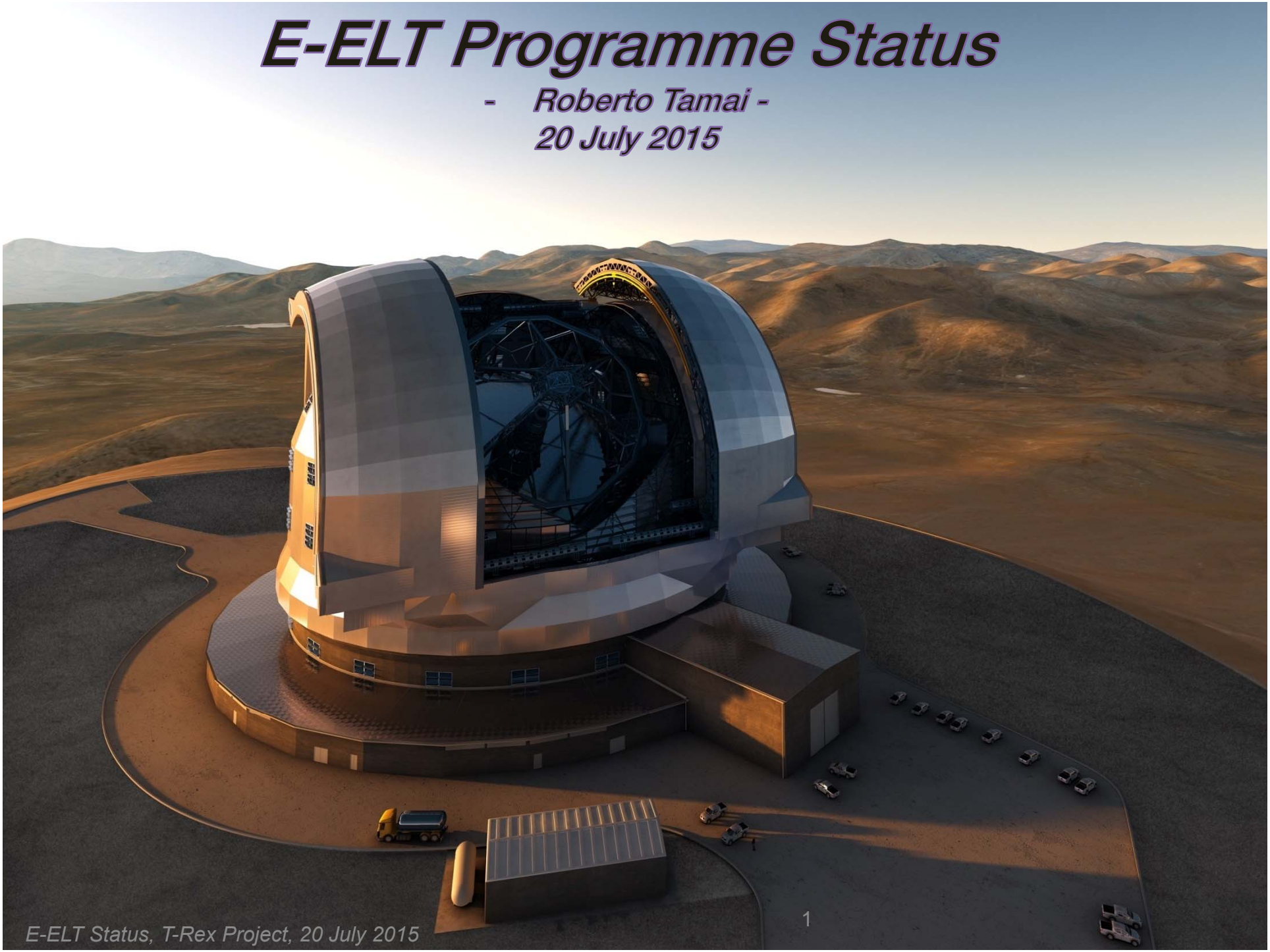
E-ELT Programme Status

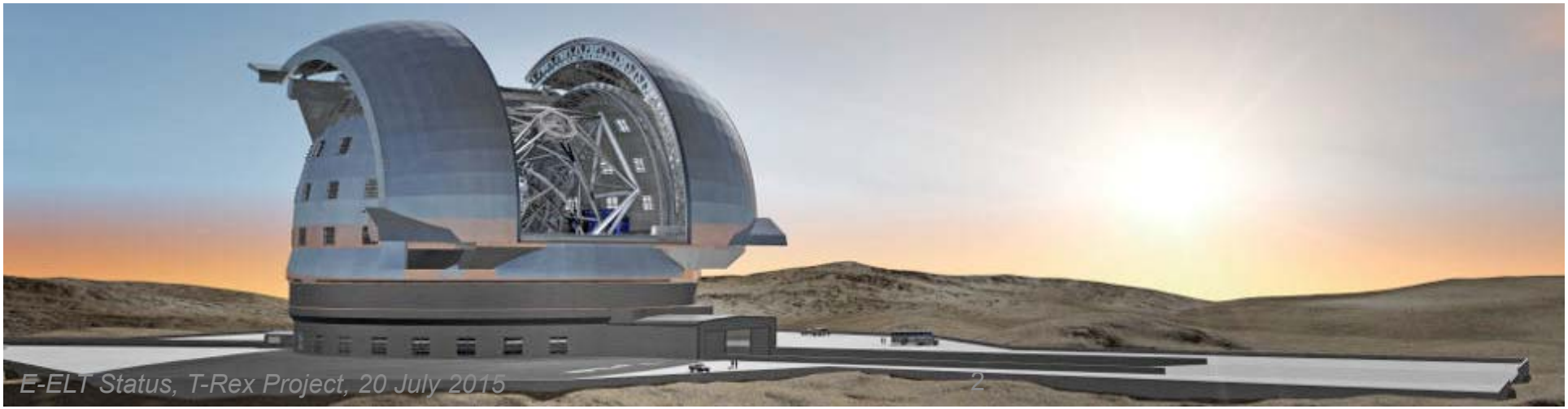
- Roberto Tamai -

20 July 2015



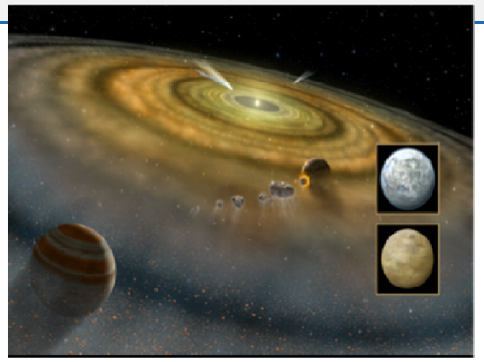
E-ELT

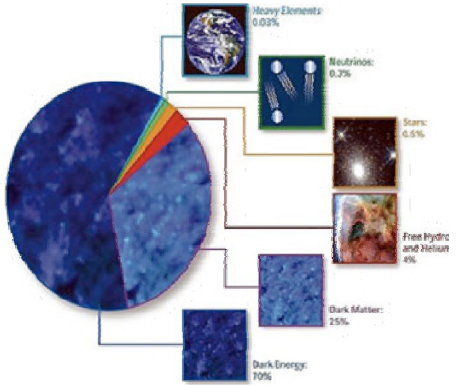
- Largest optical/infrared telescope in the world
  - 39m segmented primary mirror: transformational step
  - Science: exo-earths, deep universe, resolved populations
  - Design essentially complete, incl. instrumentation roadmap
- Project
  - Construction 2014-2024, on Cerro Armazones
    - As *integral part* of the Paranal Observatory ('one more telescope')
  - ESO cost: ~1100 MEUR incl. instruments and contingency



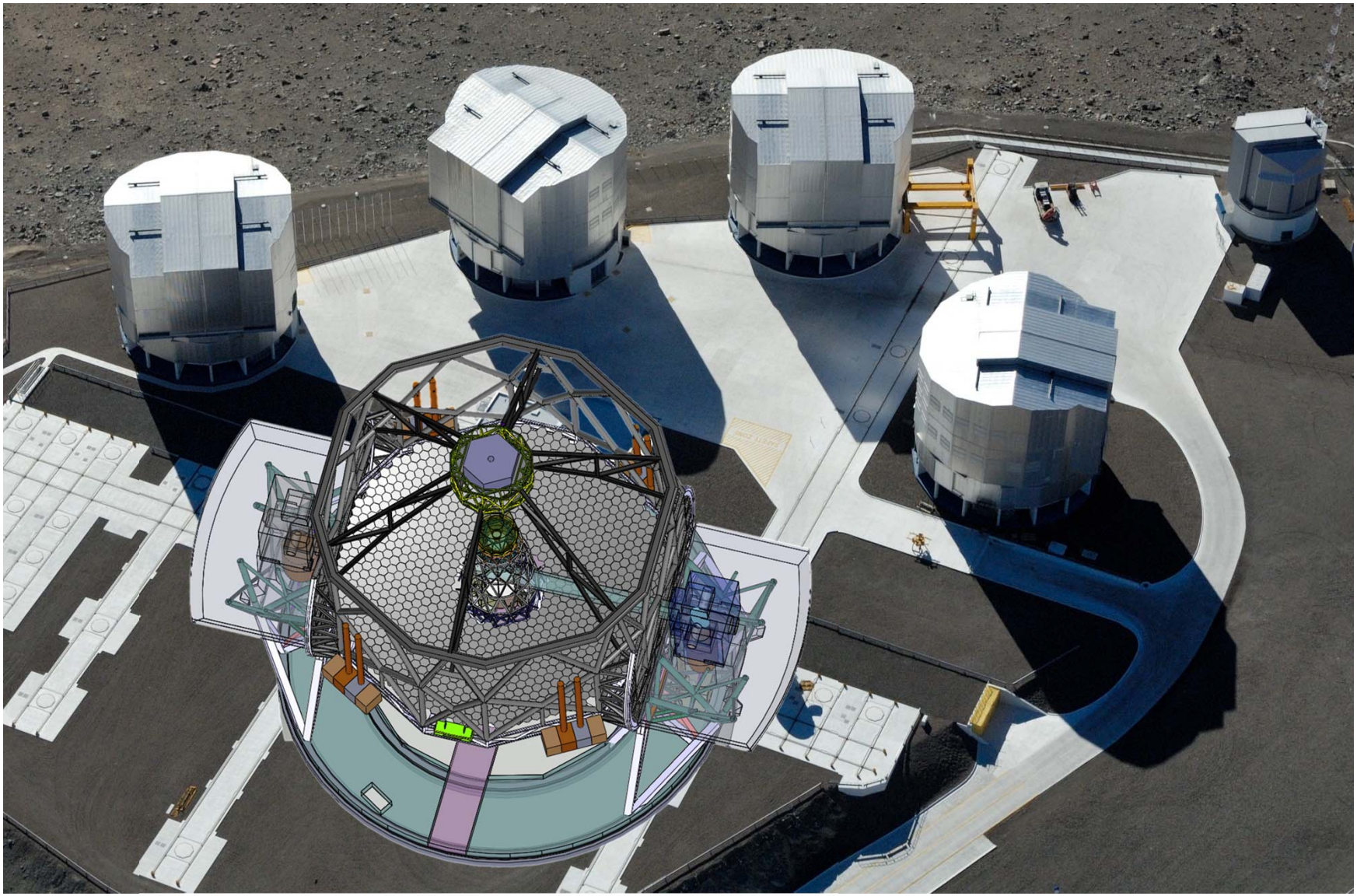
Science drivers

- 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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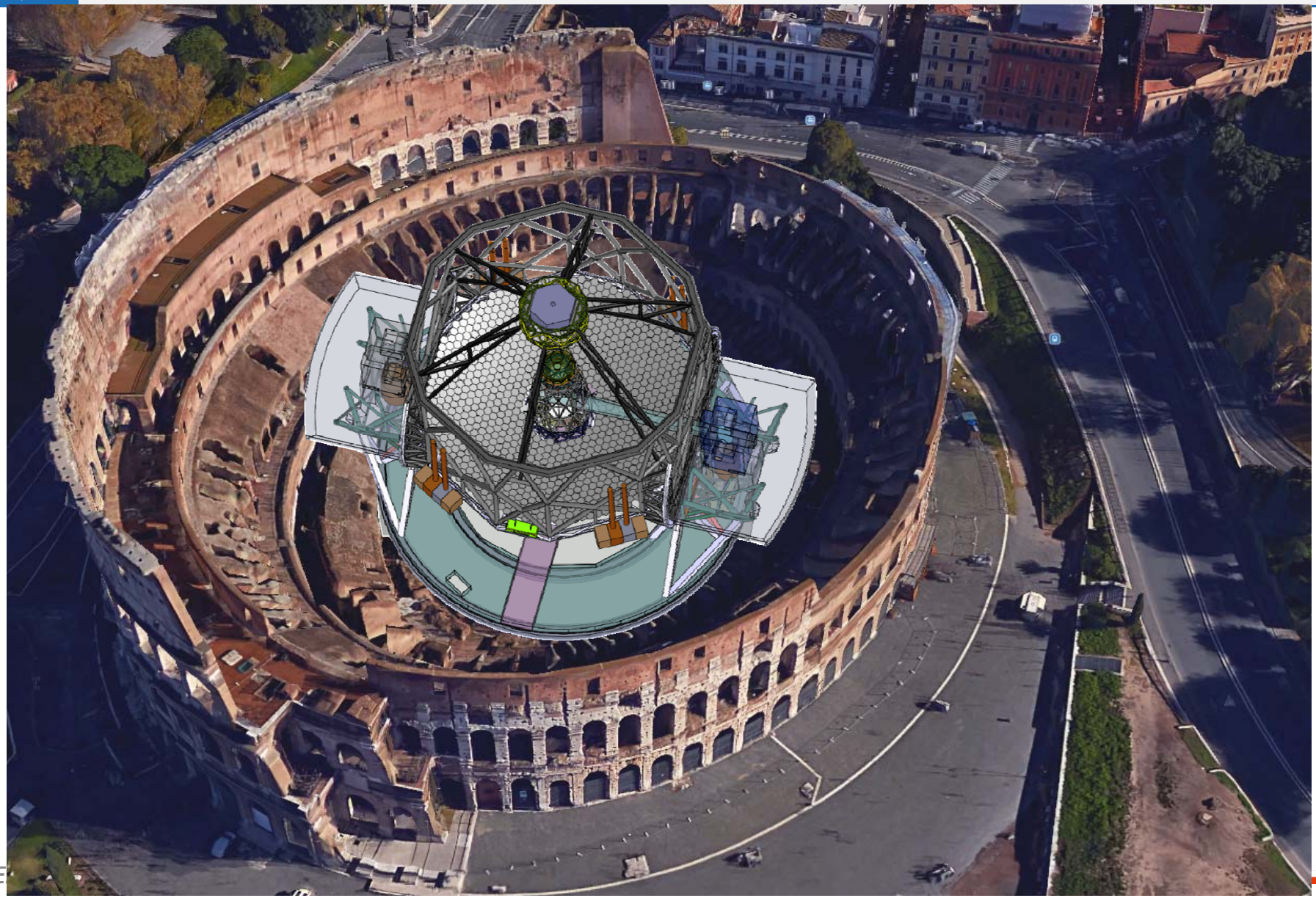


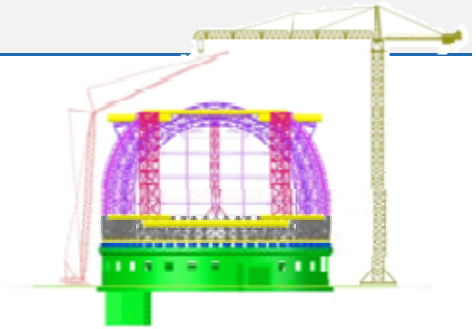
E-ELT Overview Description

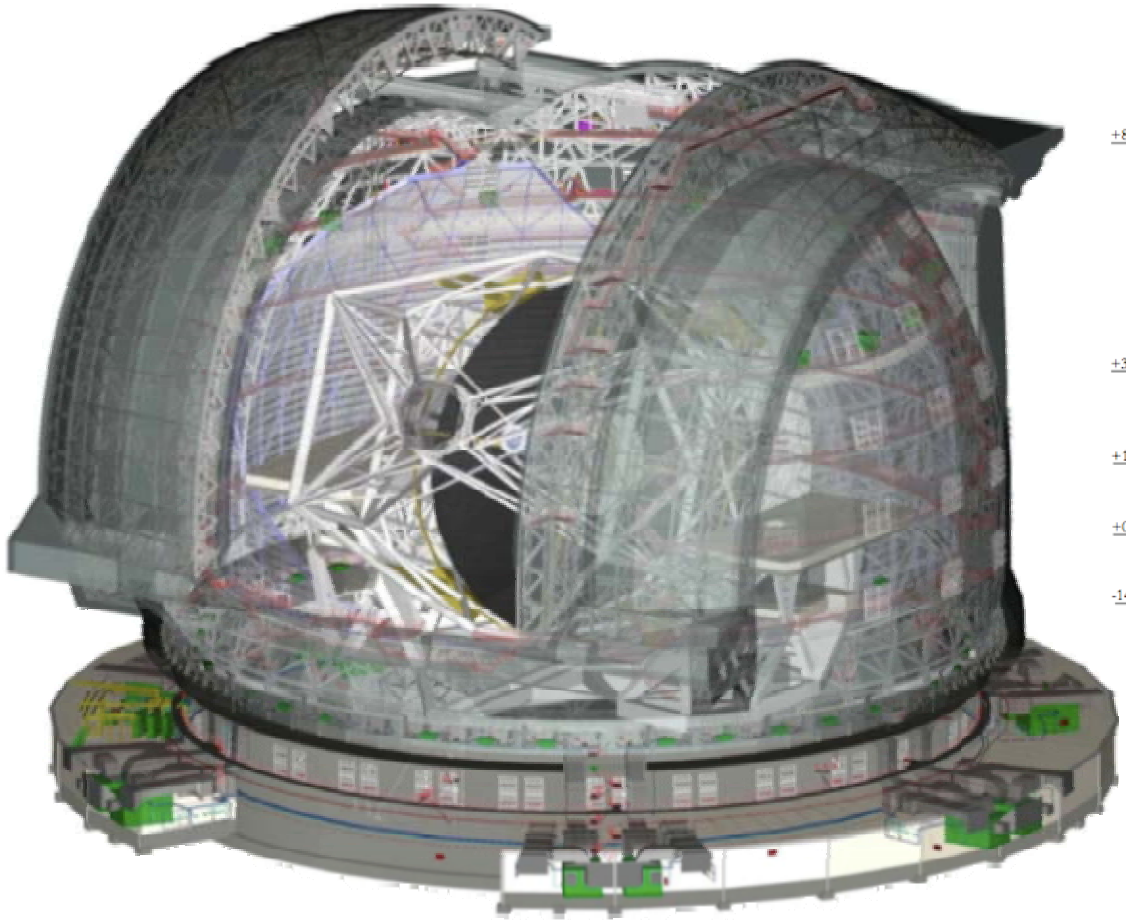
Armazones and Paranal

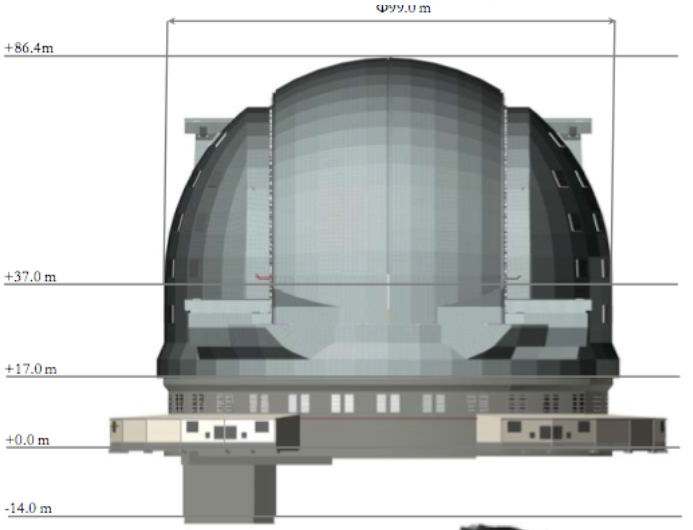
The E-ELT: overview

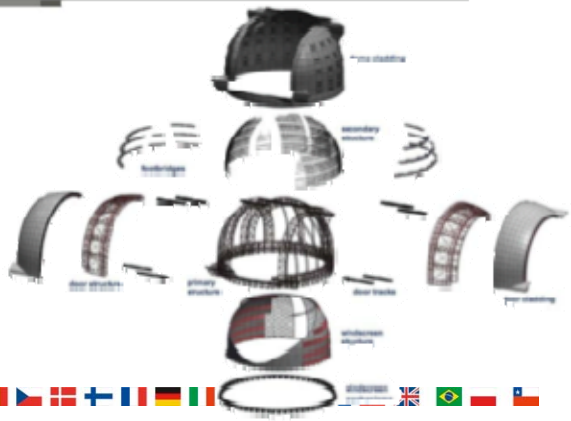
Dome

- *2 FEED contracts*
- *Erection sequence*



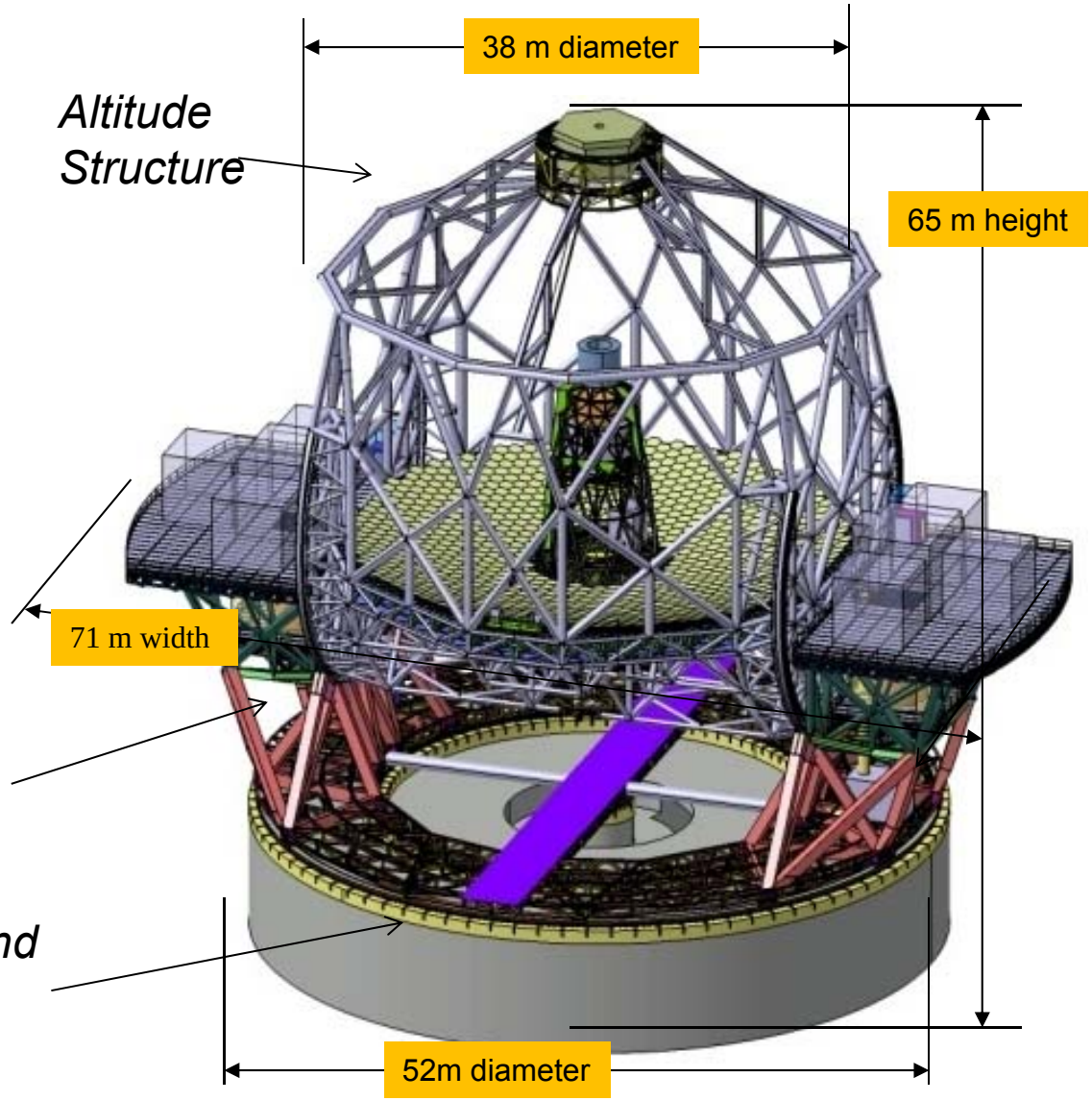




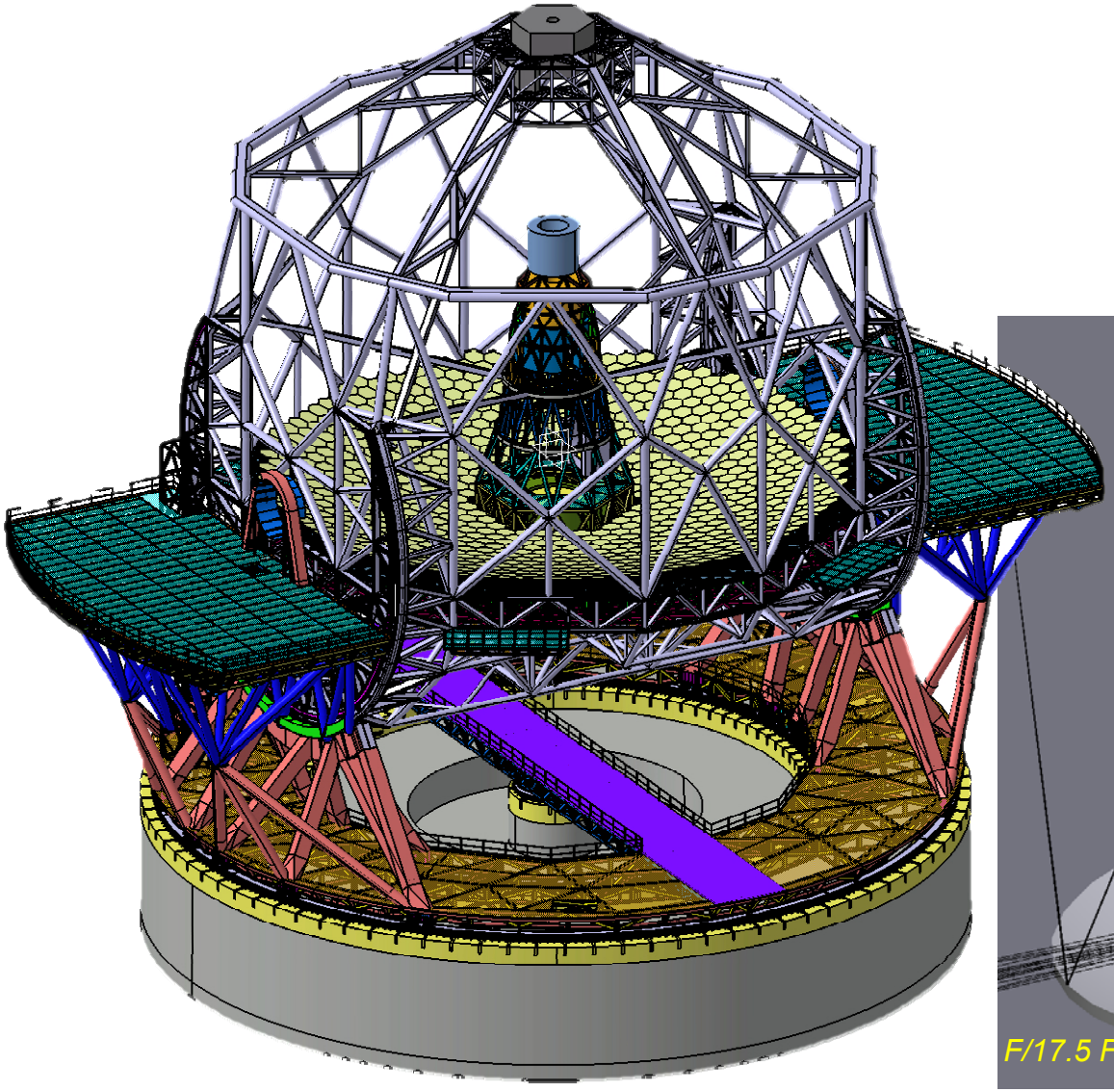


The E-ELT: Main Structure

The Main Structure is about 2500 tons of steel holding and moving 700tons of opto-mechanics and electronics around two perpendicular axes (azimuth and altitude) supported on hydrostatic bearings and driven by electrical direct drive motors with a precision of 0.3 arcsec under the maximum wind disturbance.

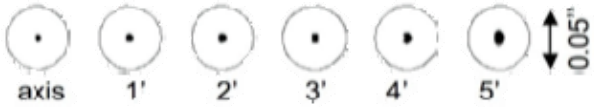


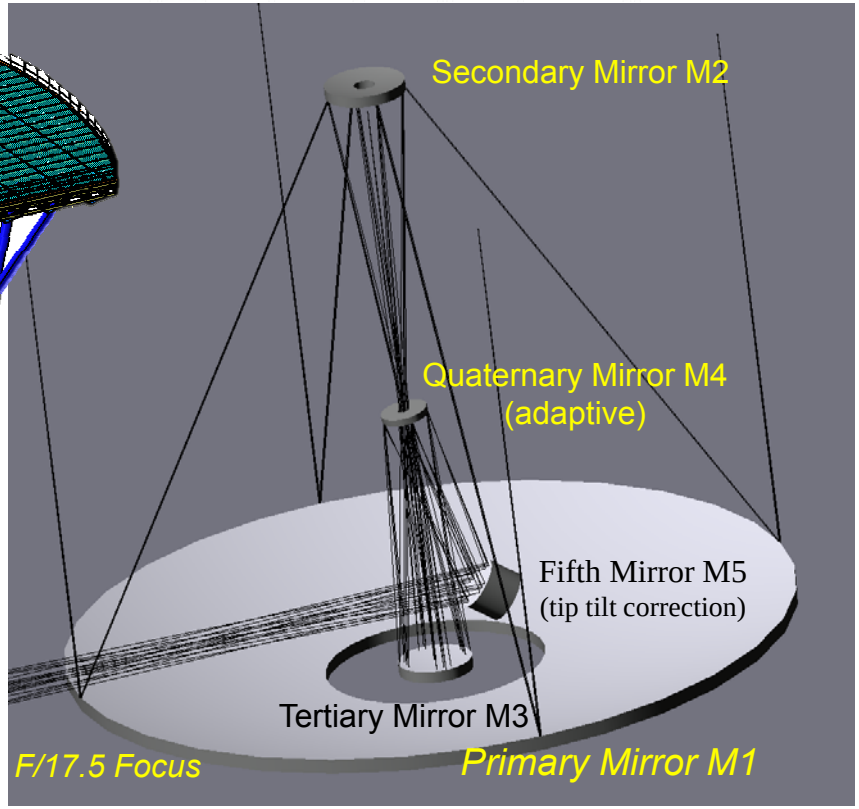
The E-ELT: overview



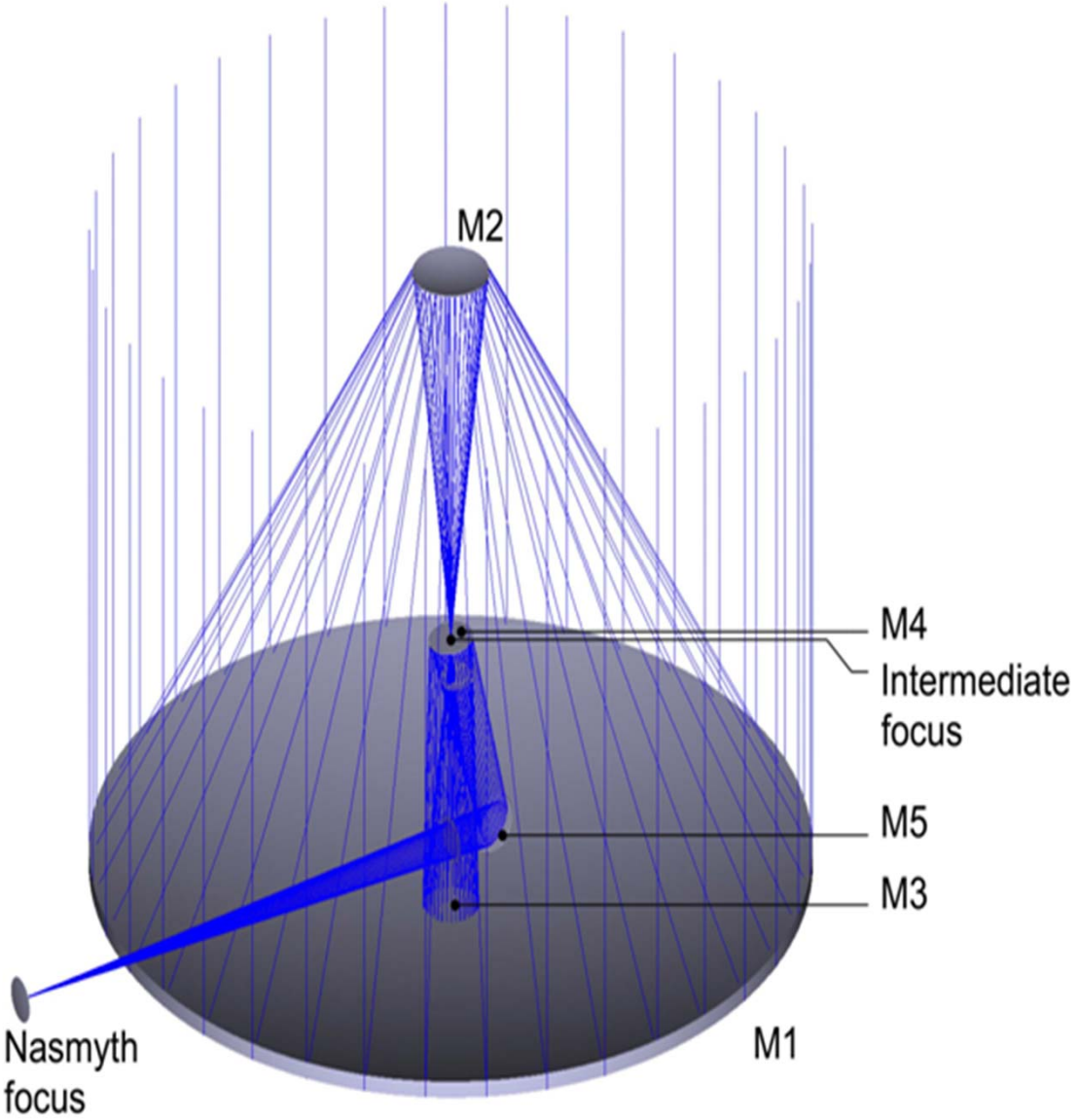
Optical design

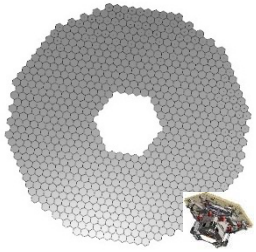
- *3-mirror anastigmat on axis + 2 flats*
- *diffraction limited over full 10' FoV*
- *very low LGS wavefront aberrations*



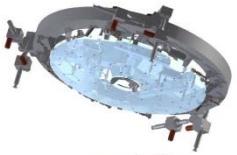


E-ELT Optomechanics



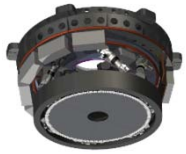


M1 Unit
39-m
Concave – Aspheric f/0.9
Segmented (798 Segments)
Active + Segment shape Control



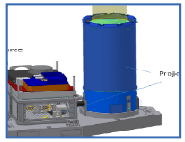
M2 Unit
4-m
Convex Aspheric f/1.1
Passive + Position Control

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



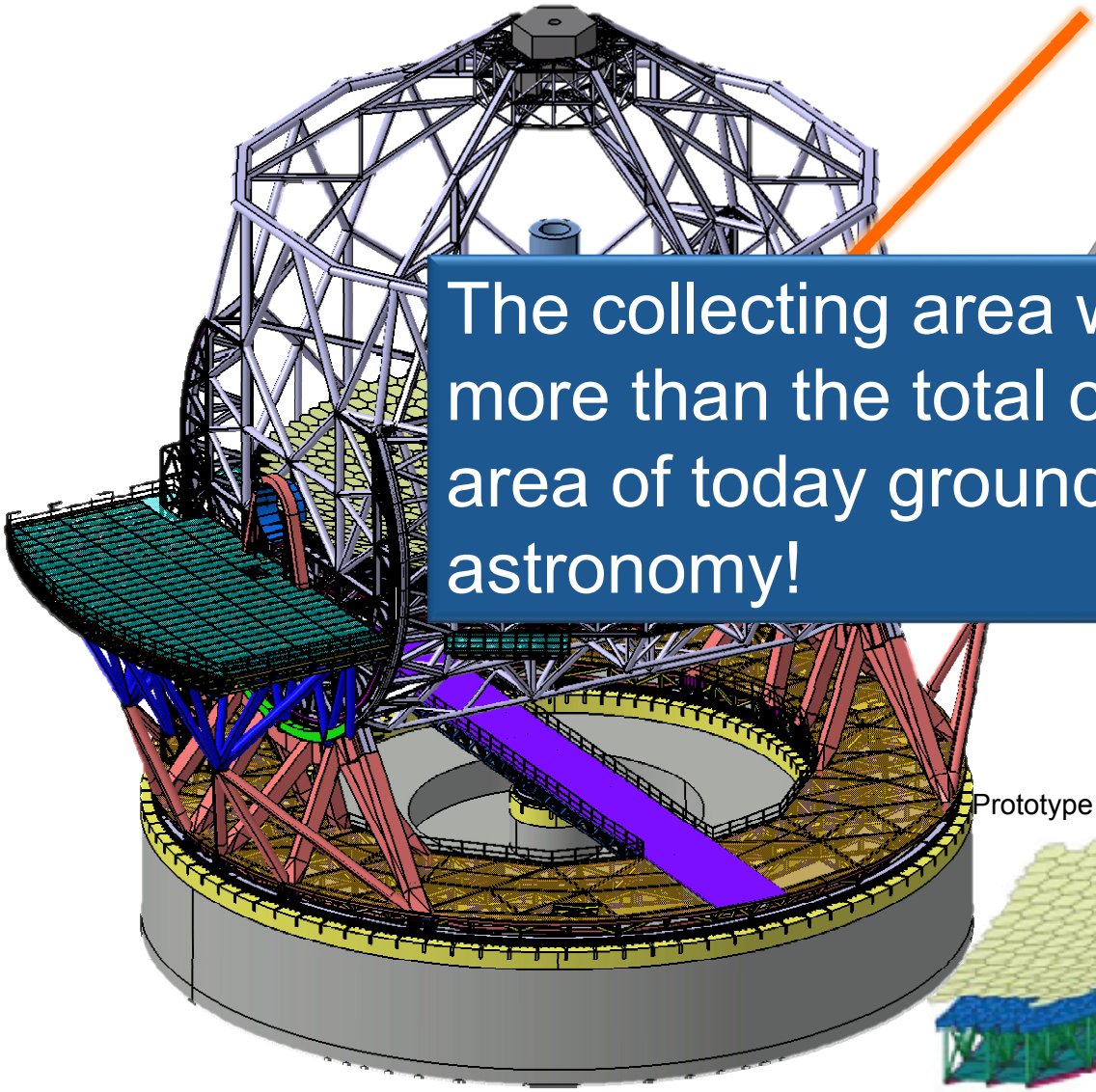
M4 Unit
2.4-m
Flat
Segmented (6 petals)
Adaptive + Position Control

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



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

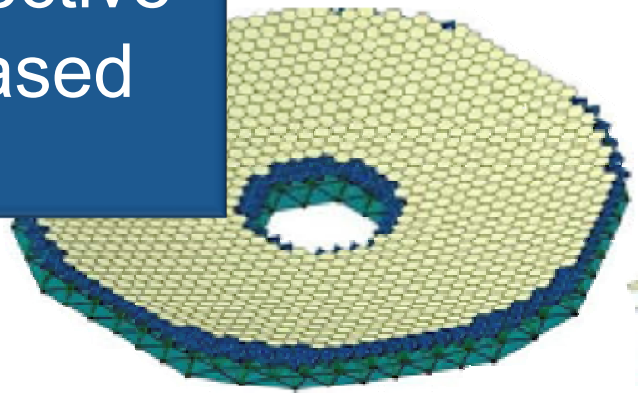
The E-ELT: overview



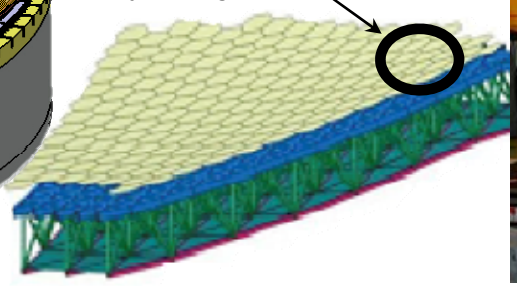
39m Primary Mirror

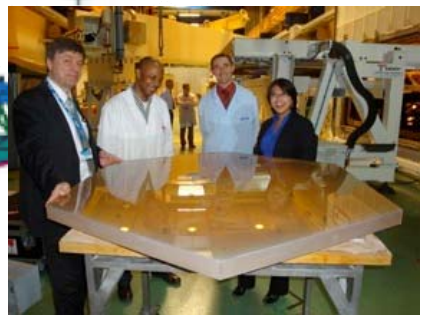
- *798 segments mirror +1/family*
- *2 x 7 prototypes FEEDs*
- *prototype support, PACTs, edge sensors*

The collecting area will be more than the total collective area of today ground based astronomy!

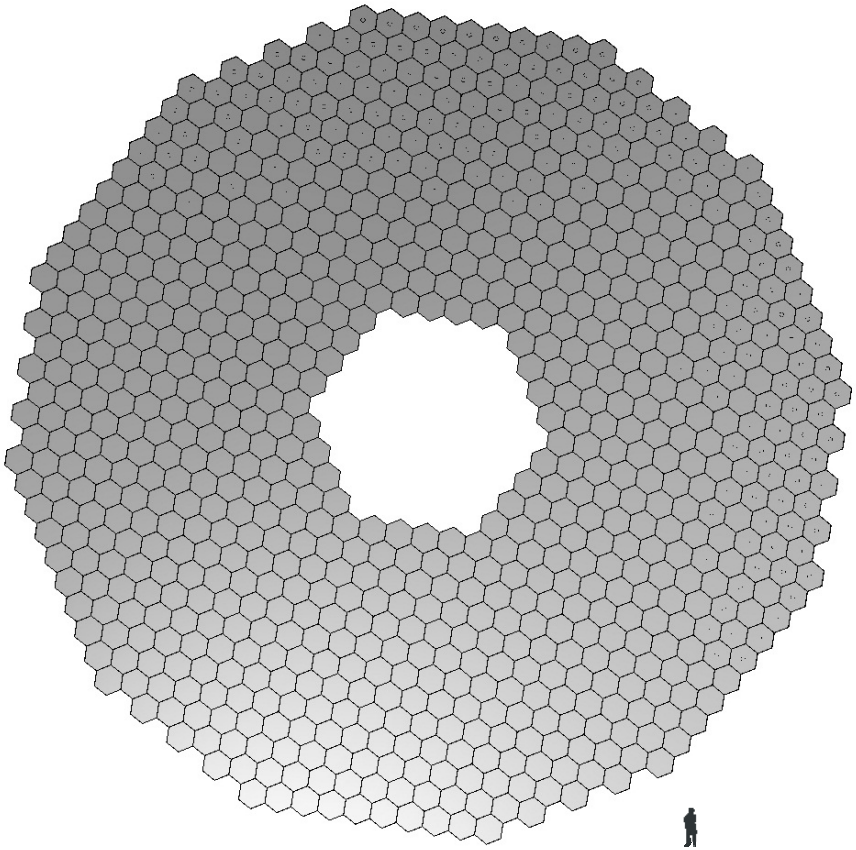


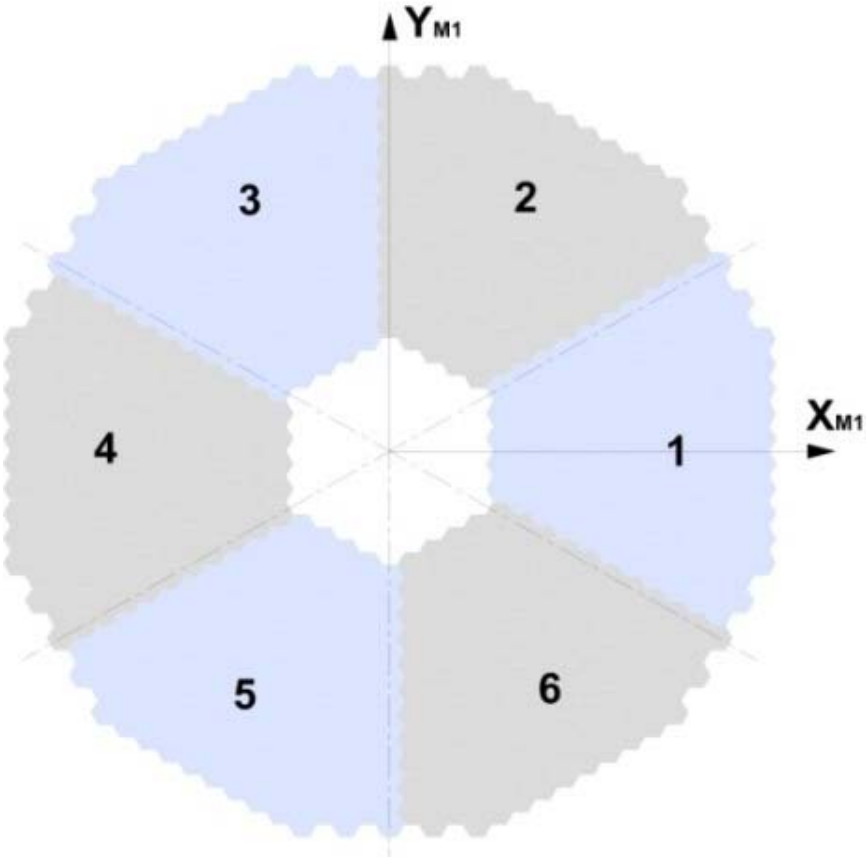
Prototype segments





M1 Unit

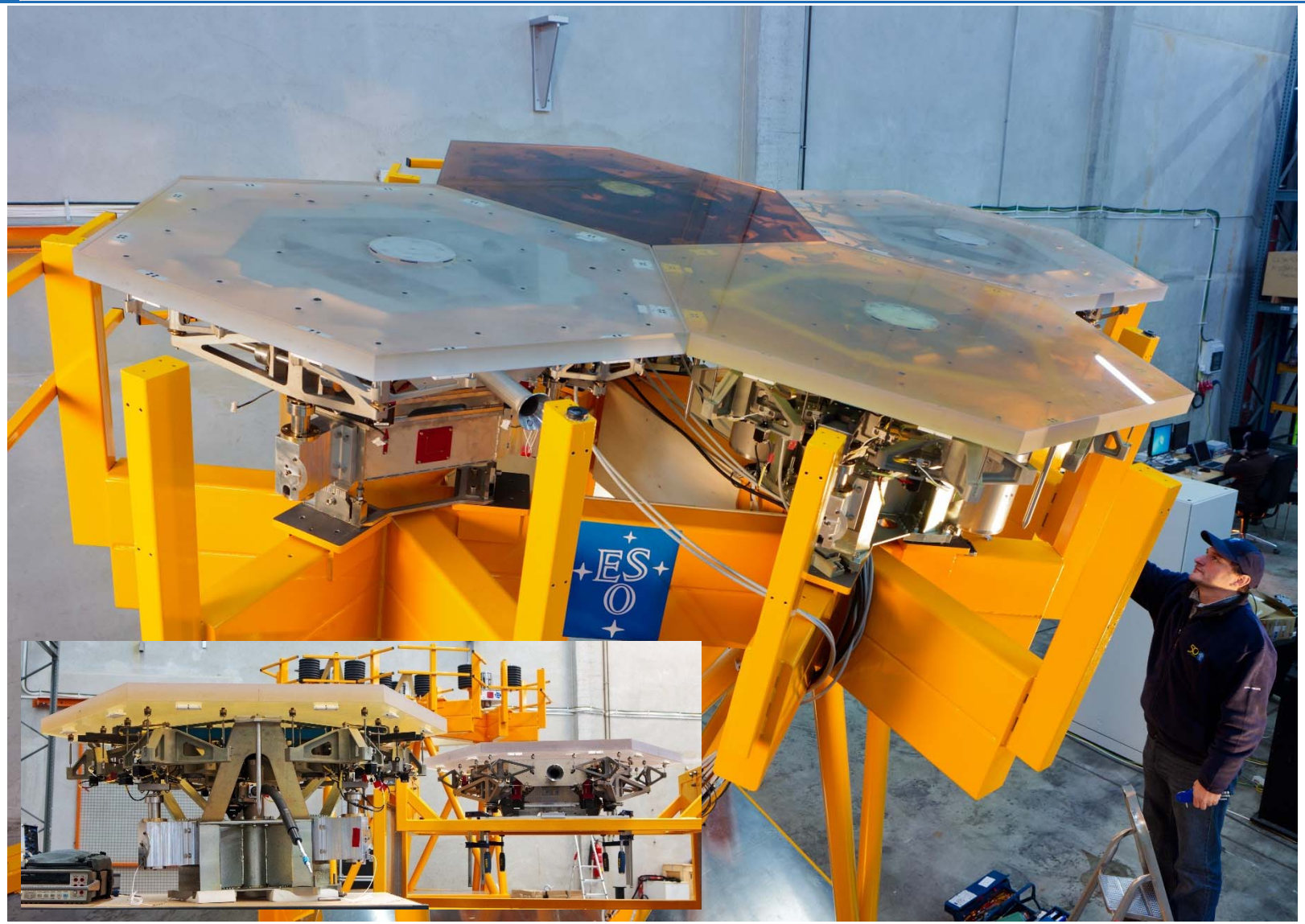




39-m diameter
6 x 133 segments (1.4-m)
1 x 133 spare segments
Total: 931 segments

M1 Mirror	
Outer diameter (mm)	39146.0
Inner diameter (mm)	9418.4
M1 Optical Prescription	
Radius of curvature (mm)	68685
Conic constant	-0.9964064

M1 Unit



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

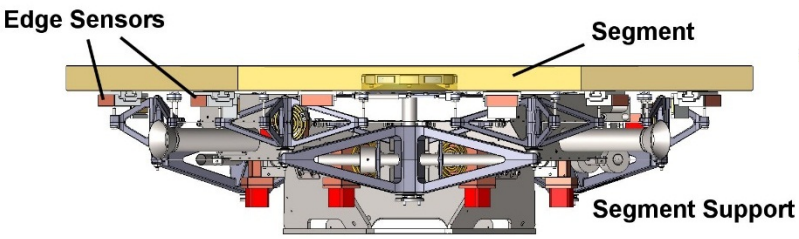
& SA Auxiliary Equipment
[SA Handling Tools, SA Transport Containers, SA AIV Tools]

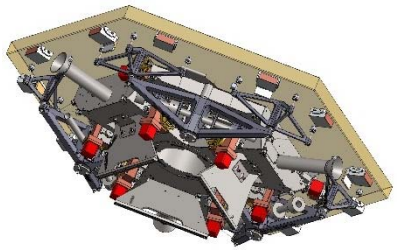
2394 x M1 Position Actuators

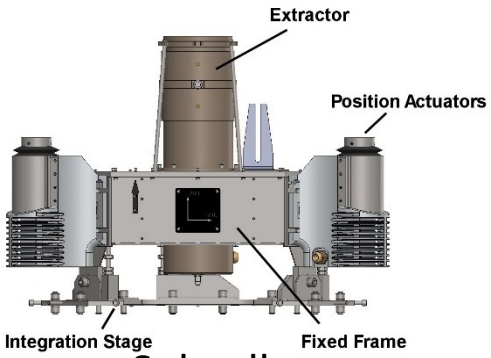
2394 x Actuators + 798 x Electronics + Spares (16 x PACT – 6 x Controllers)

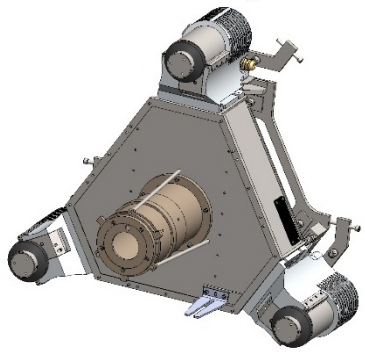
M1 Auxiliary Equipment

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









Subcell

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

M1 Unit – Segment Supports

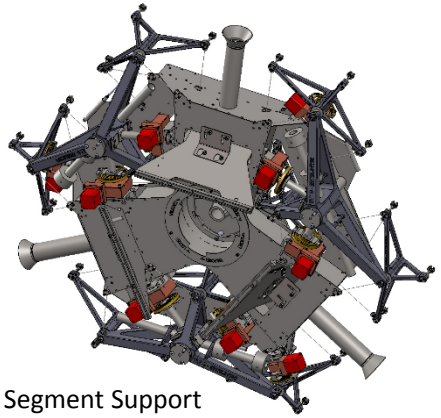
931 x M1 Segment Supports

798 x M1 Fixed Frames

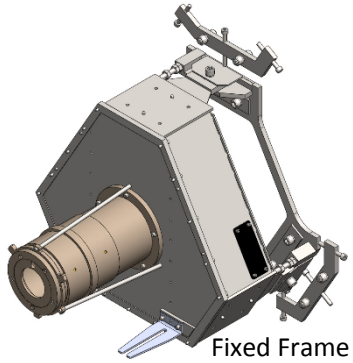
3 x M1 SA Handling Tools

798 x M1 SA Transport Containers

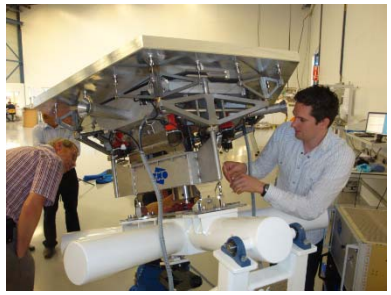
1 x M1 SA AIV Tools



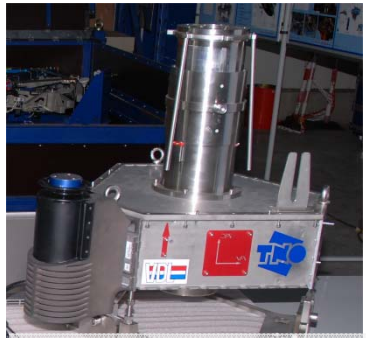
Segment Support



Fixed Frame



Prototype Segment Support



Prototype Fixed Frame

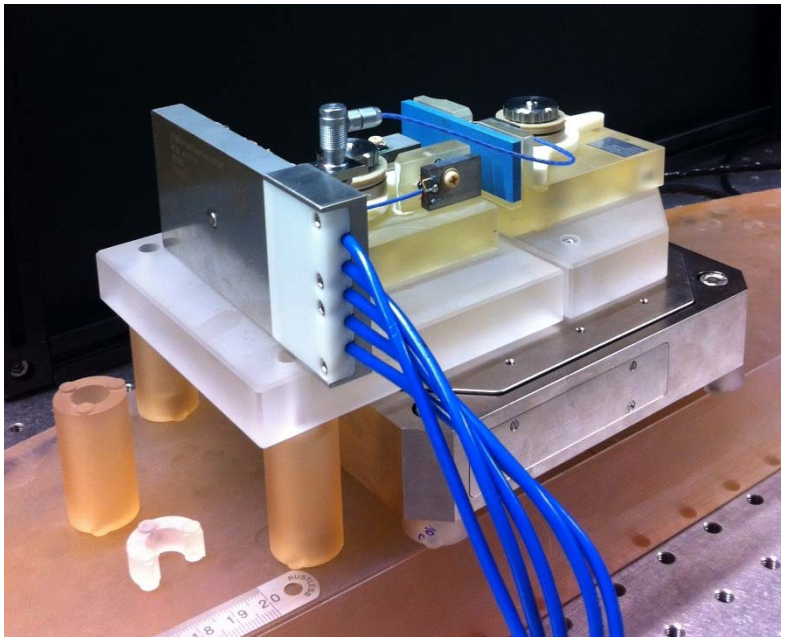
Extraction & Handling

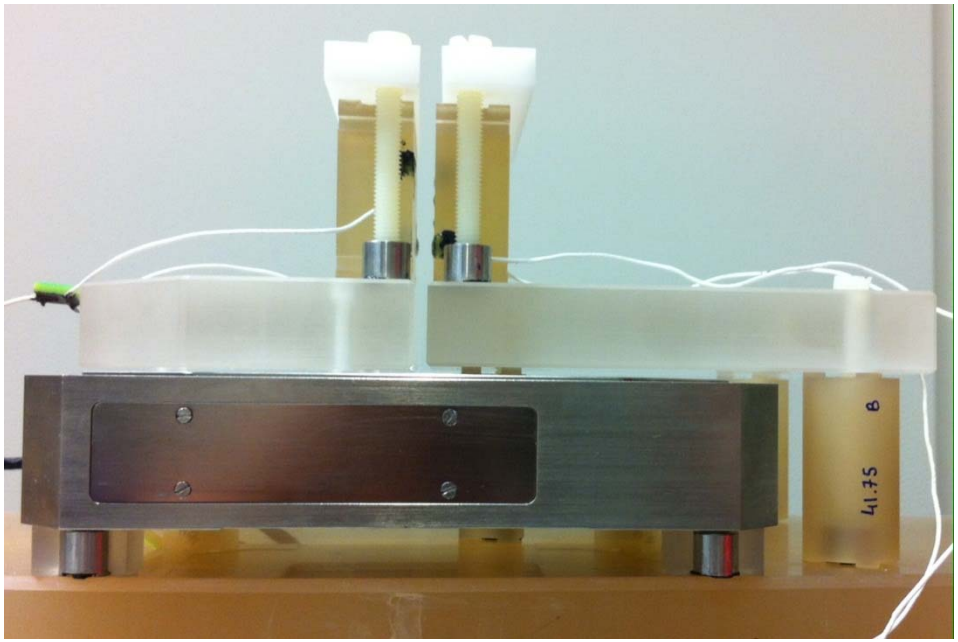
Prototype Transport Container

AIV Tooling

Handling Tool

M1 Unit – Edge Sensors





4630 x M1 Edge Sensors
(Including 100 Spares)

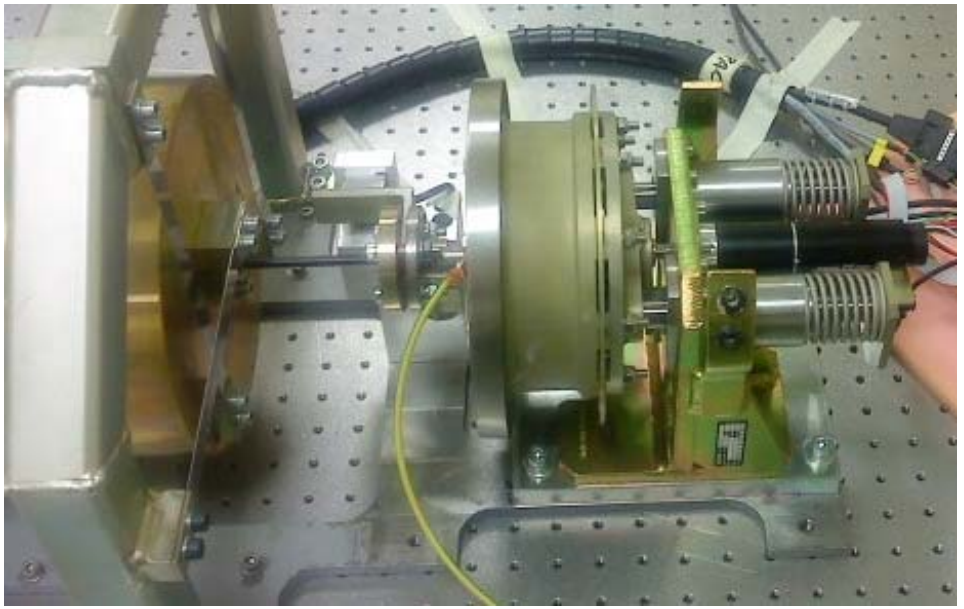
813 x Controllers & Electronics
(Including 15 Spares) – One for 6 Sensors

Dummy Masses
To equip M1 free edges
For figuring

M1 Unit – Position Actuators

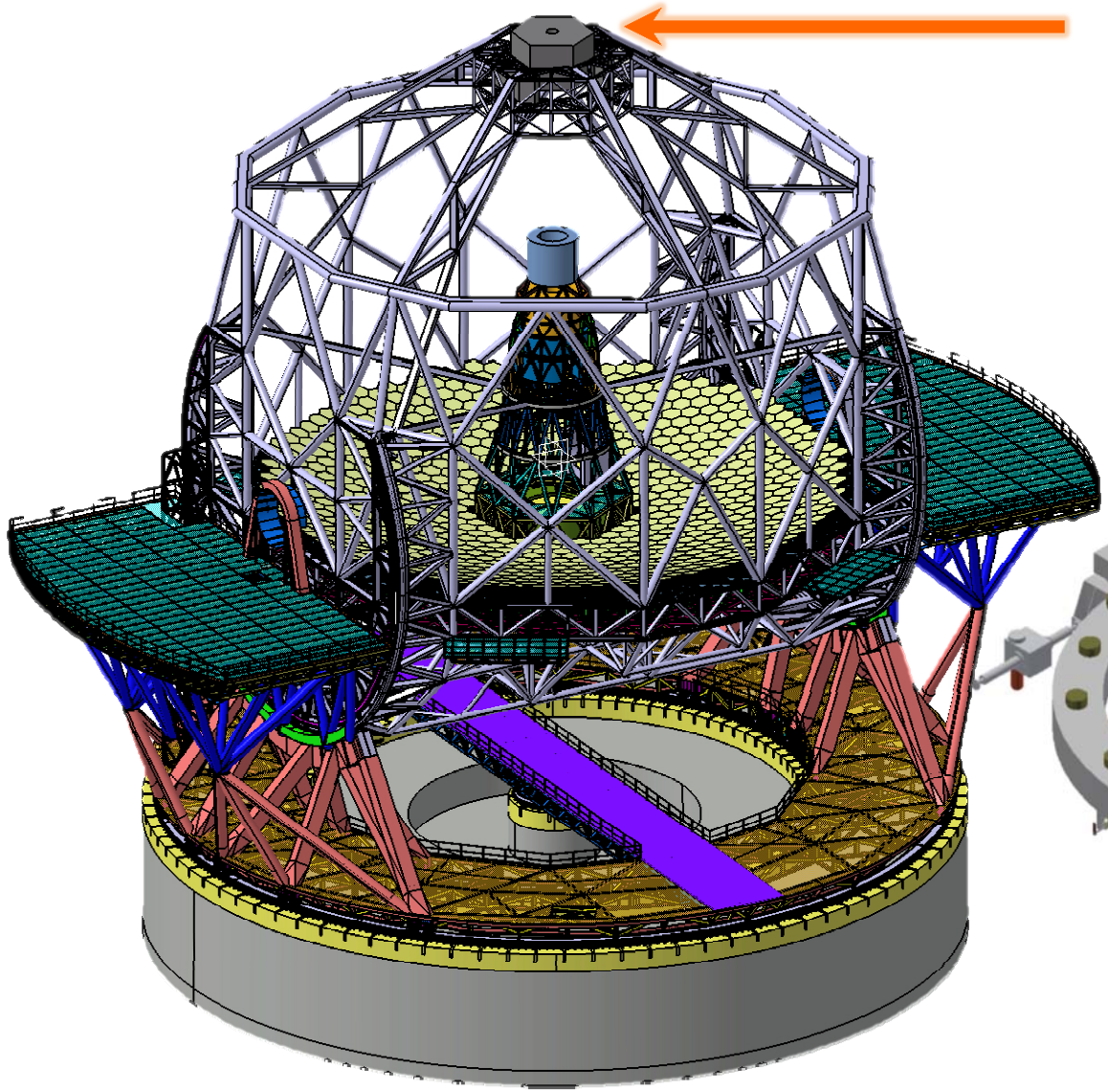
- 2 Stage actuators – nm precision along 15 mm stroke.
- 2 Technologies still competing:
  - Hard PACTs (Piezo) / Soft PACTs (voice coil)

2410 x Position Actuators
(Including 16 Spares)



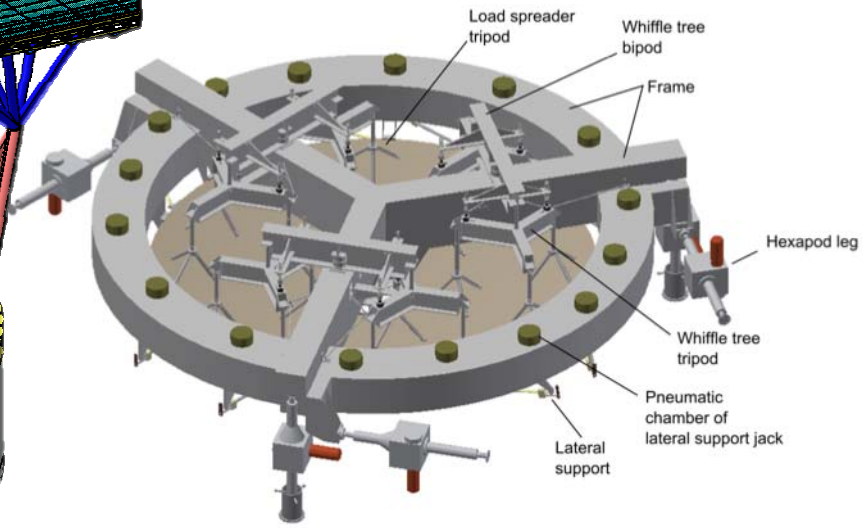
804 x Controllers & Electronics
(Including 6 Spares)
3 Channels

The E-ELT: overview



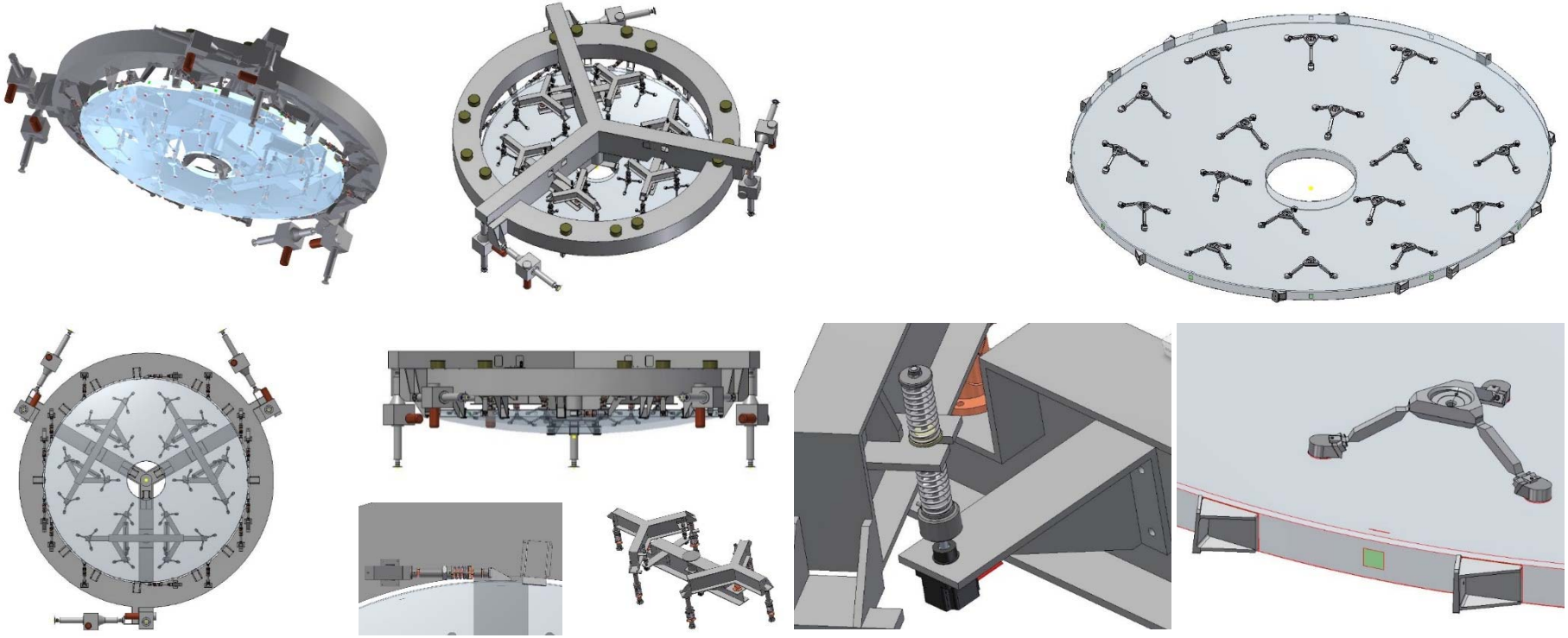
4.1m Secondary Mirror

- *M2 unit FEED, 3 polishing studies*
- *Convex shape*
- *Looking downward*
- *passive concept, with warping harnesses*
- *supported on 18 points, whiffle tree.*
- *total stiffness has increased.*
- *passive secondary simplifies the control strategy*



M2 Unit

- Passive 4-m f/1.1 convex mirror, highly aspheric (+ warping harness provision)
- Axial support: 18 points whiffletree + tripods
- Lateral support: 12 tangential struts + fixed lateral and clocking
- Positioning system: hexapod with sub-micron accuracy
- Earthquake protection: mirror restrainers + load limiters



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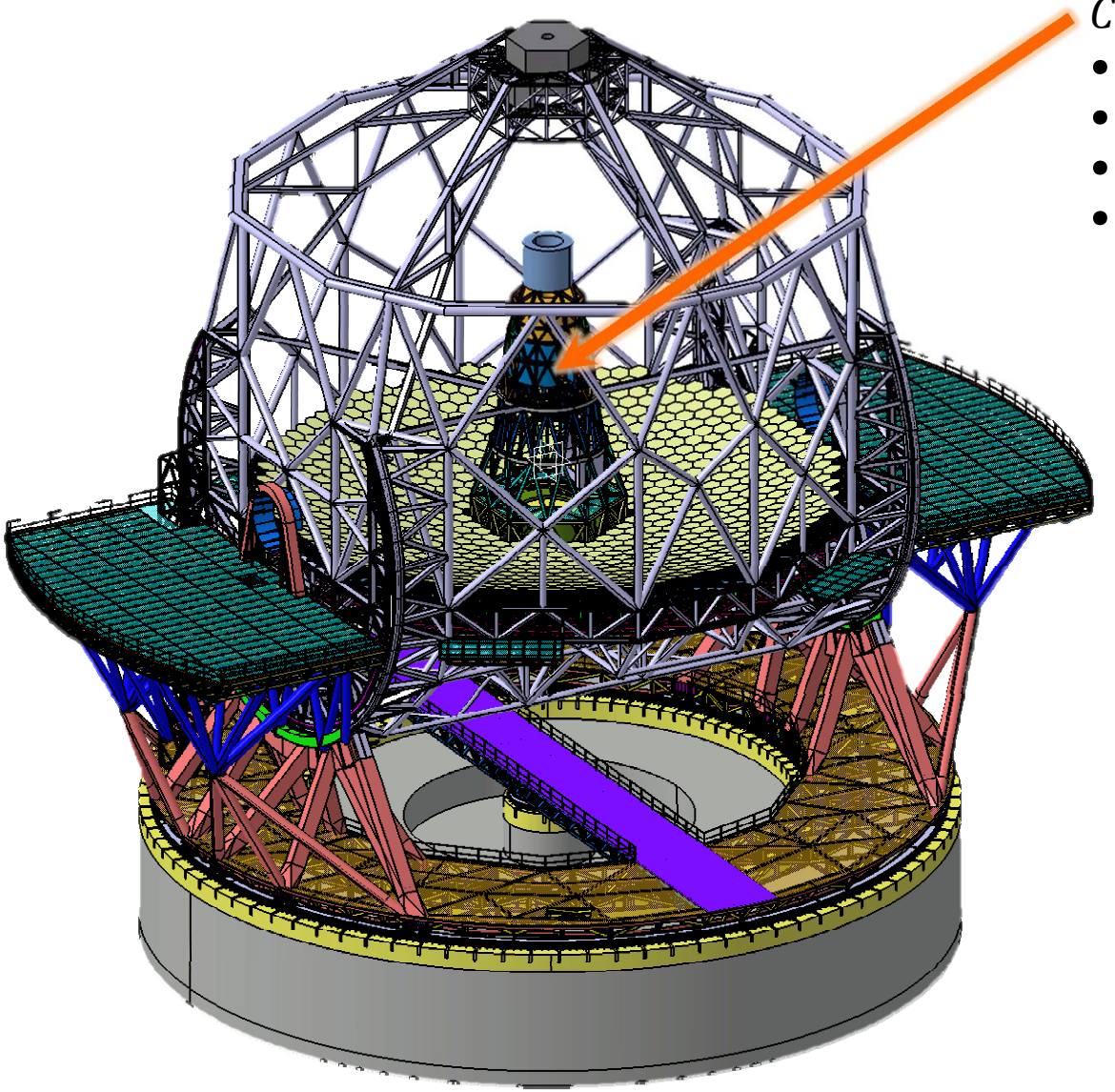
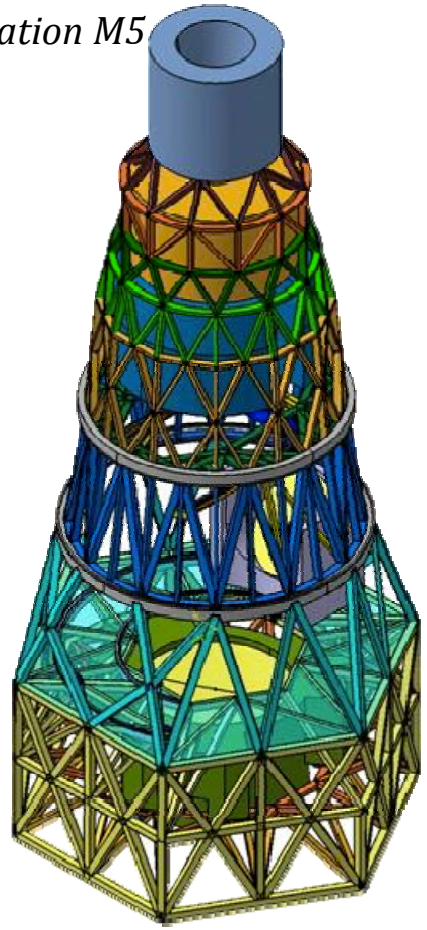


Central tower

- *ADC volume*
- *M3*
- *Adaptive M4*
- *Field stabilization M5*



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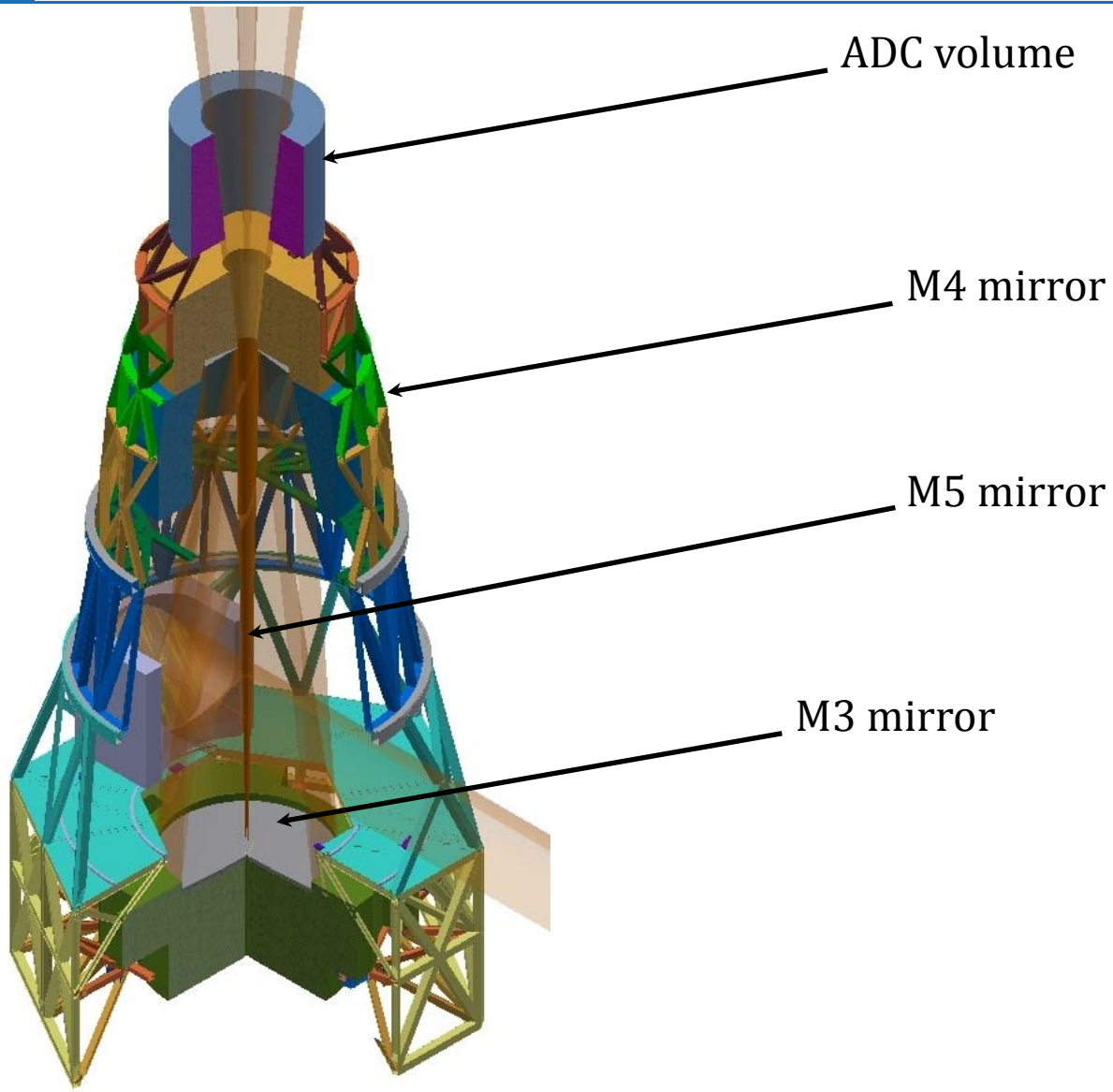
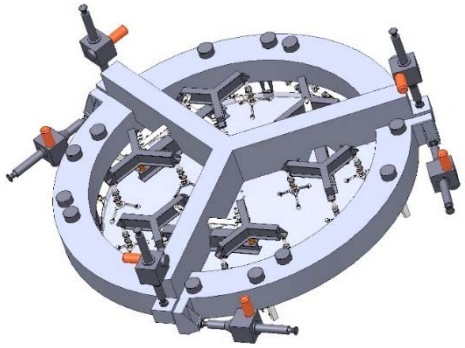
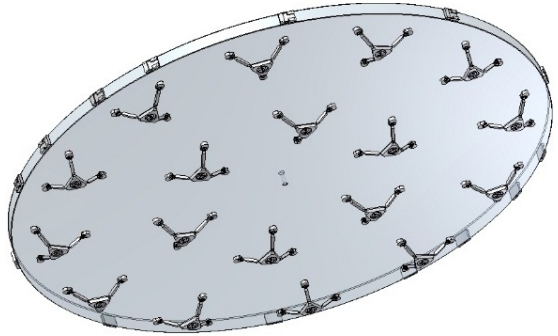
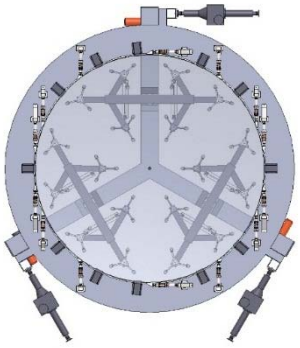
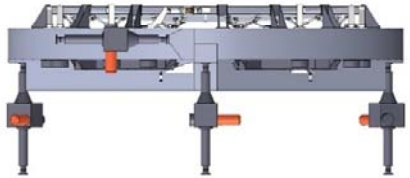
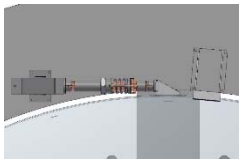
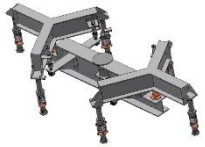
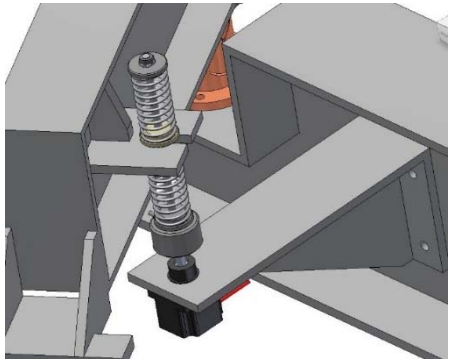
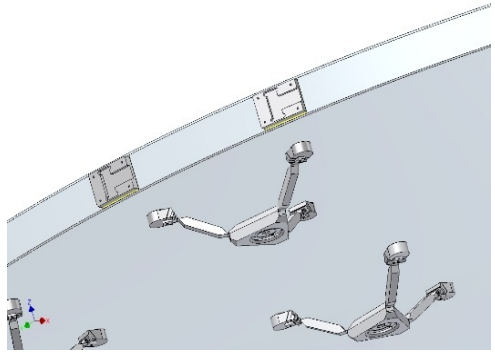


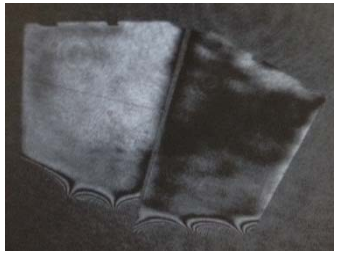
M3 Unit

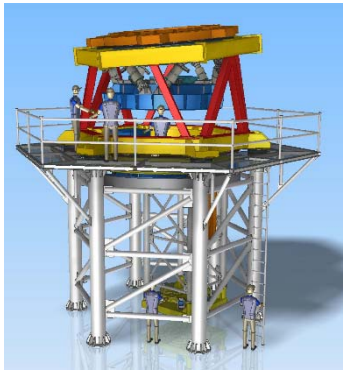
- Active 4-m f/2.6 concave mirror, mild aspheric (warping harness shape control)
- Axial support: 18 points whiffletree + tripods
- Lateral support: 12 tangential struts + fixed lateral and clocking
- Positioning system: hexapod with sub-micron accuracy
- Earthquake protection: mirror restrainers + load limiters

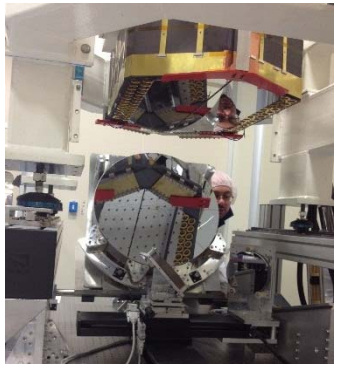










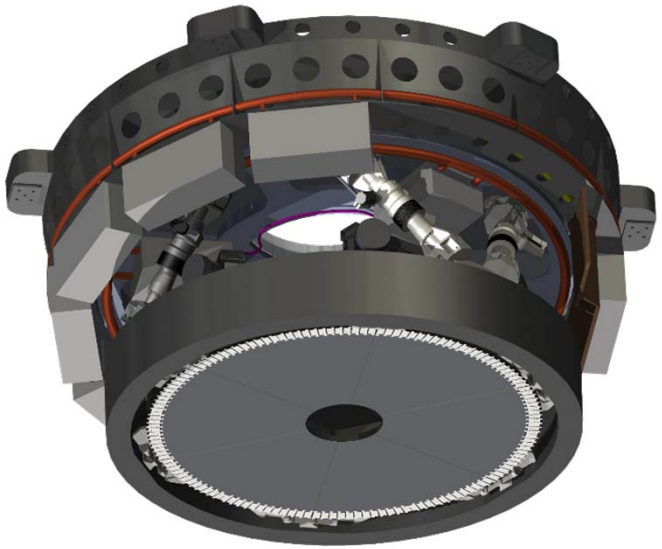
M4 Unit

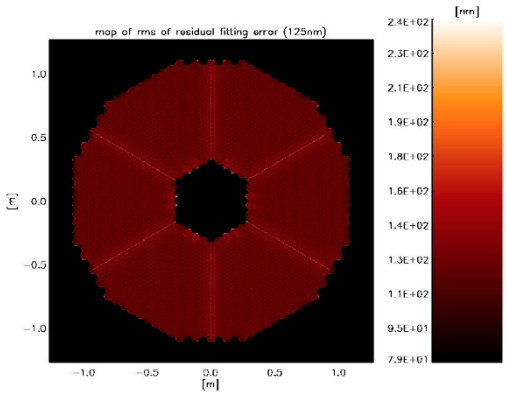
- 2.4-m flat adaptive mirror – 6 thin-shell petals only 1.95mm thick!
- ~5300 contactless actuators driving the mirror shape at 1 kHz
- Preliminary Design Study contract completed
- Contracts for Final Design and Manufacturing: awarded



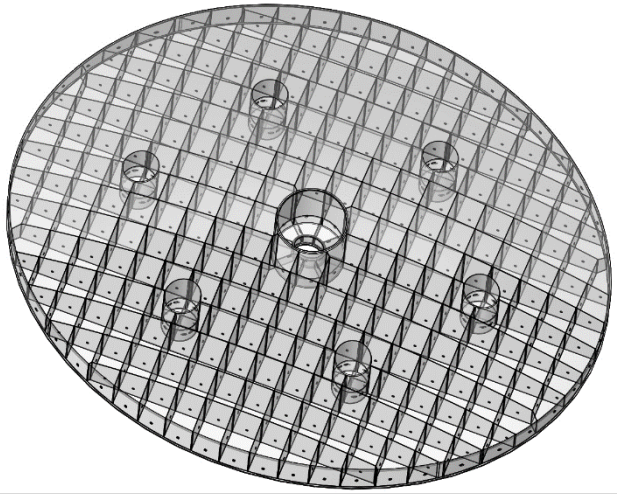




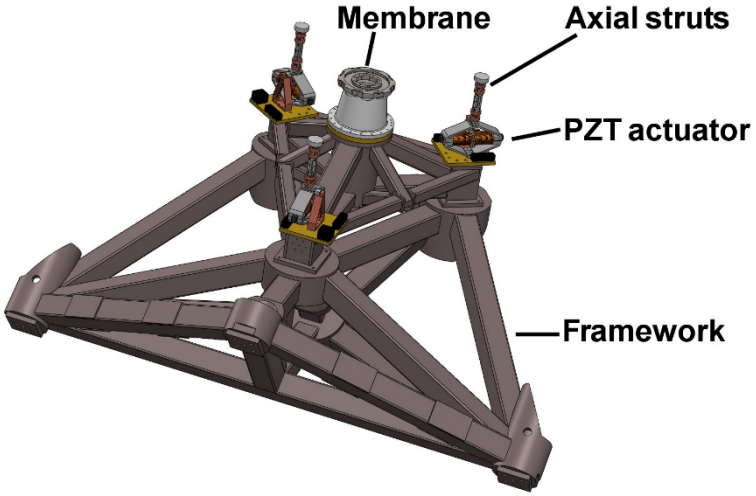




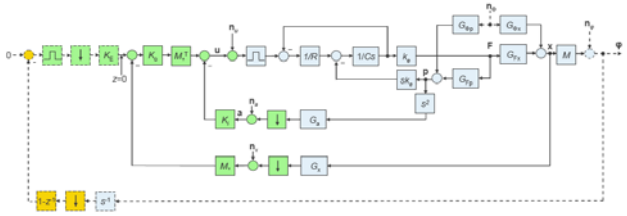
M5 Unit



M5 Mirror



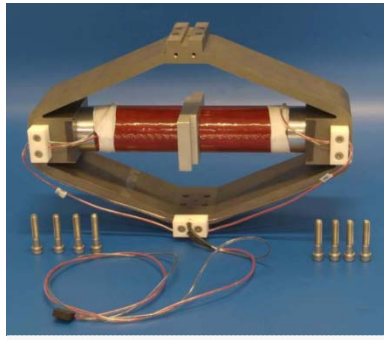
M5 Electromechanical Subunit



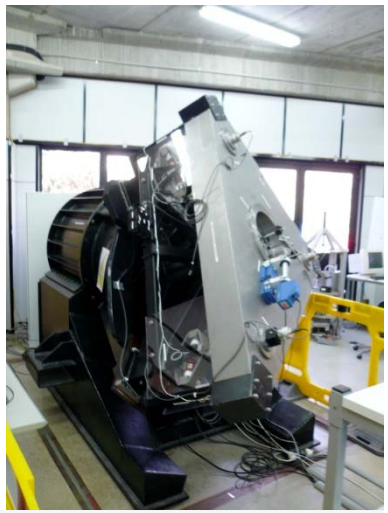
M5 Local Control System

M5 Auxiliary Equipment [Shipping, Handling, AIV]

Spare Parts

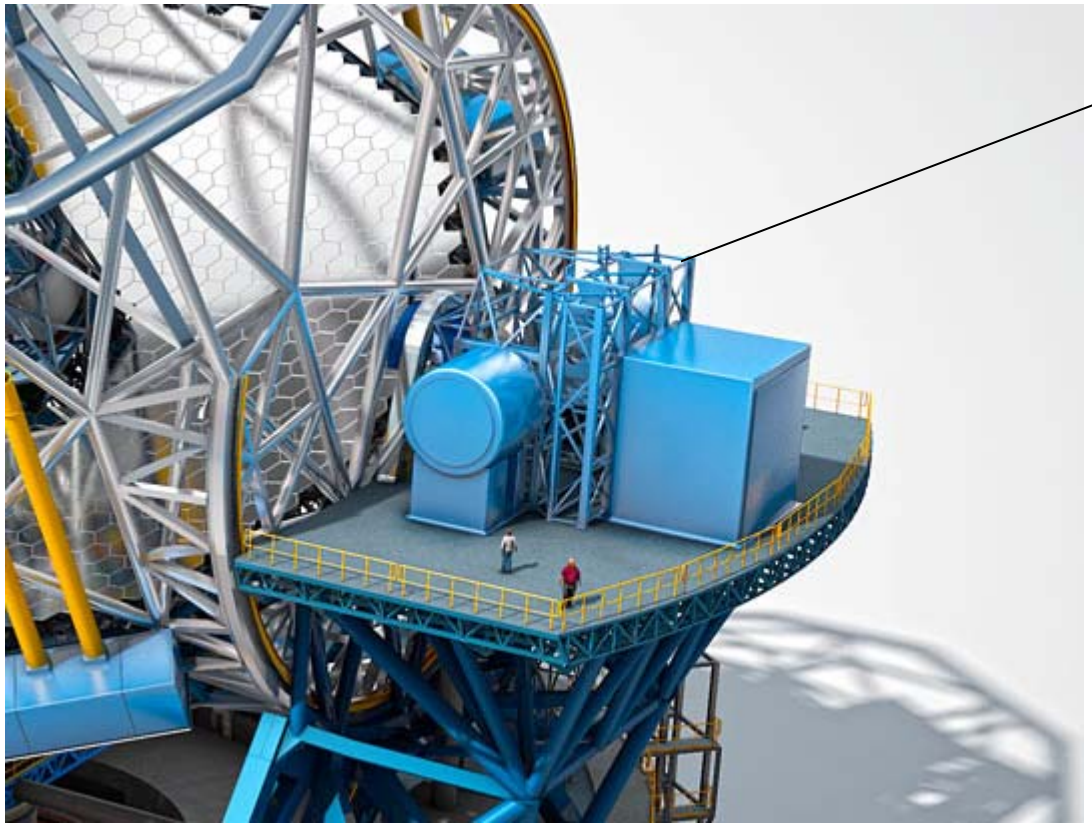


Prototype Actuator



Scale 1 Prototype Unit

Prefocal Station Overview



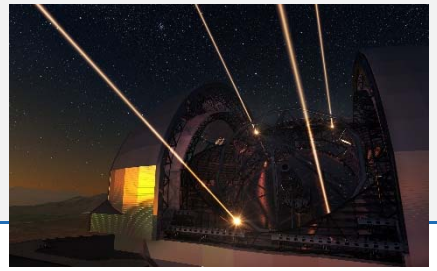
Opto-mechanical and optical sensing unit mounted on the Nasmyth platform

Distributes the light from the telescope to the instruments on the platform.

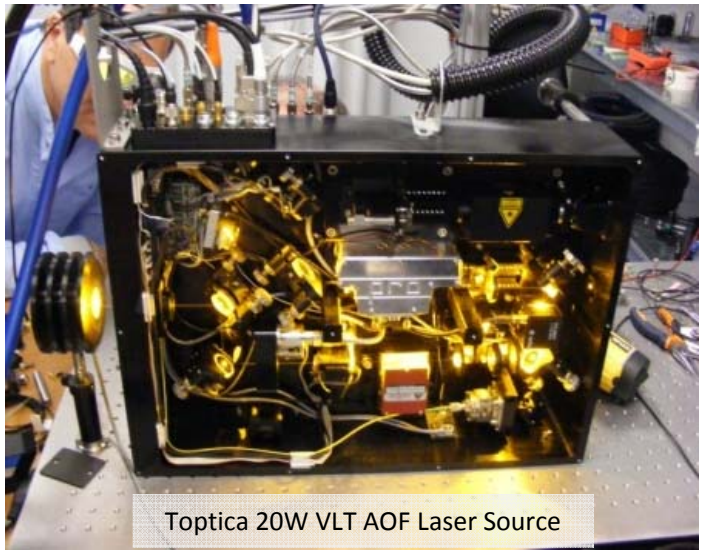
Performs optical sensing to support wavefront control of telescope.

Two PFS in total: one per Nasmyth platform

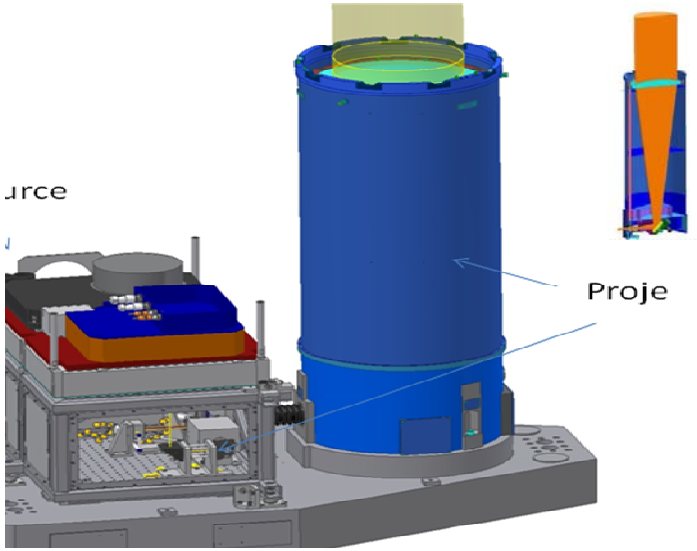
Representative dimensions approximately W5m x D4.75m x H10m

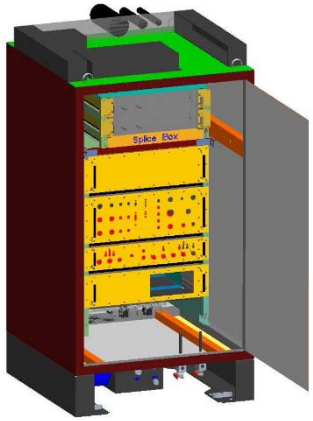


Laser Guide Star Units



Toptica 20W VLT AOF Laser Source





Laser Source Control Electronics

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

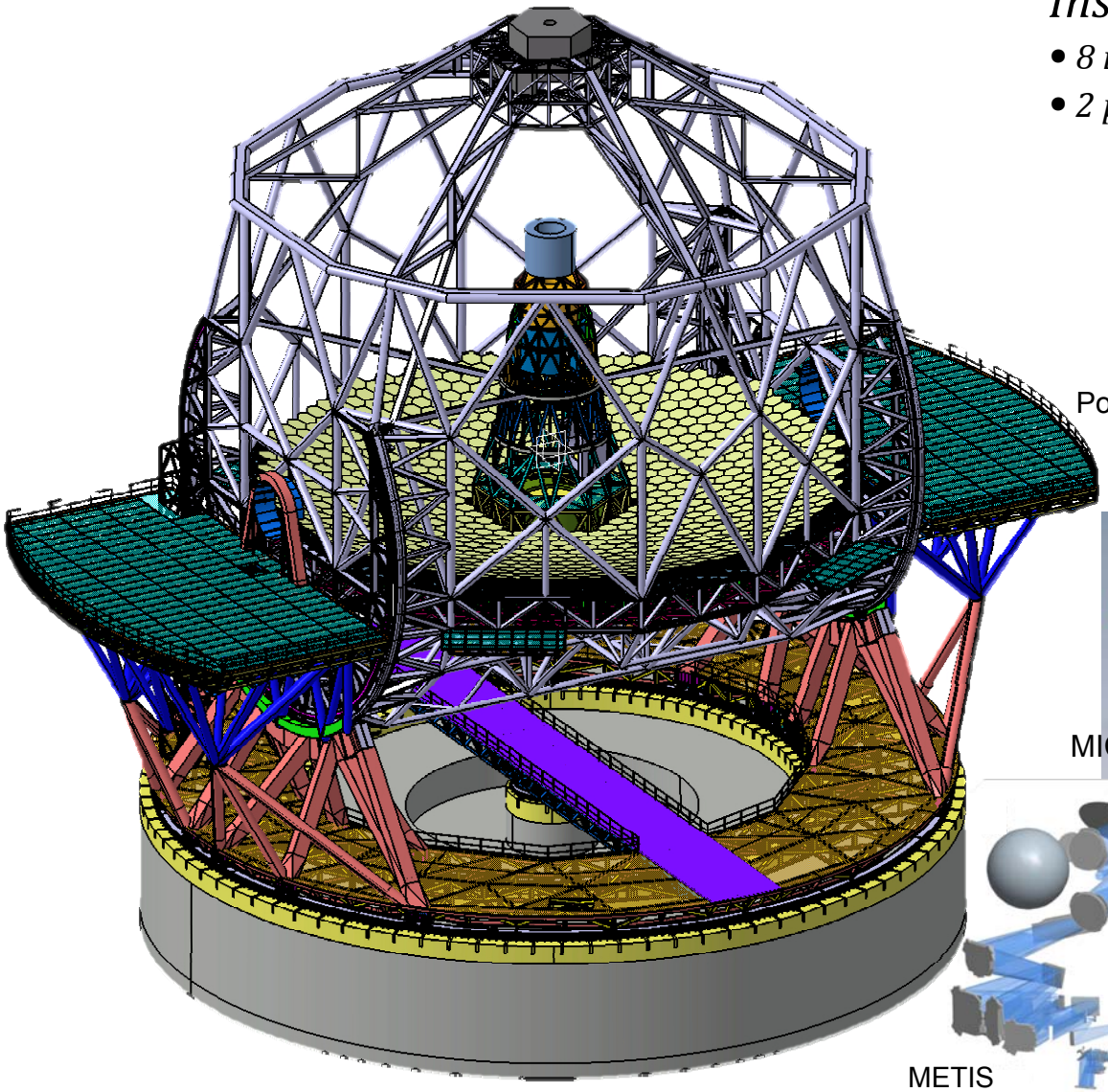
Local Electronics and Control System

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

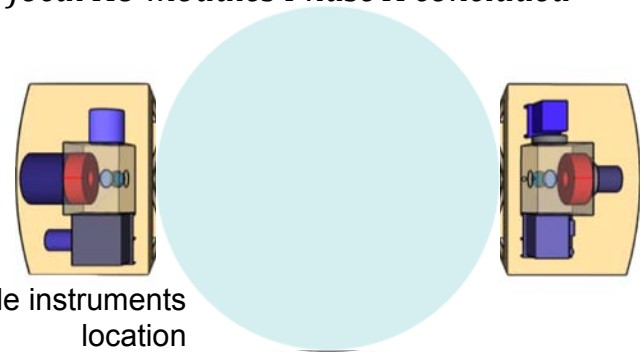
TNO 20W VLT AOF Launch Telescope

The E-ELT: instruments overview



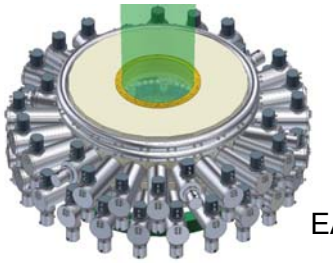
Instrumentation

- *8 instrument concepts Phase A concluded*
- *2 post-focal AO modules Phase A concluded*



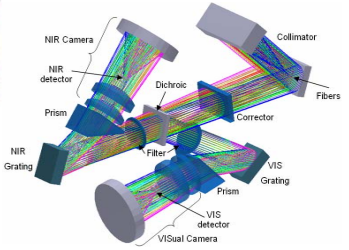
Possible instruments location

MICADO

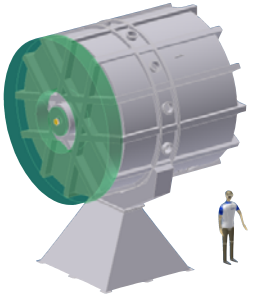


EAGLE

METIS



OPTIMOS/EVE



HARMONI

The instruments

Recent Development

A brief of History 1/2

- In December 2012 ESO Council approved E-ELT construction as a Supplementary Programme.
- But
  - not all Member States were in a position to commit then, and
  - Brazil had/has not yet completed its accession,
- The approval was subject to the condition that contracts worth more than 2 M€ could not be awarded until 90% of the E-ELT's cost-to-completion had been committed.
- By June 2014, all 14 Member States had joined the E-ELT resulting in 71% of the E-ELT's cost-to-completion being in hand.

A brief of History 2/2

- Poland's accession will raise this fraction to 78% in the course of 2015.
- The Brazilian ratification process has progressed well but at present it is not yet completed.
- High risk with:
  - the competing giant telescope projects,
  - the needs of the E-ELT instrument consortia,
  - the dwindling overlap with the foreseen operational period of the James Webb Space Telescope, and
  - the need to maintain the interest of ESO's industrial partners.
- Urged to find a way to allow the project to move forward by end 2014.

Moving forward

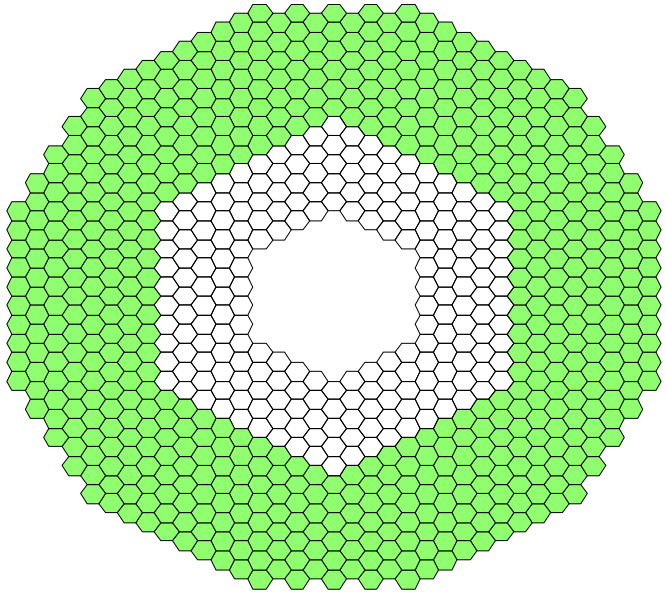
- The achieved approval (December 2014):
  - A two-phase construction plan for the E-ELT, such that the funding needed for Phase 1 does not require the completion of Brazil's ratification of its Accession Agreement or any additional funds from the current Member States.
  - Achieved by moving some 106.5 M€ of scope to Phase 2.
  - Still preserving the superb scientific capabilities of the E-ELT as much as possible;
  - Preserving the current baseline first-light date of 2024 as much as possible; and
  - Avoiding the need for any long-term loans

Deferred Items (Phase 2)

Item	Priority for restoration in Phase 2
LTAO	1
Atmospheric Monitoring	2
Inner 5 rings of M1 segments	3
7th sector of M1 segments	4
Second PFS	4
2 (out of 6) Laser Guide Star Units	4
De-scope of First PFS (see new Optical Control Project)	5
Power Conditioning	6
Armazones Support Building	7

Performance

- 39-m resolution 588 segment flux collecting area (100 more than TMT).
  - Still a 39-m, still the biggest telescope
  - In most cases increasing integration time can recover the science
- First light high angular resolution science maintained



The start of a new Era!

- Funding for E-ELT (Phase 1) approved by Council in December 2014!
- This was a critical and timely step to secure momentum:
  - In the team
  - In the Instrument consortia
  - In the industry

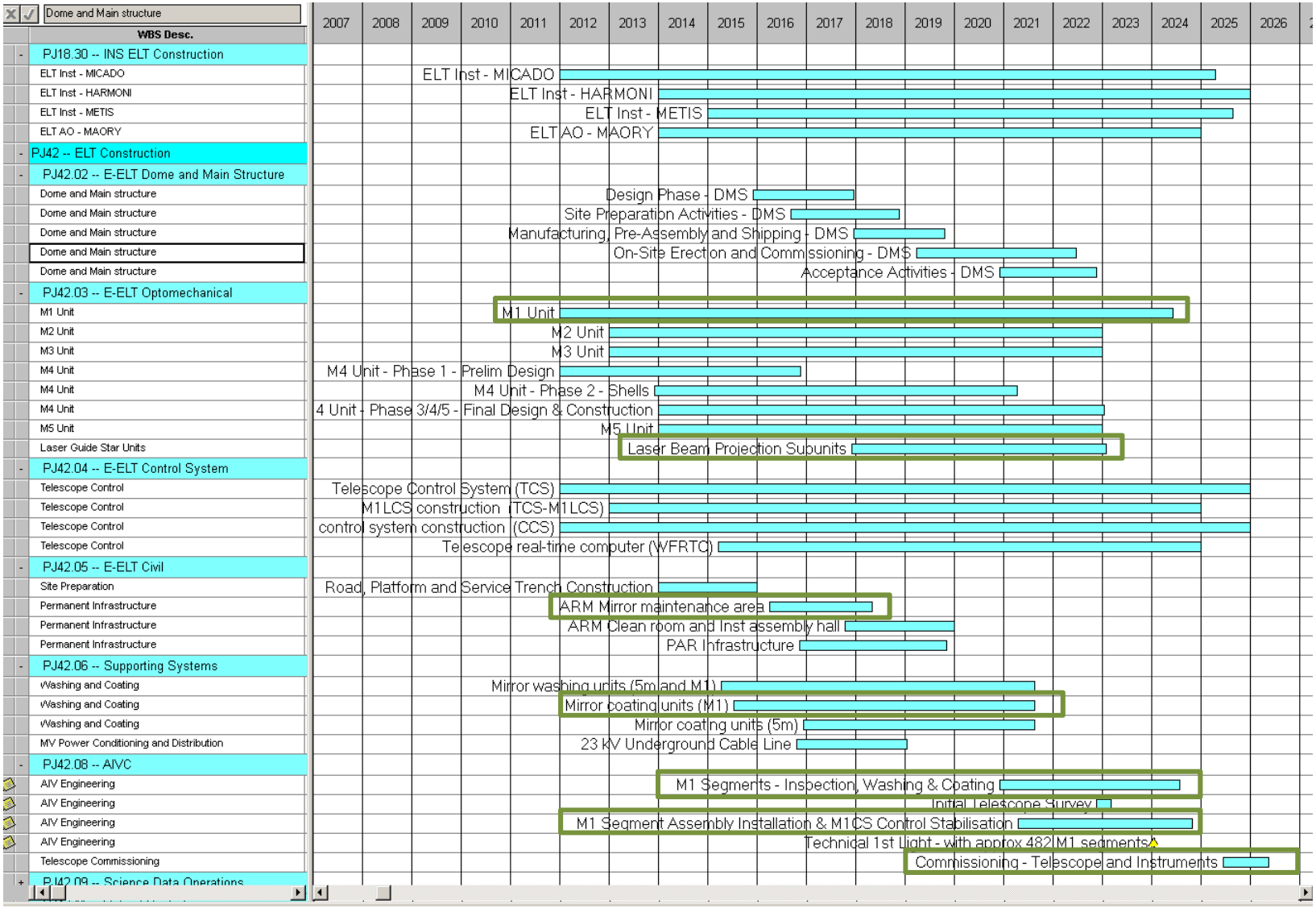
Latest News Poland & Brazil

- Poland accession:
  - ✓ Passed Lower House (Sejm) on 5 Mar 2015
  - ✓ Passed Upper House (Senate) on 19 Mar 2015
  - ✓ Published in the Official Journal on 20 Apr 2015
  - ✓ Signature by President Komorowsky … few days ago!
  - ➢ Instrument of ratification deposited at Ministry of Foreign Affairs in Paris
- Brazil accession:
  - ✓ Approved by House on 19 Mar 2015
  - ✓ Approved by Senate on 14 May 2015
  - ✓ Legislative decree 99/15 published 19 May 2015
  - ✓ To President, Casa Civil & Foreign Affairs 20 May 2015
  - ➢ Signature by President Rousseff
  - ➢ Instrument of ratification deposited at Ministry of Foreign Affairs in Paris

Programme Planning Update (Two-phases approach)

- Planning assumption is to achieve first light in 2024
- Decision to implement 2 years delay (to 2026) deferred to 2016
- Schedule maintained for full, Phase 1 and 2, programme
  - Maintain full duration ‘envelope” for de-scoped M1 deliverables, PFS A and Lasers
  - Removal of MV power system, Site Monitoring, Building, PFS B,
- Schedule margins gained by the potential deferral of Phase 2 are owned by the Programme Manager
- Budget total and profile reflect only Phase 1 scope, i.e. all Phase 2 budget removed from approved budget total

E-ELT Full Programme Schedule

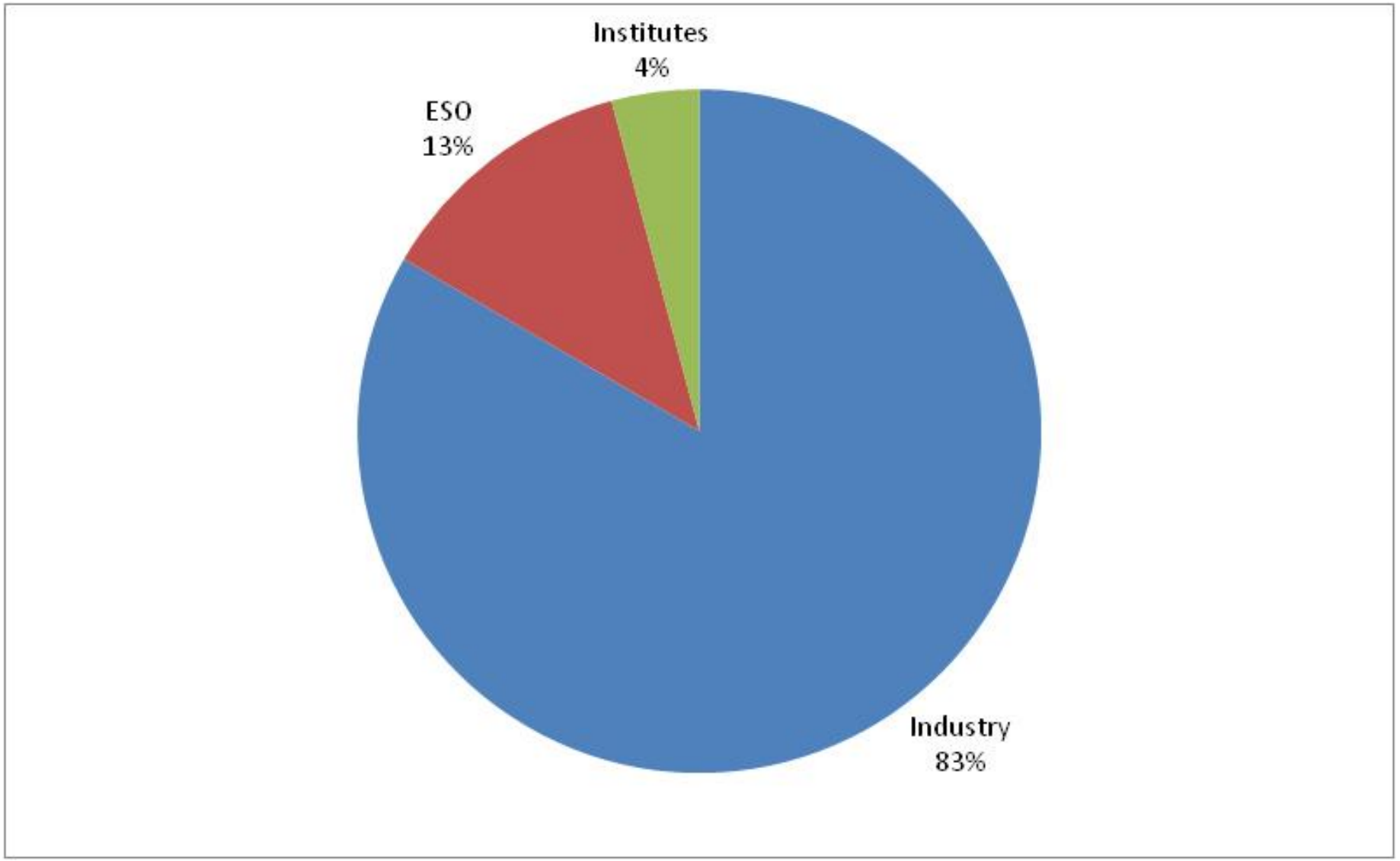


FC Approvals Schedule for 2015-2016

Optical Control Systems

JOB		2014 Q1	2014 Q2	2014 Q3	2014 Q4	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2016 Q1	2016 Q2	2016 Q3	2016 Q4	201 Q1	201 Q2
- 2015															
- CAP.FC -- Finance Committee															
HARMONI Construction	PJ18.30.32.			ESO FC Approval - Inst 2 HARMONI + LTAO											
M4 Unit	PJ42.03.02.			M4 Unit Phase 2 - Shells - FC Approval											
M4 Unit	PJ42.03.02.			M4 Unit - Phase 3/4/5 - FC Approval											
MICADO Construction	PJ18.30.30.			ESO FC Approval - MICADO											
METIS Construction	PJ18.30.34.			FC Approval - Inst 3 METIS											
MAORY Construction	PJ18.30.38.			ESO FC Approval - MCAO											
Programme Quality Assurance	PJ42.01.01.			ESO FC Approval - Independent Software V&V service											
Programme Quality Assurance	PJ42.01.01.					ESO FC Approval - QA Services									
- 2016															
- CAP.FC -- Finance Committee															
Dome and Main structure	PJ42.02.02.							ESO FC Approval - DMS							
M2 Unit	PJ42.03.02.							M2 Mirror - FC Approval							
M1 Unit	PJ42.03.02.								M1 Segments Polishing - FC Approval						
M2 Unit	PJ42.03.02.								M2 Blank - FC Approval						
M2 Unit	PJ42.03.02.								ESO FC Approval - M2 Cell						
M3 Unit	PJ42.03.02.								ESO FC Approval - M3 Mirror						
M3 Unit	PJ42.03.02.								ESO FC Approvial - M3 Cell						
Telescope Control	PJ42.04.02.							ESO FC Approval - Core integration infra construction							
Permanent Infrastructure	PJ42.05.02.								ESO FC Approval - ARM Network Room						
HARMONI ESO Deliverables	PJ18.30.32.								ESO FC Approvals - Inst 2 LGS WFS						
MAORY ESO Deliverables	PJ18.30.38.								ESO FC Approval - MAORY Detectors						
M1 Unit	PJ42.03.02.								M1 Edge Sensors - FC Approval						
- 2017															
- CAP.FC -- Finance Committee															
Optical Control Systems	PJ42.11.02.								ESO FC Approval OPC Metrology and Alignment System						
M1 Unit	PJ42.03.02.									M1 Position Actuators - FC Approval					
MV Power Conditioning and Distribution	PJ42.06.02.									ESO FC Approval - 23 kV Underground Cable Line					
METIS ESO Deliverables	PJ18.30.34.									ESO FC Approval Inst 3 Detector					
Optical Control Systems	PJ42.11.02.									ESO FC Approval PFS A Optomech sub-unit					
Optical Control Systems	PJ42.11.02.									ESO FC Approval PFS A Sensor Arms					
Optical Control Systems	PJ42.11.02.									ESO FC Approval PFS A - Phasing Station					
Telescope Control	PJ42.04.02.												ESO FC Approval - RTC I		
Permanent Infrastructure	PJ42.05.02.												ESO FC Approval - PAR		
Washing and Coating	PJ42.06.02.												ESO FC Approval - Mirror washing units		
Washing and Coating	PJ42.06.02.												ESO FC Approval - Mirror coatir		
Washing and Coating	PJ42.06.02.												ESO FC Approval - Mirror coatir		
Optical Control Systems	PJ42.11.02.												ESO FC Approval ELT		
2018															

E-ELT - Overall ESO/Industry share



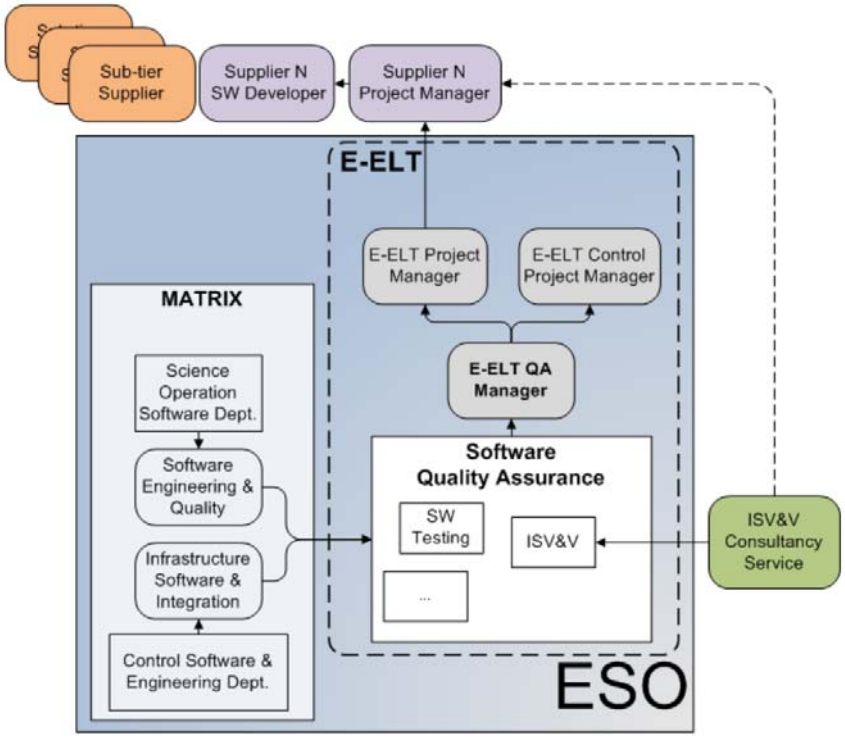
Near-term Procurements

Status of procurement processes (pre-contract)

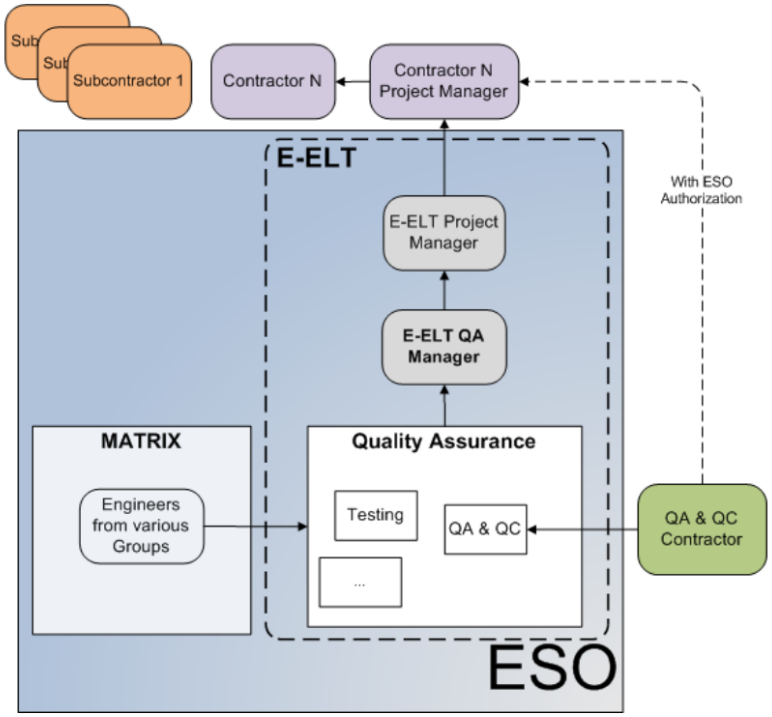
- Request for Information *(identify companies and gather information)*
  - M1 segments polishing (replies received, visit to companies done)
  - M1, M2 and M3 mirror blanks (waiting for replies in July)
  - M2 and M3 cells (in preparation for August)
  - M2 and M3 mirror polishing (ILOs, on-going for replies in October)
- Preliminary Inquiry *(pre-selection based on financial and tech. info)*
  - Edge Sensors (in evaluation)
  - M1 segment polishing, M2 blank & polishing (in evaluation)
- Three Calls for tender running
  - Dome and Main Structure (Phase 2 on going)
  - ISVV, Independent SW Validation and Verification Consultancy
  - Quality Assurance and Quality Control Consultancy Service

Organizational Arrangement

ISVV Services



QA Services



Dome and Main Structure (CfT on-going)

- Dome and Main Structure
  - Detailed design, manufacturing, transport, construction (civil engineering), on-site assembly and verification
  - CfT on-going,
    - Step 1 (technical and managerial offer): evaluation in progress
    - Step 2 (commercial offer): due date July 2015
  - Procurement continues in 2015 (Feb 2016 FC) to run for 9 years

DMS Call for Tender Planning

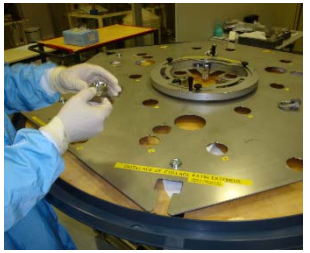
✓ Site visit	29 January 2014
✓ Release Call for Tender Phase 1	5 May 2014
✓ Bidders Conference	12 June 2014
✓ **Deadline questions phase 1**	**5 January 2015**
✓ **Closing date phase 1**	**31 January 2015**
✓ **Visit to all bidders**	**March 2015**
✓ **Release Call for Tender Phase 2**	**15 April 2015**
✓ **Closing date phase 2**	**17 July 2015**
➢ Release BAFO	November 2015
➢ FC Report ready	January 2016
➢ Extraordinary FC	3 February 2016

Near Term Procurements

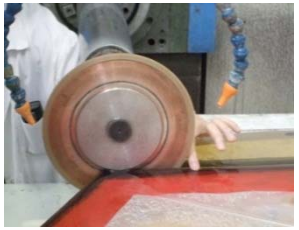
- Polishing of the M1 Mirror Segments
  (Phase 1: 588 segments, Phase 2: 343 additional)
  - 1) Pre-polishing
    - CfT planned for Q3 2015 with contract award in Q3 2016.
  - 2) Polishing and integration with segment supports. Delivery to site at Armazones
    - CfT planned for Q3 2015 with contract award in Q3 2016. Contract expected to run for 7 years.
  - Looking for suppliers in MS and Chile with track record in large size, high performance, optics manufacturing and testing
- Position Actuators for M1
  - Design, manufacture and deliver Electro-mechanical precision actuators (φ1: 1764, φ2: +646) and electronic controllers (φ1: 588, φ2: +216) to be mounted on each M1 Cell
  - Procurement start 2016 (TBC) expected to run for 5-6 years
  - Suitable for medium size (turnover 10-15 MEURO) to large suppliers in MS and Chile with track record in high precision position actuators design and manufacturing

M1 Unit - Blanks and Polishing

- ✓ RFI for blanks procurement: ongoing.
- ✓ RFI for Polishing: completed.
- ➢ PI for Polishing: July 2015.
- ➢ CfT for Polishing: planned Nov 2015



Pads Bonding

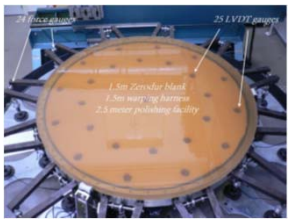


CNC - Cutting

Blanks

High Precision grinding

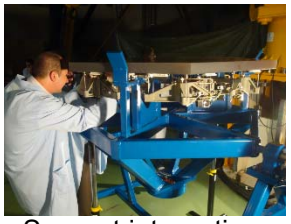
Bonnet Polishing and Lapping



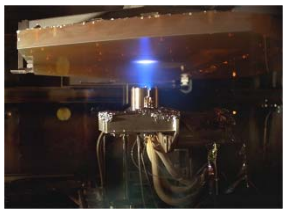
Stressed Mirror Polishing

Pre-Polished Roundel

Polishing



Support integration



Ion Figuring

Instruments Procurement
Next steps

- ✓ Recommendation from STC (April)
  - To complete negotiations for construction
- ✓ Approval from Finance Committee (May)
  - To complete negotiations for construction
- ✓ Approval of GTO from Council (June)
- ■ Completion and signature of documentation (Sep)
  - Technical specifications
  - Statements of work
  - Construction agreements

Status of procurement processes (approved new contracts)

- Two contract awards approved by May FC
  - M4 Shells to REOSC/SAGEM (FR) (signed)
  - M4 Unit final design and construction to AdOptica (IT) (signed)
- Instruments procurements approved by May FC (contingency needed) and GTO approved by Council in June
  - MICADO
  - MAORY
  - HARMONI including LTAO study to PDR
  - METIS
- See details in Marc Casali's presentation

Status of Running Contracts

Overview

Running contracts, and their status

- M1 Segment Support (x2, VDL and CESA):
  - Started early 2015
  - Design to FDR and delivery of 4 qualification models
- M4 Cell (AdOptica) and M4 Shell (REOSC)
  - Just signed!
- Managerial and DMS Consultancy (Ramboll):
  - on-going
- Road and Platform (ICAFAL):
  - Continuing progress (details below)

M1SS VDL/CESA Parallel Contracts Status

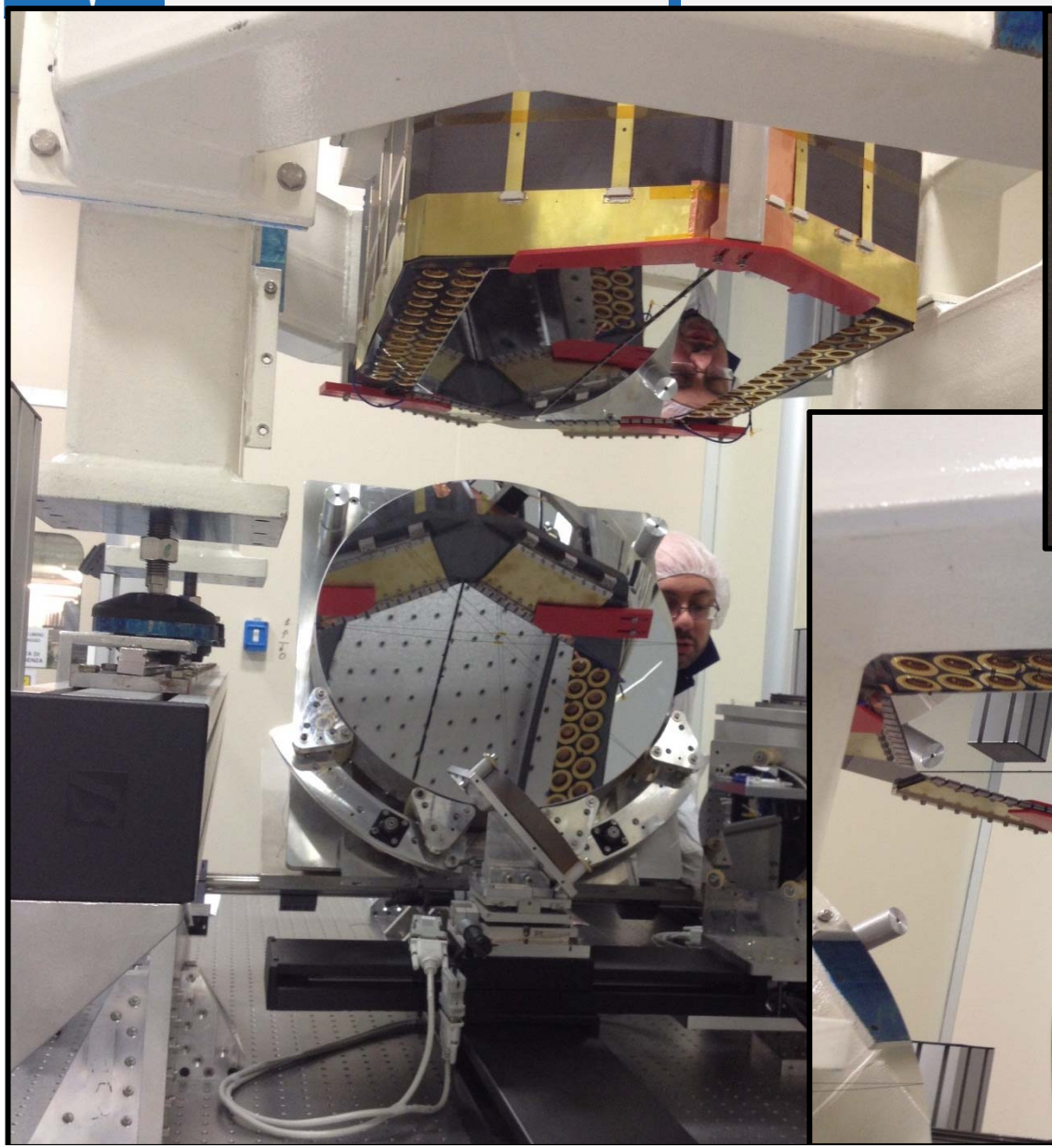
VDL/TNO Eindhoven/Delft (The Netherlands)

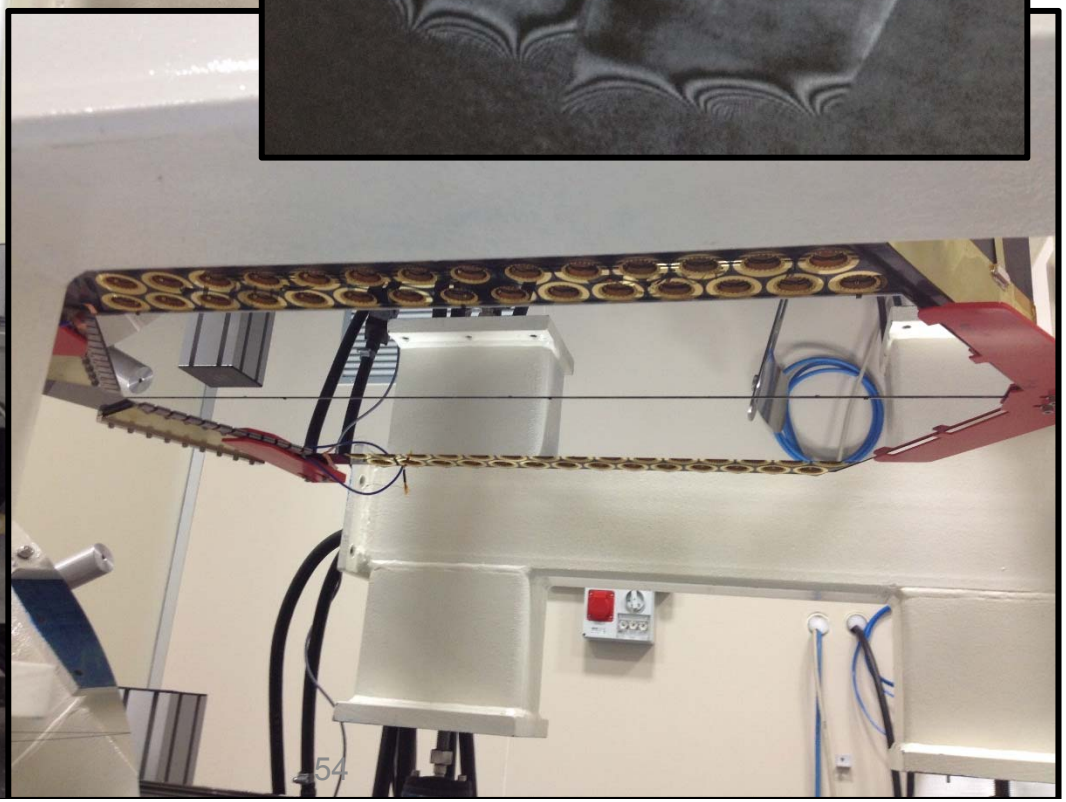
- Contract Signature: 14.12.14
- Kick Off: 26.01.15
- Last PM(5): 10.06.15
- PDR: 02.09.15 (T_0+8M) Confirmed

CESA Madrid (Spain)

- Contract Signature: 14.01.15
- Kick Off: 10.02.15
- Last PM(3): 13.05.15
- PDR: October 2015 (T_0+8M) Open

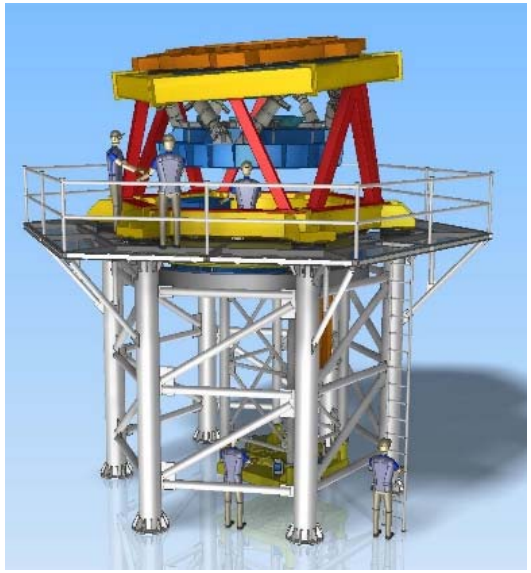
M4 Unit, Demonstration Prototype final optical tests (Q1 2015)

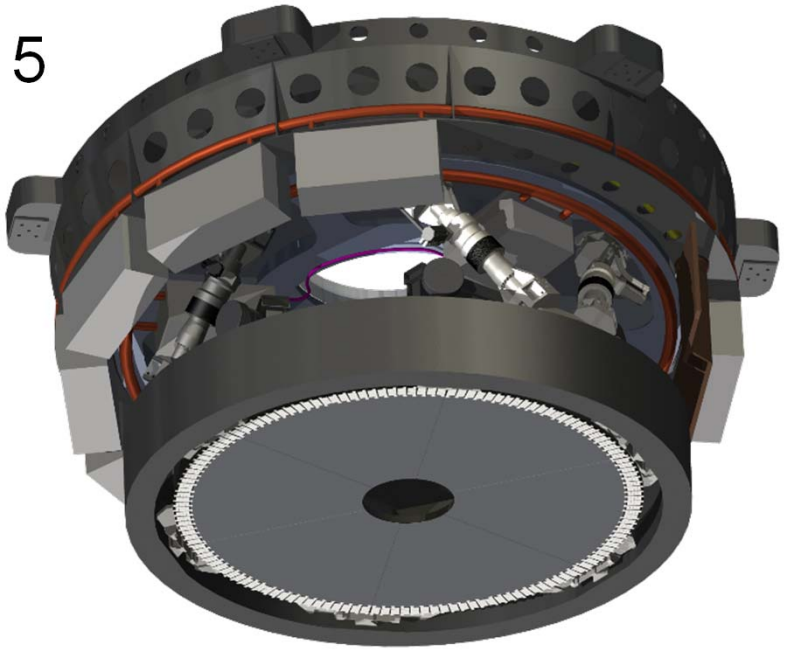




M4 Unit Design & Manuf. Contract

- M4 unit with c.a. 5300 actuators, able to do adaptive optics correction at 1kHz with nanometric precision
- Final design, manufacturing, integration, testing, integration in Europe, transport to site, reintegration and verification on site
- Contract signed on 19 June 2015



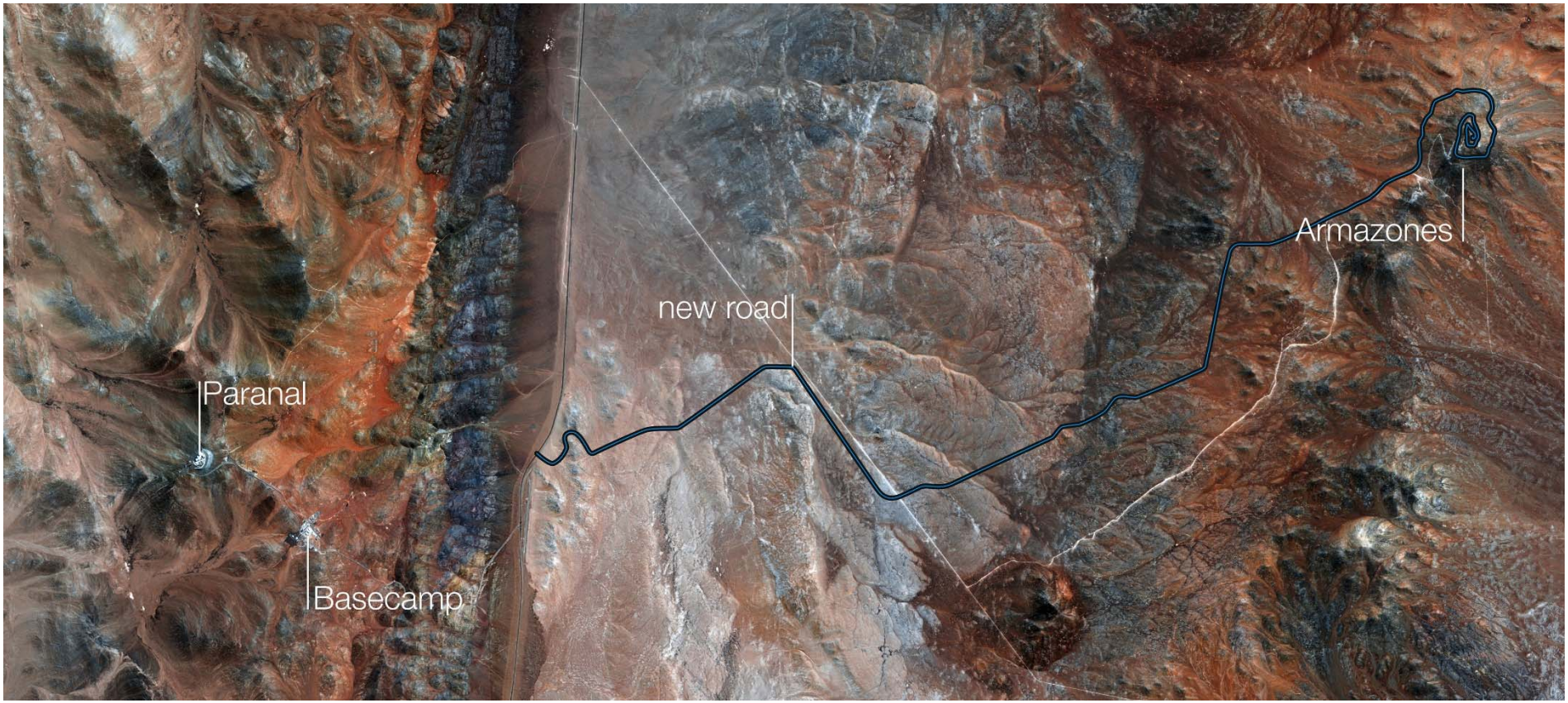


M4 Shell Contract

- Manufacturing of 2 sets of 6 shells (blank, polishing, testing)
- Diameter 2.4m, 1.95mm thick 10nm RMS figuring errors
- Completion in 8 years
  (First set in 5 years, 2nd set in 8 years)
- Contract signed on 8 July 2015

Most Recent Progress

- Road By-pass at the connection of the new E-ELT Road with the B710 near Paranal



Most Recent Progress

Most Recent Progress

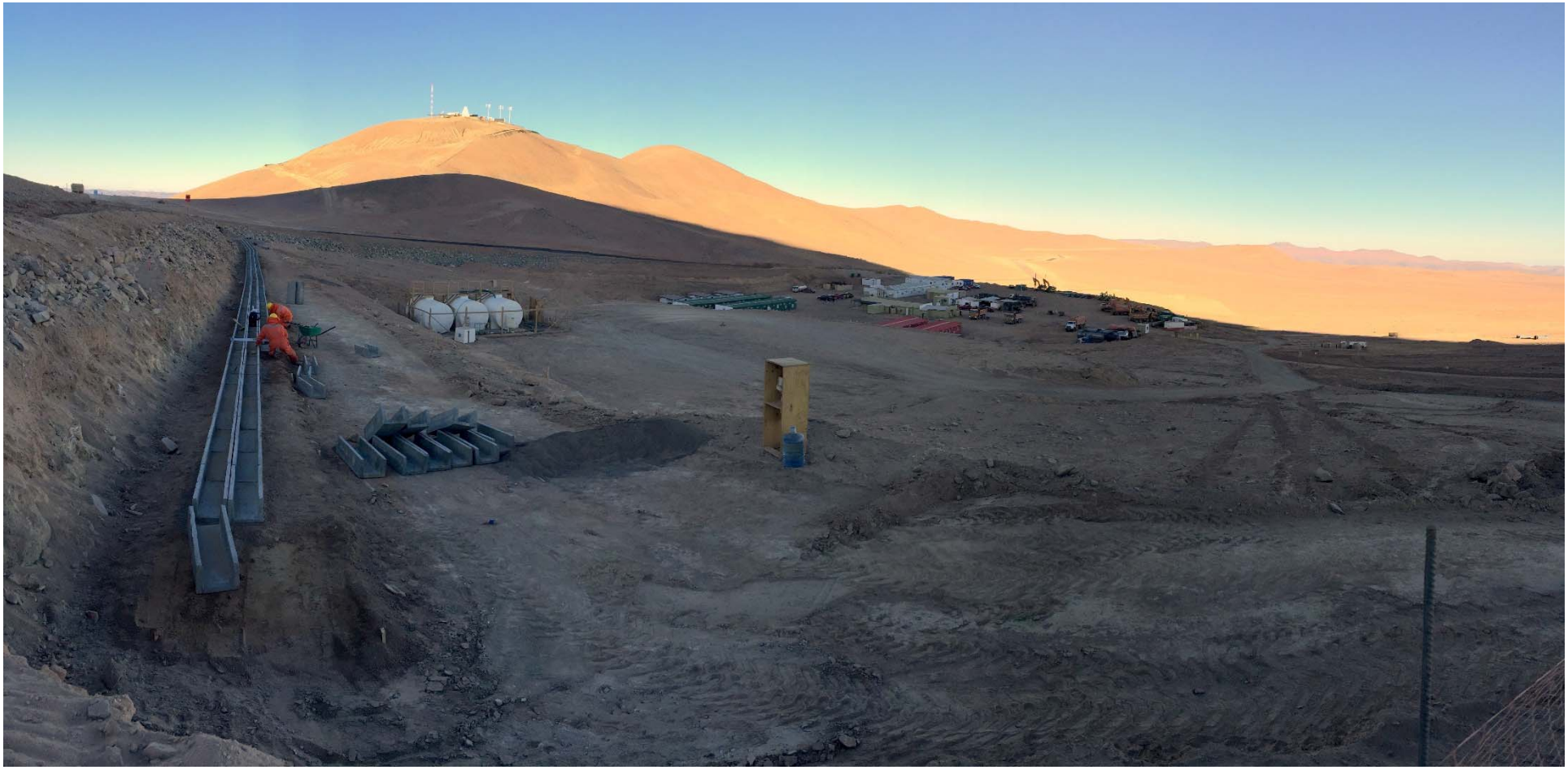
Most Recent Progress

Most Recent Progress

Most Recent Progress

Most Recent Progress

Most Recent Progress

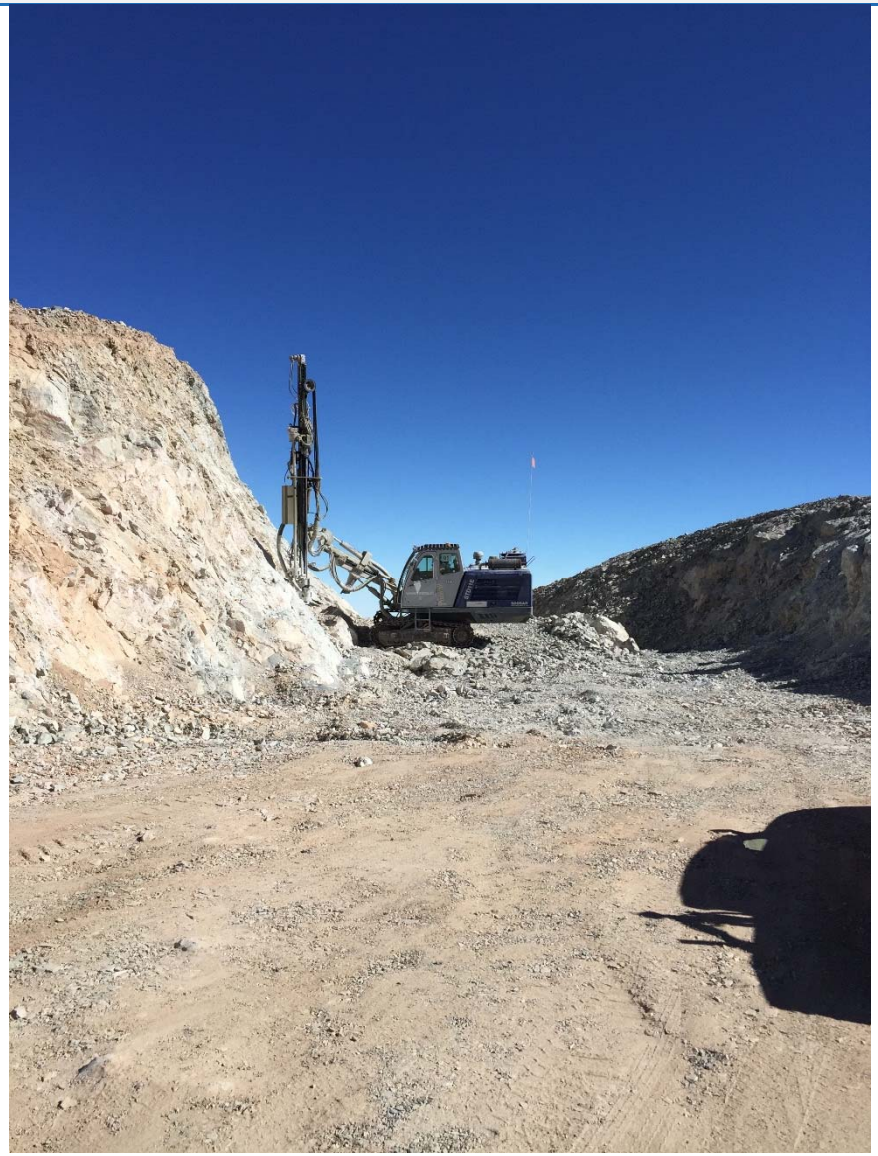


Most Recent Progress

Most Recent Progress

Most Recent Progress

Most Recent Progress
(20 May 2015)



Most Recent Progress

Most Recent Progress
(20 May 2015)

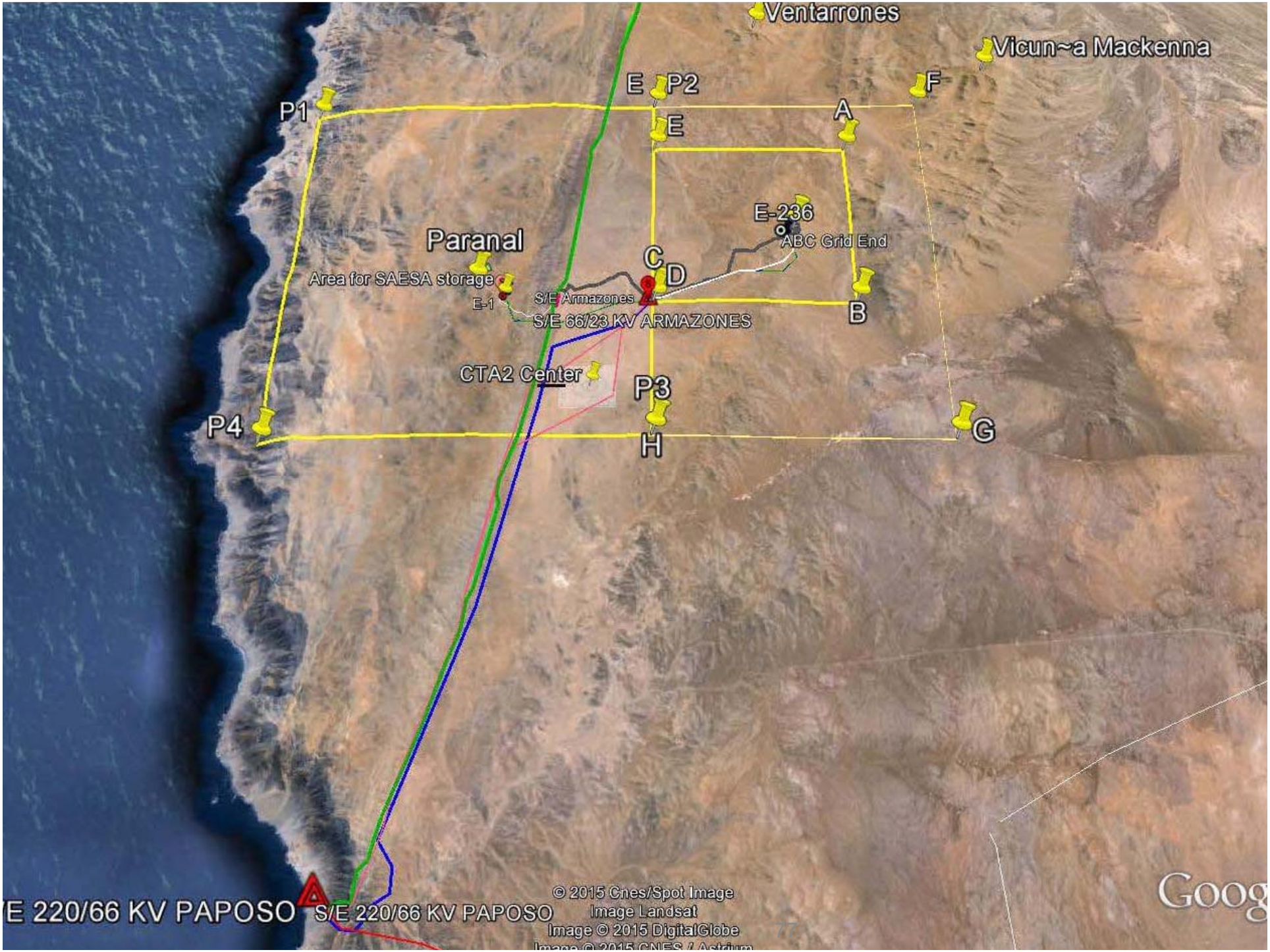
Most Recent Progress
(20 May 2015)

On-site work

On-site work

On-site work

Most Recent Progress


Ventarrones
Vicun~a Mackenna
P1
E
P2
F
E
A
E-236
ABC Grid End
Paranal
Area for SAESA storage
E-1
C
D
S/E Armazones
S/E 66/23 KV ARMAZONES
B
CTA2 Center
P3
P4
H
G
S/E 220/66 KV PAPOSO
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