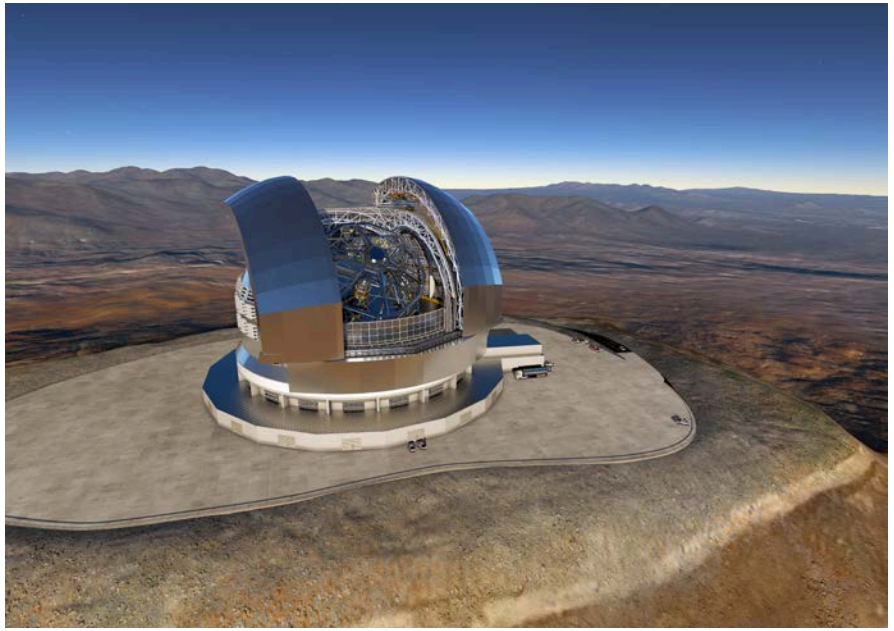
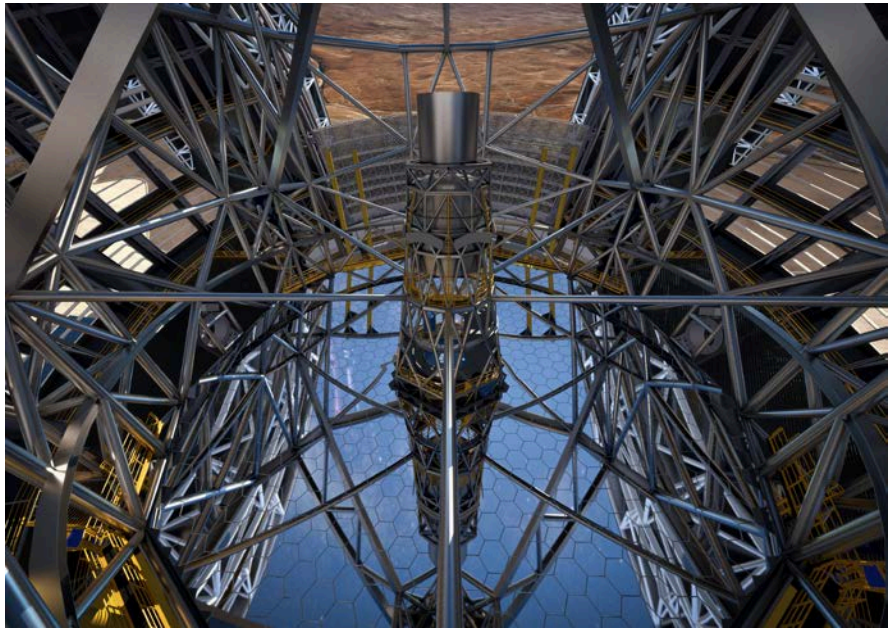
ELT Programme Status

Roberto Tamai
ELT Programme Manager

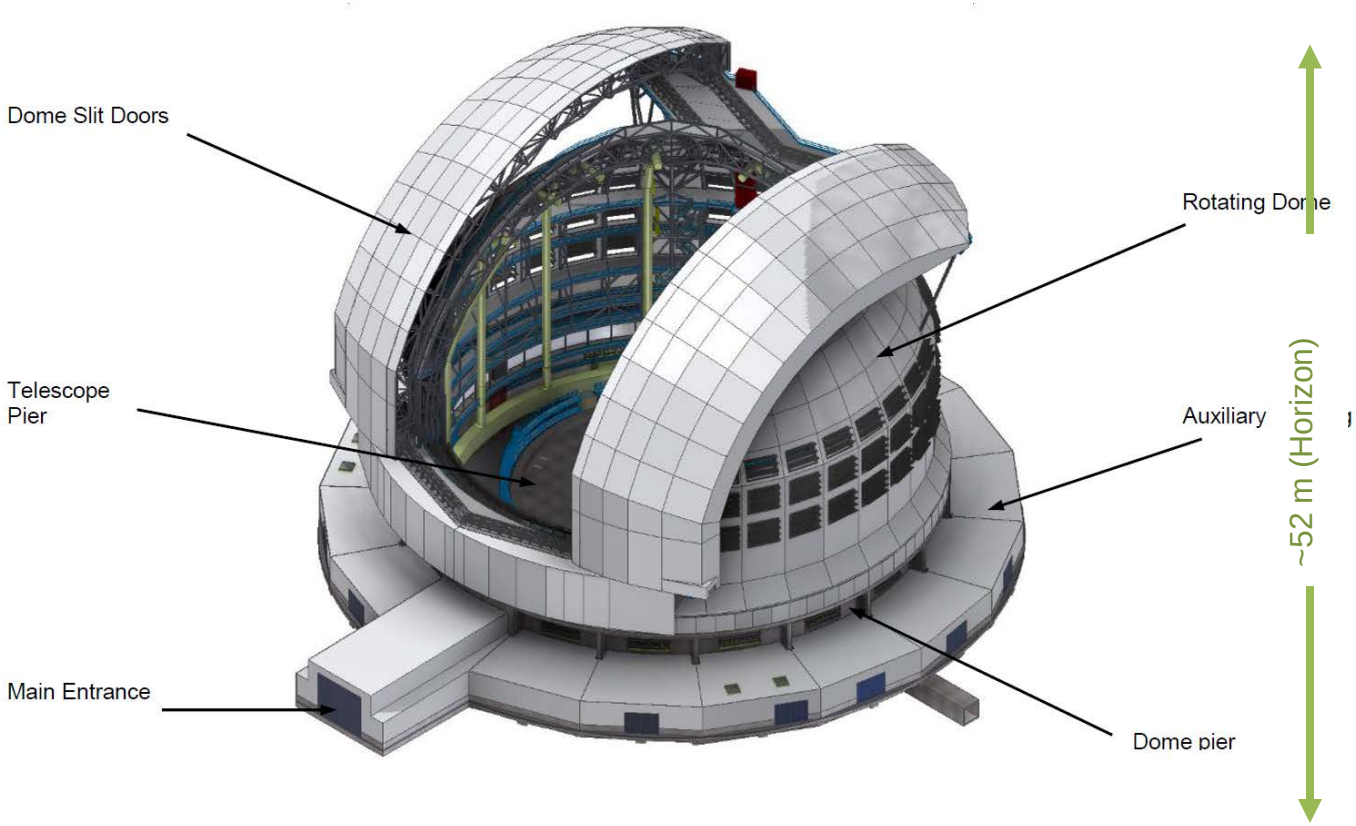
Extremely Large Telescope (ELT)

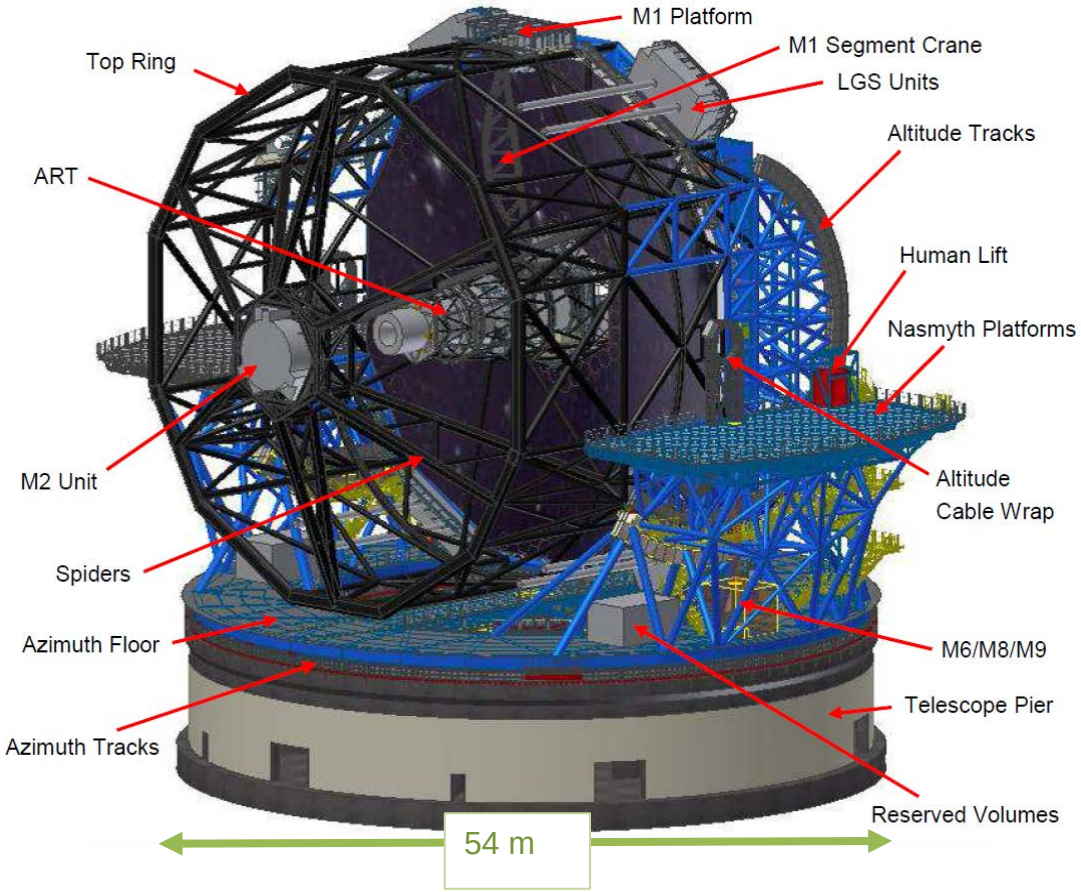
- Largest optical/infrared telescope in the world
  - 39.3 m segmented primary mirror & adaptive optics
  - Construction 2014-2027 (~1300 MEUR)
  - First science light by the end of 2027
  - On Cerro Armazones, to be operated as part of the Paranal observatory



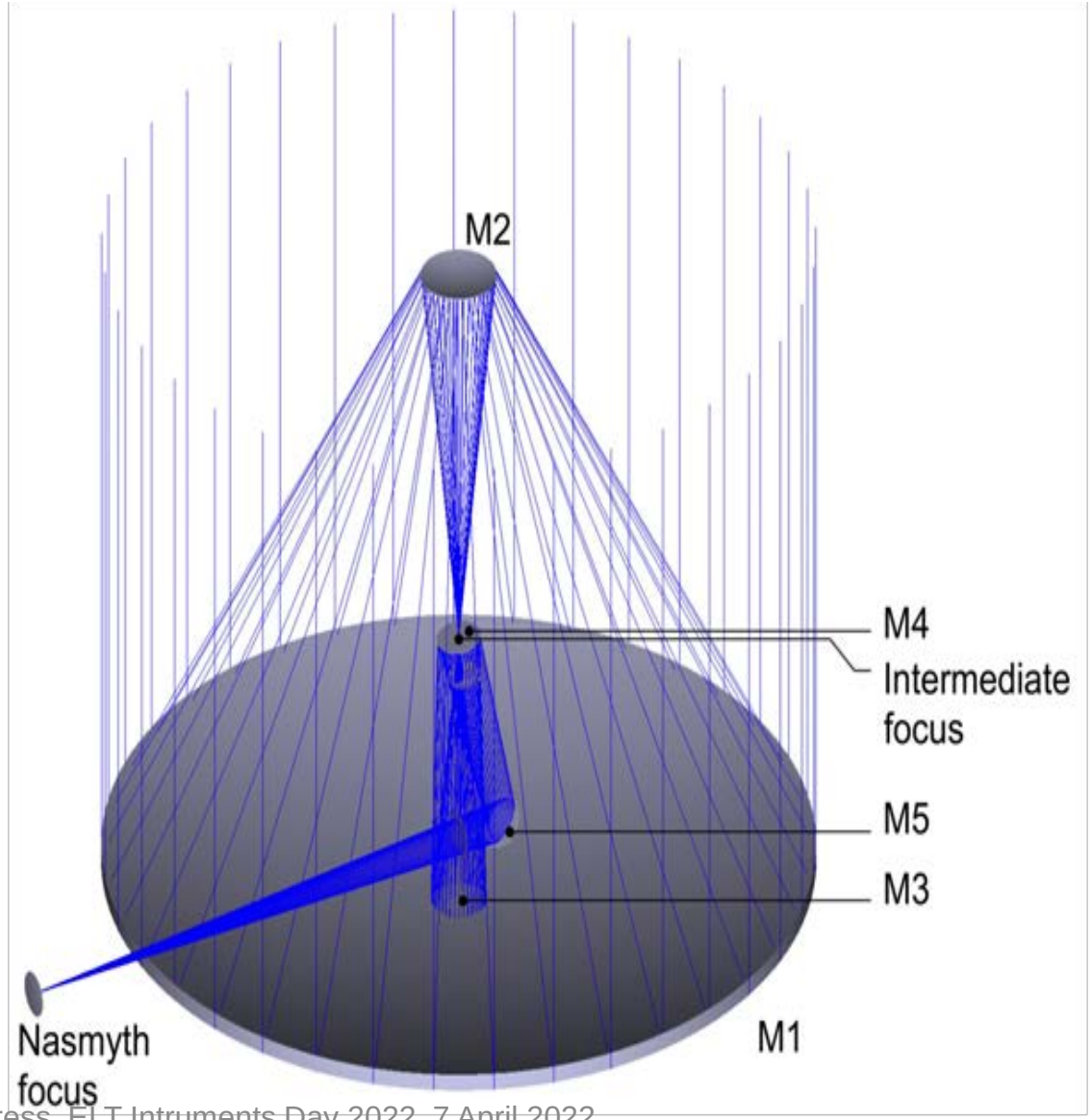


Dome & Main Structure (DMS)





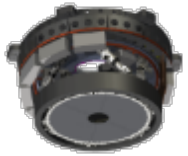
ELT Optomechanics



M1 Unit
39-m
Concave – Aspheric f/0.9
Segmented (798 Segments)
Active + Segment shape Control

M2 Unit
4-m
Convex Aspheric f/1.1
Passive + Position Control

M3 Unit
4-m – Concave – Aspheric f/2.6
Active + Position Control

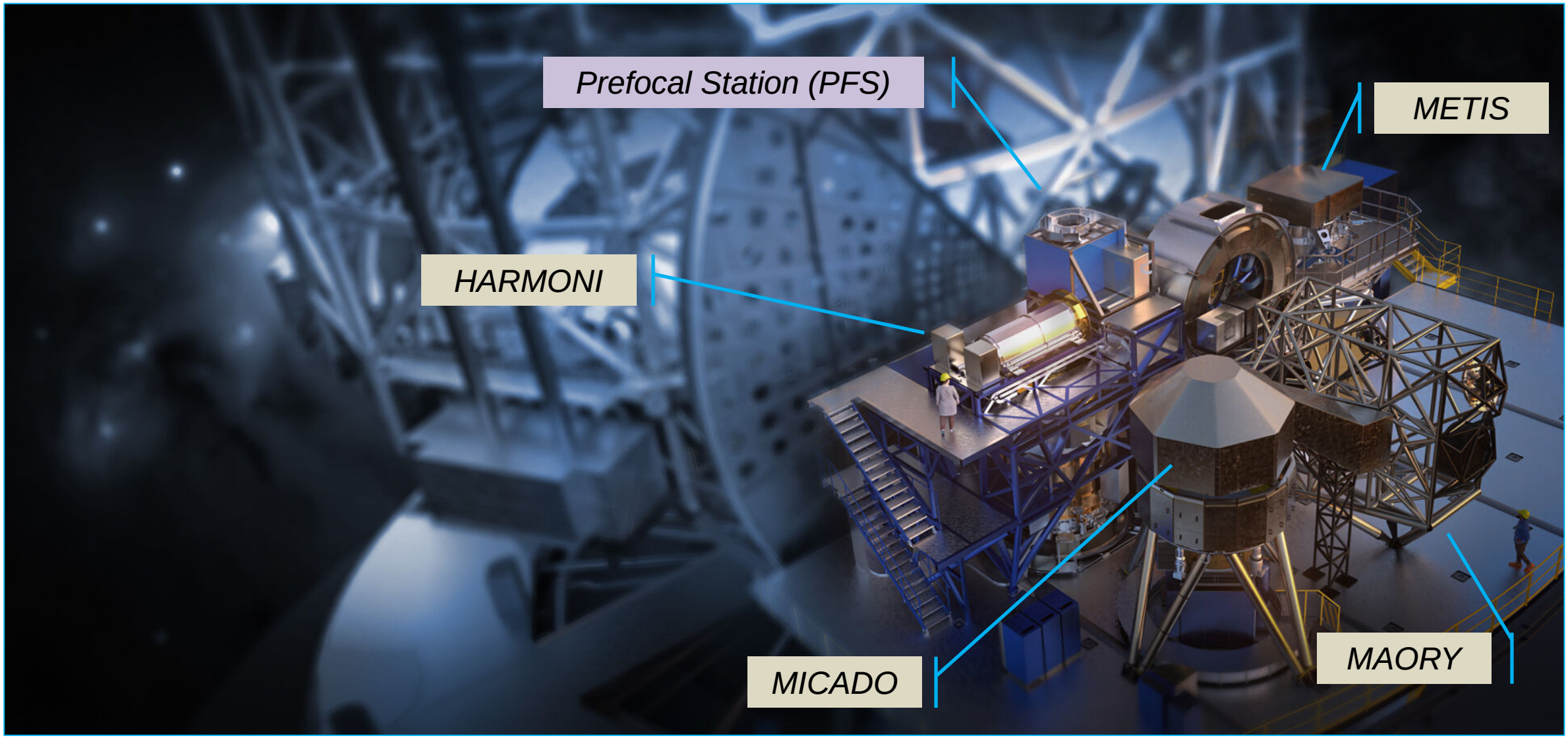


M4 Unit
2.4-m
Flat
Segmented (6 petals)
Adaptive + Position Control

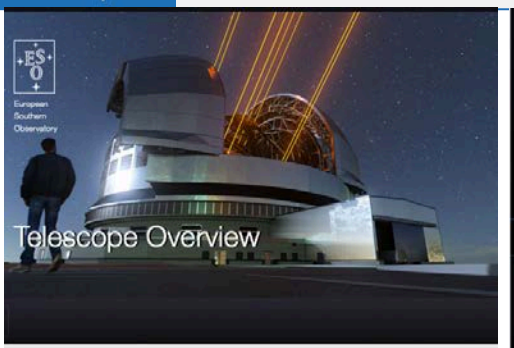
M5 Unit
2.7x2.1-m
Flat
Passive + Fast Tip/Tilt

LGSU
(Laser Guide Star Units)
Laser Sources + Laser Beacons
shaping and emitting

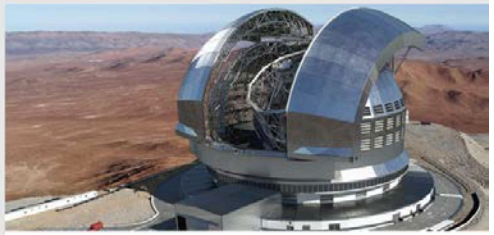
ELT First set of Instruments



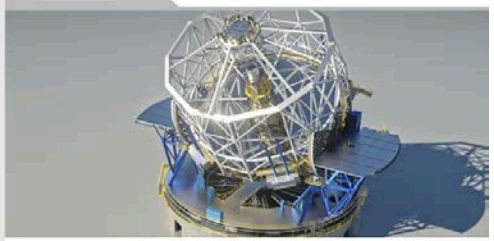
ELT.eso.org



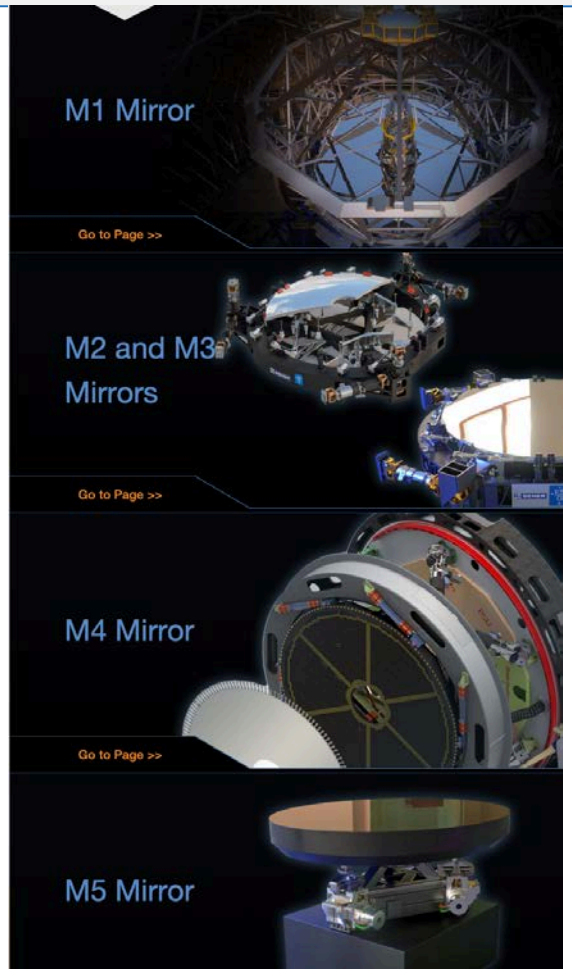
Dome and Main Structure

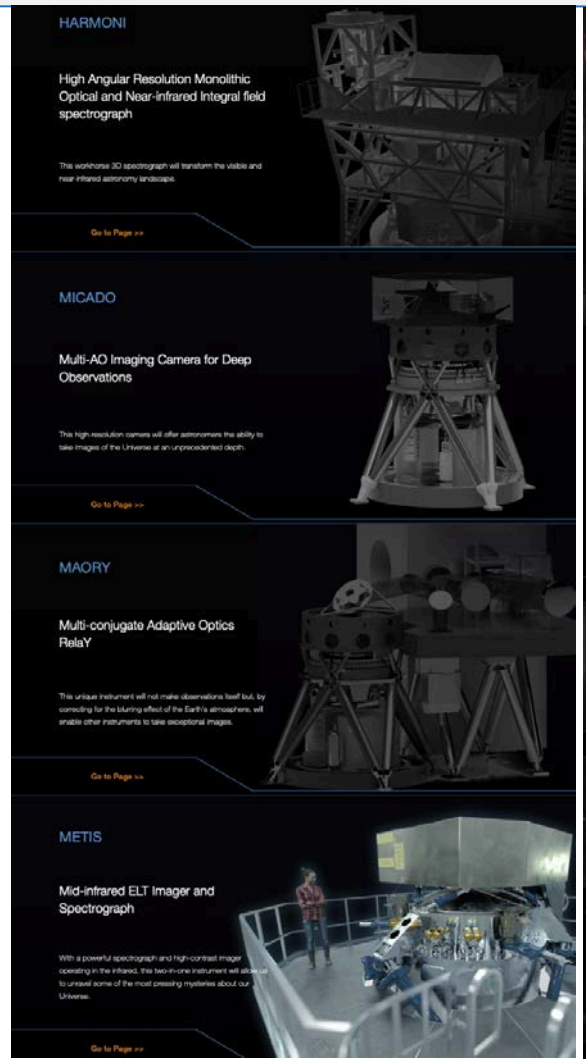


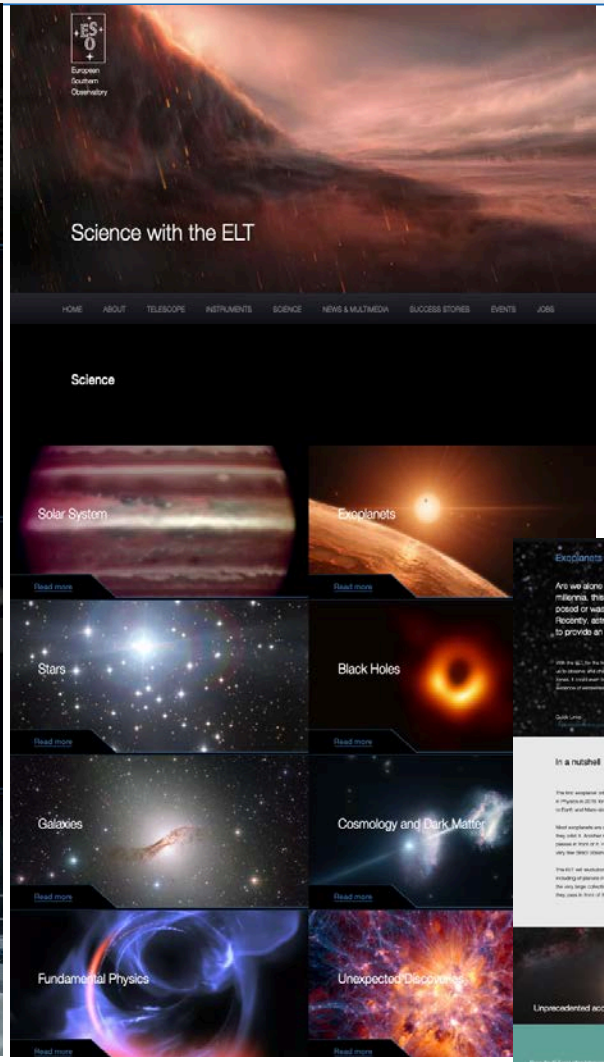
Read more Dome

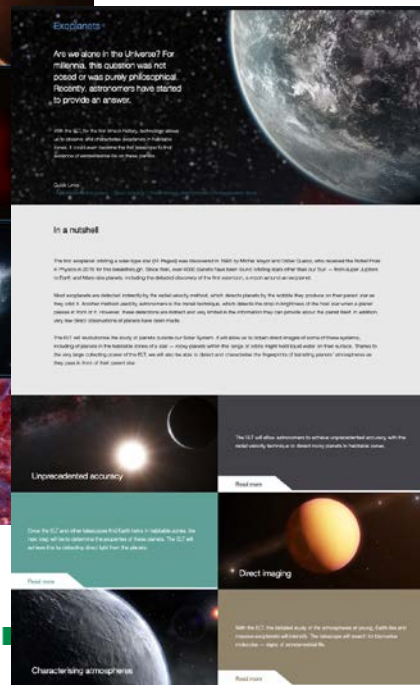


Read more Main Structure









Current Status

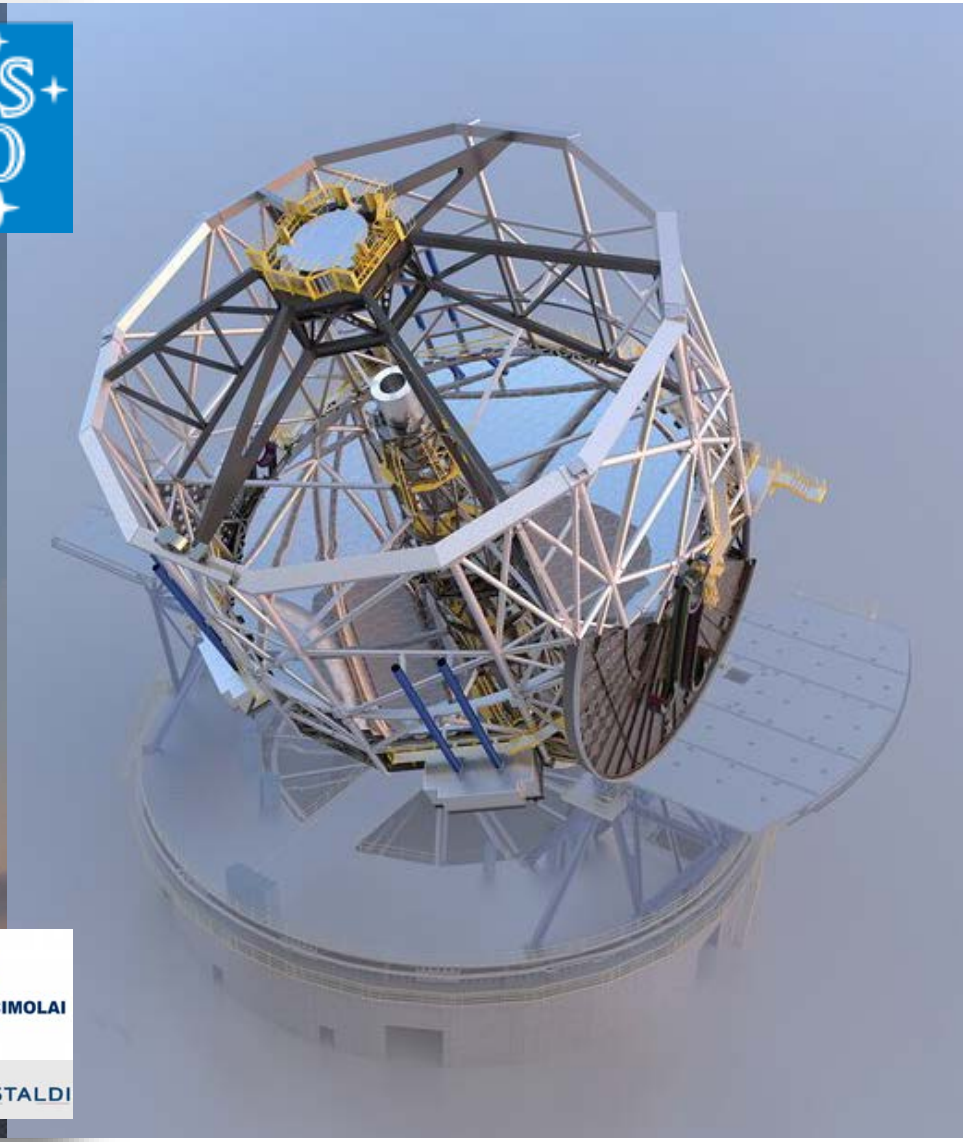
Overview

Contracts status progress
95-100%
50-95%
<50%

- 37 running contracts including the 4 Instr. agreements
- 11 contracts closed or in warranty period

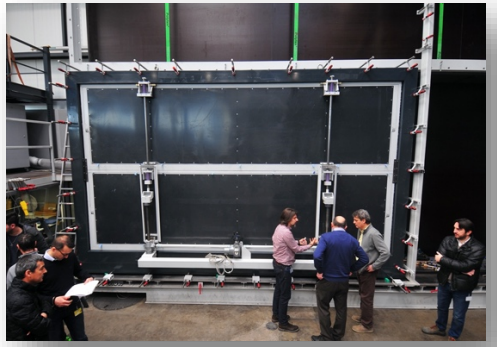
ELT Project	Description of Work	Contract Signature Date	Contractor	Status	Design	Manufacturing	Integration
PJ42.02 DMS	DM&S Design and Construction Contract	May-16	ACe Consortium	On-going	100%	65%	22%
PJ42.03 Optomechanics	M4 Phase 1 Preliminary Design	May-12	AdOptica	Closed	100%	100%	100%
PJ42.03 Optomechanics	M4 Unit Final Design and Manufacturing	Jun-15	AdOptica	On-going	100%	88%	70%
PJ42.03 Optomechanics	M1 Segment Supports - Qual. Units	Jan-15	VDL	Closed	100%	100%	100%
PJ42.03 Optomechanics	M1 Segment supports - Qual. Units	Feb-15	CESA	Closed	100%	100%	100%
PJ42.03 Optomechanics	M4 Mirror Shells Supply	Jul-15	Safran Reosc	On-going	100%	85%	N/A
PJ42.03 Optomechanics	M2 Mirror and Auxiliary Equipment Supply	Jul-16	Safran Reosc	On-going	100%	60%	N/A
PJ42.03 Optomechanics	M2 Blank Supply	Jan-17	Schott	Closed	100%	100%	100%
PJ42.03 Optomechanics	M3 Blank Supply	Jan-17	Schott	Under warranty	100%	100%	100%
PJ42.03 Optomechanics	M3 Mirror and Auxiliary Equipment Supply	Feb-17	Safran Reosc	On-going	100%	25%	N/A
PJ42.03 Optomechanics	M2 and M3 Cell Design and Manufacturing	Jan-17	Sener	On-going	95%	60%	40%
PJ42.03 Optomechanics	M1 Edge Sensors Design and Manufacturing	Jan-17	FAMES	On-going	100%	5%	N/A
PJ42.03 Optomechanics	M1 Mirrors Polishing	May-17	Safran Reosc	On-going	95%	24%	[illegible]
PJ42.03 Optomechanics	M1 Blanks Supply	May-17	Schott	On-going	100%	[illegible]	[illegible]
PJ42.03 Optomechanics	M1 Position Actuators	Jun-17	PI	On-going	[illegible]	[illegible]	12%
PJ42.03 Optomechanics	M1 Segment supports - Production	Apr-18	VDL	On-going	[illegible]	37%	31%
PJ42.03 Optomechanics	M5 Blank Supply + Polishing	Mar-19	Safran Reosc	On-going	85%	55%	0%
PJ42.03 Optomechanics	M5 Cell Design and Manufacturing	Nov-19	Sener	On-going	95%	10%	0%
PJ42.03 Optomechanics	M1 Segment Assemblies Manipulator	Jan-21	Sener	On-going	50%	0%	0%
PJ42.03 Optomechanics	M1 Segment Assemblies Local Coherencer	May-21	IDOM	On-going	15%	0%	0%
PJ42.04 Control	Core Integration Infrastructure	Jul-17	Cosylab AB	Under warranty	100%	100%	100%
PJ42.04 Control	M1LCS Cabinets Procurement and AIV	Dec-20	PRO[illegible]	On-going	100%	15%	0%
PJ42.04 Control	M1LCS Cabinets Heat Exchanger	Nov-20	[illegible]	Under warranty	100%	100%	100%
PJ42.05 Civil Infrastructure	Road and Platform	[illegible]	ICAFAL	Closed	100%	100%	100%
PJ42.05 Civil Infrastructure	[illegible] Technical Facility Design and Construction	Mar-18	Abengoa	Under warranty	100%	100%	100%
PJ42.06 Support Infrastructure	Supply and Installation of ABC Power Substations (23kV - 0.4 kV)	Oct-16	SIEMENS	Closed	100%	100%	100%
PJ42.06 Support Infrastructure	M1 Coating Plants Supply	Jun-18	AGC	On-going	100%	100%	85%
PJ42.06 Support Infrastructure	Large Mirrors Coating Plant Supply	May-21	AGC	On-going	40%	0%	0%
PJ42.06 Support Infrastructure	M1 Mirror Washing & Stripping plant Supply	Jan-20	Fagerström Industrikonsult	On-going	60%	10%	0%
PJ42.06 Support Infrastructure	Power Conditioning System	Nov-19	SAESA	On-going	N/A	N/A	N/A
PJ42.09 Science Data Ops	Dataflow Software Components for ELT	Nov-18	Etamax	On-going	N/A	N/A	N/A
PJ18.10 Instrumentation	MICADO Construction	Oct-15	MPE	On-going	90%	10%	0%
PJ18.10 Instrumentation	HARMONI Construction	Oct-15	STFC	On-going	60%	0%	0%
PJ18.10 Instrumentation	METIS Construction	Oct-15	NOVA	On-going	75%	0%	0%
PJ18.10 Instrumentation	MAORY Construction	Feb-16	INAF	On-going	50%	0%	0%
PJ18.10 Instrumentation	IR Detectors for HARMONI, MICADO, METIS	Jul-18	Teledyne	On-going	100%	70%	N/A
PJ18.10 Instrumentation	C-RED Cameras for MAORY	Jul-18	FLI	Under warranty	100%	100%	100%
PJ18.10 Instrumentation	CCD-220 Detectors for MAORY, MICADO, HARMONI, PFS-A, PDS	May-19	Teledyne	Under warranty	100%	100%	100%
PJ18.10 Instrumentation	MUSE type detectors	Sep-19	Teledyne	On-going	100%	80%	N/A
PJ42.11 Optical Control	PFS-A Main system Design and Manufacture	Apr-18	IDOM	On-going	100%	40%	0%
PJ42.11 Optical Control	Laser Sources	Dec-17	Toptica	On-going	100%	83%	33%
PJ42.11 Optical Control	Laser Projection Subunits	Dec-20	TNO	On-going	80%	0%	0%
PJ42.11 Optical Control	Laser Trackers	Oct-21	Hexagon Wetzar	On-going	N/A	15%	0%

Dome and Main Structure Design Activities in Europe



Dome and (Telescope) Main Structure (DMS)

- **Largest contract** in ground-based astronomy signed in 2016 with ACe (IT)
- **Design Activities** in Europe
  - ✓ Dome Preliminary Design Review (PDR): 2017
  - ✓ Main Structure (MS) PDR: 2018/2019
  - ✓ Dome Final Design Review (**FDR**): Feb. 2020
  - ✓ Telescope MS **FDR**: September 2022
- As part of the design process, many **prototyping & qualification** activities undertaken and completed



- Use of Critical Design Review (**CDR**) on sub-systems to allow progress on manufacturing of schedule-critical items (e.g. foundations, steel structure, dome rotation trolley, etc.) before FDR's

Dome Manufacturing Activities

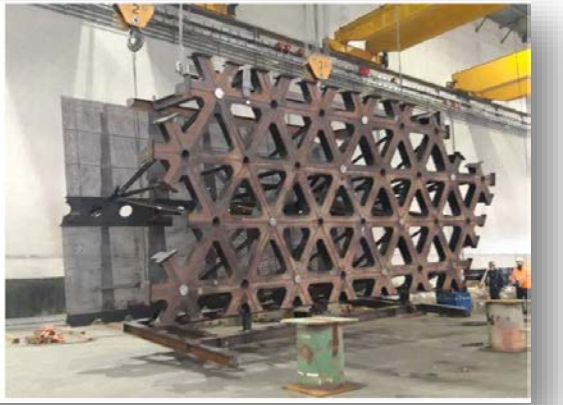
- **Dome steel structure (5000tons!):**
  - 100% manufactured,
  - >50% shipped to Chile, rest in coming months
- **Dome Rotation Trolley (each 27tons!)**:
  - All 36 produced and tested
  - 18/36 already in Chile, rest in coming months
- **Rotation Track & Rail**: completed
- **Doors & Wind screen**: manuf. on-going
- Already **on-site**:

Main Structure Manufacturing Activities

- **Isolation and Locking systems:**
  - Manufacturing completed; shipment on-going

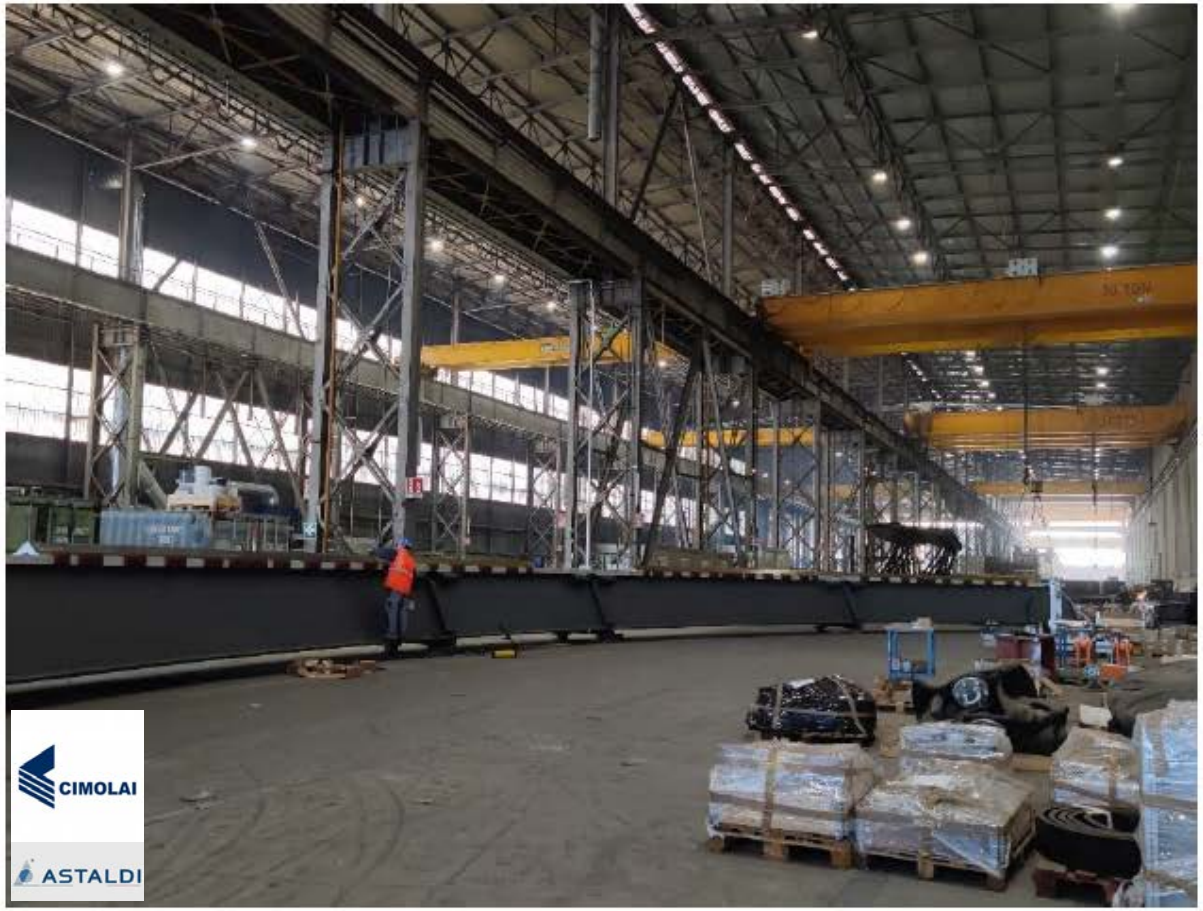
- **Azimuth Tracks and hydrostatic pads**:
  - cutting/welding done; machining/painting on-going

- **M1 Cell Mock-up** (First Article)
  - For testing M1 segment installation, access, electronic cabinet and cabling installation



- **Az and Alt Structure**:
  - Manufacturing Readiness Review (MRR) ongoing (>2000 drawings)

Recent Pictures



Assembly of the RM Track in Monfalcone factory

RM Track ready for shipment in Monfalcone factory

Construction Status on-site at Armazones

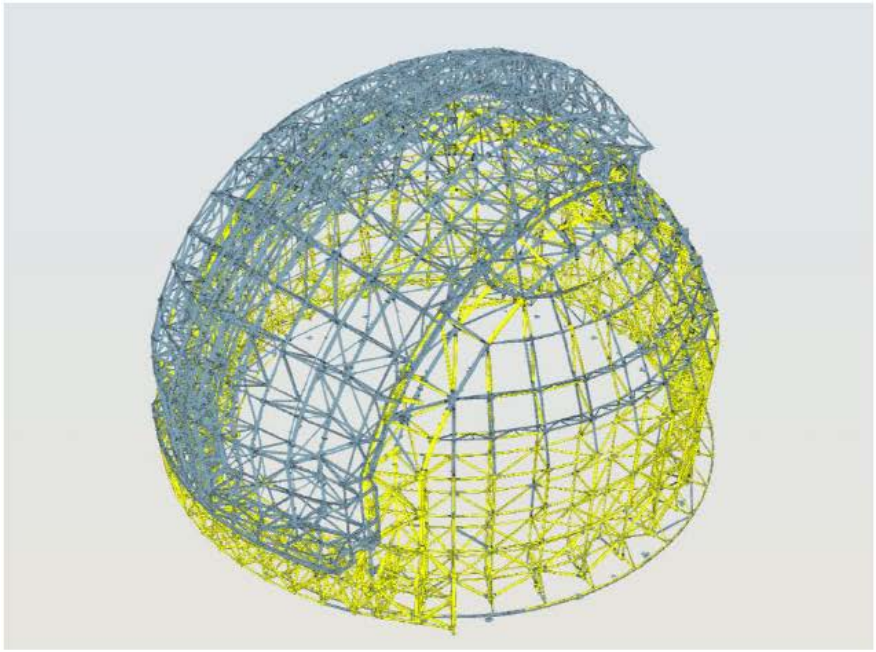
- Site managed by ACe consortium in charge of Dome & Main Structure (DMS)
  - Since May 2017 (“First Stone”) until DMS completion (~ end 2025)
- Site closed June 20 – May 21
  - COVID-19 pandemic
- Rapid progress has resumed
  - About 150 people on-site (Covid-limited)
  - Seismically isolated floor for Auxiliary Building (Dome periphery) completed
  - Dome pier started
  - Telescope pier starting
  - More than 200 ISO containers delivered
  - Large Dome structural elements being shipped

Recent Pictures

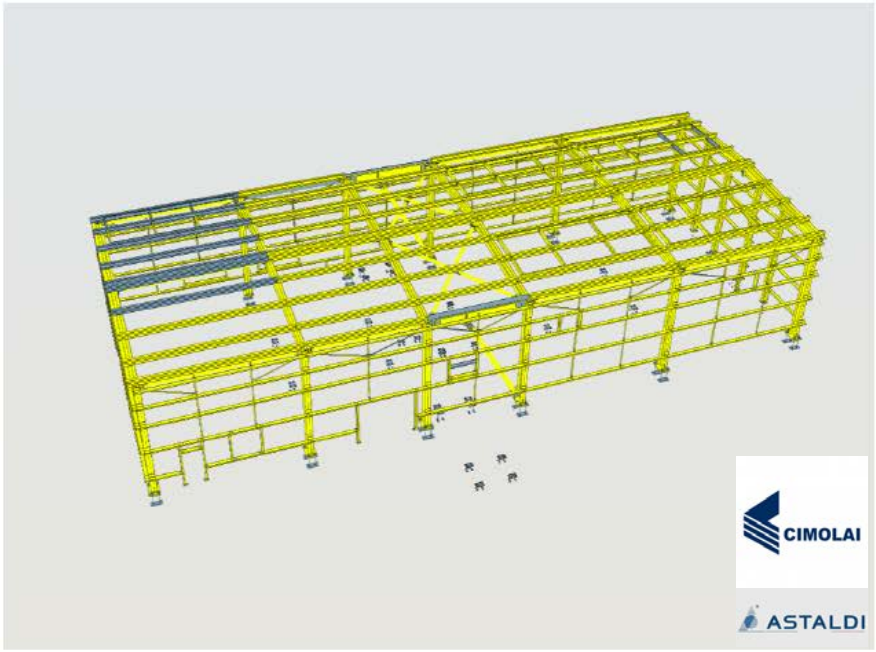
Recent Pictures

Shipments

- By mid-March 2022: **277 containers** shipped, another 310 expected by end-2022



DOME STEEL STRUCTURE
Steel structure parts shipped to the construction site



CHILLER STATION
Steel structure parts shipped to the construction site

M1 Unit

931 x M1 Segments
931 x Blanks + 19 x Spare Blanks
931 x Segments Polishing

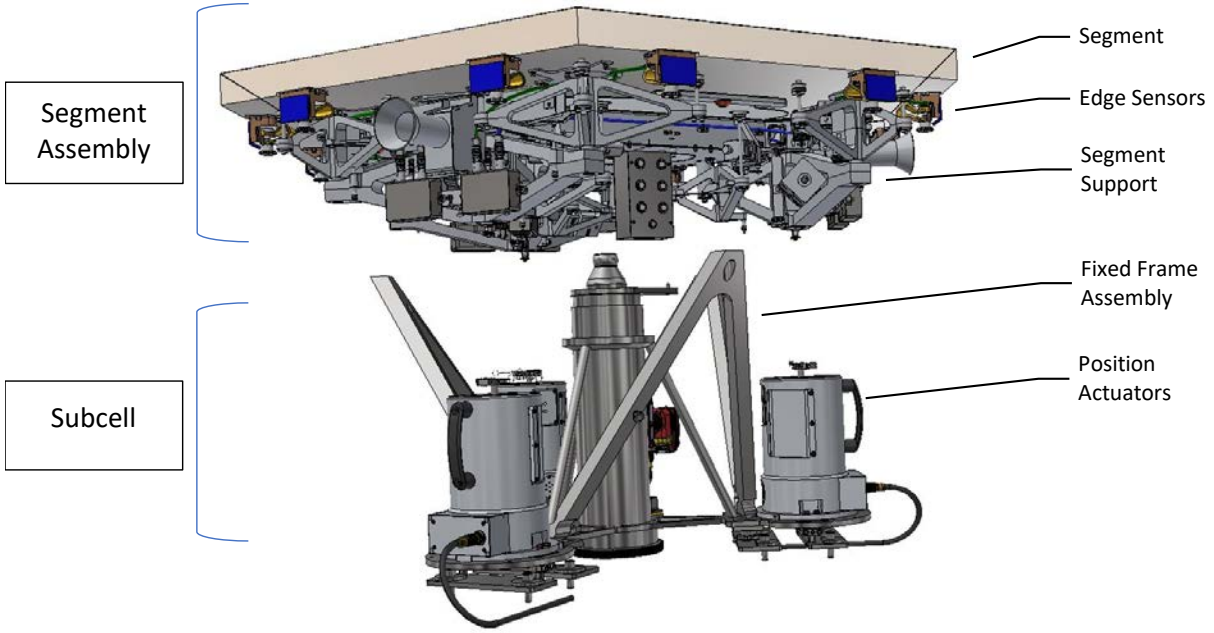
4566 x M1 Edge Sensors
4566 x Sensors +805 x Electronics + Spares

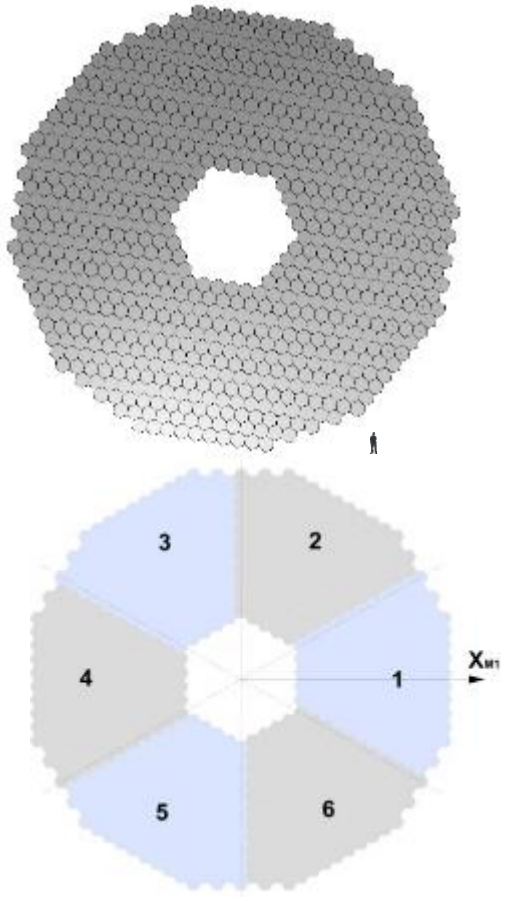
931 x M1 Segment Supports
& SA Auxiliary Equipment
[SA Handling Tools, SA Transport Containers, SA AIV Tools]

2418 x M1 Position Actuators
2394 x Actuators + 806 x Control Modules + Spares

M1 Auxiliary Equipment
Aux. Sensors, Mass Dummies. Carts, Stands, Manipulator, Phasing Gun, Alignment Tools

39-m diameter
6 x 133 segments (1.4-m)
1 x 133 spare segments
Total: 931 segments





Including glass, mechanics, electronics:
⇒ more than 10 000 components

M1 Mirror	
Outer diameter (mm)	39146.0
Inner diameter (mm)	9418.4
M1 Optical Prescription	
Radius of curvature (mm)	68685
Conic constant	-0.996473

M1 Blanks

- Produced by **SHOTT** (DE)
  - Glass-ceramics (Zerodur®), circular (D1520 mm), 50-mm thick,
  - Machined and acid-etched all surfaces except optical surface (spherical)
  - Delivered by batches (27x) to Safran-Reosc for manufacturing / polishing

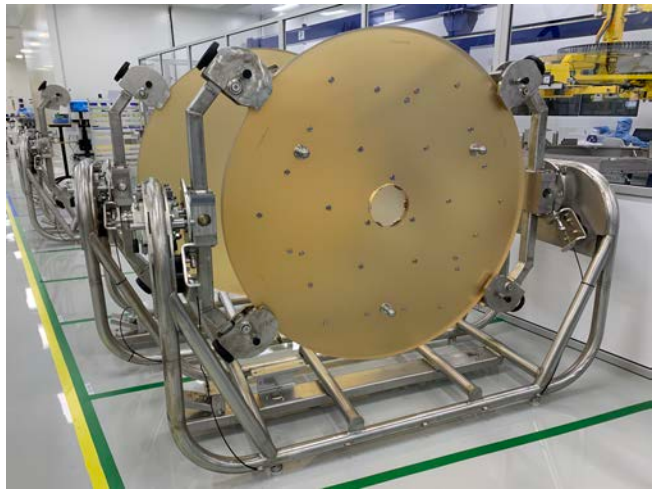
M1 Segment Support

- Produced by **VDL** (NL) based on a design by **TNO** (NL)
  - “Build-to-print” contract for series production
  - 27-points whiffletree support
  - Interface to Position Actuators (PACTs), handling tools, “extractor”
  - Validation of manufacturing process completed and series production running full speed

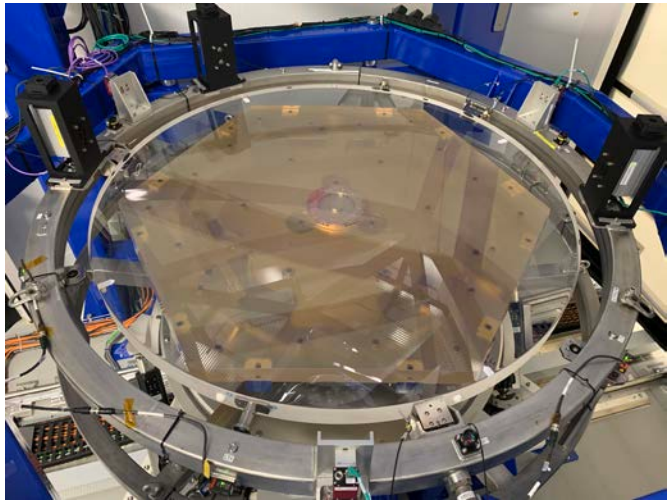
M1 Segment Blanks and Supports

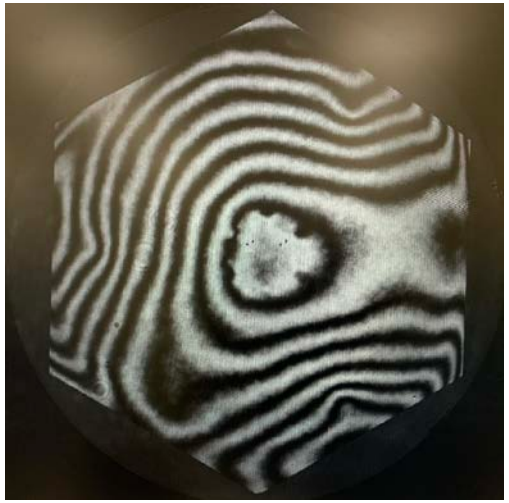
- M1 segment **blanks** (Zerodur®) produced by SHOTT (DE)
  - Total: 949
  - **Delivered**: 414 **(~45%)**
- M1 segment **supports** produced by VDL (NL)
  - Total: 936
  - **Delivered**: 347 **(~40%)**
- Delivered to Safran-Reosc (FR) for **optical manufacturing / polishing**:
  - Support pads bonding, grinding/polishing, hex-cutting, IBF final polishing, testing, …
  - All 13 processes validated
  - **38 first segments in production**

M1 Polishing



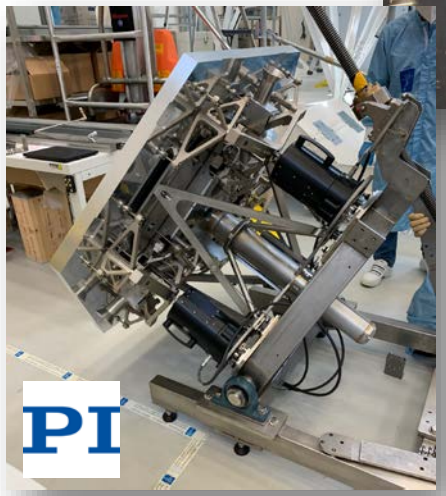
SAFRAN





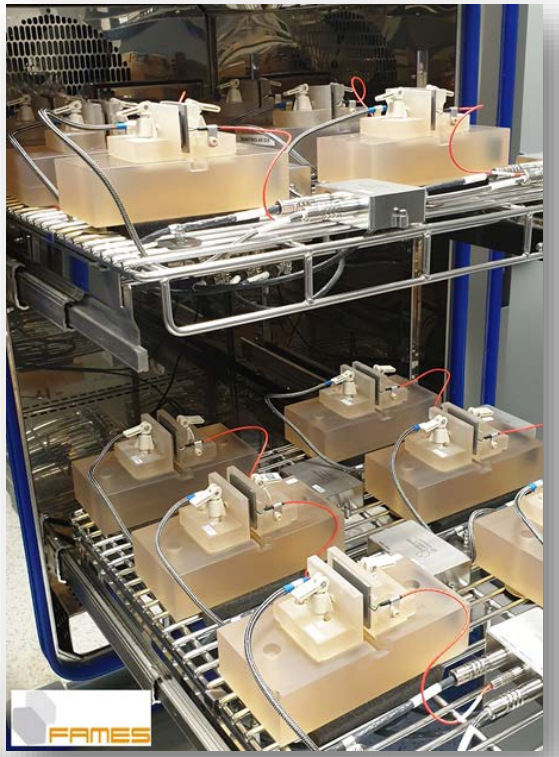
M1 Position Actuators (PACTs)

- M1 PACTs developed by Physik Instrumente - PI (DE)
  - Stroke: ±5mm; **tracking error: 2nm**; absolute accuracy: 5 µm;
  - **Two-stages** motor/spindle + Piezo
  - **intensive testing** at contractor (climate chamber, gravity test rig) and at ESO (M1 Test Bench).
  - Total: ~2500 heads (+ 800 control electronics)
  - Delivered: first series batch 177 actuator heads (+ hundreds of control modules)



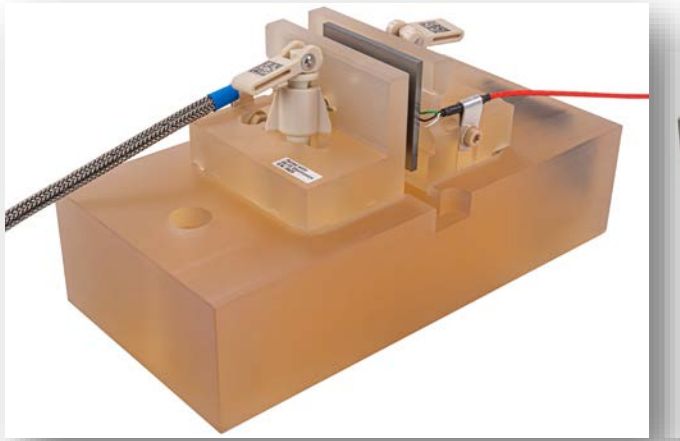
M1 Edge Sensors

- M1 ES developed by FAMES – Fogale / Micro-epsilon (FR / DE)
  - Custom **Low-noise inductive** sensors + electronics;
  - Measure **piston** (+gap & shear) between segments (6/segment);
  - Range: ±0.2mm; **resolution: <1nm**; Repeatability: 10 nm;
  - **Intensive design and qualification** phase completed;
  - Total: ~4500 heads (+ 800 reading electronics);
  - Delivered: first series batch (230 sensors);



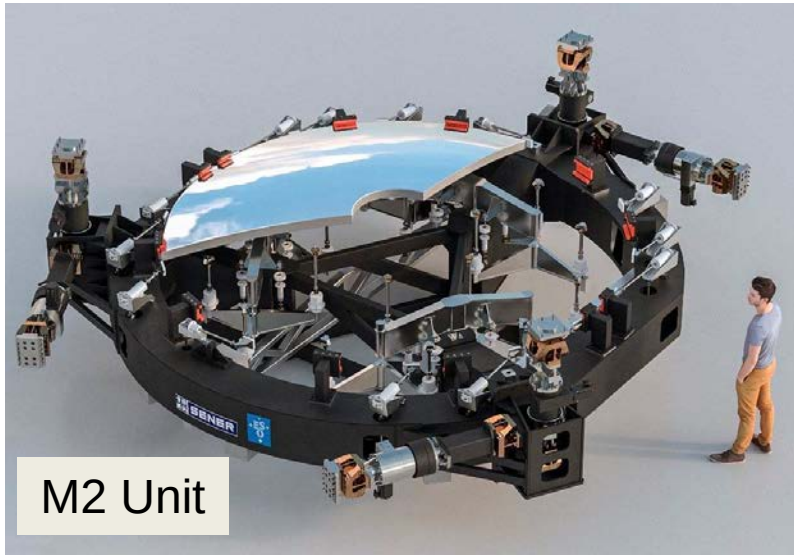
FAMES

FOGALE nanotech

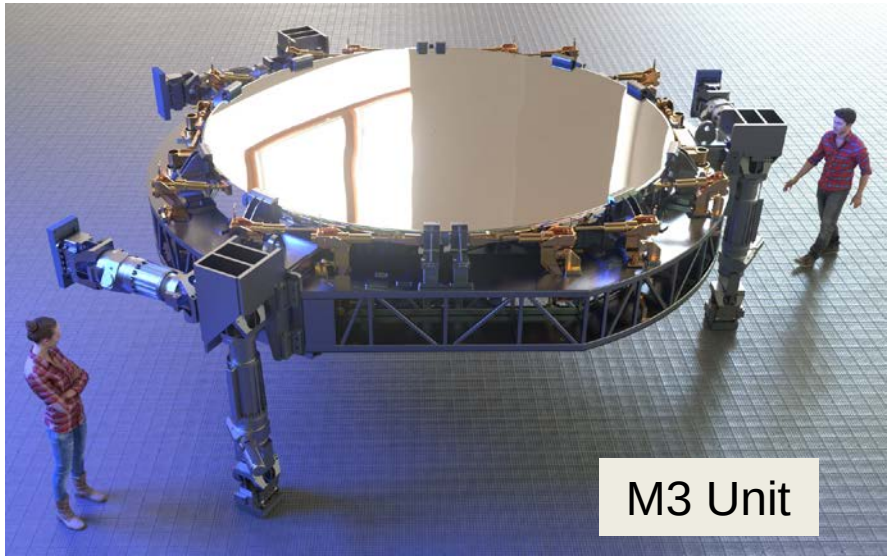


M2 & M3 Units : Synergies

- M2: Passive 4-m f/1.1 convex mirror, highly aspheric (+ shape control provision)
- M3: Active 4-m f/2.6 concave mirror, mild aspheric (+ shape control)
  - Same size, support (18pts axial, 12 lateral), mass, stiffness, shaping system (warping harness), positioning system (sub-micron precision hexapod), common auxiliary equipment (handling, transport, …)
  - ➔ One single contract for M2/M3 Cell design and manufacturing to SENER (SP)
  - Two Polishing contracts to Safran-Reosc (FR)
  - Optional Tests Mirror in Cell at Reosc

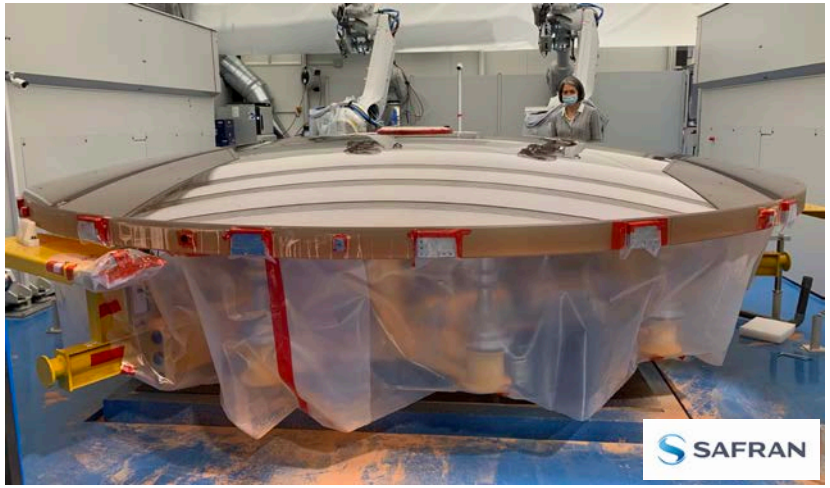


M2 Unit


M3 Unit

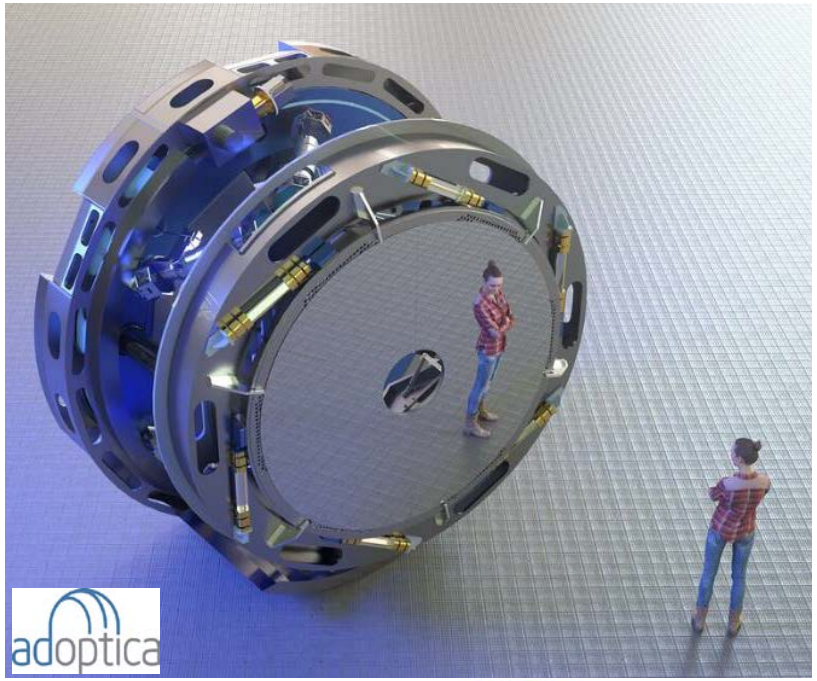
M2 Unit

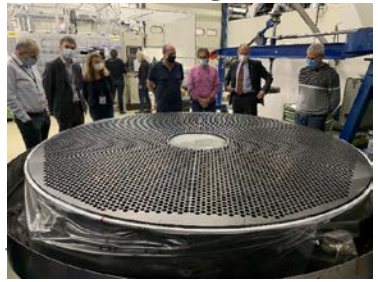
- M2 blank (4.2m) delivered by SHOTT (DE) in 2019
- M2 polishing well underway at Safran-Reosc (FR)
  - World's largest convex mirror, highly aspheric
    - Challenging testing: difficult aspheric reference optics, stitching method
  - Facility (VLT M1) refurbished for M2 & M3 polishing
  - Interface Pads bonding completed
  - Pre-polishing (grinding) completed (~2µm surface error)
  - Metrology tower ready
- M2 Cell developed by SENER (SP)
  - Combined M2/M3 cells design and qualification completed
  - M2 cell AIT on-going
  - M3 cell manufacturing completed and AIT on-going

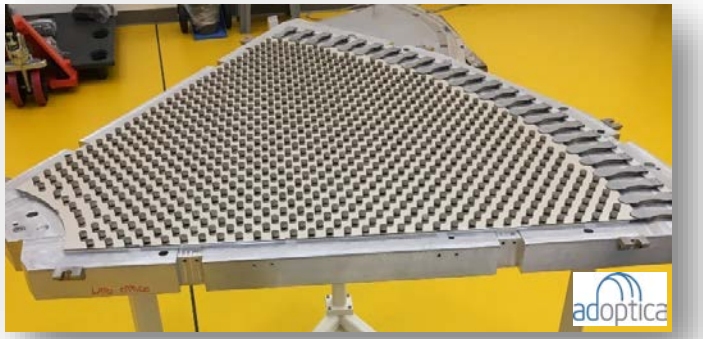


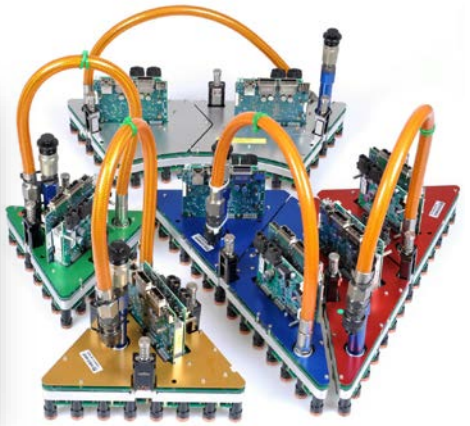
M4 Unit

- M4 Shells polished by Safran-Reosc (FR)
  - Blank (Zerodur®) by SHOTT (DE)
  - Mirror D2.4m made of 6 sectors,1.95mm thick only!
  - 6 + 2 (spares) shells completed and delivered to AdOptica
- M4 Adaptive Support developed by AdOptica (IT)
  - >5000 voice coil actuators & capacitive sensors
  - High bandwidth control @ 1kHz
  - Design & qualification completed
  - Procurement and sub-assembly almost completed
  - Technical difficulties with lapping of SiC reference body delaying final integration



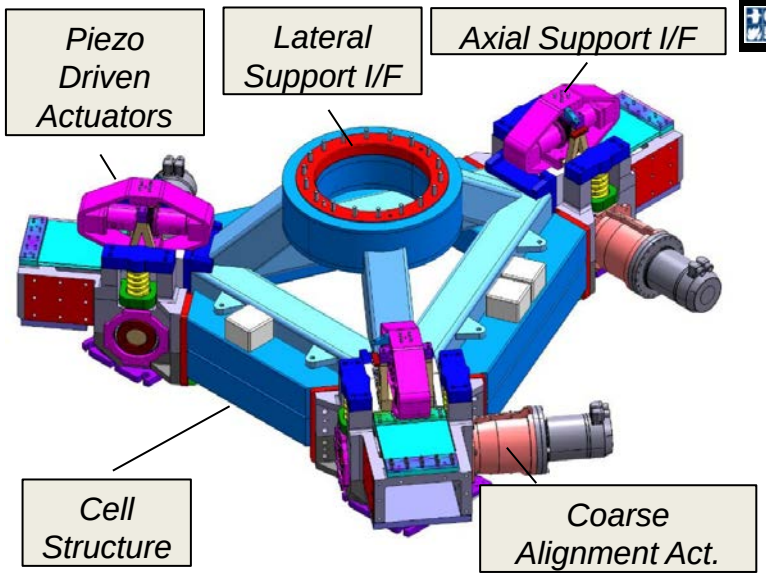






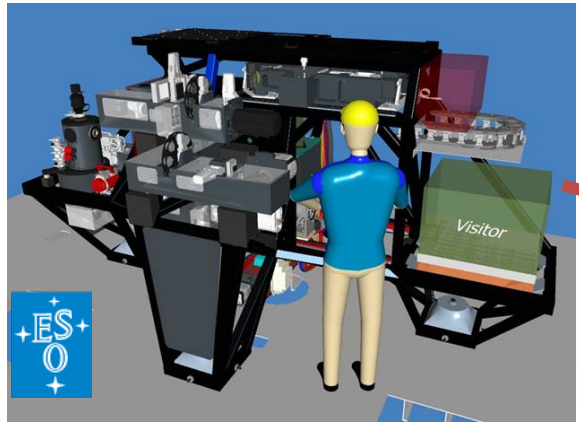
M5 Unit

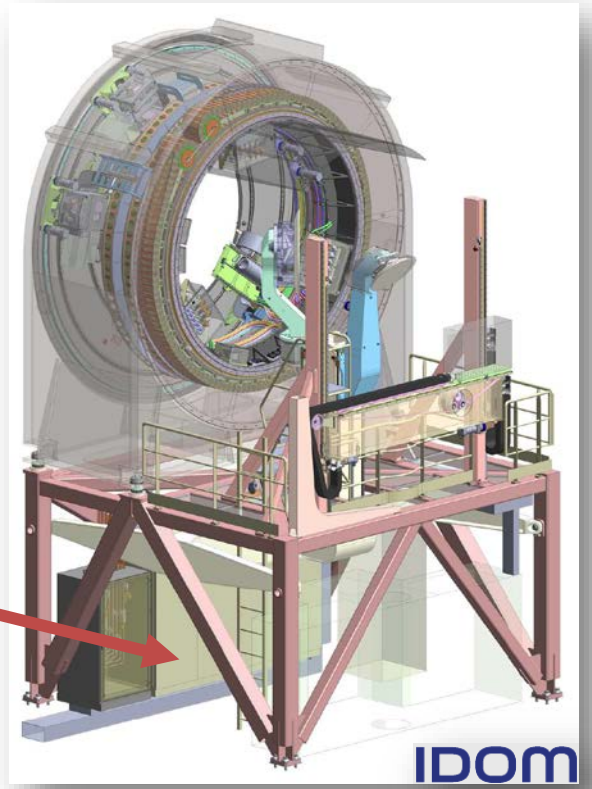
- M5 mirror produced by Safran- Reosc (FR)
  - 2.7 x 2.3 m flat made of 6 sectors in SiC
  - Technical challenges: CVD coating & brazing (Boostec)
  - 6 sectors already manufactured and CVD coated
  - Ready for brazing before delivery to Reosc for polishing
- M5 Cell developed by SENER (SP)
  - Custom-designed Piezo act. for fast tip-tilt stabilisation
  - Final design and qualification about to be completed



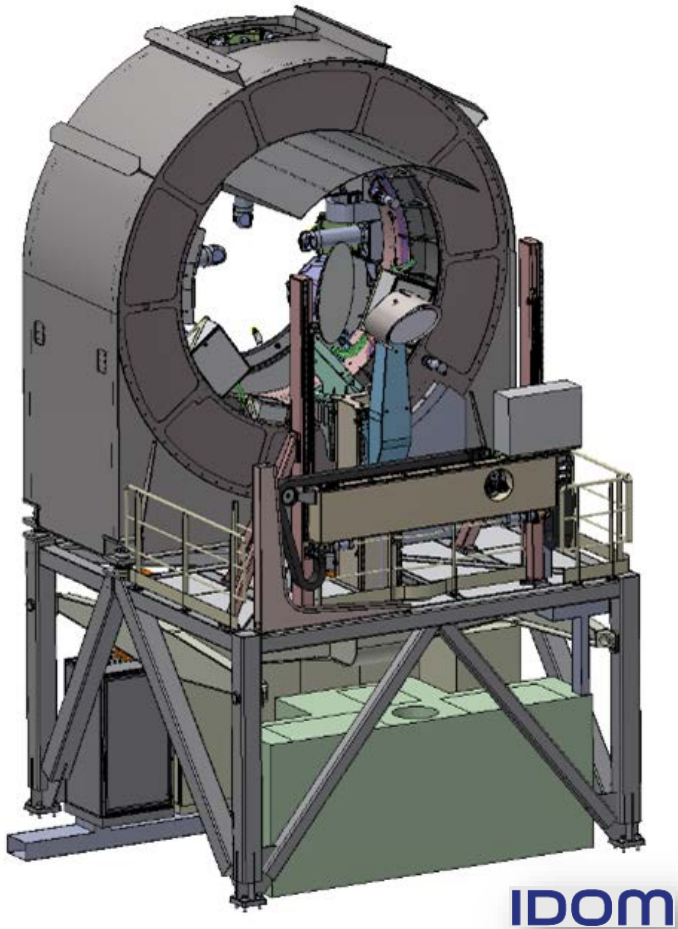
Pre-focal Station (PFS) and Phasing and Diagnostic Station (PDS)

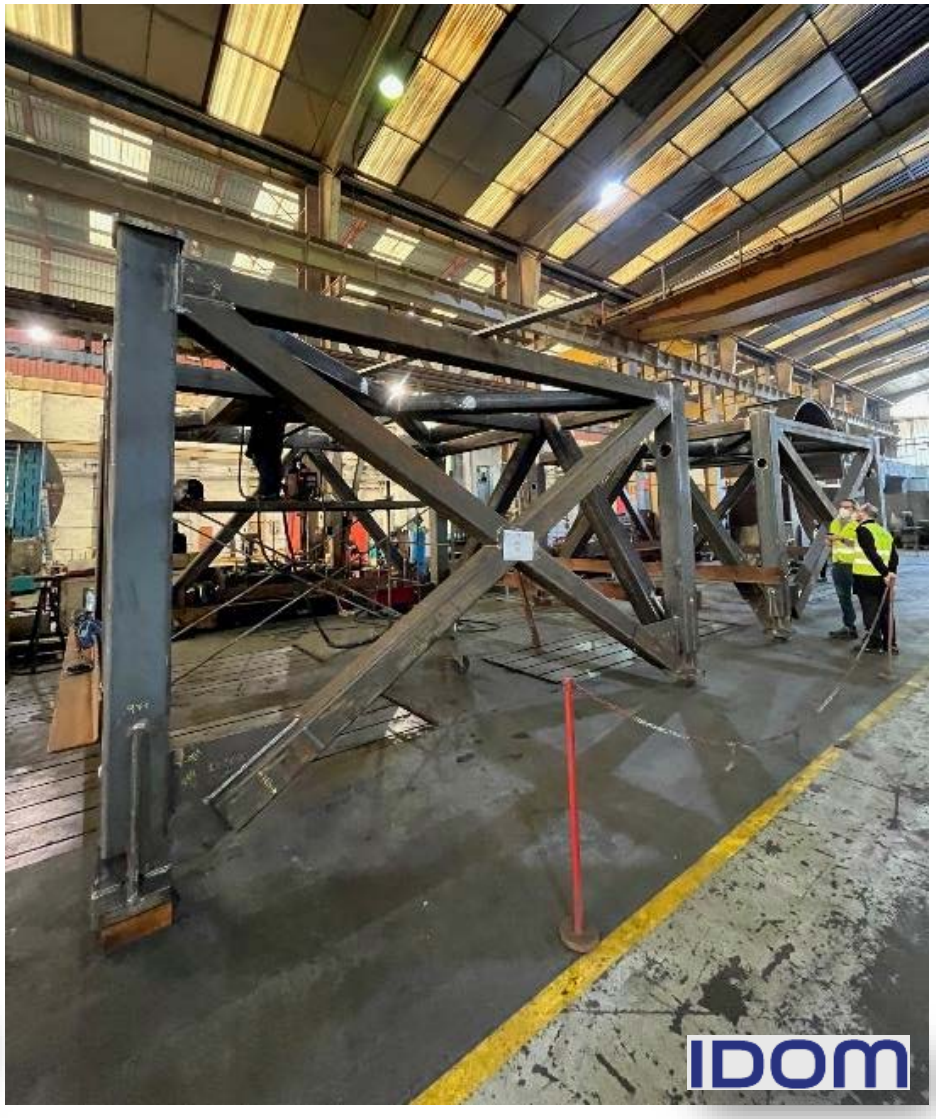
- Two identical PFS, one on each Nasmyth Platform developed by IDOM (SP)
  - Controls and redirects the telescope beam to the various foci (straight-through, lateral, Coude)
  - Hosts the (Natural Guide Star) wave front sensors for telescope control
    - Beam acquisition and guiding,
    - Mirror positioning/shape control (active optics)
  - Hosts the Phasing and Diagnostic Station (PDS)
    - M1 segment phasing sensor
    - Basic Adaptive Optics before hand over to instruments
    - Camera and tools for telescope commissioning
    - Stable reference and diagnostics during operations
- PFS design and qualification completed
  - Manufacturing on-going
- PDS (ESO internal) in final design phase
  - Long-lead items procurement review held

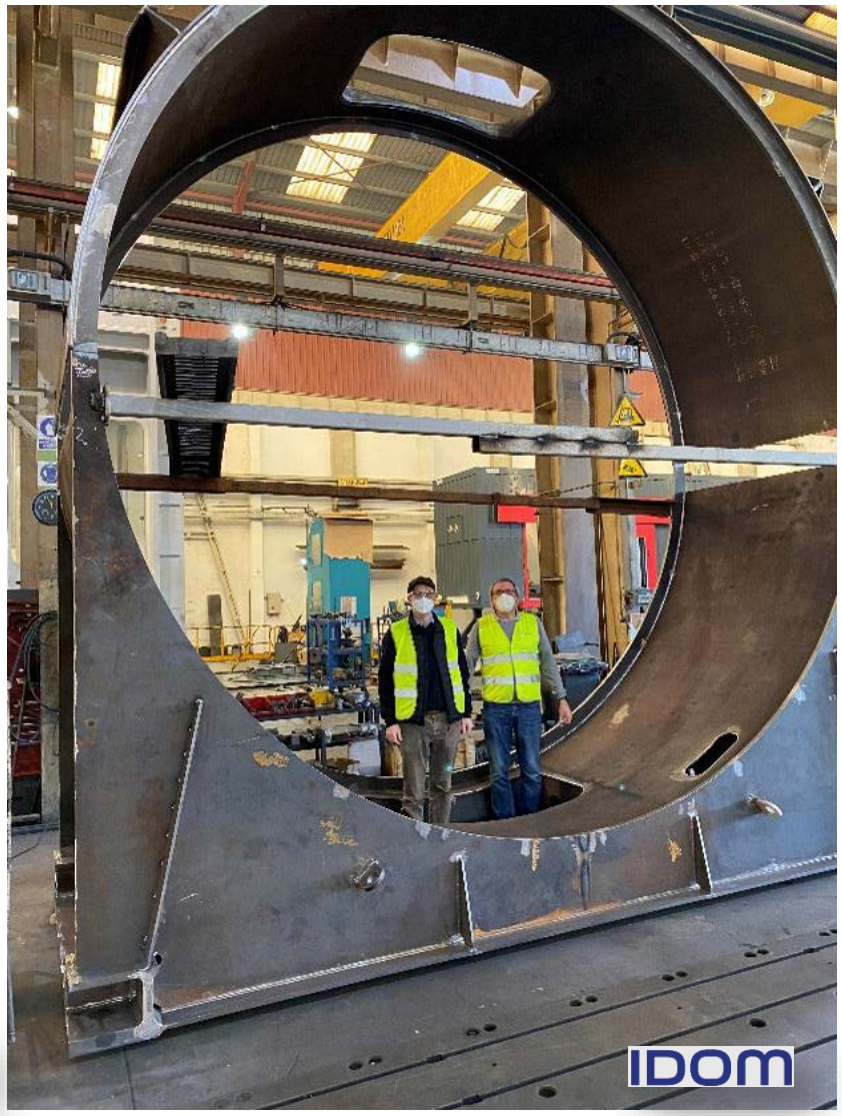




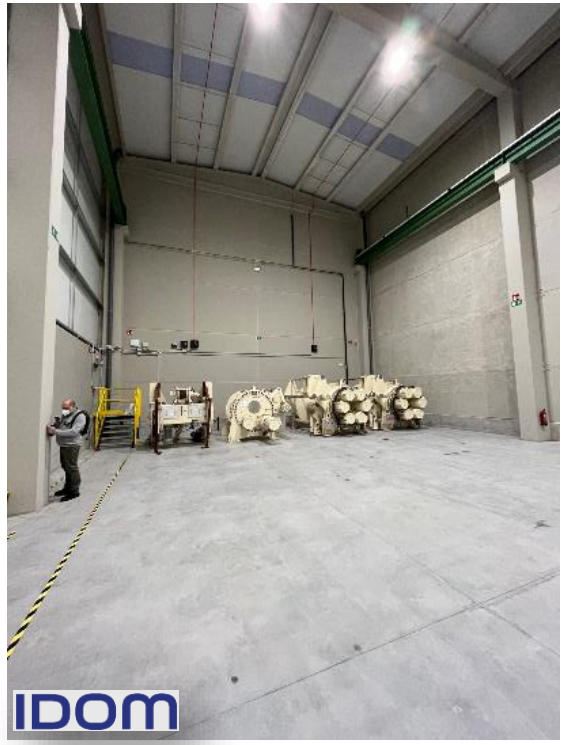
Recent Pictures

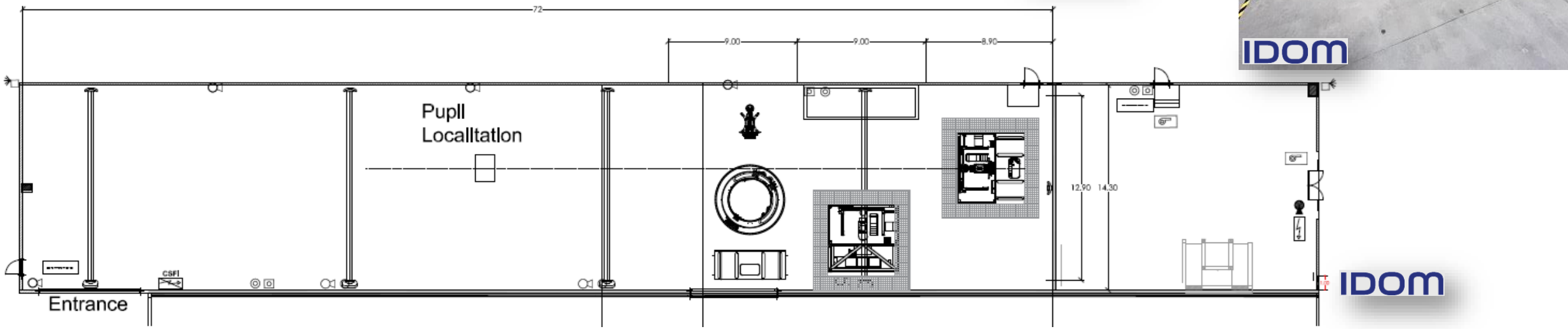






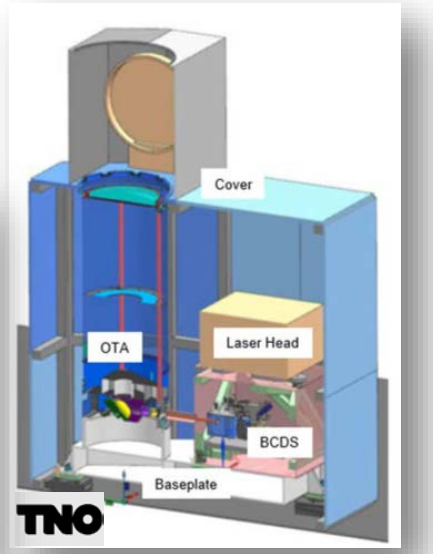
System Test Area (warehouse)





Laser Guide Star System (6 units)

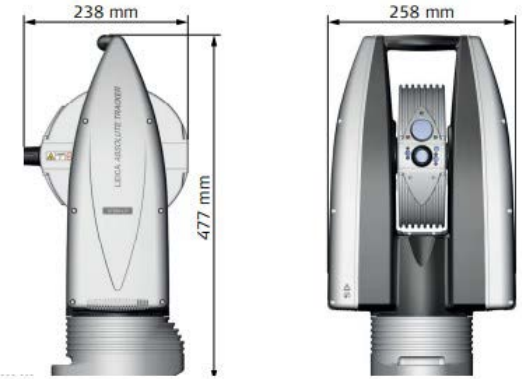
- Laser sources produced by Toptica (DE)
  - ESO => Industry spin-off (VLT, ELT)
  - All 6 laser sources manufactured (2 delivered)
- Laser projection subunits by TNO (NL)
  - Final Design Review planned in May 2022
- Special Heat Exchanger by Tecnoelectra (IT)
  - Critical design review complete Oct 2021
  - First unit delivered; acceptance tests started
- System Prelim. Design Review (ESO internal)
  - Held in Feb 2022



Coarse Alignment Metrology

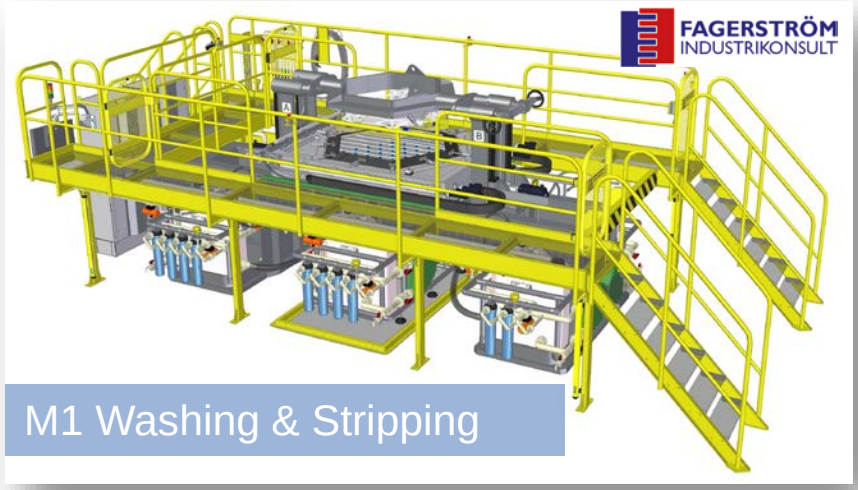
- Distributed network of 8 Leica AT930 laser trackers and targets for pre-aligning the mirror units and aligning the M1 segment supports during AIV

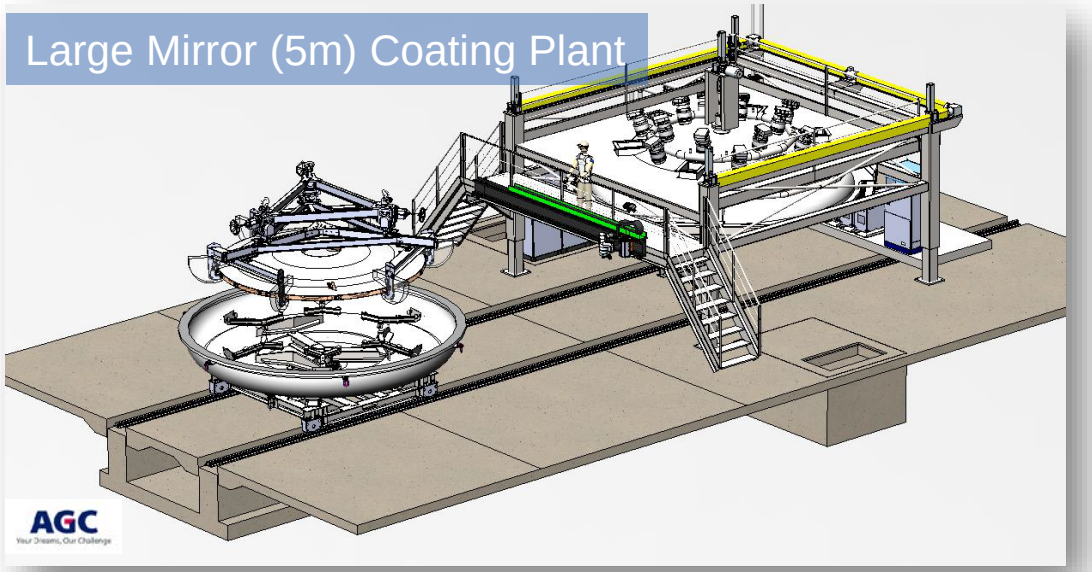
Example of metrology rays accessible from the Alt/Az Laser Tracker. (rays and targets not to scale).Credits S.Guisard/J.Marrero



HEXAGON

Mirror Maintenance





… and many more!

ELT Assembly & Maintenance Infrastructure

- ELT Technical Facility (ETF) built by Abengoa (Chile) at Paranal
  - Will house most of the subsystems assembly activities before installation on the ELT and most of the mirror maintenance activities (recoating).
  - Building completed in June 2020 and fitting work almost completed (M1 storage racks, cranes, offices, etc.)

Entrance gate

Existing Workshops

ETF

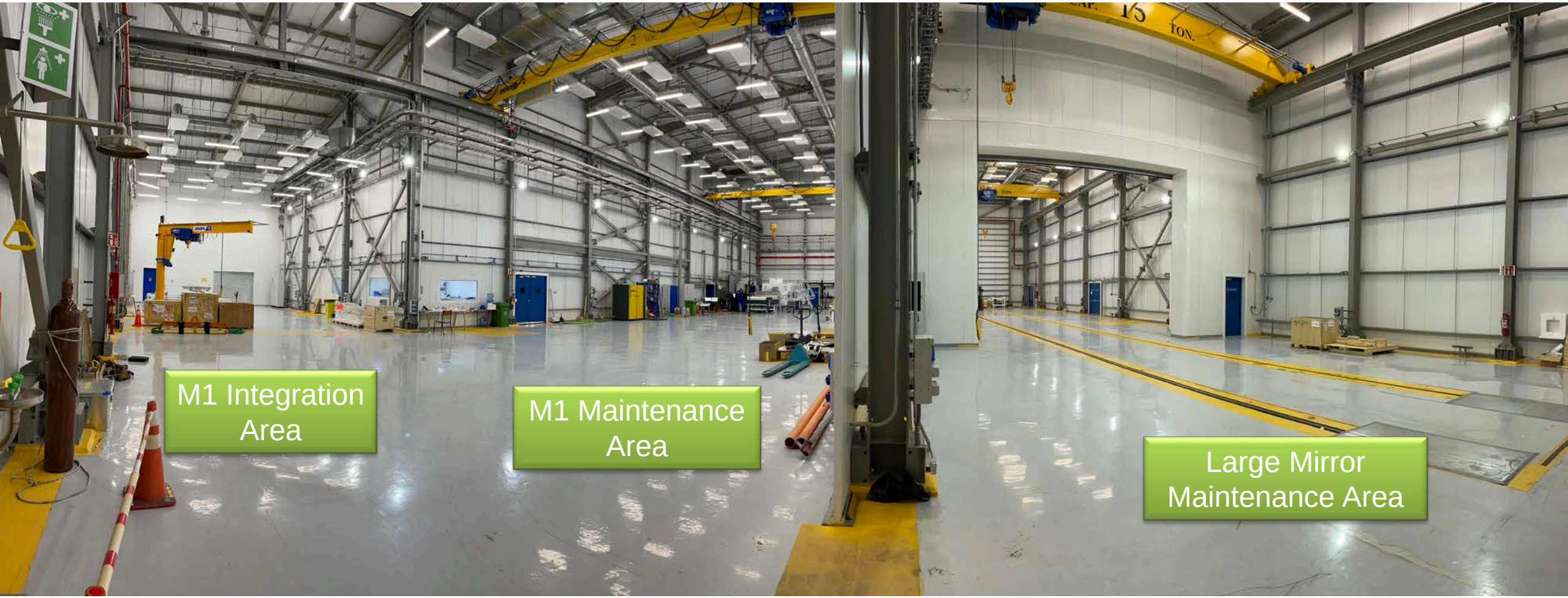
… an Extremely Large Building !

M1 Coating Plant in storage (2020)

Residencia

VLT Mirror Maintenance Building

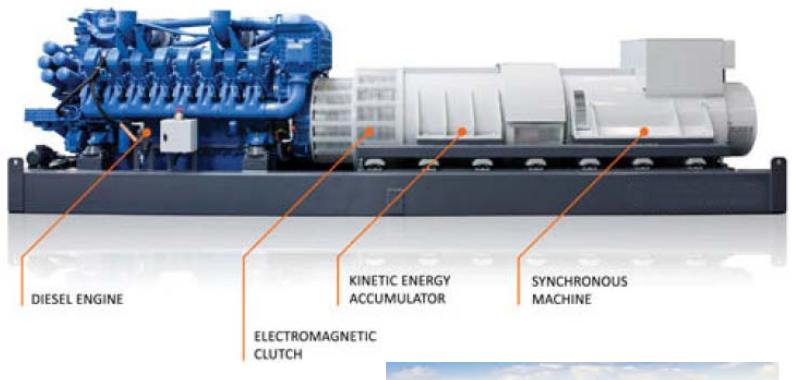
Recent Pictures



M1 Coater integration and commissioning status

Power Conditioning (PCS) and Photo-Voltaic Plant (PVP)

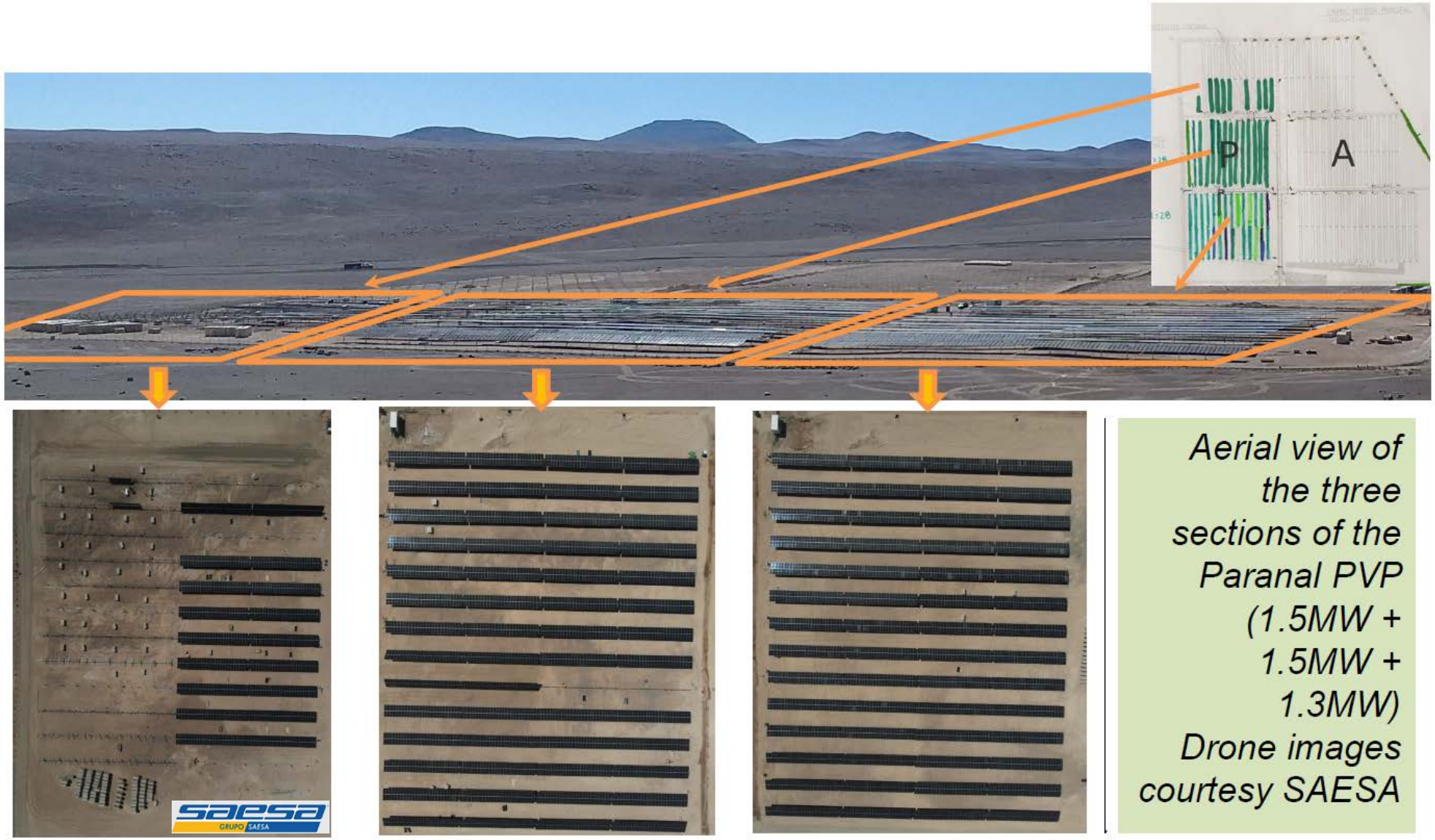
- After 20 years on diesel generators then gas turbines, both Paranal and Armazones got **connected to Chilean grid** in 2017
- Contracts signed with **SAESA** (Chile) in 2019 for PCS and PVP. Completion in 2022.



- **Power Conditioning System** (PCS):
  - Avoids power supply interruptions
  - Improves: power quality, harmonics to/from grid, dynamic power factor
  - Capacity: 5MW with full backup generation

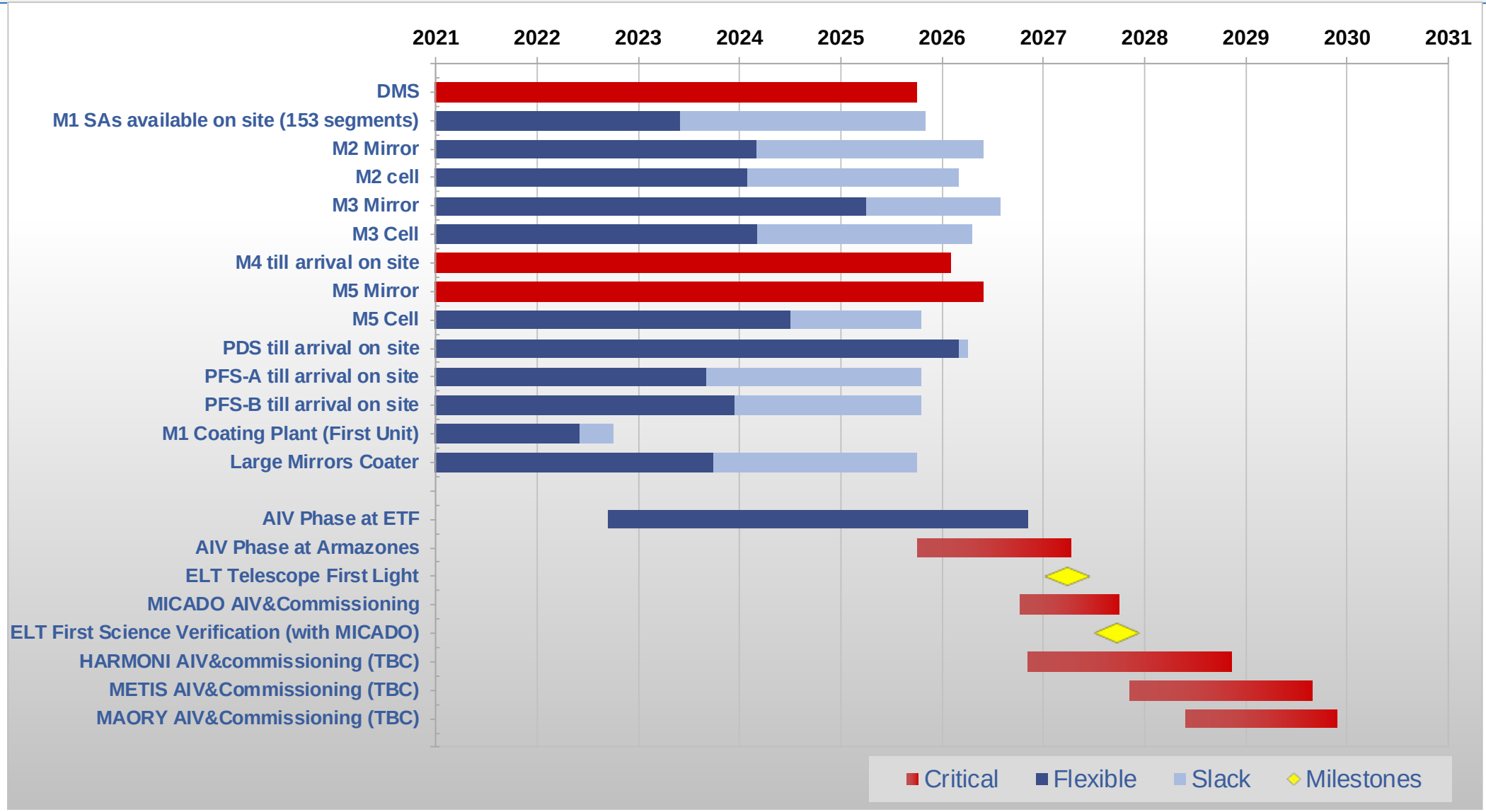
- **Photo-Voltaic Plant** (PVP):
  - Improves ESO environmental footprint (main consumption daytime)
  - Capacity: 9MW covering needs from Paranal, Armazones, future Cherenkov Telescope Array Observatory (CTA)

The Paranal PVP is completed at 80%



Aerial view of the three sections of the Paranal PVP (1.5MW + 1.5MW + 1.3MW) Drone images courtesy SAESA

ELT Schedule – Critical Path Analysis (TFL March 2027 – SV Sept 2027)

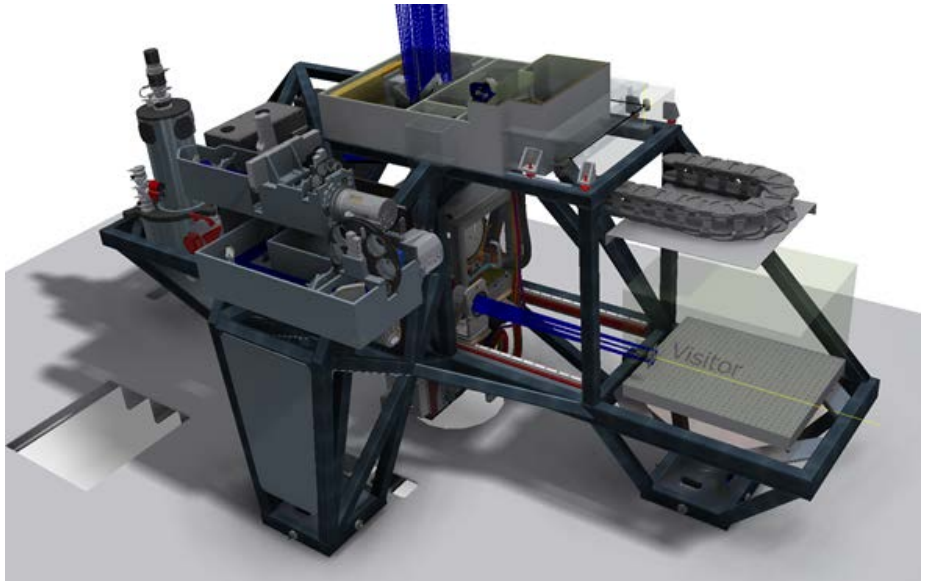


On-going / Up-coming Procurements

(potential opportunities as contractor or sub-contractor)

Phasing and Diagnostic Station

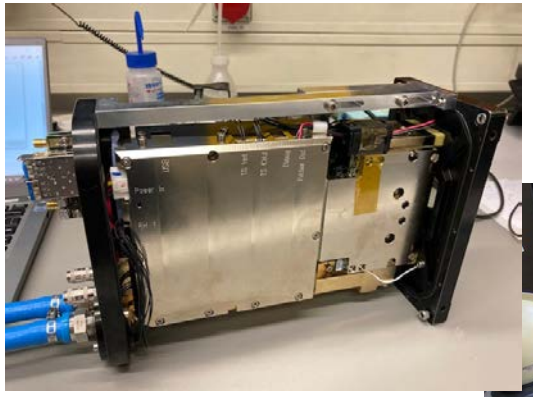
- ESO-internal Final Design on-going
- Several procurements expected:
  - **Optics** (8 separate contracts – drive schedule)
    - Powered optics (mounted in barrels)/ Mirrors / Dichroic beam splitters / Pyramid optics / Lenslets / Phase retardation plates / Optics for one subsystem (ready soon) / One ⌀310mm mirror (w/ transmission reqs)
  - **Mechanics**
    - Framework structure / subsystem housings / optomechanical mounts / cryostat components / cooling services / MAIT tools / Interfaces / …
  - **Actuators** (total quantity ~40)
    - Rotating motors / linear stages in the low µm repeatability range / Modulation stage for 500Hz application and some µrad accuracy
  - **Electronics** / Devices / Control System
    - Cabinets / power distribution / controllers / safety system / PLCs / …

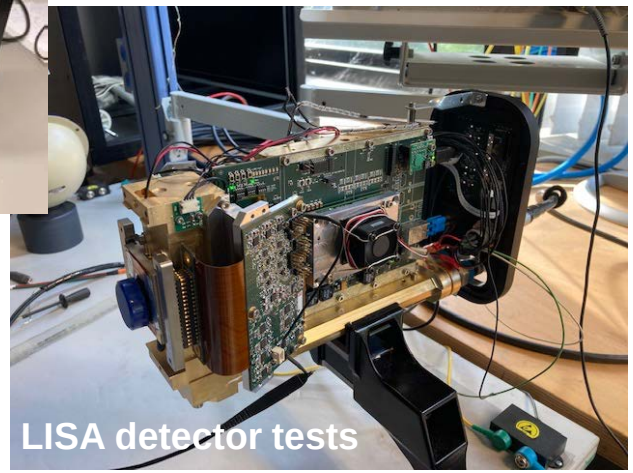


- **Optics**: Inquiries/Call for Tender to **start in 2022**
- **Mechanics/actuators/electronics**: After FDR **(Q2/2023)**

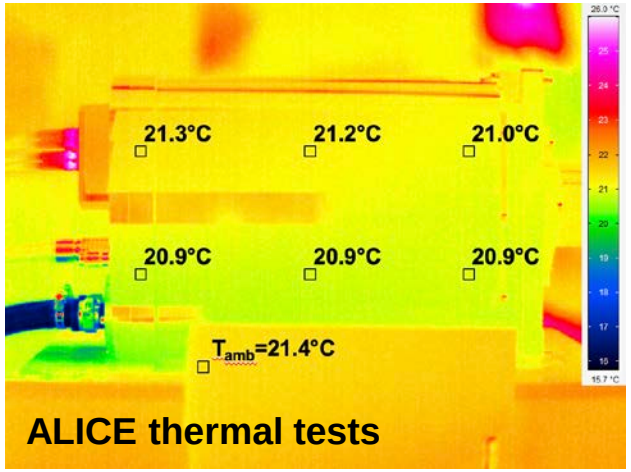
Cameras for LVSM and CCD220

- Design & Development contract completed
  - Manufacturing Readiness Review (MRR) in Mar'22
  - CfT planned in Q2 2022
- Specialties for potential (sub)contractor:
  - Manufacturing and testing of small mechanics
  - Manufacturing and testing of low-noise electronics
  - Minimum understanding of detectors
  - Understanding of camera/detector testing




LISA detector tests


ALICE EMC tests



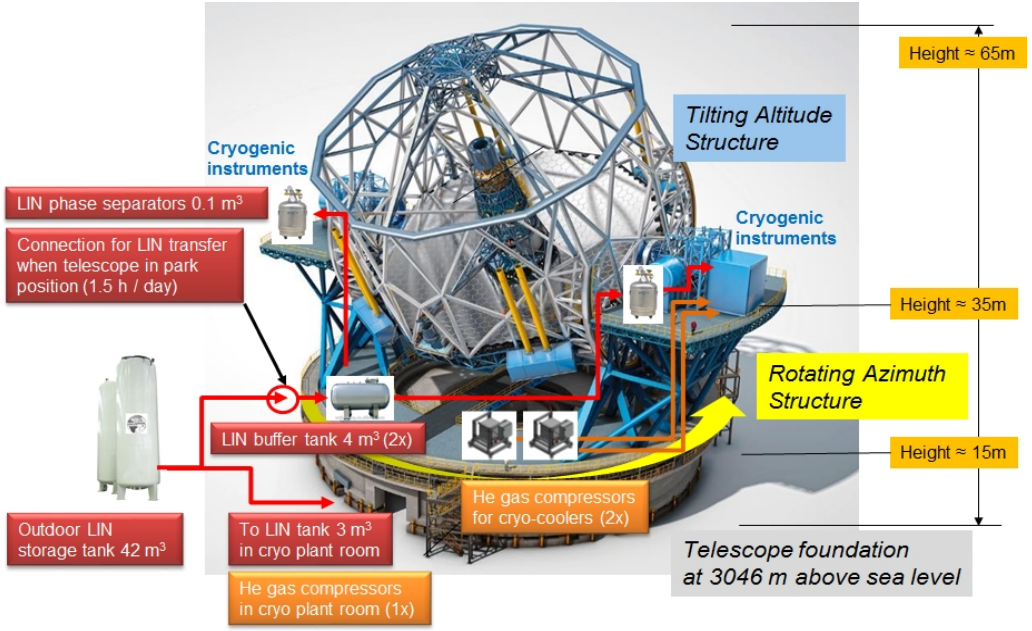
ALICE thermal tests


ALICE environmental tests

LN2 Distribution Infrastructure

- Scope:
  - Design, manufacturing, testing and on-site installation of the LN2 distribution infrastructure (tanks, piping, valves, safety installation, Nitrogen gas exhaust system, …)
- Expected Contract Duration:
  - ~ 3-4 years
- Turn-over: <3 M€
- Timeline:

Request for Info	Q2 2022
Release Call for Tender	Q3 2022
Closing date	Q4 2022
FC Approval	Feb 2023 (TBC)



LN2 Distribution Infrastructure

- Specialties for potential (sub)contractors:
  - Industrial LN2 supply systems (tanks, piping, valves, safety installation, …) for few thousands liters/day flow
  - Closed forced-flow system based on differential pressure (between outside tank & consumers) without auxiliary pumps
  - Automatic (goal) pipe connection systems
  - Dedicated Nitrogen gas heaters

Plan for 2022
(Small Procurements)

JOB	Activity Desc.
Permanent Infrastr. Buildings	Service vehicles (x2) - TBC
M1 Unit	
Common Lifting, Handling and Transport Equipment	40t Truck heavy duty 6x6 with Palfinger
Permanent Infrastructure Buildings	Service vehicles
Laser Guide Star Units	Laser Pointing Camera
Subsystem Control	SW Licenses + SW Development Environment
ELT Washing and Coating	Mirror Washing/Stripping unit (5m) Procurement
Permanent Infrastructure Buildings	Service vehicles