

# *The European Extremely Large Telescope (E-ELT)*

*Roberto Tamai (Programme Manager) , Bertrand Koehler (managerial assistance)*



*The E-ELT, 2nd PACMAN Workshop, 13th June 2016, Debrecen*



# The European Southern Observatory

(ESO)





# European Southern Observatory

## ■ 1962

- ESO created by five Member States with the goal to build a large telescope in the southern hemisphere
  - Belgium, France, Germany, Sweden and The Netherlands
- This became the 3.6m telescope on La Silla (1976)

## ■ 2016

- 15+1 Member States (~30% of the world's astronomers)
- Paranal is the world-leading ground-based observatory
- ALMA (in partnership) on Chajnantor almost completed
- Construction of 39m E-ELT on Armazones started

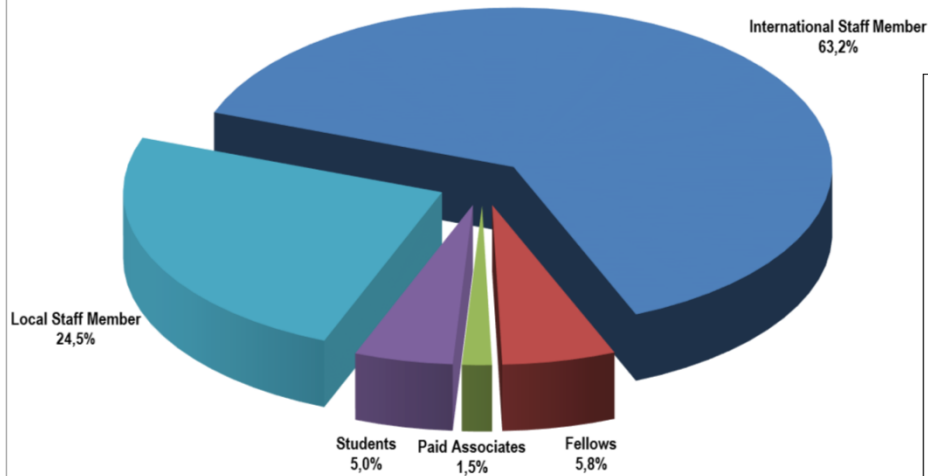




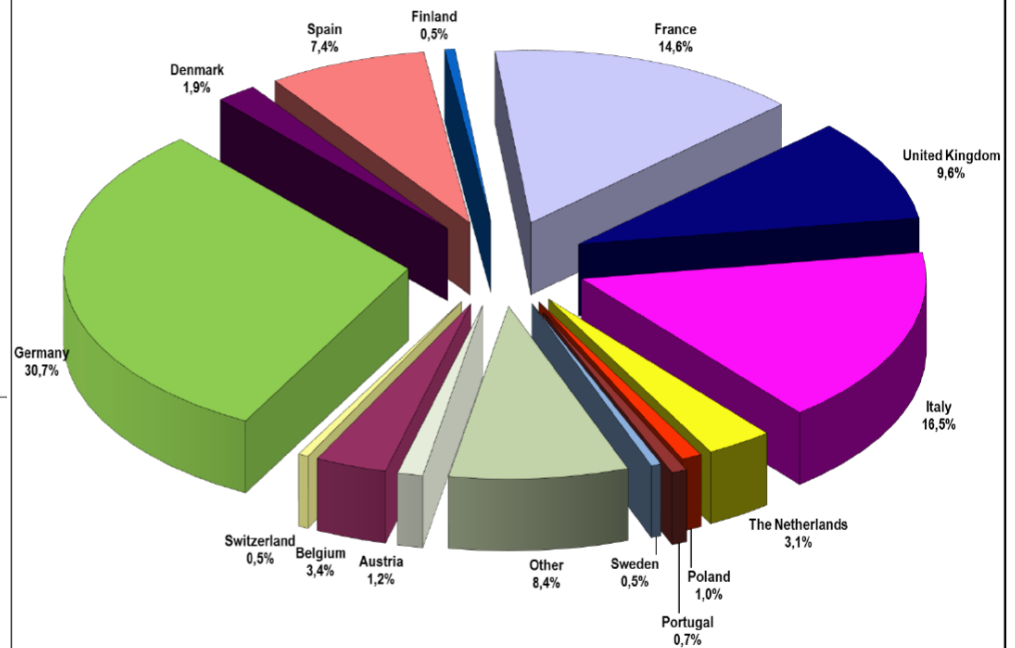
# ESO Staff

■ Total 660 staff (~60%EU, 40%Chile)

Members of the Personnel by Category and Percentage (= 660)  
- December 2015 -



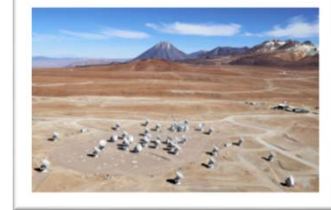
Distribution of International Staff Members by Nationality (= 417)  
- December 2015 -







# ESO in Chile



ALMA  
Observatory

Paranal Observatory  
+ ... Armazones (E-ELT)



La Silla Observatory



Administration, Science &  
ALMA Offices  
and Guest House

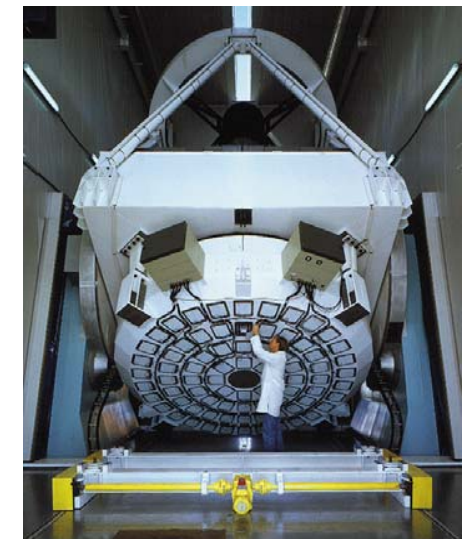




# La Silla



3.6m



3.5m NTT







# Paranal (VLT/VLTI, VST, VISTA)





NINS



ALMA



- Atacama Large Millimeter/submillimeter Array
  - 54 x 12m + 12 x 7m antenna's on Chajnantor at 5050m
  - 7 – 0.35 mm (30-900 GHz) in 10+ atmospheric windows
  - World's most powerful radio interferometer
  - Cold Universe: formation of planets, stars and galaxies

- Global partnership
  - North America (37.5%), East Asia (25%) & ESO (37.5%)
  - In cooperation with Chile







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# Development Model for Optical Observatories (La Silla, VLT, E-ELT, ...)

- Telescopes and Infrastructure developed by ESO
  - ESO is 'System Architect'
  - Subsystems are built by Industry under fixed-price contracts from ESO
  - ESO Integrates
  - ESO Operates

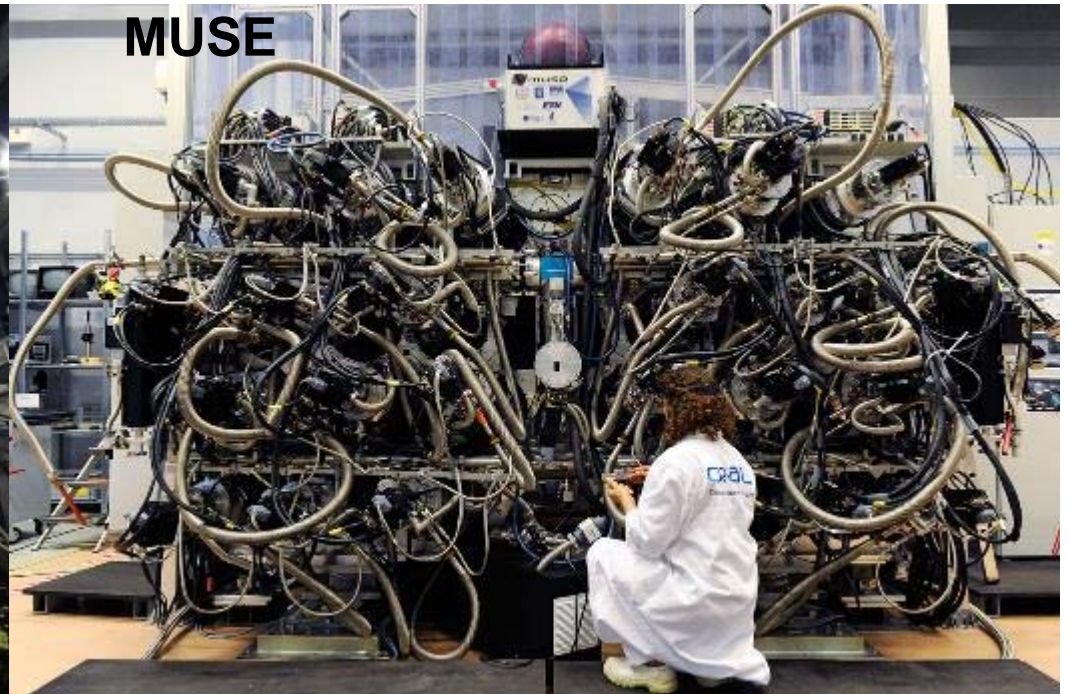






# Development Model for Optical Observatories (La Silla, VLT, E-ELT, ...)

- Most instruments built by *consortia of institutes*
  - ESO pays hardware (~1/3<sup>rd</sup> of total cost)
  - Consortia provide staff; compens. in Guaranteed Time
  - This corresponds to ~250 nights per instrument (E-ELT)
- Constitutes a very powerful support network





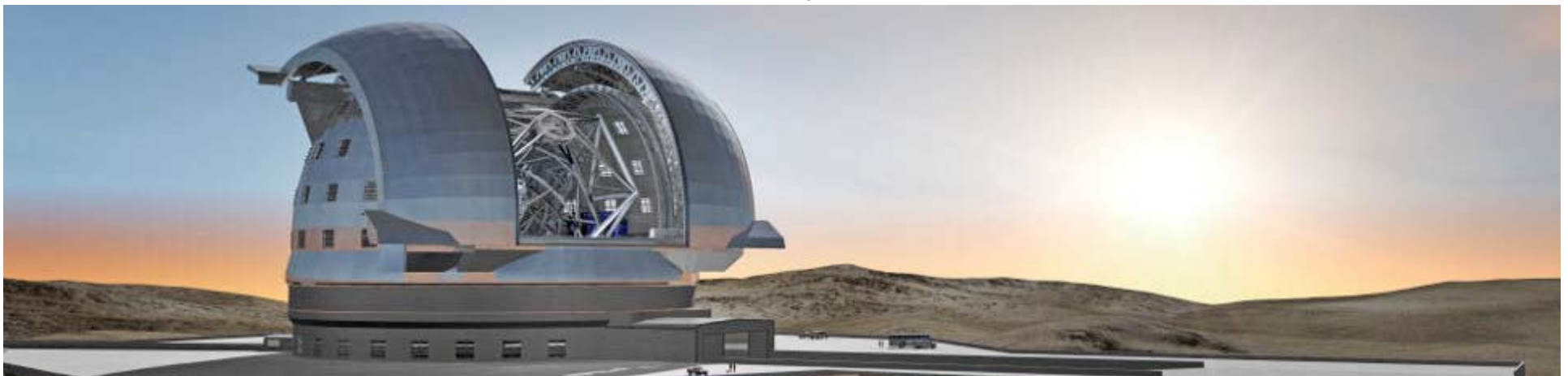
# The E-ELT

## Overview



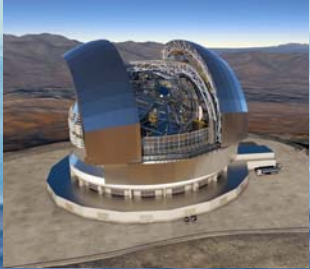


- Largest optical/infrared telescope in the world
  - 39m segmented primary mirror: transformational step
  - Science: exo-earths, deep universe, resolved populations
  
- Project
  - Construction 2014-2024, on Cerro Armazones
    - As *integral part* of the Paranal Observatory ('one more telescope')
  - ESO cost:
    - Capital cost: ~1125 MEUR incl. instruments, staff and contingency
    - Operation cost: ~50 MEUR / year





# Armazones and Paranal



E-ELT  
(Armazones)

## Armazones Site :

- Altitude: 3046 m
- c.a. 360 nights clear sky
- Very stable atmospheric and weather conditions
  - Rare and short-duration storms. Typ. 1/year, -10C (min), rain or snow fall, possibly high winds
- Very dry and high UV radiation
- Very active seismic area !

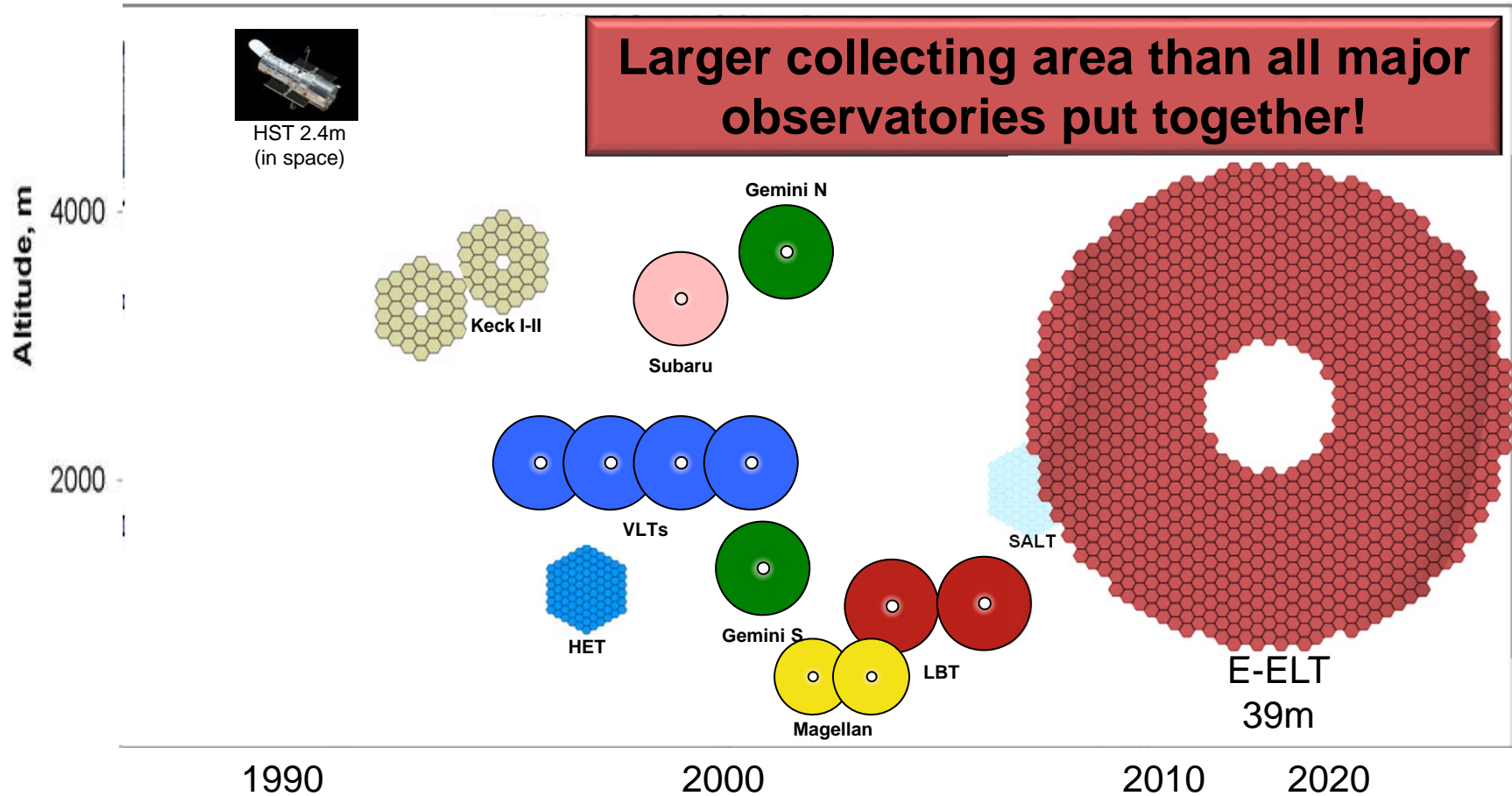
25 km

VLT (Paranal)





# Huge Collecting Area





# Spectacular Resolution



VLT+AO



HST



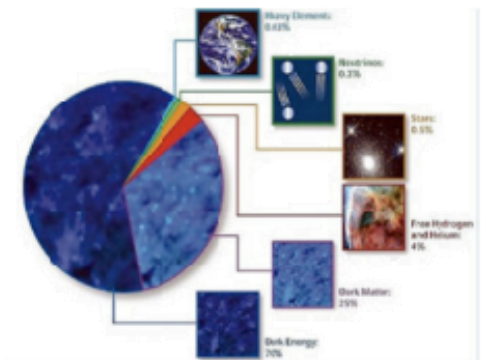
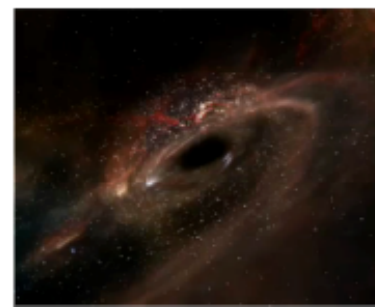
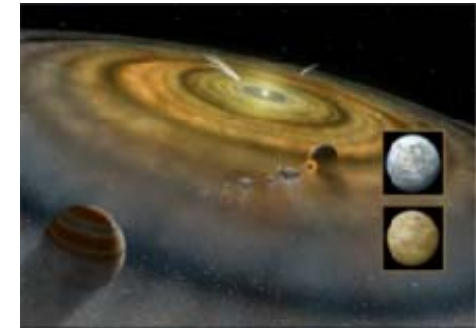
E-ELT



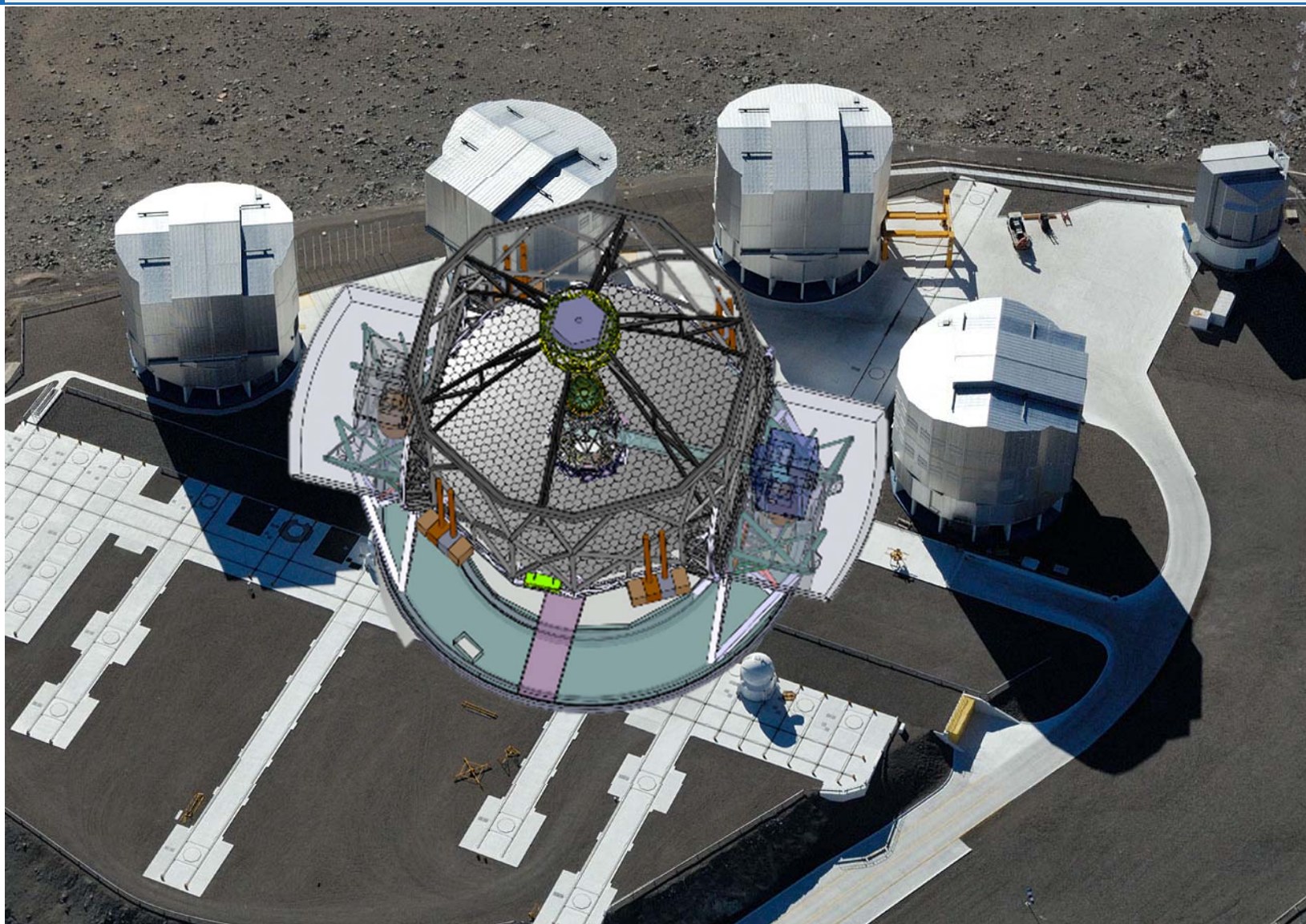


# Science drivers

- Planets in other stellar systems
  - Imaging **and** spectroscopy
  - *The quest for Earth-like exo-planets*
- Stellar populations
  - In galaxies inaccessible today (e.g. ellipticals in Virgo cluster)
  - Across the whole history (i.e. extent) of the Universe
- Cosmology
  - The first stars/galaxies, closer to Big Bang
  - Direct measure of deceleration
  - Evolution of cosmic parameters
  - Dark matter, dark energy
  - Tests of GR around black holes
- The unknown
  - Open new parameter space



# To put it in perspective...



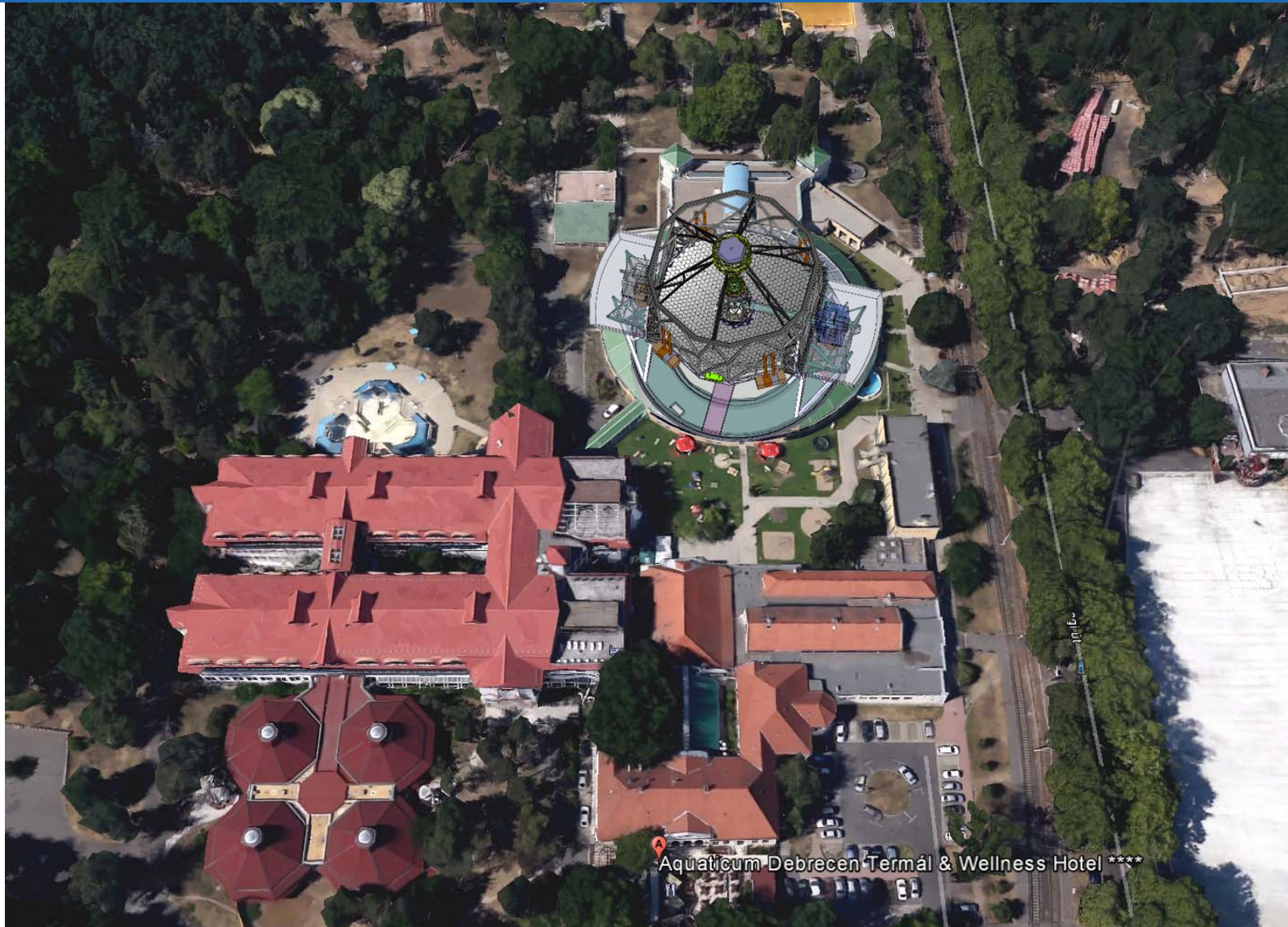
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# To put it in perspective...



The E-ELT, 2nd PACMAN Workshop, 13th June 2016, Debrecen





# E-ELT Programme

Organisation

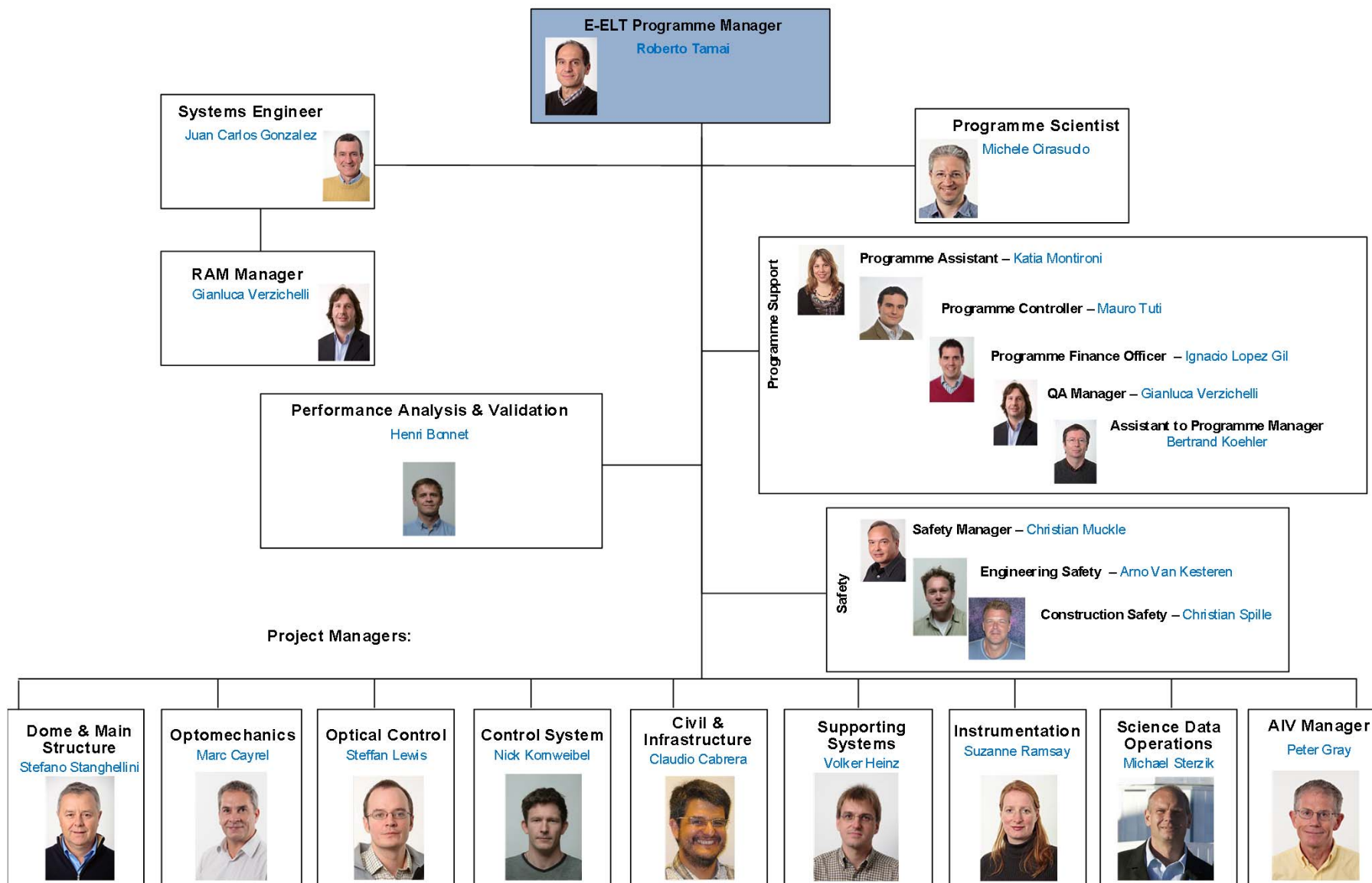






# E-ELT Organigram

E-ELT Organisation Chart (2015-10-07)



Activity Desc.	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
<b>PJ18.30 -- INS ELT Construction</b>																			
Construction Activities- MICADO (Available on Site)																			
Construction Activities- HARMONI (Available on Site)																			
Construction Activities- METIS (Available on Site)																			
Construction Activities- MAORY (Available on Site)																			
<b>PJ42 -- ELT Construction</b>																			
<b>PJ42.02 -- E-ELT Dome and Main Structure</b>																			
DMS - Design Phase																			
DMS - Site Preparation Activities and Foundations Construction																			
DMS - Manufacturing and Pre-Assembly																			
DMS - Packing and Shipping																			
DMS - On-Site Erection and Commissioning																			
DMS - Preliminary Transfers and Acceptance Activities																			
DMS PROVISIONAL ACCEPTANCE Complete without OPT																			
<b>PJ42.03 -- E-ELT Optomechanical</b>																			
M1 Segment Support Qualification Units																			
M1 Segment Support Production Units																			
M1 Edge Sensors - Design and Manufacture Contract																			
M1 Segment Blanks - Manufacture Contract																			
M1 Segments Polishing - Manufacture Contract																			
M1 Position Actuators - Design and Manufacturing Contract																			
M2 Blank - Manufacturing Contract																			
M2 Mirror - Manufacturing Contract																			
M2 Cell - Manufacturing Contract																			
M3 Blank - Manufacturing Contract																			
M3 Mirror - Manufacturing Contract																			
M3 Cell - Manufacturing Contract																			
M4 Unit - Phase 2 - Shells																			
M4 Unit - Phase 3/4/5 - Final Design & Construction																			
M5 Mirror - Phase 3 - Mirror Finishing																			
Laser Beam Projection Subunits (LGSU) - Manufacture (Phase 1)																			
Laser Source Subunits																			
<b>PJ42.04 -- E-ELT Control System</b>																			
Telescope Control System (TCS)																			
M1 LCS construction (TCS-M1LCS)																			
Central control system construction (CCS)																			
Telescope real-time computer (WFRTC)																			
<b>PJ42.05 -- E-ELT Civil</b>																			
Road, Platform and Service Trench Construction																			
PAR Technical Buildings (incl. Offices) - EMF, ETB, Warehouse and SSY																			
<b>PJ42.06 -- Supporting Systems</b>																			
Procurement - Handling tools and equipment																			
Procurement - General Lifting Equipment																			
Mirror washing unit (M1)																			
Mirror washing unit (5m)																			
Manufacturing Activities - Mirror coating units (M1)																			
Manufacturing Activities Mirror coating units (5m)																			
Grid Power Available at ABC																			
<b>PJ42.08 -- AVC</b>																			
Initial Telescope Survey & Phase 1 Alignment																			
M1 Segment Installation in Telescope																			
MAJOR MILESTONE - Technical 1st Light - 798 segments																			
Commissioning - Telescope plus Instruments																			
<b>PJ42.11 -- Optical Control</b>																			
Design and Manufacture - PFS A (Phase1)- Optomech Subunit																			
Design and Manufacture - Coarse Metrology and Alignment																			
Design and Manufacture - Calibration Equipment																			
TCS - Test Camera Development (ESO internal)																			
Design and Manufacture - Test Camera																			
Design and Manufacture - TCAM Test Camera Detector																			

**First Light in late 2024**





# E-ELT Programme

Design overview





# The E-ELT: an Overview

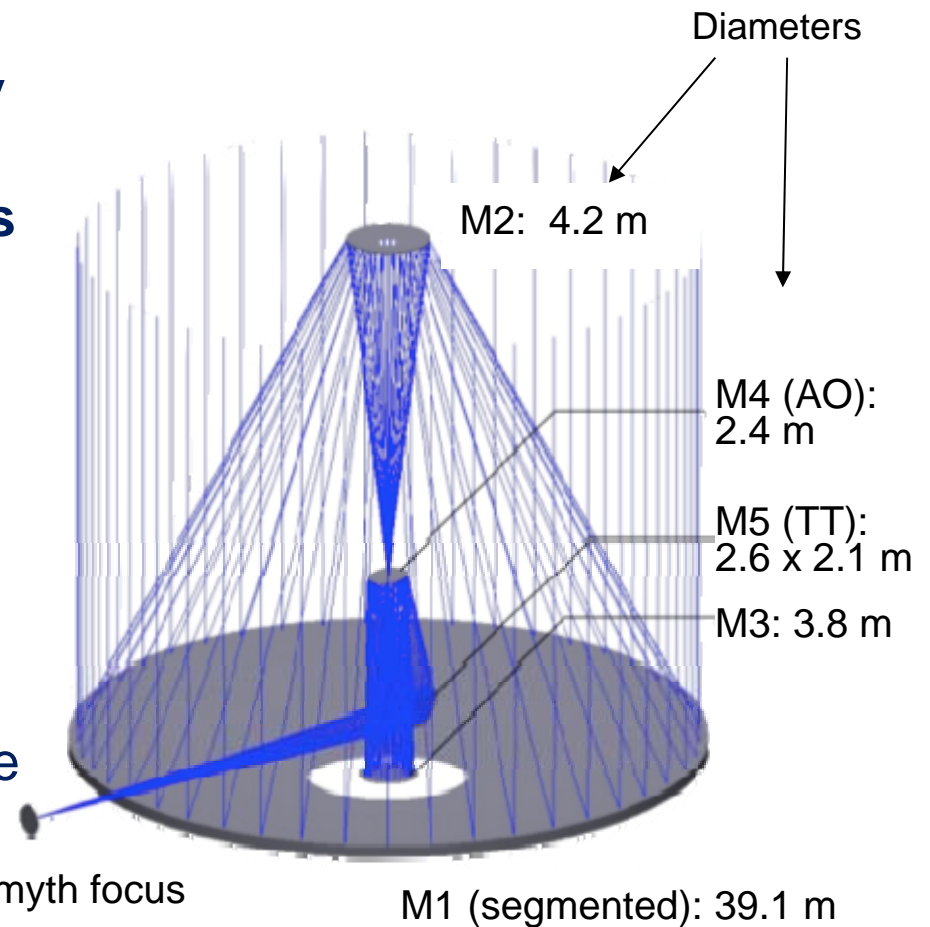






# A truly active/adaptive Telescope

- M1: 798 aspherical hexagonal segments (1.4-m) each controlled by **position actuators** and **Edge Sensors (ES) + warping harnesses**
- M2 and M3 convex and concave aspherical: active **position** and **shape** control
- M4 adaptive deformable flat mirror: **5613 fast VC actuators** and capacitive sensors (400Hz)
- M5 flat: fast Tip-Tilt correction (image motion) (10Hz)
- Nasmyth platforms: instruments and on-sky metrology (WF sensor) for wavefront control





# M1 Unit

## Segment Assembly

### 931 x M1 Segments

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

### 4530 x M1 Edge Sensors

4530 x Sensors + 813 x Electronics + Spares  
(100 sensors – 15 x controllers)

### 931 x M1 Segment Supports

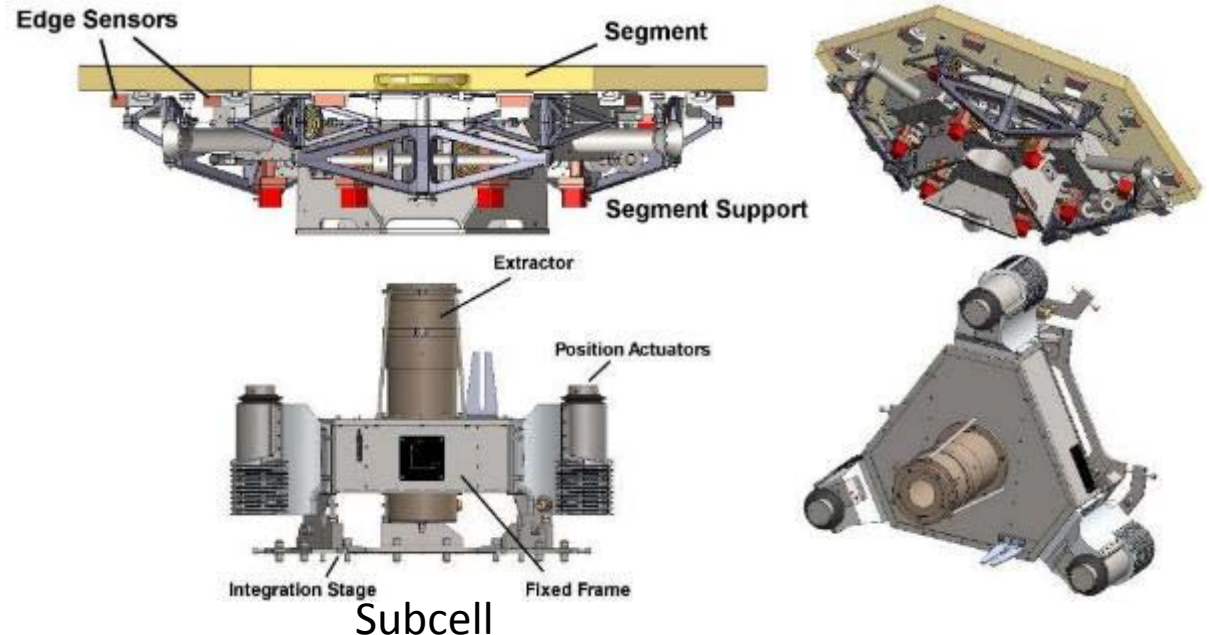
& SA Auxiliary Equipment  
[SA Handling Tools, SA Transport Containers,  
SA AIV Tools]

### 2394 x M1 Position Actuators

2394 x Actuators + 798 x Electronics +  
Spares (16 x PACT – 6 x Controllers)

### M1 Auxiliary Equipment

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

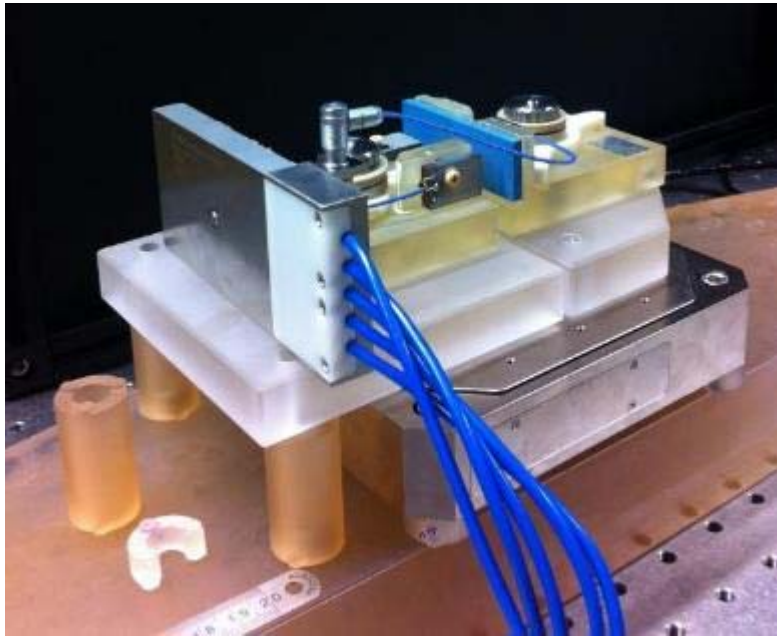


**Including glass, mechanics, electronics:  
⇒ more than 10 000 components**

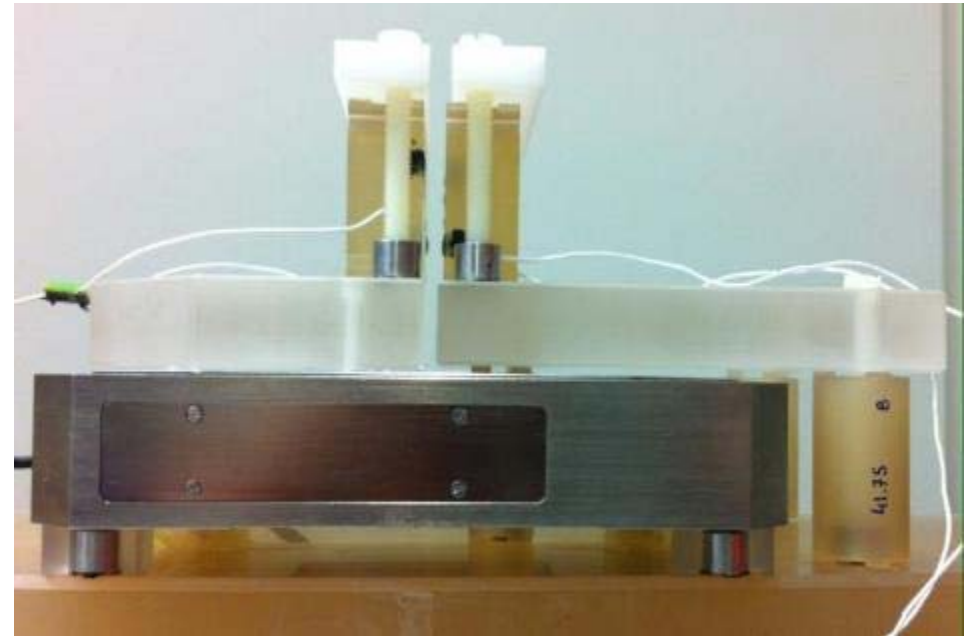




# M1 Unit – Edge Sensors



**4630 x M1 Edge Sensors  
(Including 100 Spares)**



**813 x Controllers & Electronics  
(Including 15 Spares) – One for 6  
Sensors**

**Dummy Masses  
To equip M1 free edges  
For figuring**



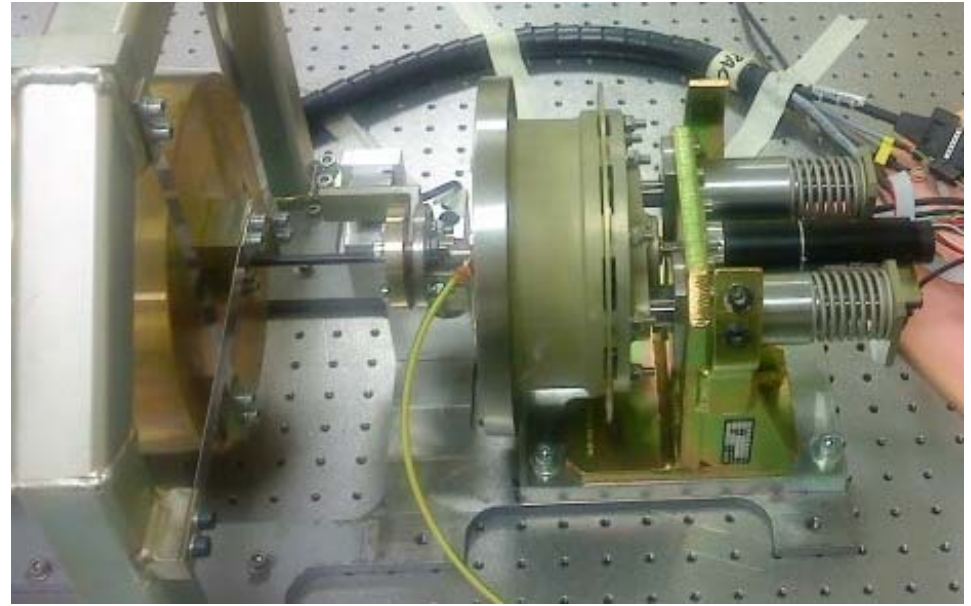


# M1 Unit – Position Actuators

- 2 Stage actuators – nm precision along 15 mm stroke.
- 2 Technologies still competing:
  - Hard PACTs (Piezzo) / Soft PACTs (voice coil)



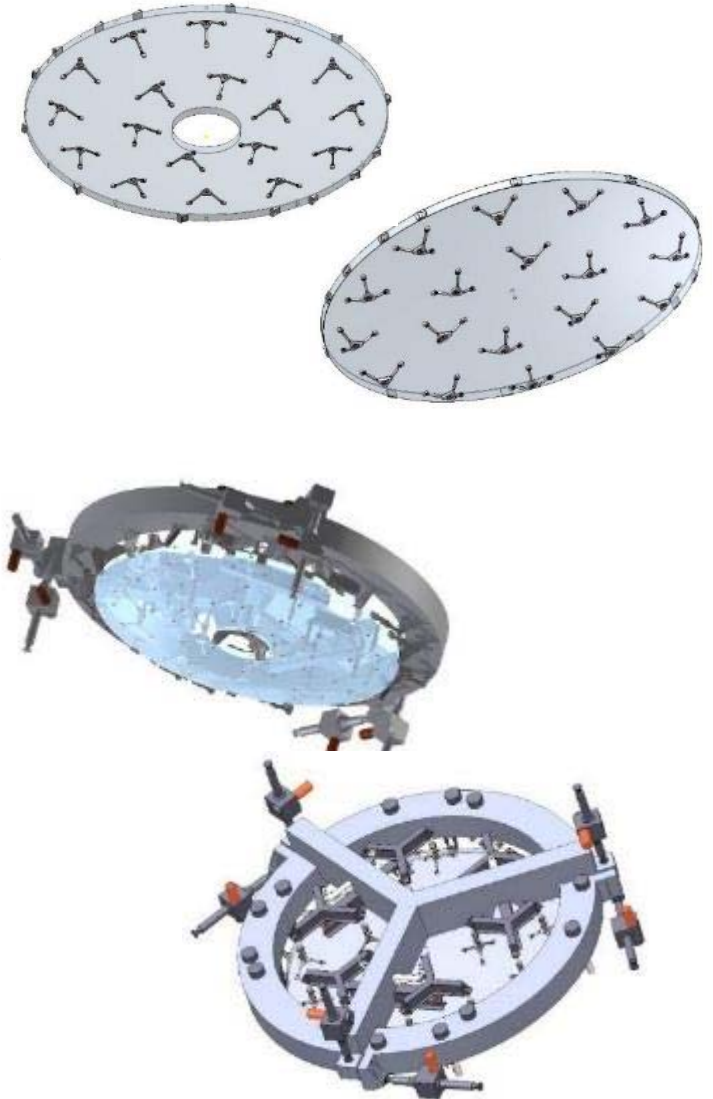
**2410 x Position Actuators  
(Including 16 Spares)**



**804 x Controllers & Electronics  
(Including 6 Spares)  
3 Channels**

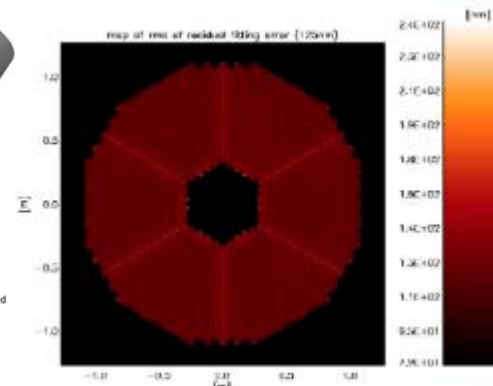
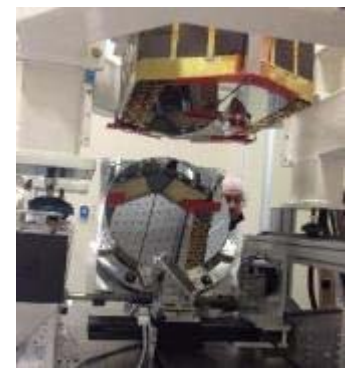
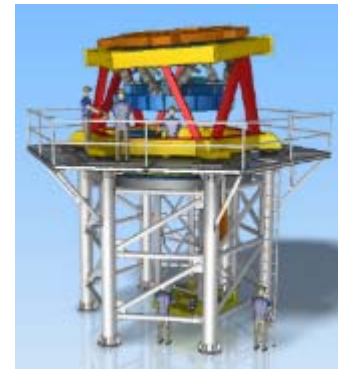
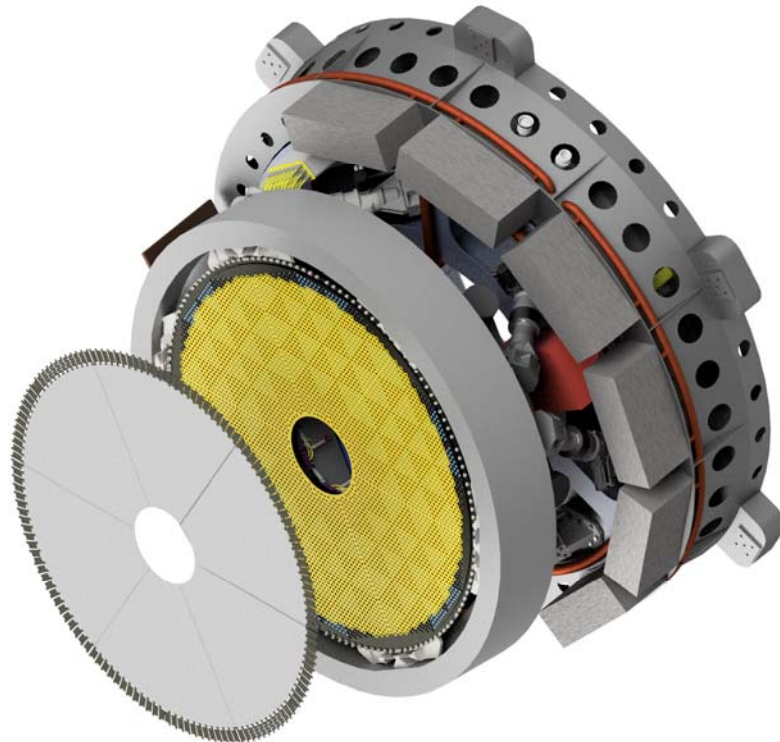
# M2 & M3 Units

- M2 Mirror: 4-m f/1.1 **convex, highly aspheric**,
  - passive
- M3 Mirror: 4-m f/2.6 concave, mild aspheric,
  - **active** shape control (warping harness) to **nanometer precision**
- M2 & M3 Cells:
  - One single procurement (synergy)
  - Axial support: 18 points whiffletree + tripods
  - Lateral support: 12 tangential struts + fixed lateral anc clocking
  - Positioning system: **hexapod with sub-micron accuracy**
  - Earthquake protection: mirror restrainers + load limiters



# M4 Unit

- 2.4-m flat adaptive mirror – 6 thin-shell petals only 1.95mm thick!
- ~5300 Voice Coil actuators driving the mirror shape at  $F_s=1$  kHz
- Contracts for Final Design and Manufacturing is running

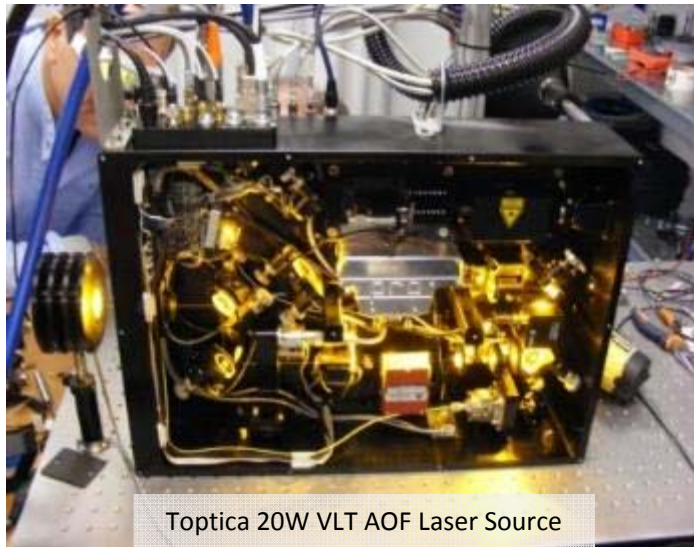


AdOptica consortium - [www.adoptica.it](http://www.adoptica.it)  
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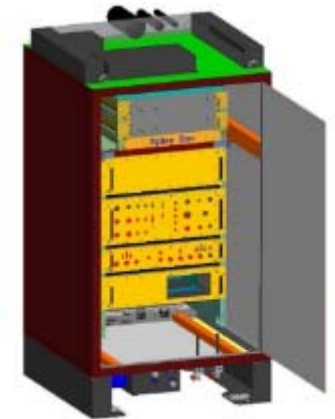
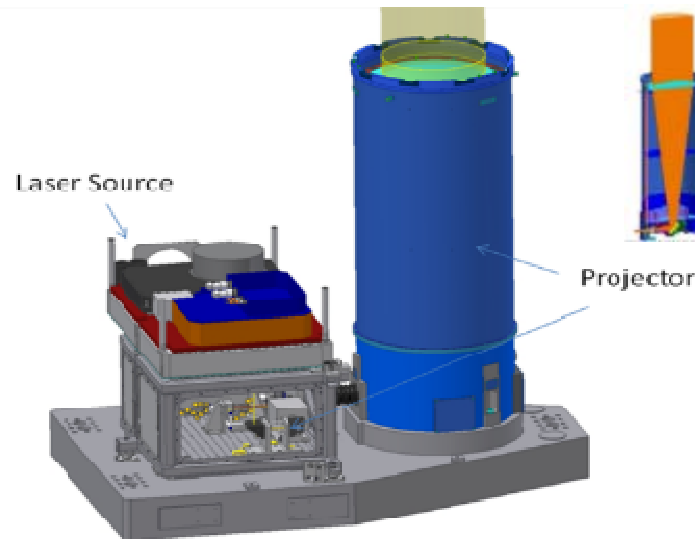




# Laser Guide Star Units



Toptica 20W VLT AOF Laser Source



Laser Source Control Electronics

**6 +1 Laser Sources**  
(Including 1 Spare)  
20/25W Raman Fiber Amplifier

**Local Electronics and Control System**

**Auxiliary Equipment**  
(AIV, handling, shipping, testing)

- 6 Laser Beam Projection Subunits**
- Mechanical Structure & enclosure
  - Beam relay and diagnostics
  - Launch Telescope
  - Baffle towers
  - Cooling
  - Control Electronics

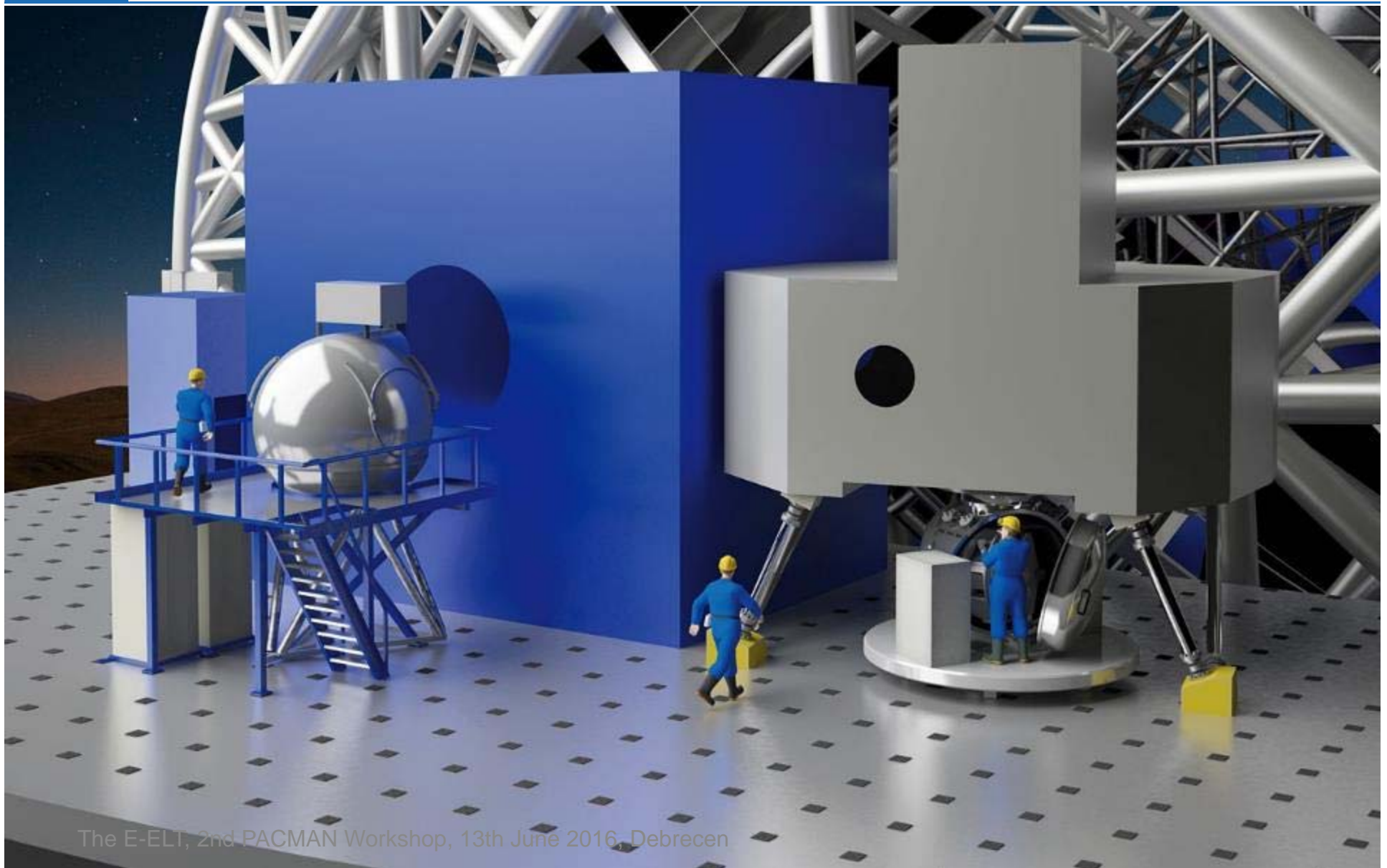


TNO 20W VLT AOF Launch Telescope





# The instruments



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# Status of Running Contracts

Overview







# Site Preparatory Work completed (Access Road & Platform)



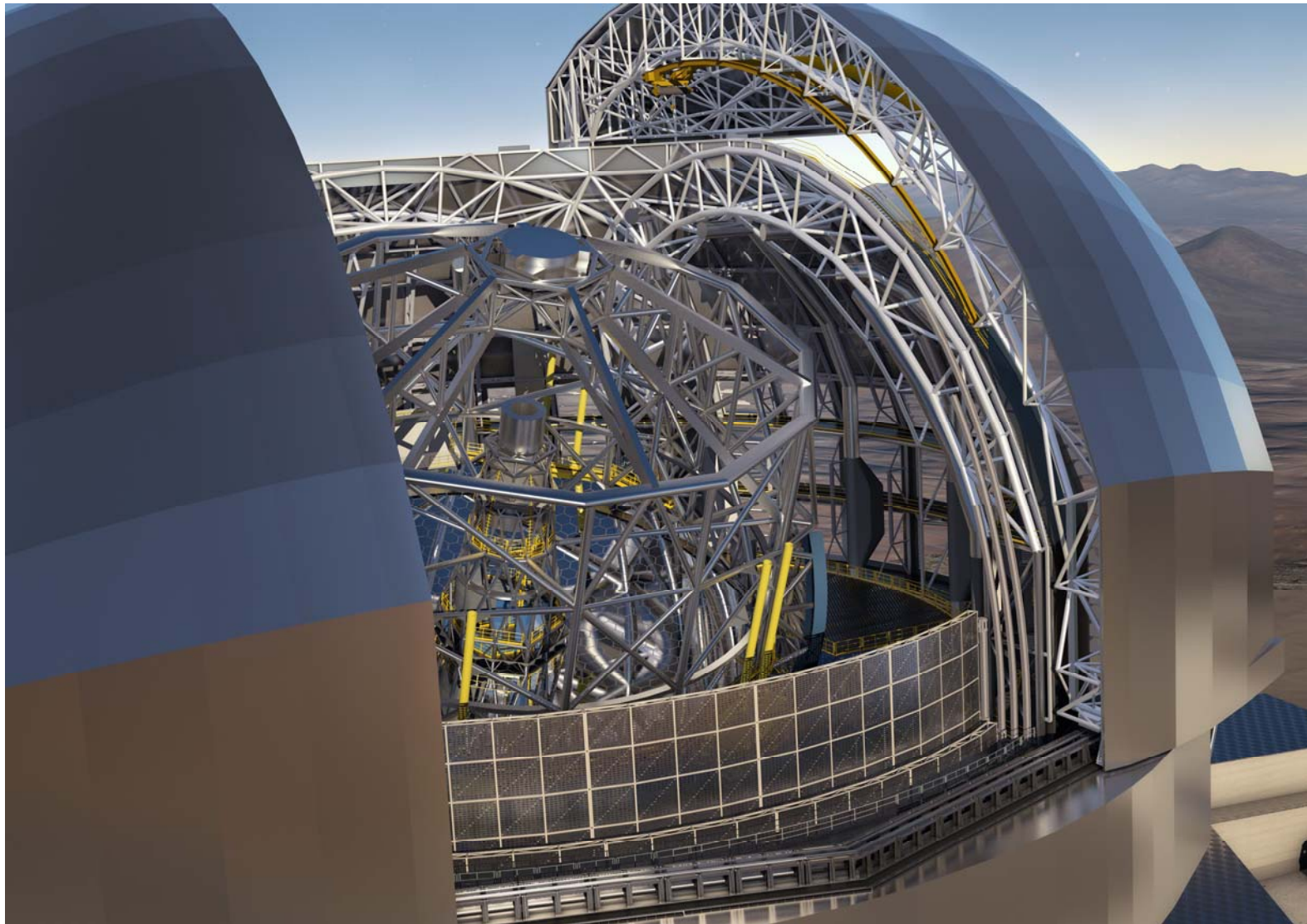
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# Dome & Main Structure contract just signed (25<sup>th</sup> May)!



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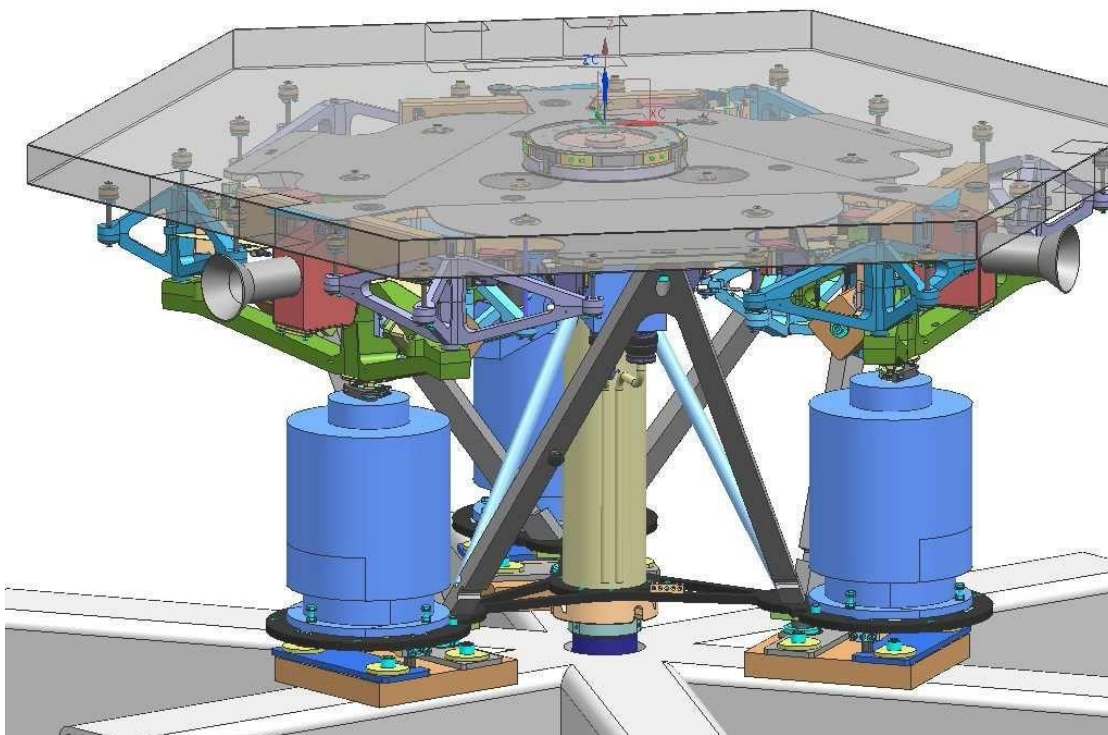
# Running contracts Status

- M1 Segment Support (x2, VDL and CESA):
  - Design to FDR and delivery of 4 qualification models
  - FDR VDL held 31 Mar
  - FDR CESA planned 22 Jun



↑  
Dummy segment for force tests

← VDL FDR Design

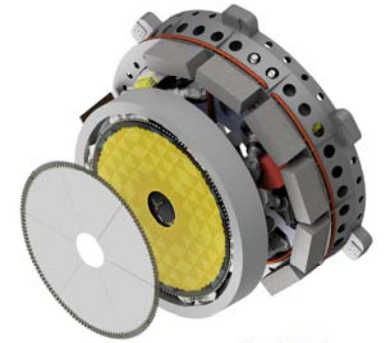




# Running contracts Status

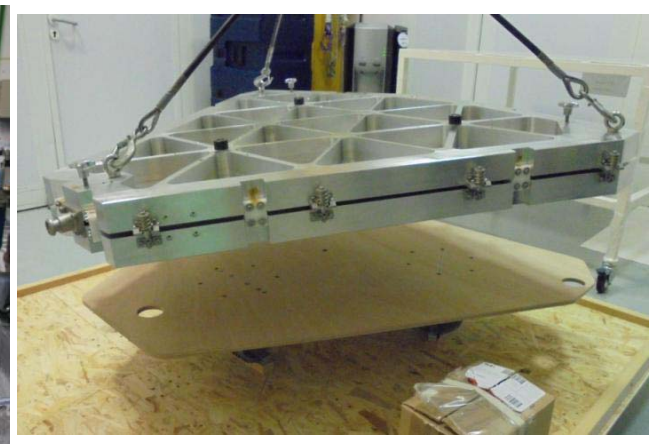
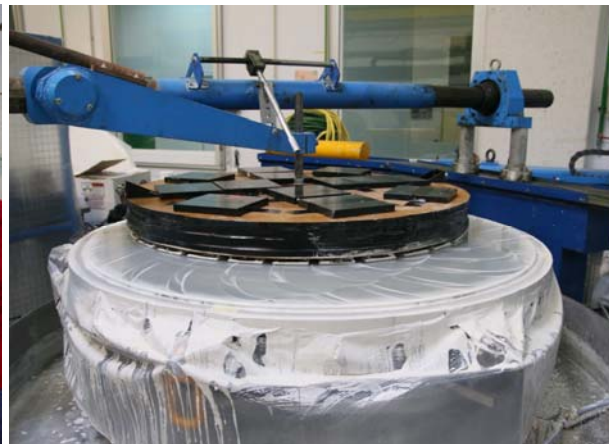
## ■ M4 Cell (AdOptica)

- Interim design review meeting held early April
- FDR planned for November



## ■ M4 Shell (REOSC)

- 4 blanks (Schott) delivered and accepted by Reosc (8 more on-going)
- Manufacturing validated by Prototype
- Packing and transport validated with dummy shell
- Cutting procedure being finalized



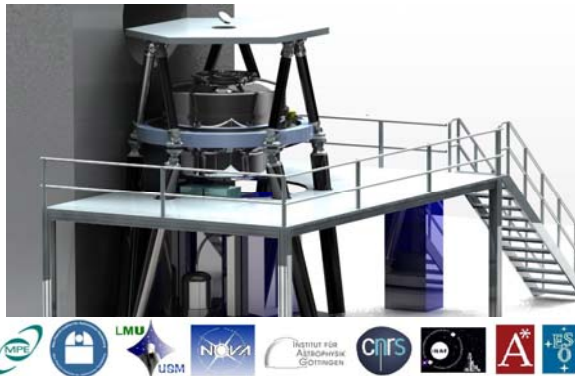
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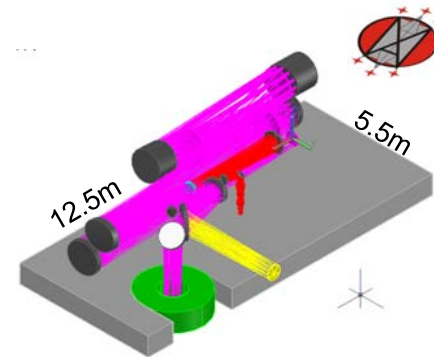
# Running contracts

## ■ Instruments

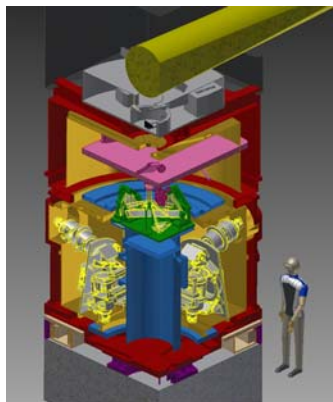
- MICADO, HARMONI, METIS, MAORY: all kicked-off, making first progress
- MOS & HIRES: Phase A Study Contract signed (Mar 18th and 22nd). Would need 2<sup>nd</sup> PFS



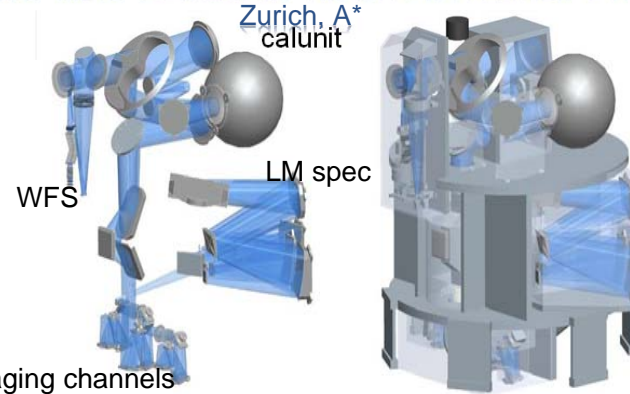
INAF OA Bologna  
IASF Bologna  
OA Arcetri  
OA Brera  
OA Capodimonte  
OA Padova  
INSU/CNRS-IPAG



Uni. Oxford,  
UK ATC,  
CRAL,  
CSIC,  
IAC,  
RAL,  
IPAG,  
ONERA,  
LAM,  
ESO



NOVA, MPIA, CEA-Saclay, UK ATC, K.U.Leuven, ETH





# Contracts (>500k) coming soon

Year	Month	Item
2016	Feb	DMS
	May	M2 Polishing
	Nov	M2 Blank
	Nov	M2 Cell
	Nov	M3 Cell
	Nov	M3 Mirror
	Nov	M1 Segments Polishing
2017	May	M1 Position Actuators
	May	M1 Edge Sensors
	May	Core integration infrastructure construction
	May	23 kV Underground Cable Line
	Nov	PFS A Optomech Sub Unit (Phase 1)
	Nov	PFS A Sensor Arms
	Nov	PFS A - Phasing Station
	Nov	Mirror washing units (M1 and 5m)
	Nov	Mirror coating units (M1)
	Nov	Paranal Storage Hall
	Nov	RTC Infrastructure
	Nov	Mirror coating unit (5m)

## ***Planned Approval Dates by ESO Finance Committee***





Thank You !





# Science with the E-ELT

