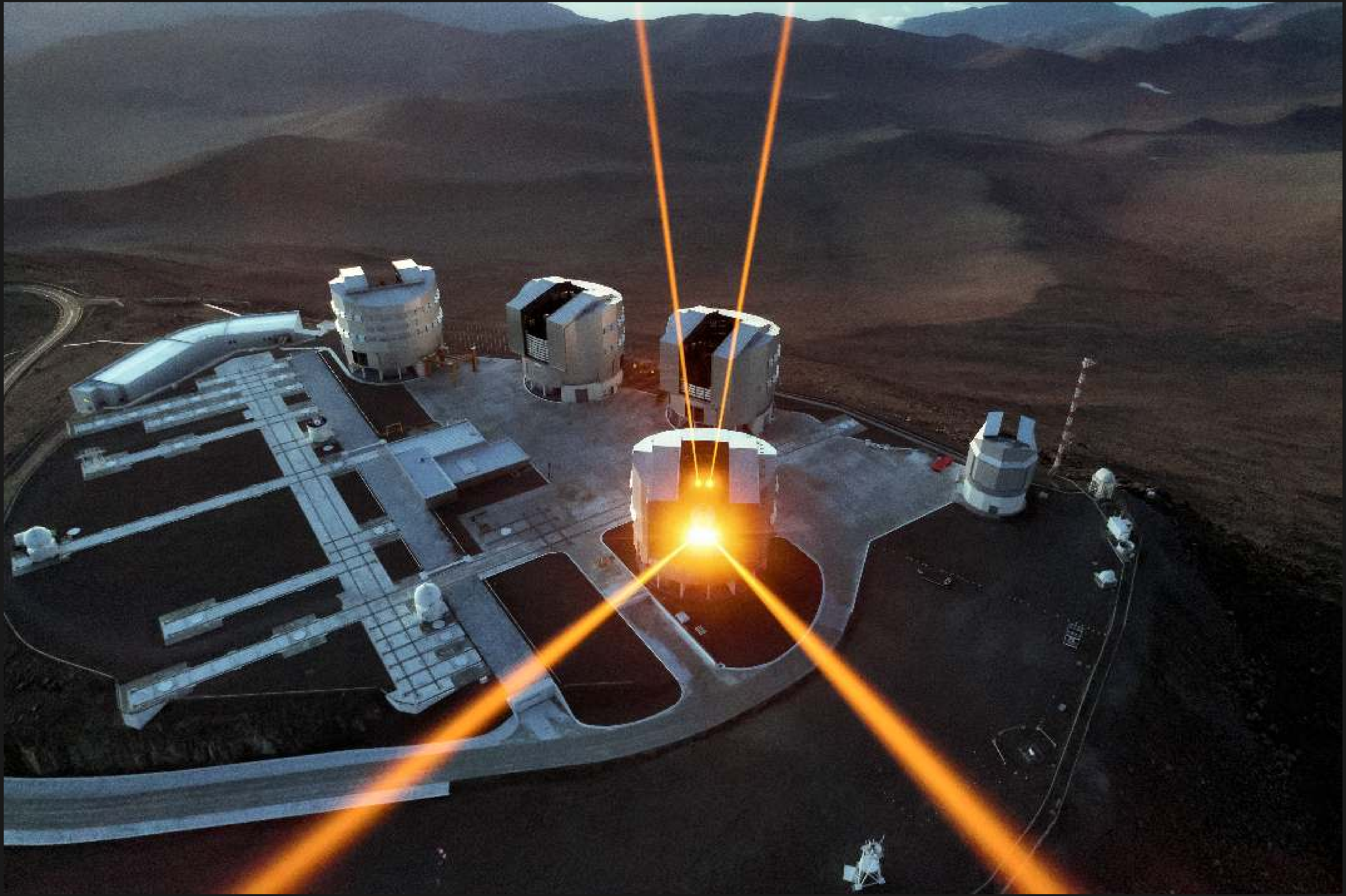


Credit: Modified from original by Claude Nicollier

La Silla, 2400 m: ESO 3.6m-Telescope, New Technology Telescope, ...

Credit: Zdeněk Bardon/ESO

Paranal, 2600 m: VLT, VLTI, VISTA, ...



Credit: ESO/G. Hüdepohl (atacamaphoto.com)

Chajnantor, 5000 m: ALMA (ESO with partners)

Credit: ESO/Angelos Tsaousis

REASONS FOR A NEW TELESCOPE

- Scientists want to study:
  - Earth-like exoplanets
  - Biomarkers on exoplanets
  - Dark matter
  - Faint objects in our solar system

- Therefore
  - increase angular resolution ⇒ larger primary mirror diameter
  - increase light collecting surface ⇒ increase mirror size
  - more light ⇒ fainter objects observable, shorter exposure times

THE EXTREMELY LARGE TELESCOPE (UNDER CONSTRUCTION)

Rendering, Credit: ESO

THE EXTREMELY LARGE TELESCOPE

- 39.3 m primary mirror diameter
- Site: Cerro Armazones, 3045 m
  ≈23 km east of the Cerro Paranal (VLT)

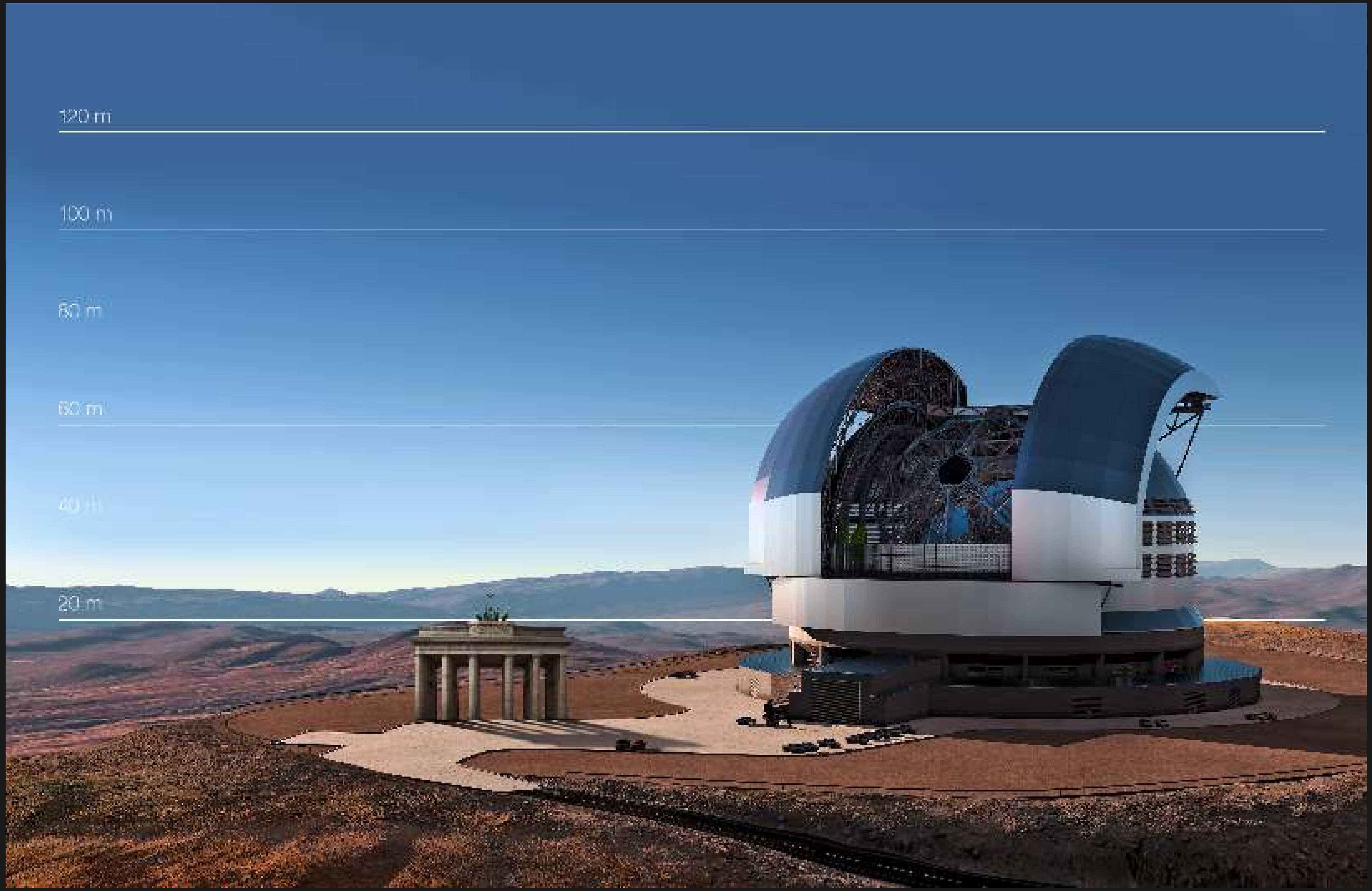
- Cost: ≈1300 M€ (2014 - 2028)
- First Light planned for end of 2028

- Similar projects: GMT (25 m), TMT (30 m)

Rendering, Credit: ESO

DOME (ENCLOSURE)

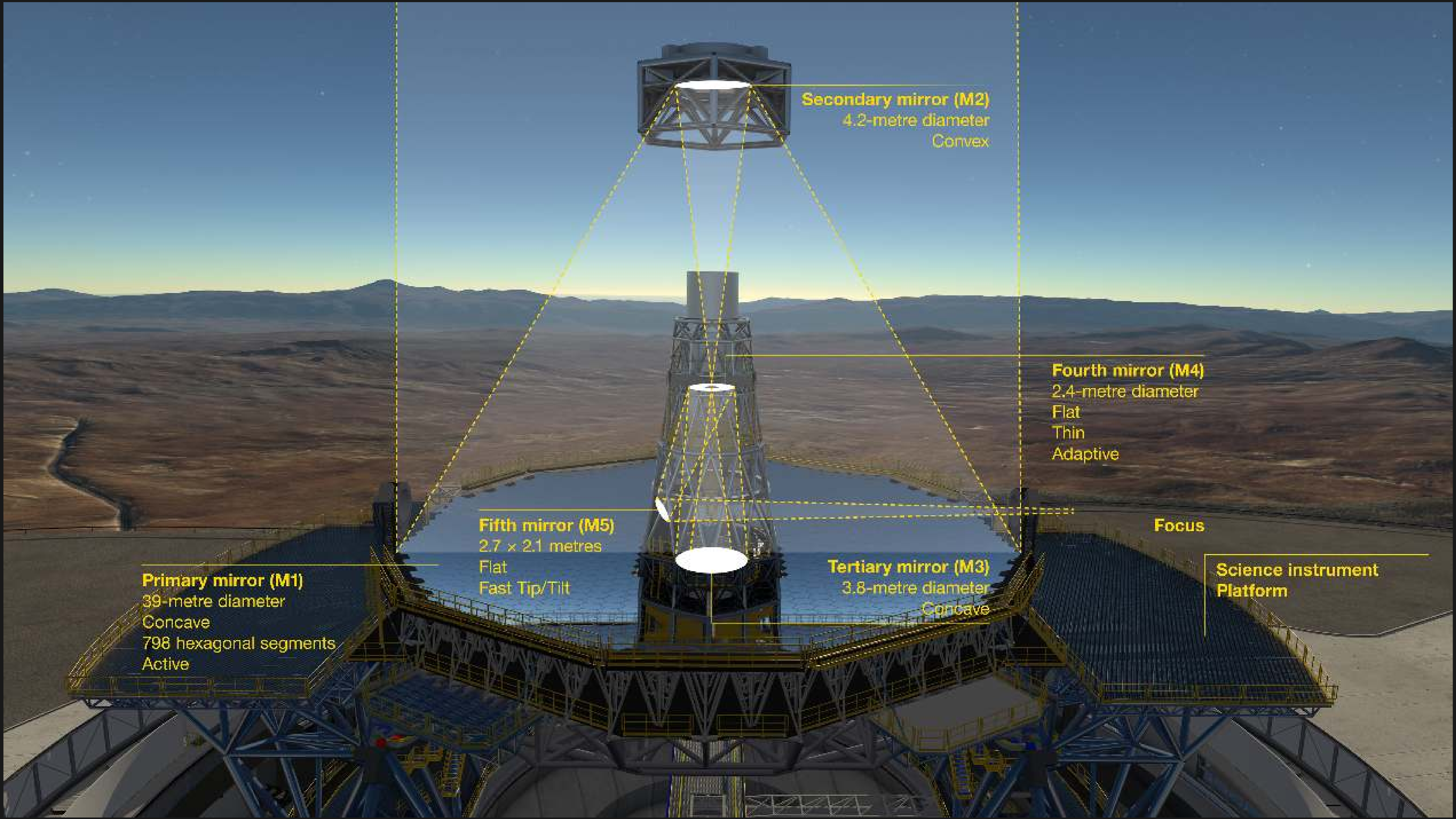
- Protection from the environment (sun, wind, temperature, dust, rain)
- Ventilation and air-conditioning to prevent "dome seeing"
- Wind screen to deflect wind away from the mirrors
- Seismic isolators, separate foundations for Dome and Main Structure



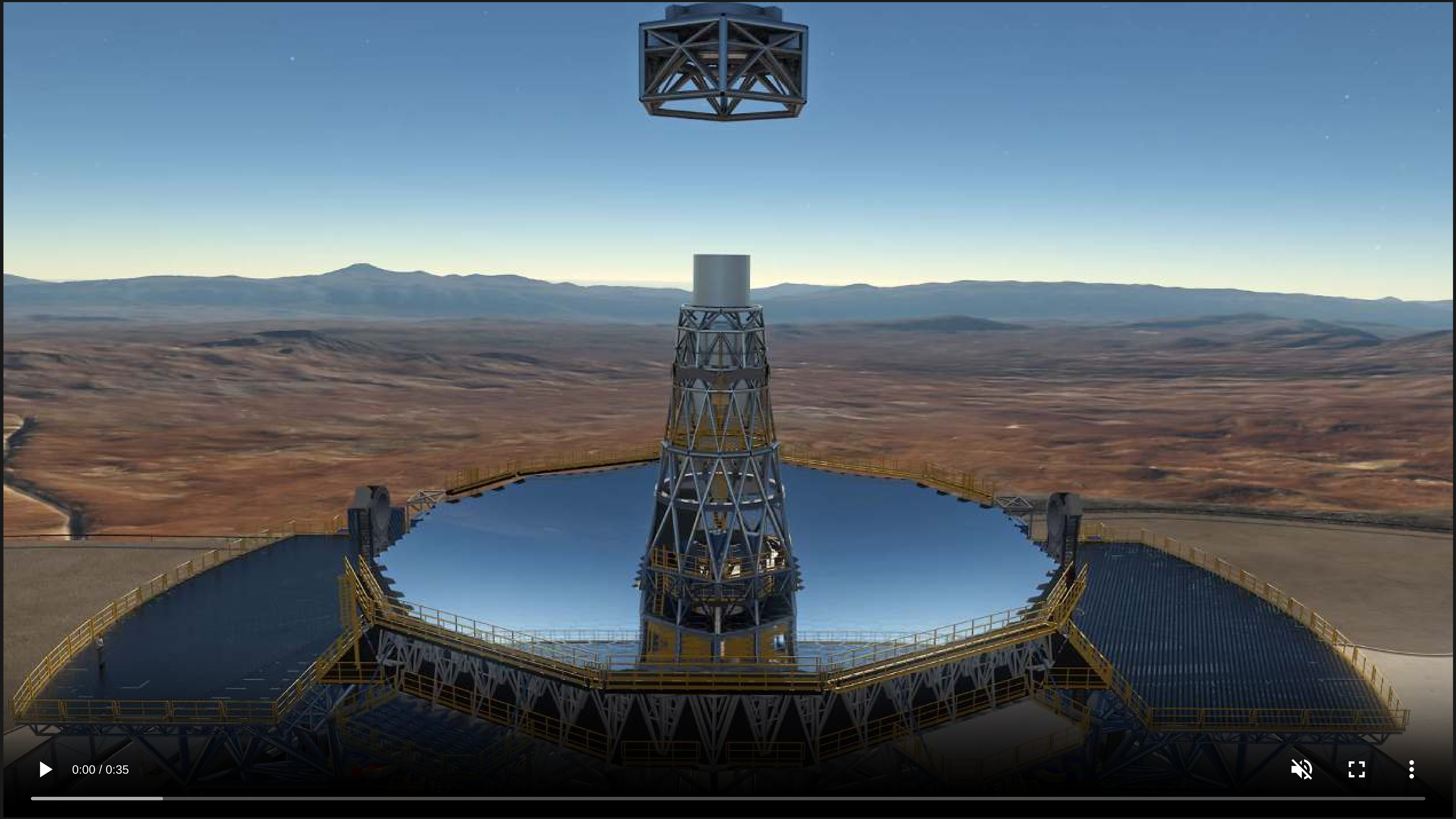
Credit: ESO

MAIN STRUCTURE

Credit: ESO


Secondary mirror (M2)
4.2-metre diameter
Convex
Fourth mirror (M4)
2.4-metre diameter
Flat
Thin
Adaptive
Fifth mirror (M5)
2.7 × 2.1 metres
Flat
Fast Tip/Tilt
Focus
Primary mirror (M1)
39-metre diameter
Concave
798 hexagonal segments
Active
Tertiary mirror (M3)
3.8-metre diameter
Concave
Science instrument
Platform

Credit: ESO



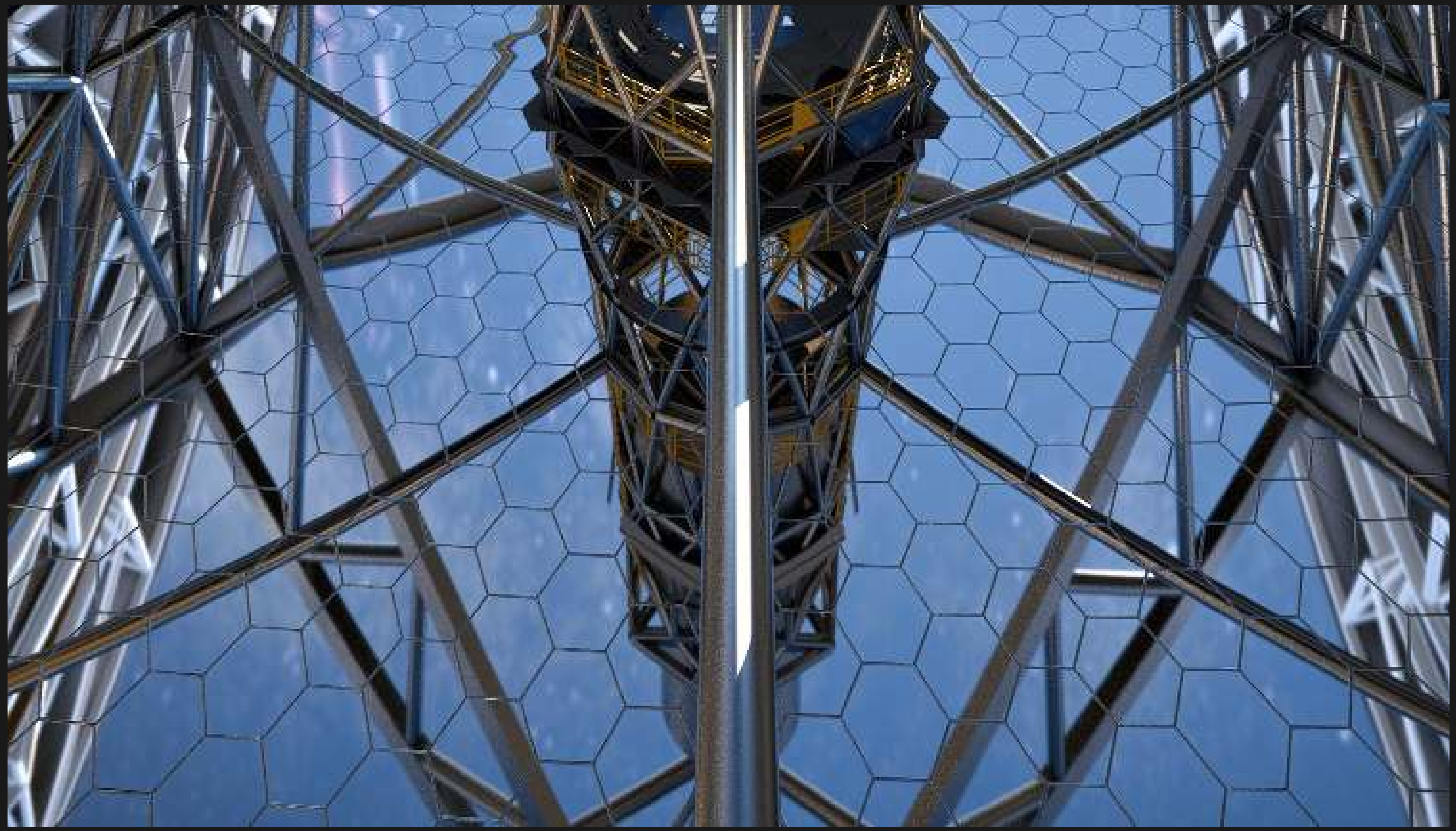
Credit: ESO/L. Calçada/ACe Consortium

M1

Monolithic mirror:

- Feasible up to ≈10 m diameter
- Heavy, e.g. VLT M1 (8.2 m) ≈23 t
- Expensive
- Logistics/transportation by truck and ship

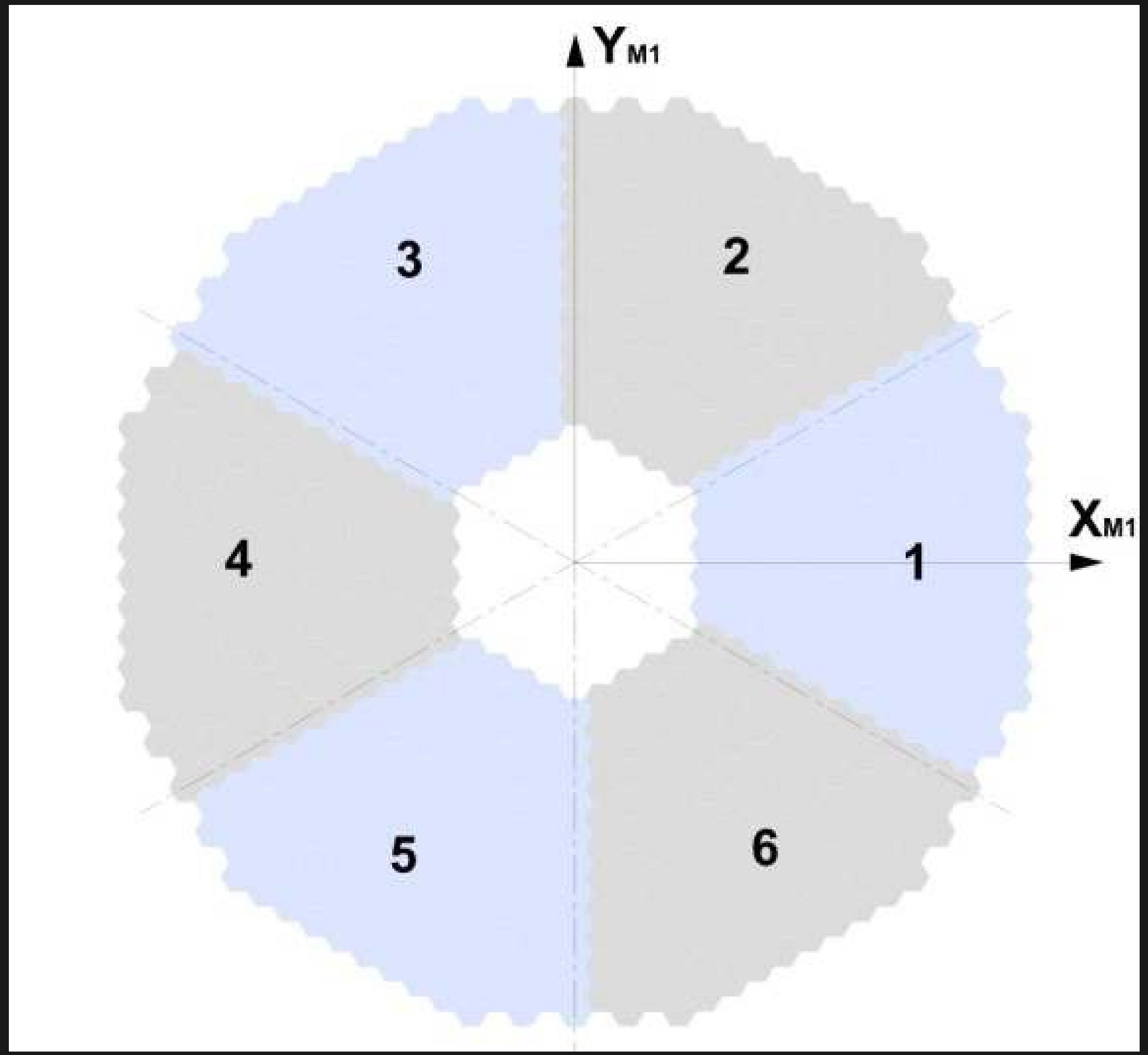
⇒ Segmented mirror design



Credit: ESO/L. Calçada/ACe Consortium

M1

- 6 * 133 = 798 hexagonal segments (+ 133 spares)
- Silver coating to be renewed every 2 years
  2 segment exchanges per day
- 6-fold symmetry, 1 spare sector
- Position and shape must be maintained to an accuracy of tens of nm



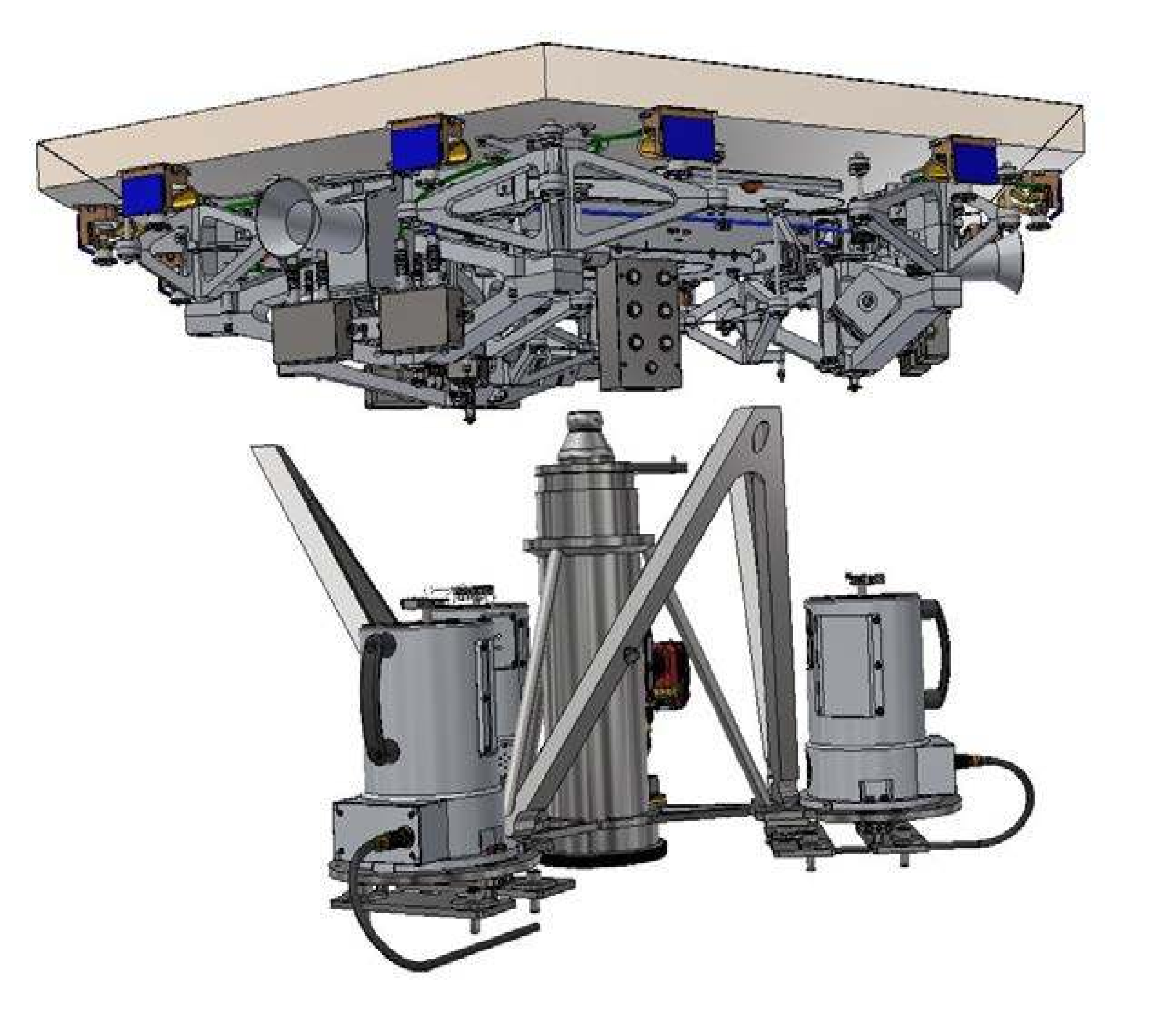
Tamai, R. (2022). "ELT Telescope Progress", ELT Instruments Day 2022

M1 SEGMENT UNIT

- 50 mm thick Zerodur glass-ceramic, 1.4 m diameter
- ≈250 kg including segment support

- 3 Position Actuators (PACT) to change piston, tip, tilt (2394 PACTs)
- 6 Edge Sensor pairs (ES) to measure piston, gap and shear to the adjacent segment (≈4500 ES pairs)
- 9 shape actuators (warping harness, WH) to change optical characteristics (≈7182)

- 500 Hz rate for ES read-out and PACT command



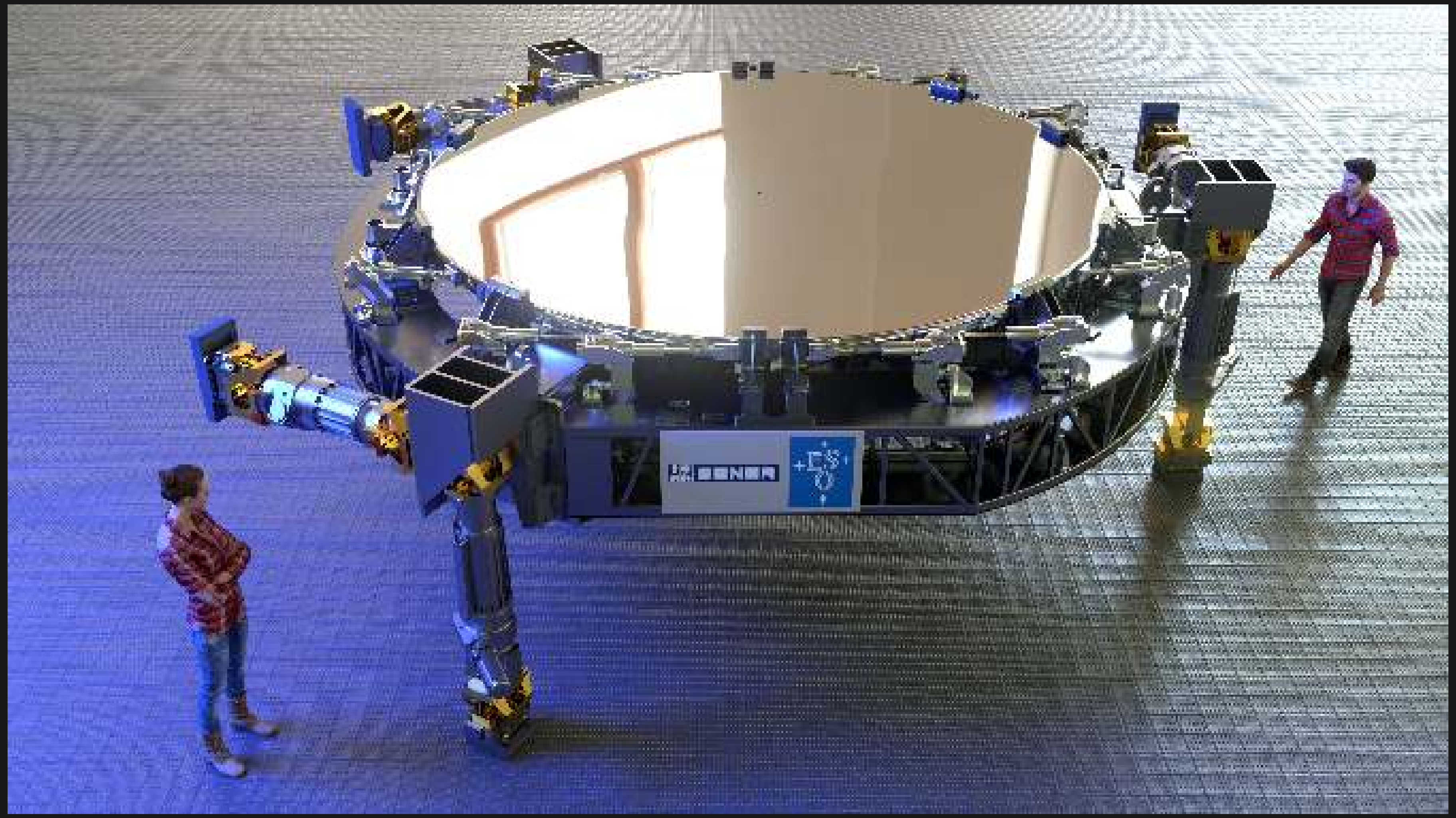
Tamai, R. (2022). "ELT Telescope Progress", ELT Instruments Day 2022

Credit: Safran

M2 AND M3

- M2: 4.25 m, convex, highly aspheric
- M3: 4.00 m, concave, mild aspheric
- Sub-micron precision hexapod positioning system
- ≈3 t per mirror, ≈12 t per assembly

M2 unit, Credit: SENER



M3 unit, Credit: ESO (L. Calçada)/SENER

ATMOSPHERIC DISTORTION

- Turbulence in the atmosphere distorts the path of light
- Objects appear blurry, seem to twinkle

⇒ Adaptive Optics

Credit: Fabian Horst

Credit: ESO

NATURAL AND LASER GUIDE STARS

- Use a bright star as reference

- Sufficiently bright natural star is not always available, create an artificial star with lasers (≈20 W optical power)
- Excite sodium atoms in the upper atmosphere (80-105 km)
- Automatic shut-off when an airplane approaches

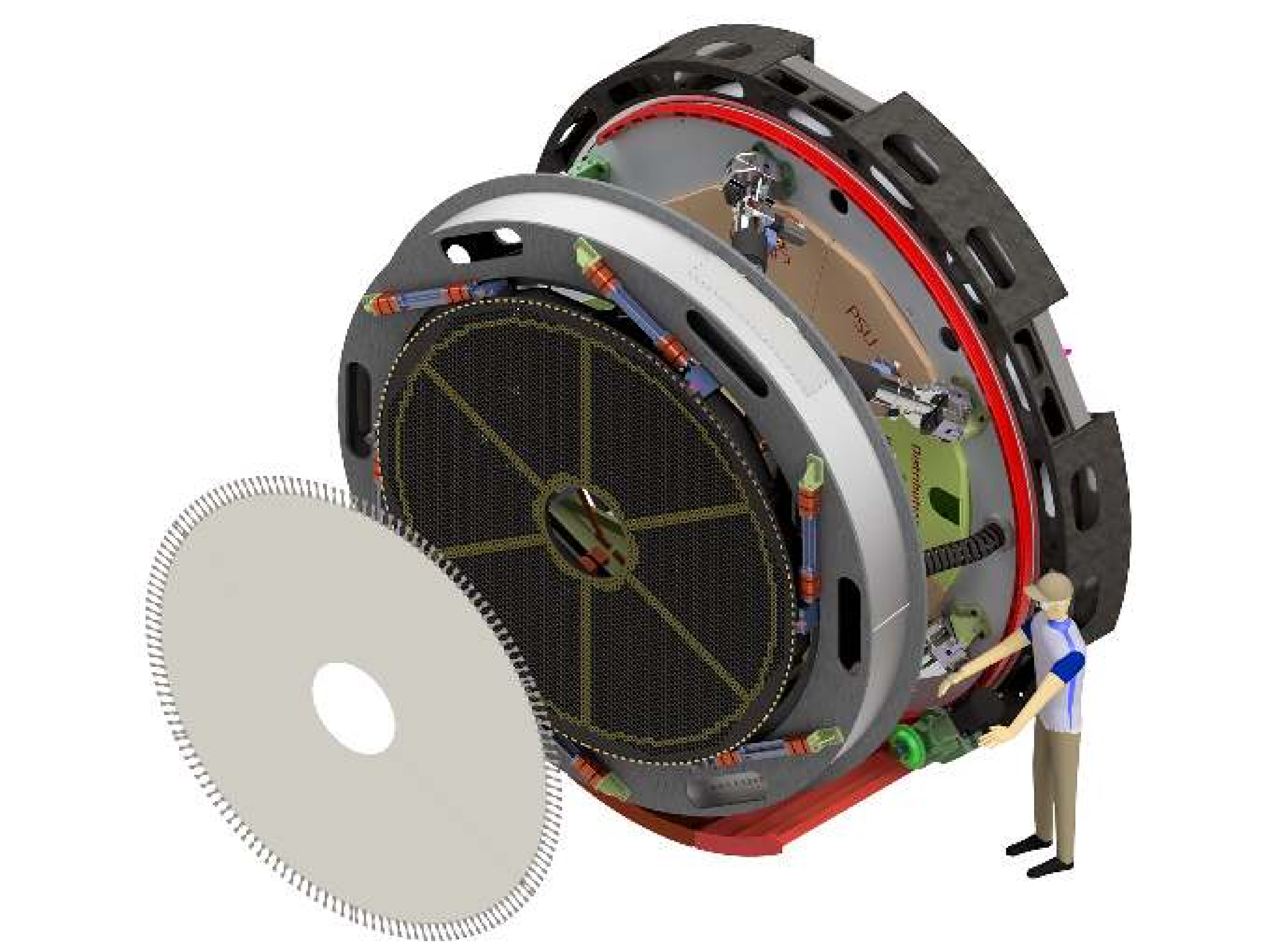
Credit: ESO/G. Hüdepohl

Neptune with and without AO, Credit: ESO/P. Weilbacher (AIP)

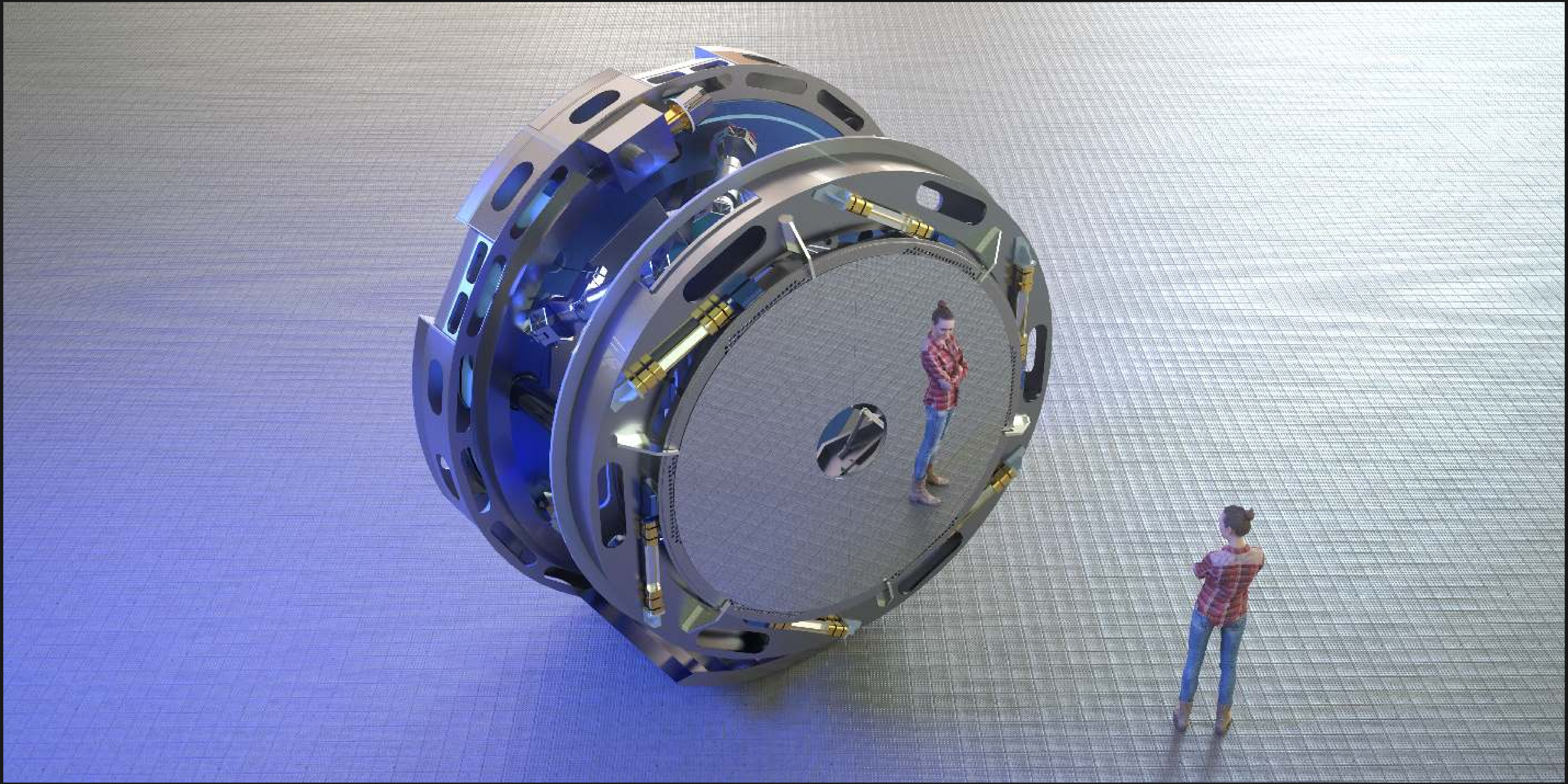
M4

- Main adaptive (deformable) mirror
- Flat, 2.4 m diameter, 1.95 mm thin

- SiC reference body for stiffness and low weight
- 5352 voice-coil actuators
- +/- 50 µm (max) displacement
- 1 kHz (max) update rate



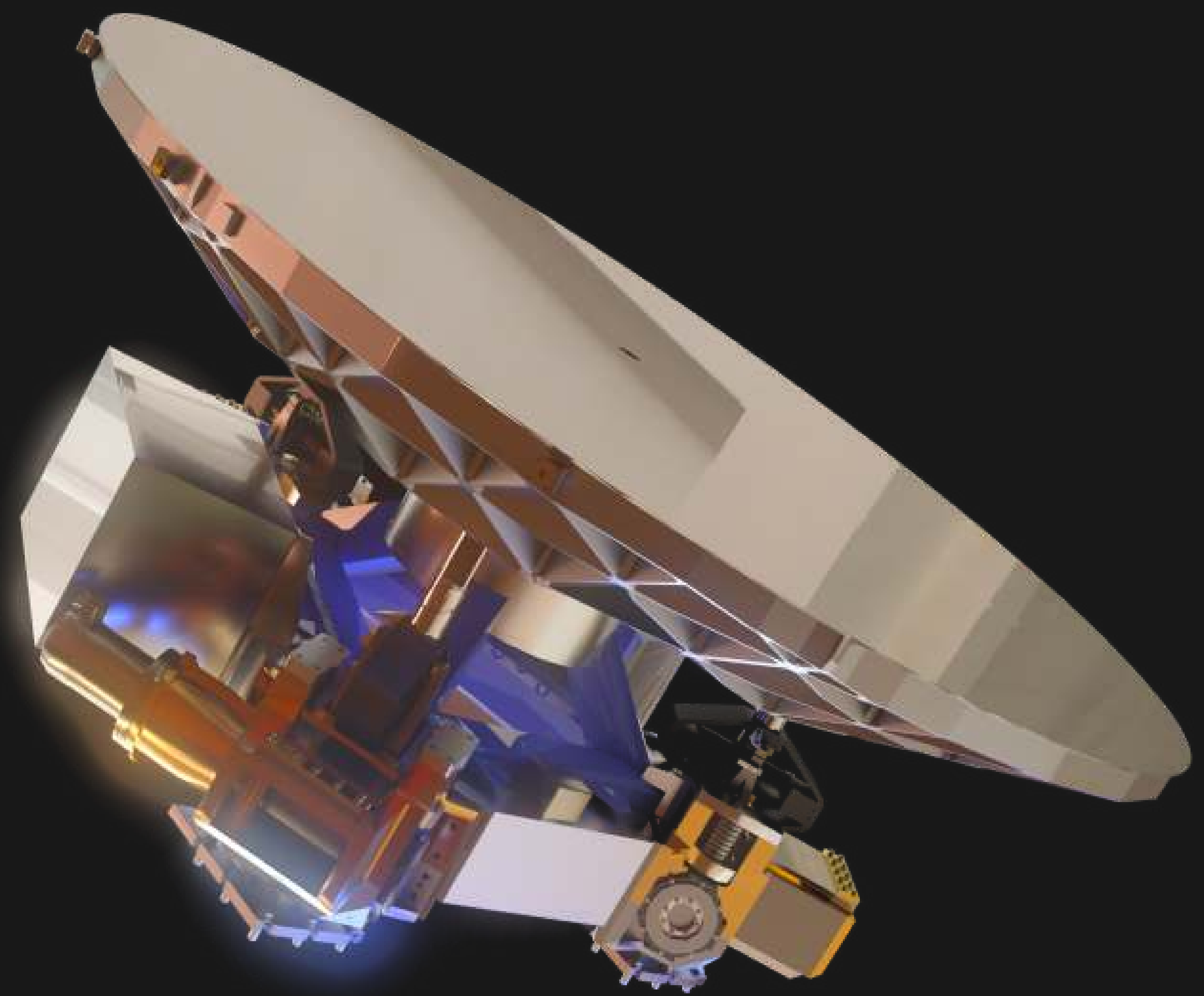
Credit: Adoptica/ESO



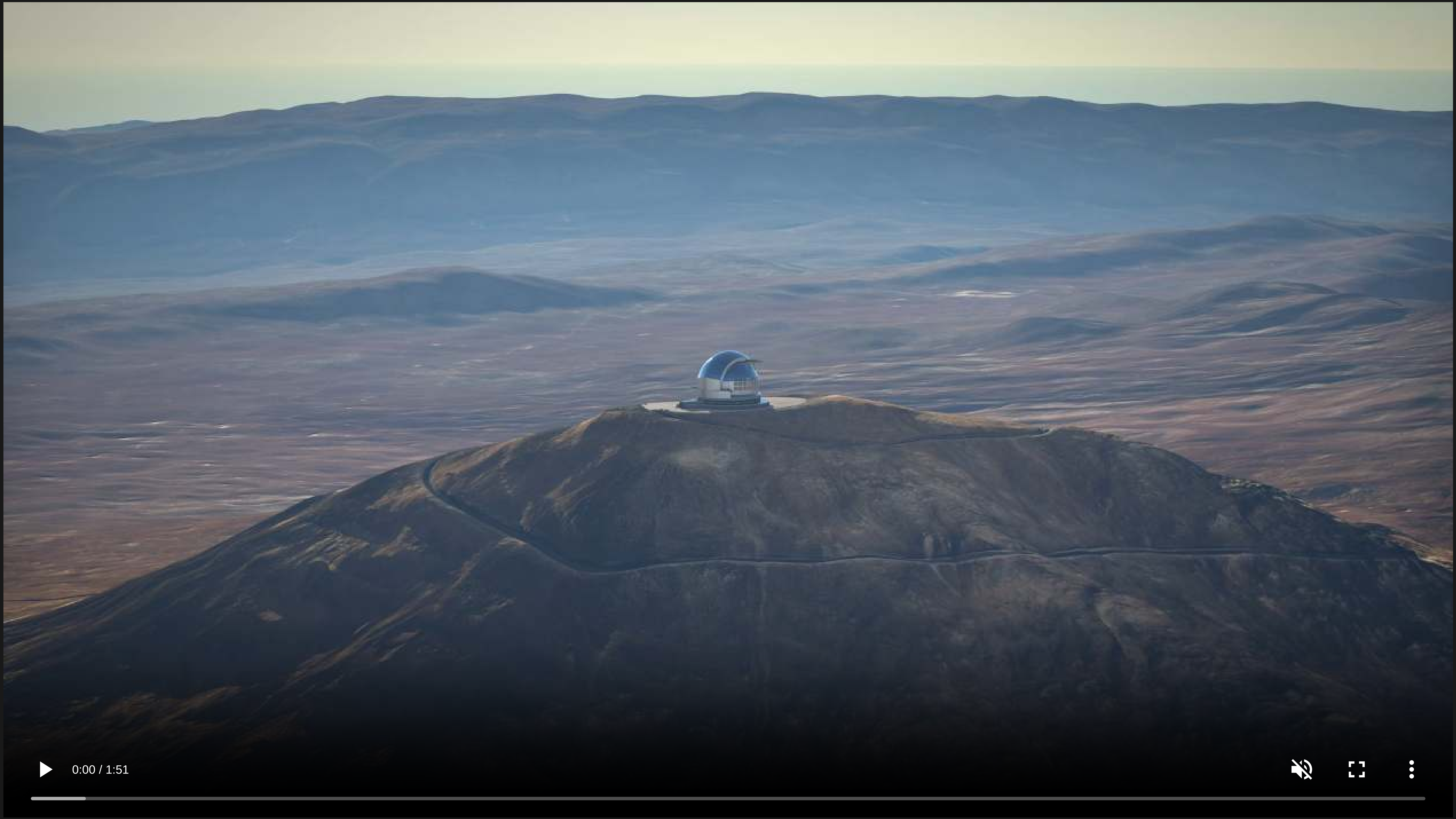
Credit: ESO

M5

- Flat, 2.7 m * 2.2 m elliptical
- Tip-tilt corrections to stabilize the image
- Must be very lightweight and very rigid
- Switching mechanism selects between instrument platforms (Nasmyth foci)

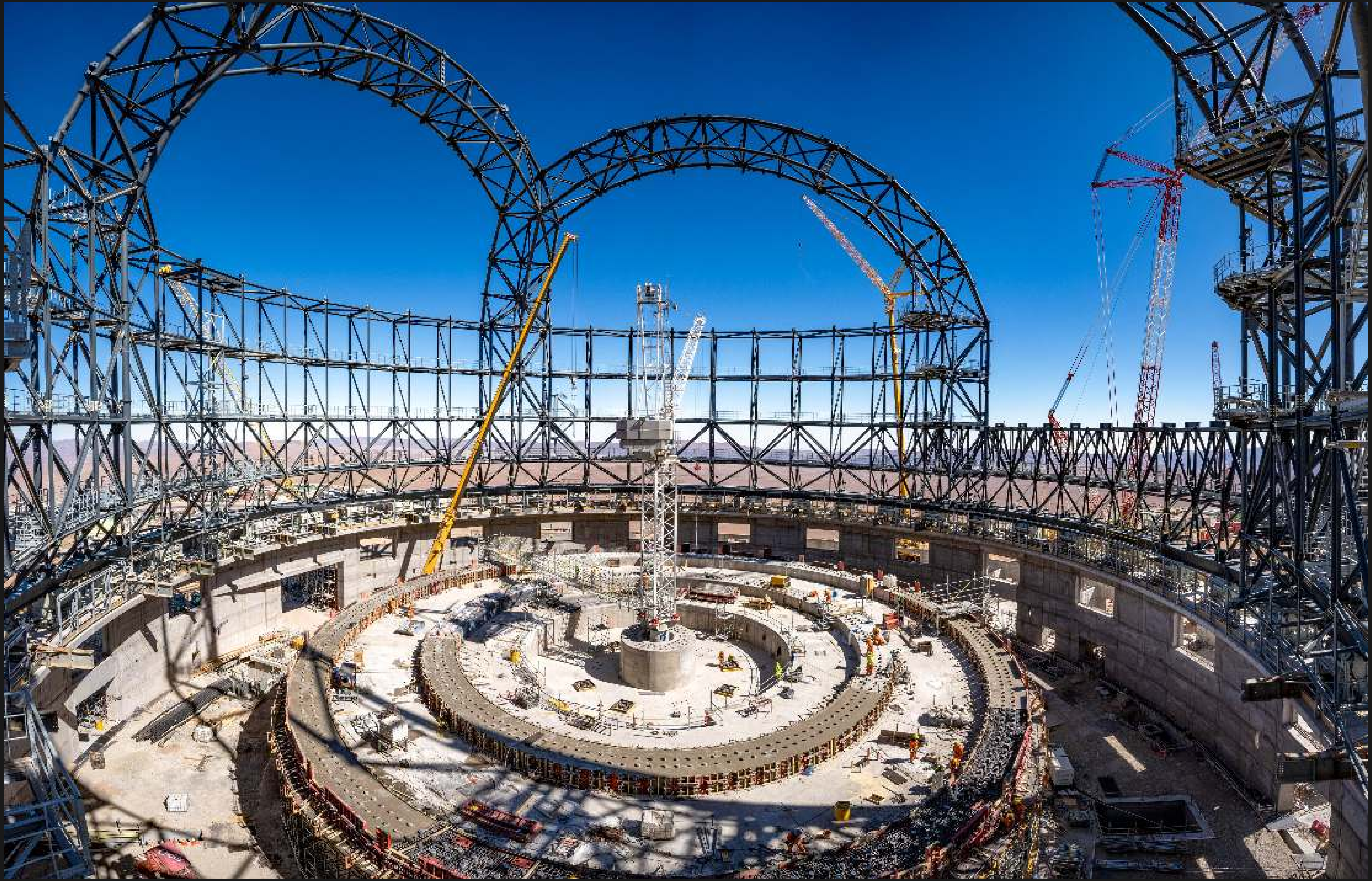


Credit: ESO



Credit: ESO/ACe Consortium/L. Calçada/M. Kornmesser

Credit: ESO/G. Vecchia



Credit: G. Hüdepohl (atacamaphoto.com)/ESO

THANK YOU

Credit: J. Beltrán/ESO

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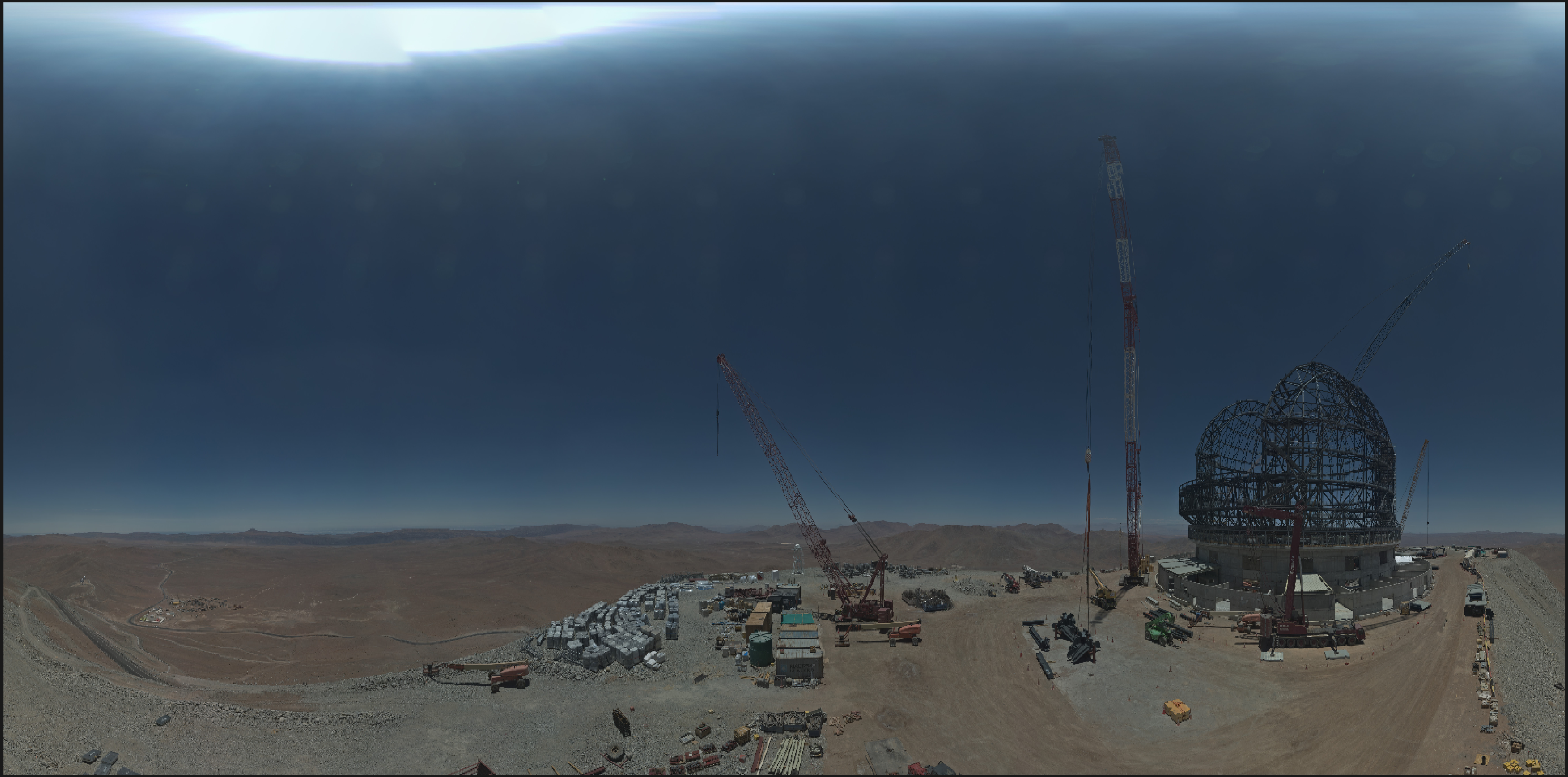
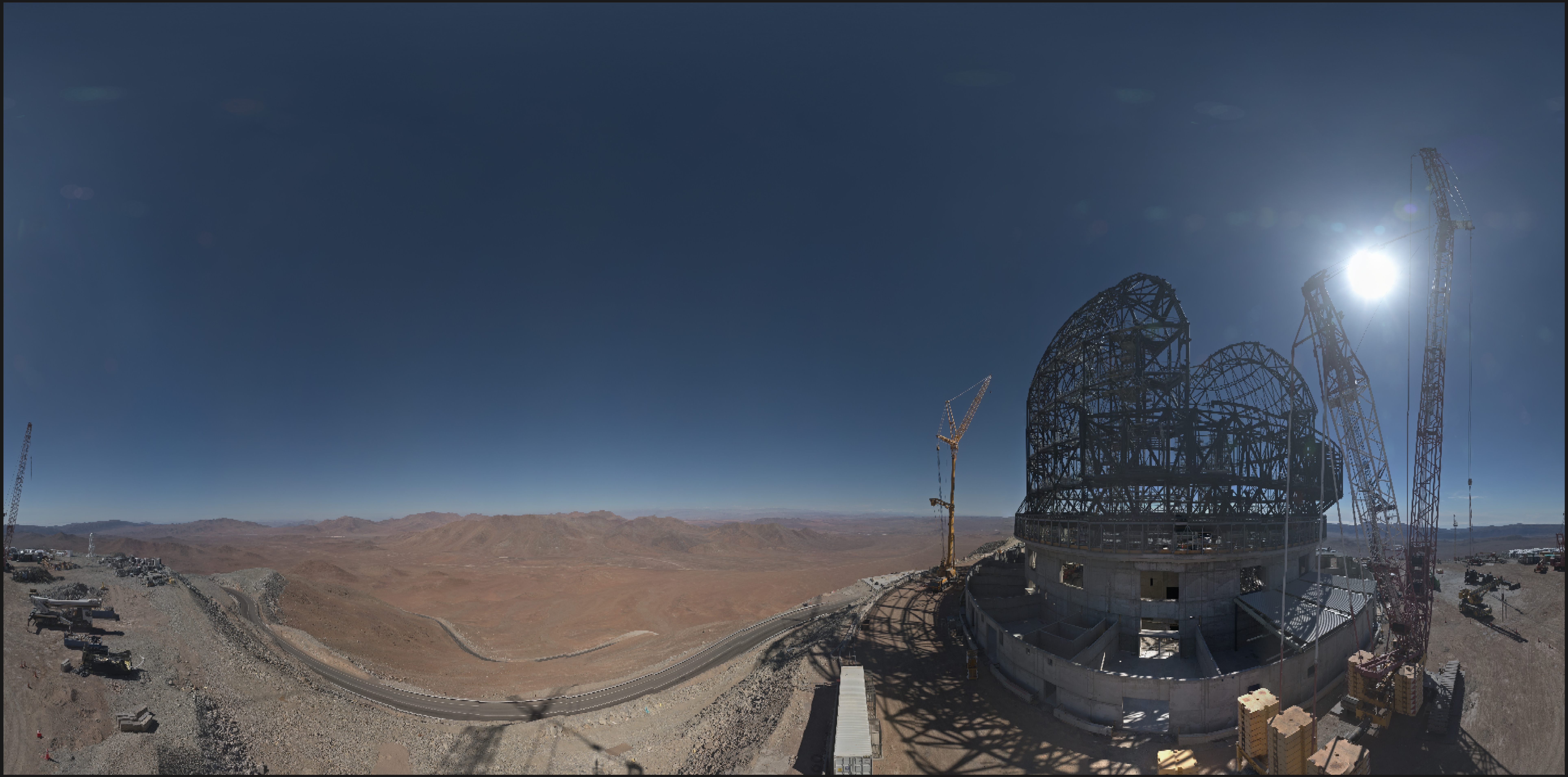
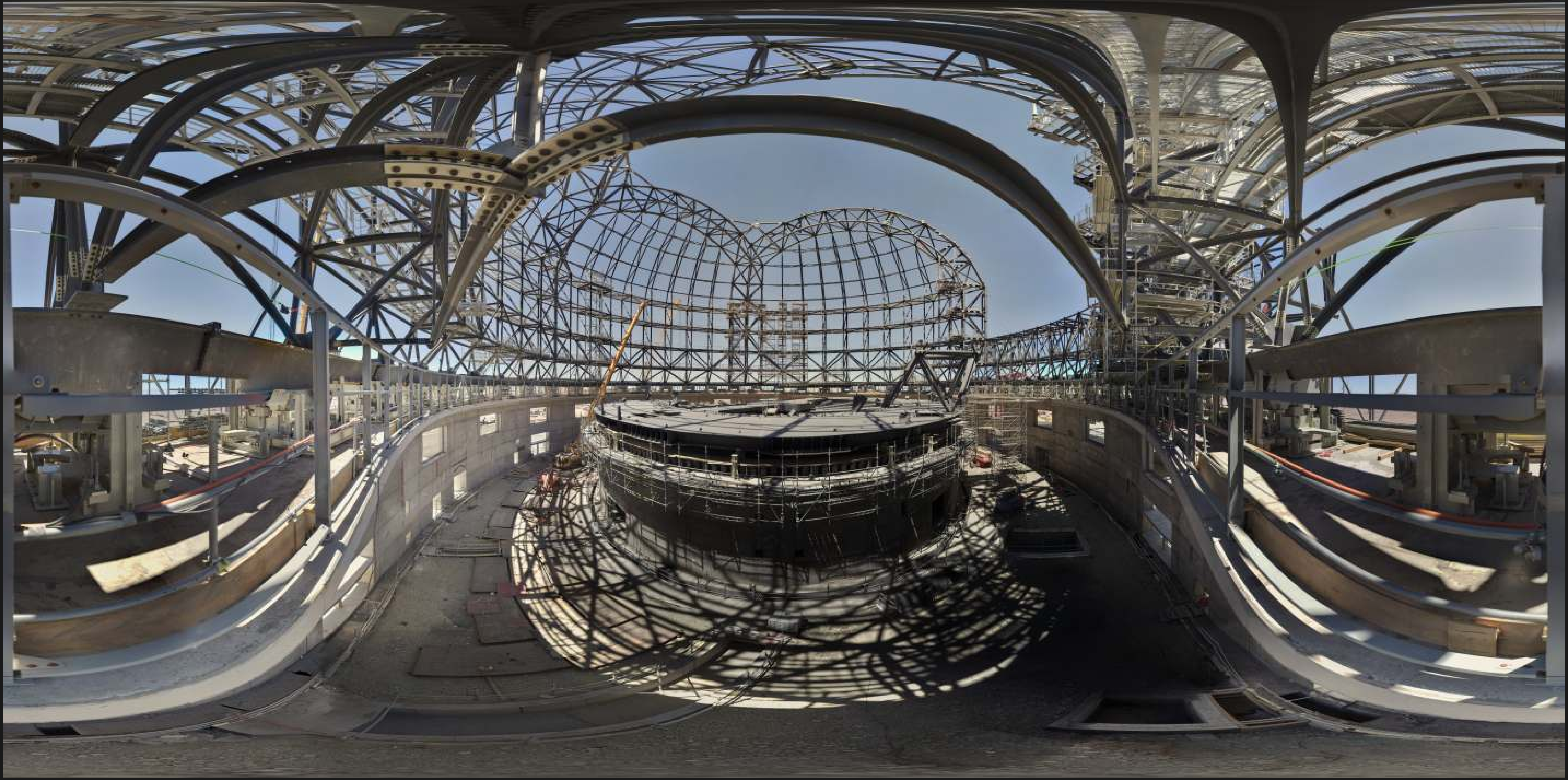
- You can find us at the SFT assembly

WEBCAMS

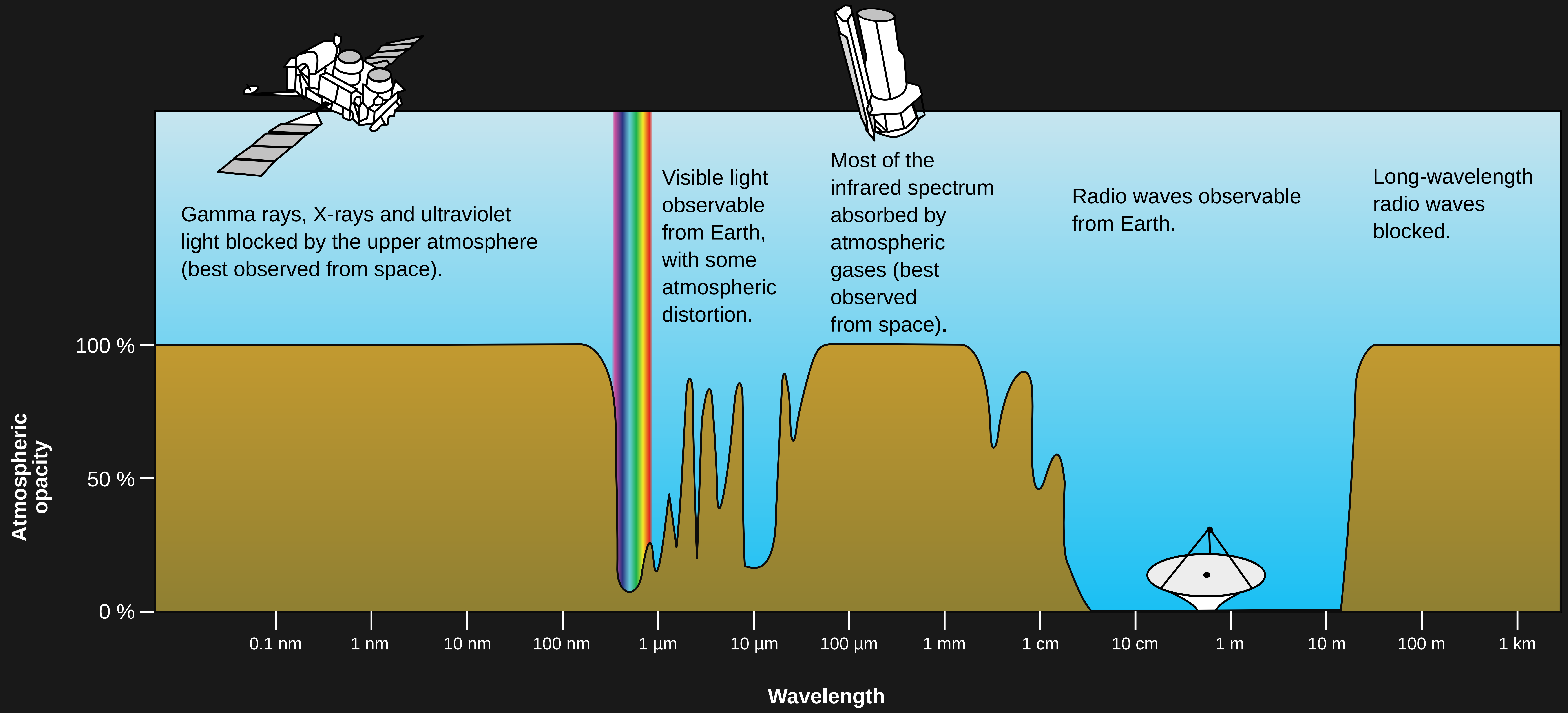






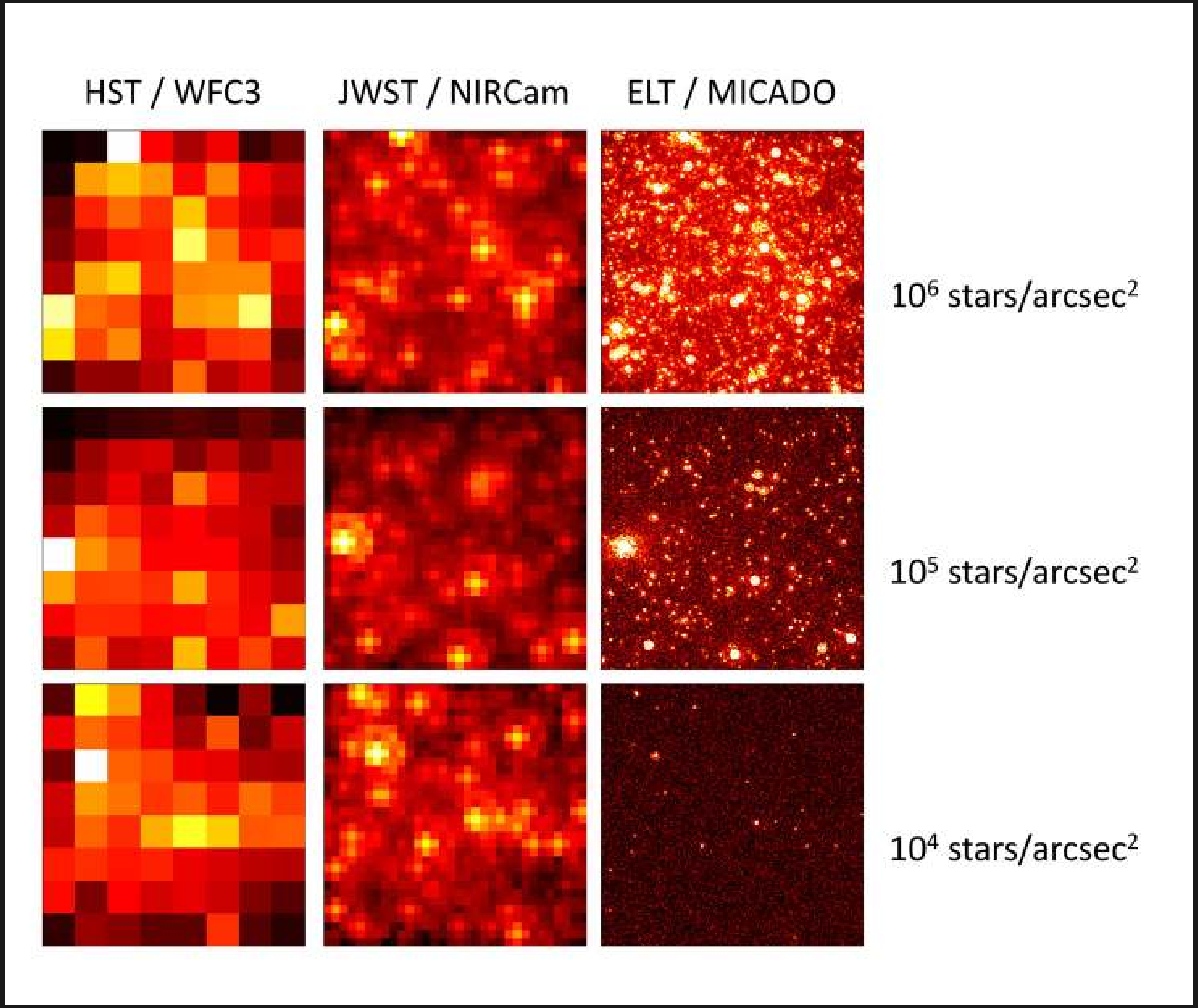
Bonus Slides

ATMOSPHERIC ELECTROMAGNETIC OPACITY



Credit: NASA

RESOLUTION COMPARISON

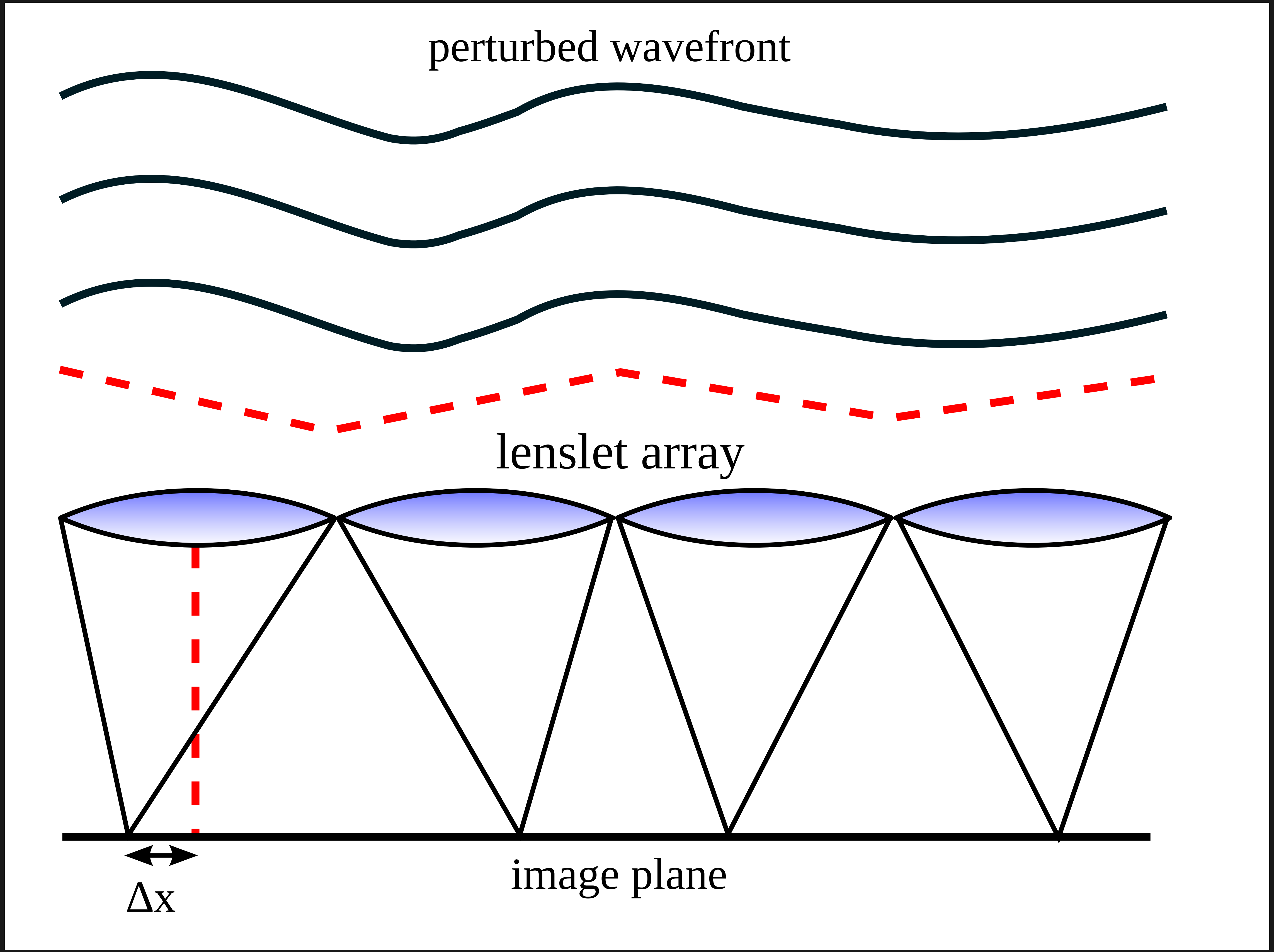


Credit: ESO/MICADO consortium

SEISMIC ISOLATORS

Credit: ESO/S. Egner

SHACK HARTMANN WAVEFRONT SENSOR



Credit: 2pem