

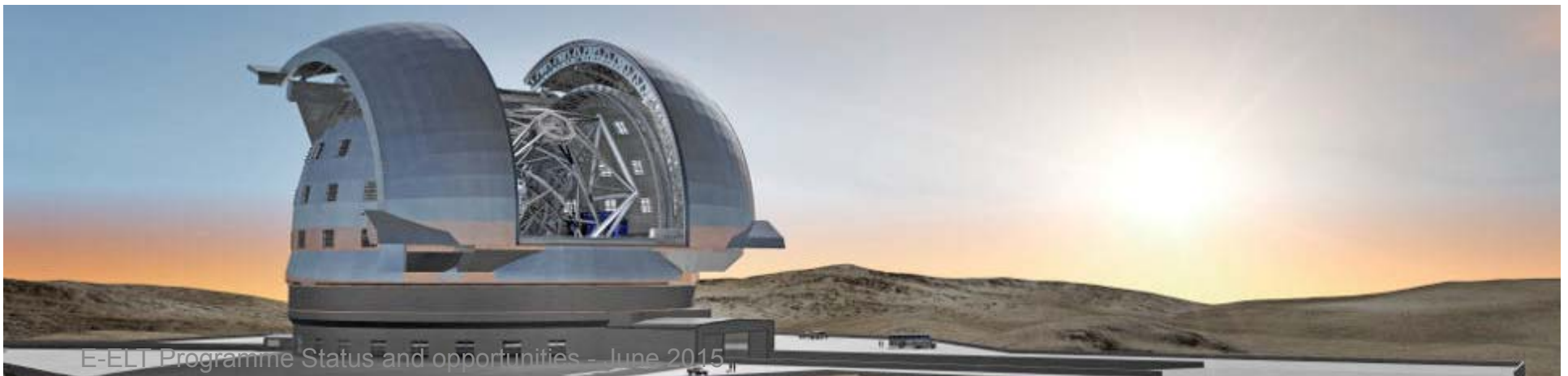
E-ELT Programme

- *Roberto Tamai -*
- *Programme Manager -*
- 18 June 2015*



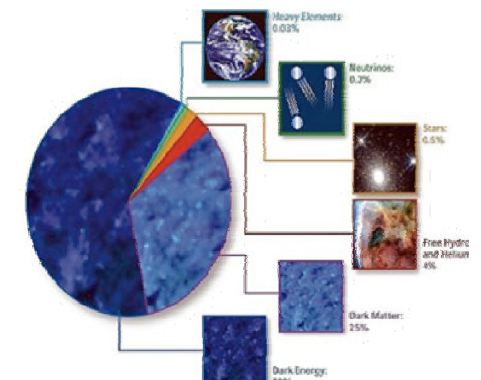
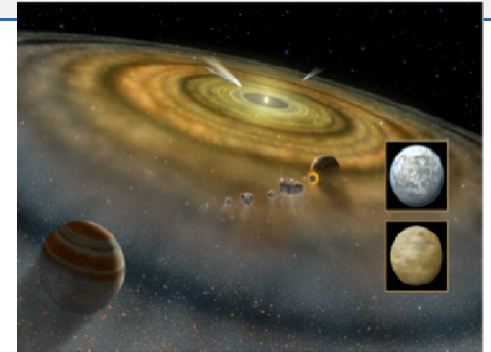
- Largest optical/infrared telescope in the world
 - 39m segmented primary mirror: transformational step
 - Science: exo-earths, deep universe, resolved populations
 - Design essentially complete, incl. instrumentation roadmap

- 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



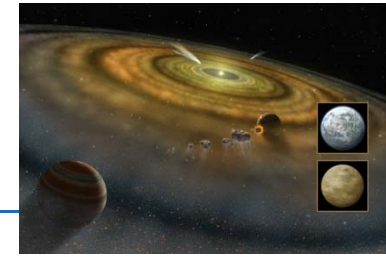
Science drivers

- 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



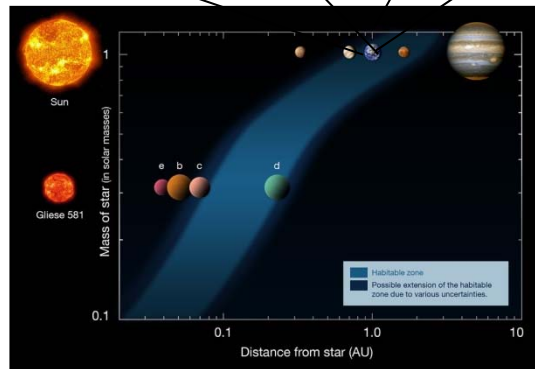
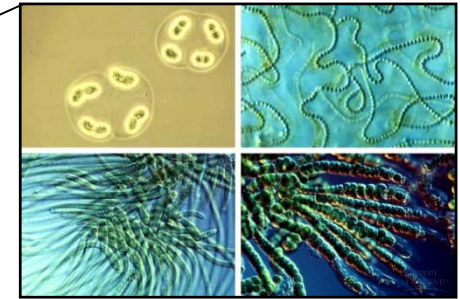
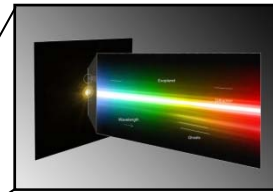


One top goal of the E-ELT is to find and to characterise exo-planets...



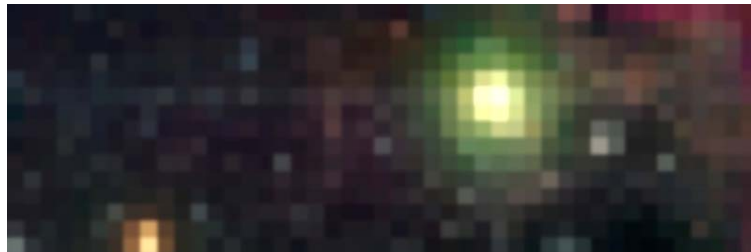
... it is the first telescope ever that can explore Earth-twins...

... with ultimately the chance to find life beyond the Solar system.

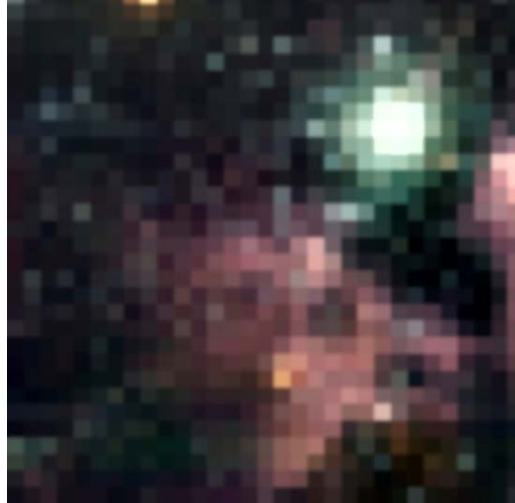




Spectacular Resolution



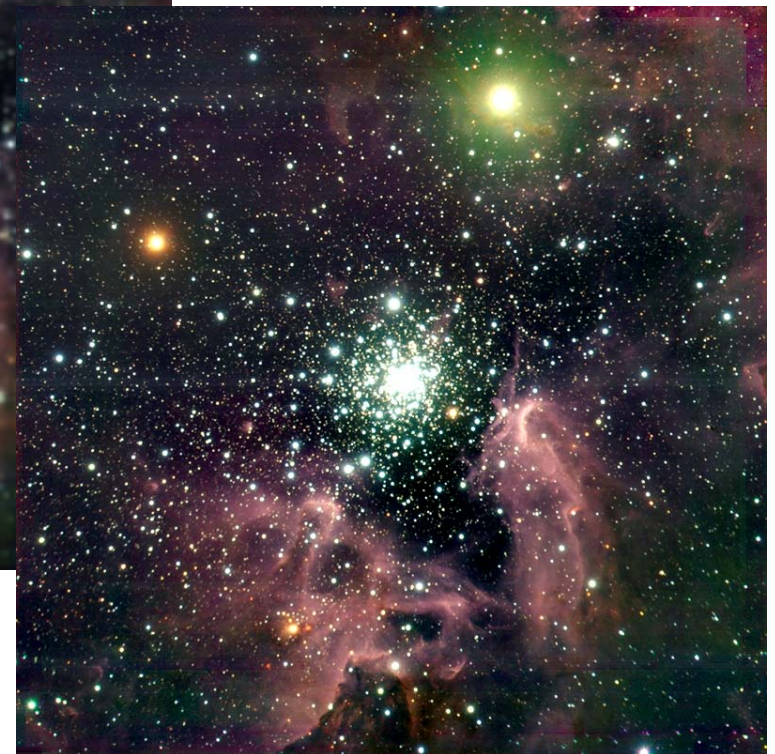
VLT+AO



HST

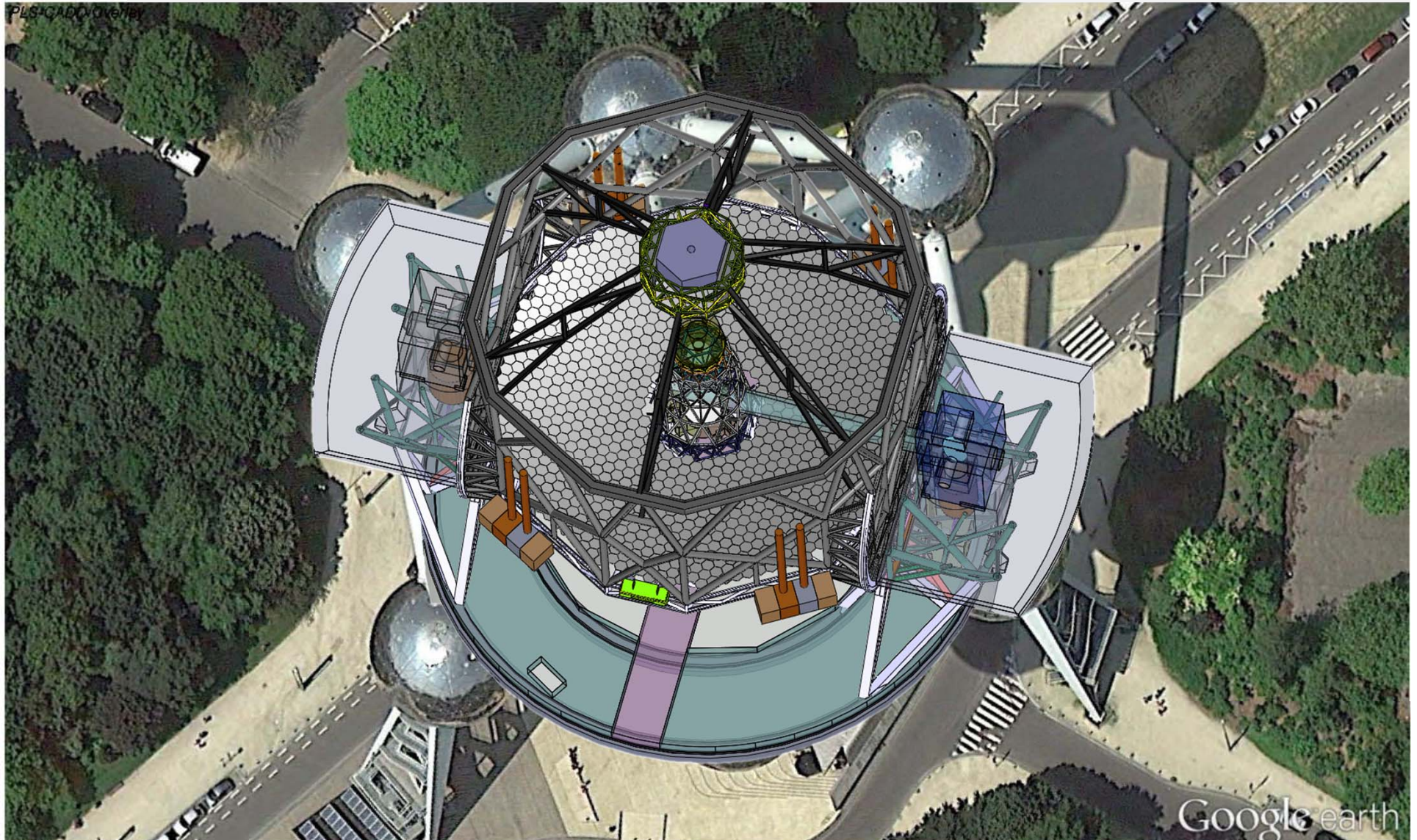


E-ELT





To put it in perspective...



E-ELT Programme Status and opportunities - June 2015





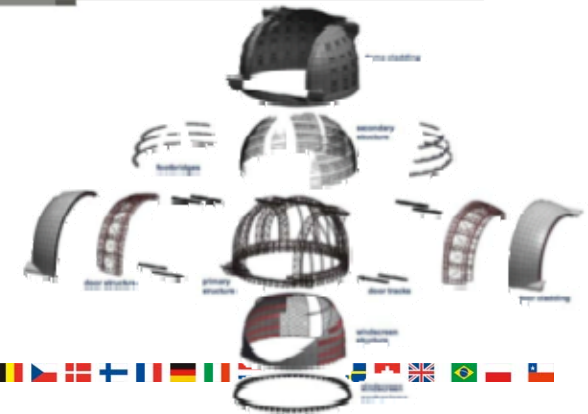
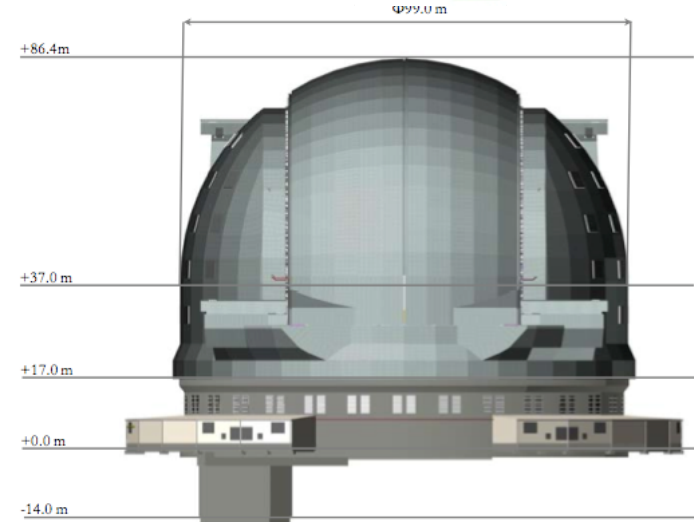
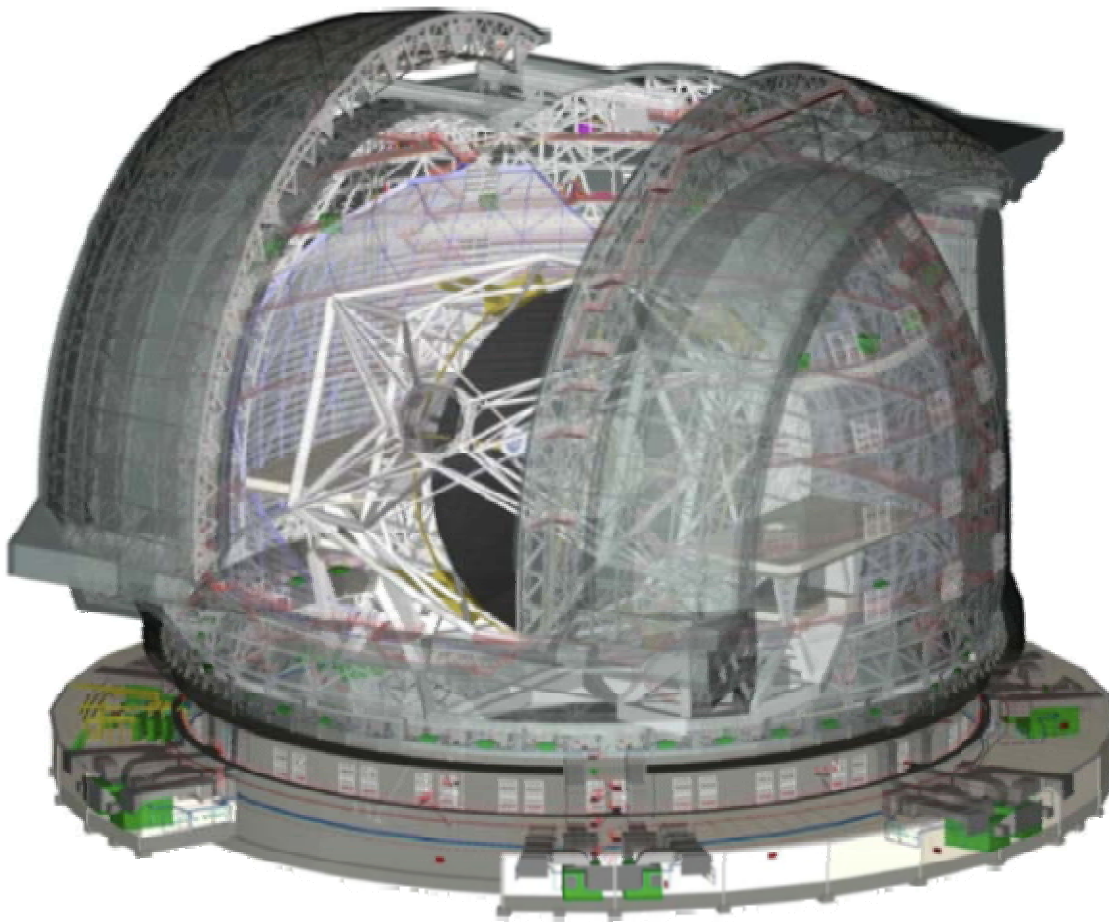
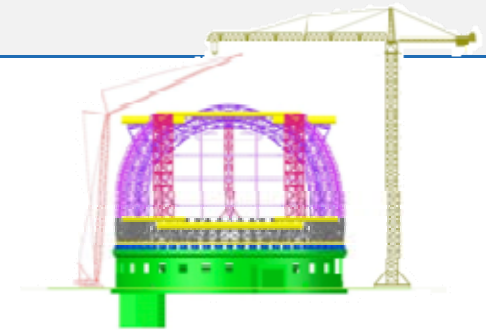
Armazones and Paranal



The E-ELT: overview

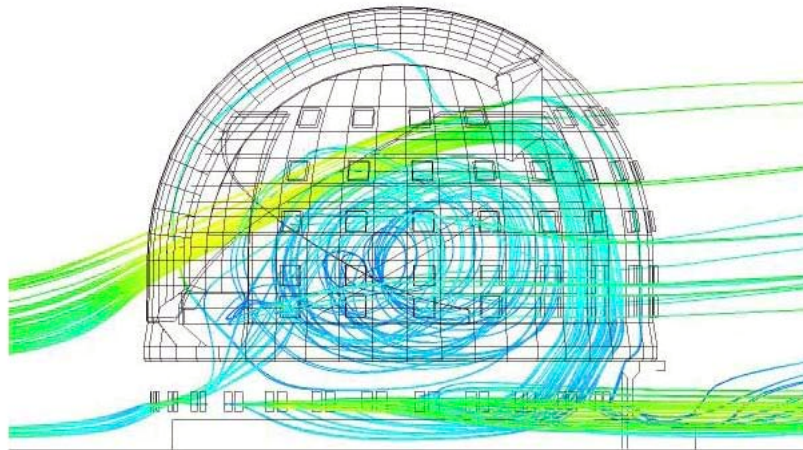
Dome

- 2 FEED contracts
- Erection sequence

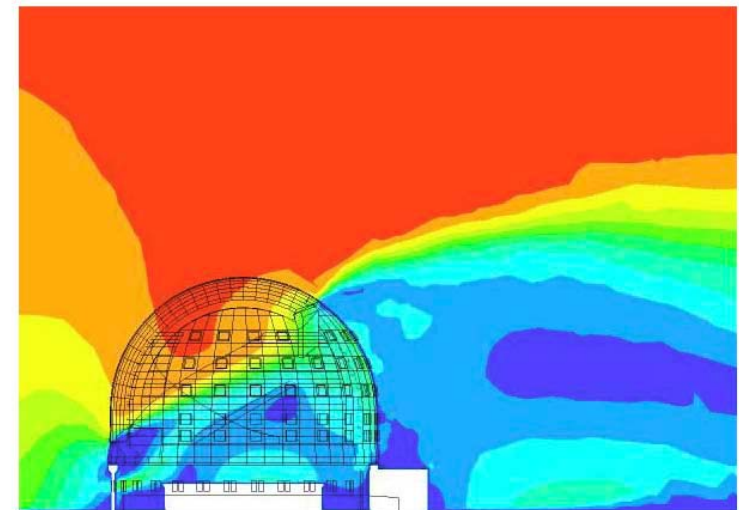


CFD Studies

- Computational Fluid Dynamics analyses of the E-ELT dome were performed to assess the **wind flow conditions** in view of **telescope seeing**. The analysis results caused the decision to implement louvers in the dome foundation design



Streamlines distribution in the E-ELT Dome structure



Velocity distribution in the E-ELT Dome at the symmetry plane.

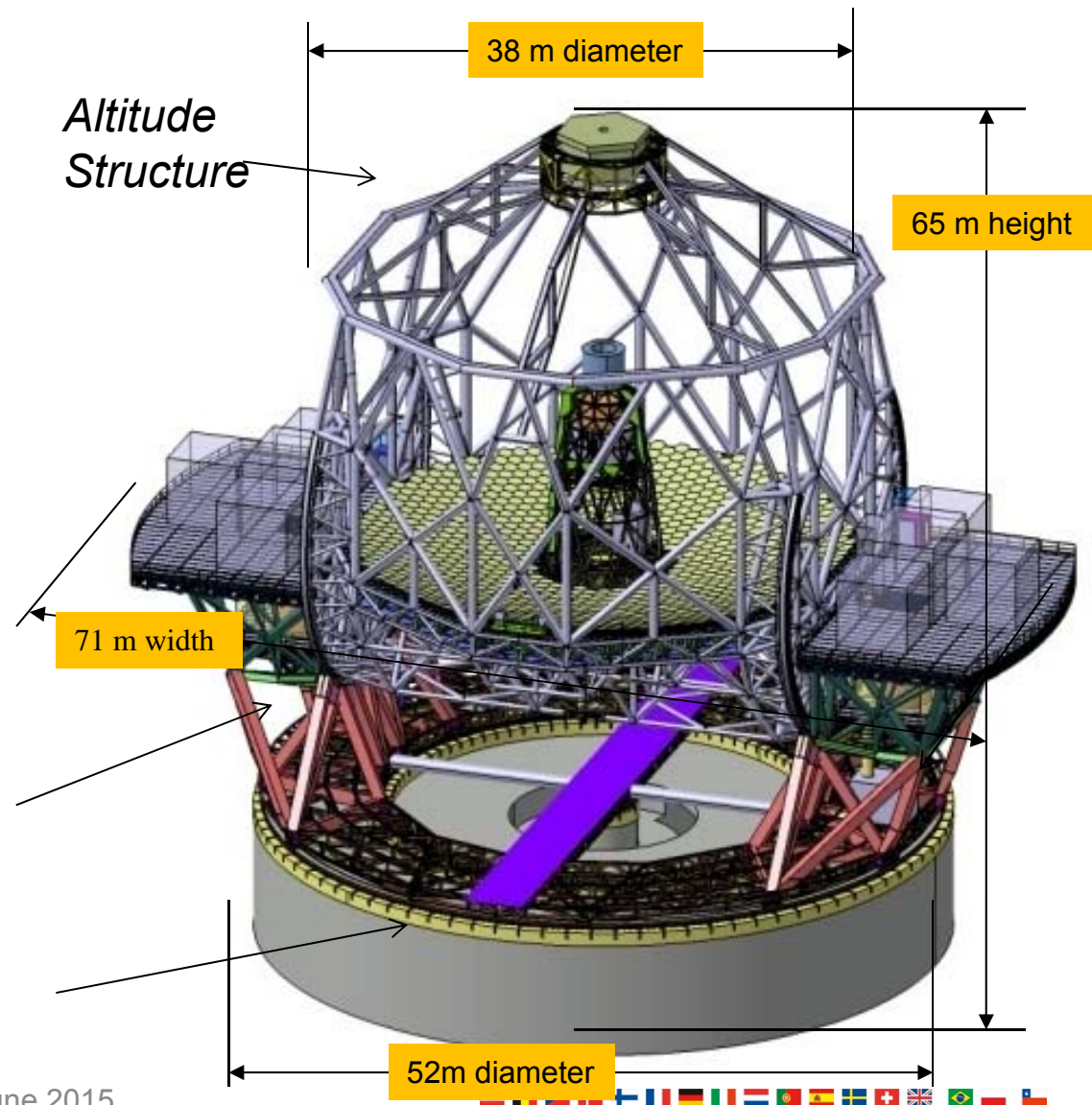


The E-ELT: Main Structure

The Main Structure is about 2500 tons of steel holding and moving 700 tons 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.

Azimuth Structure

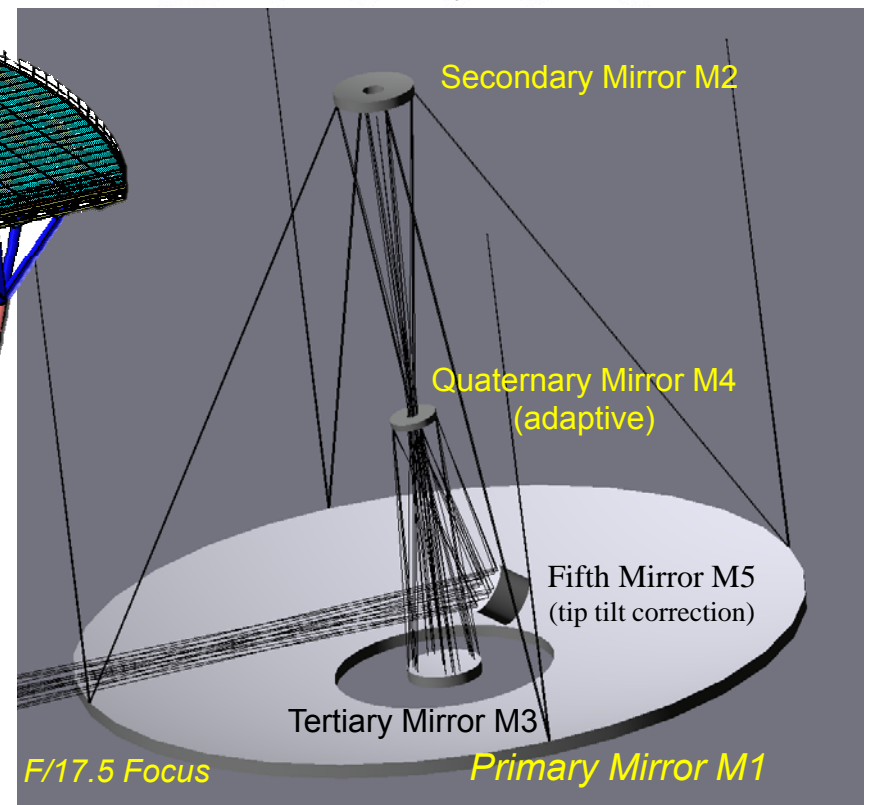
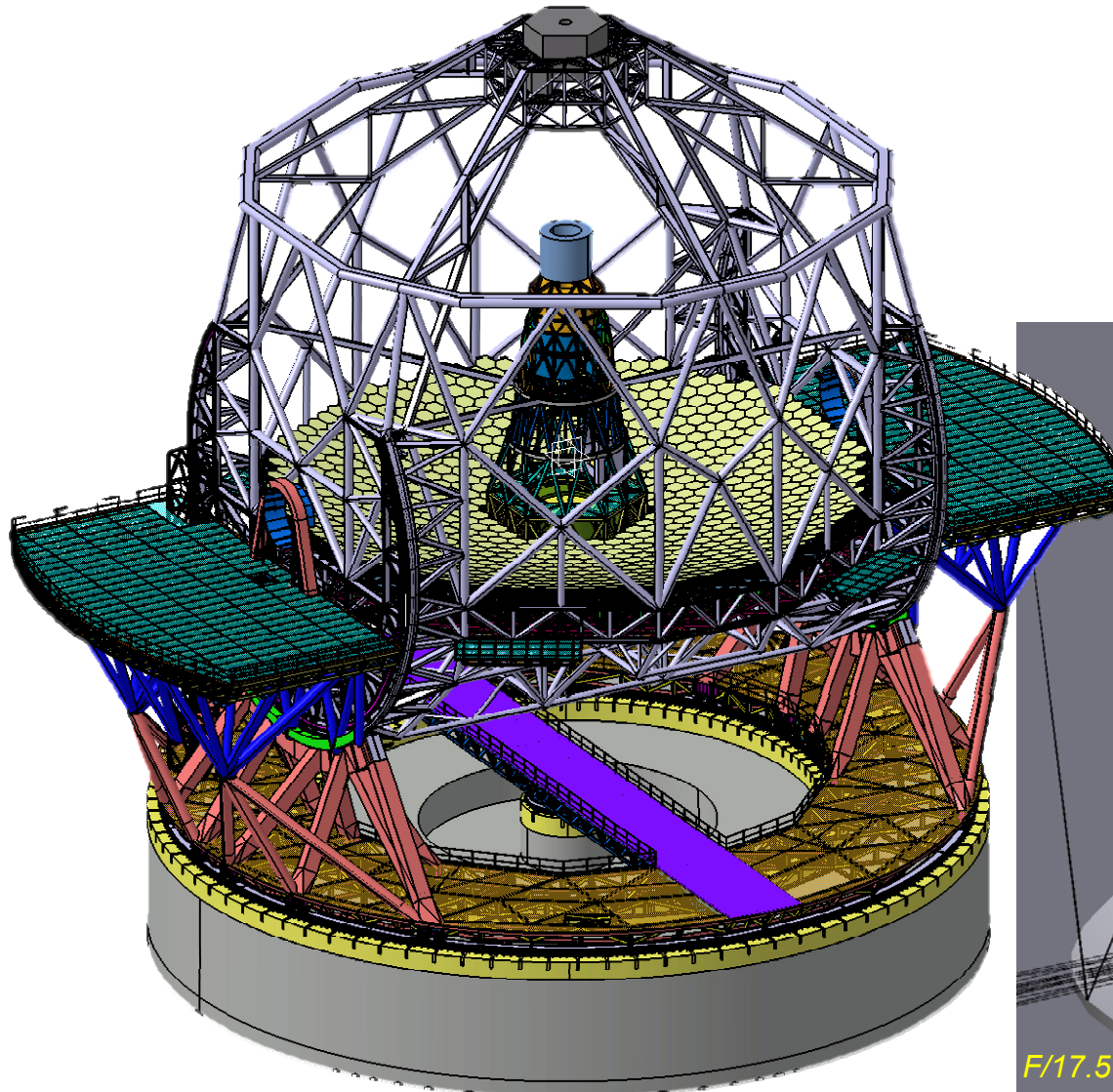
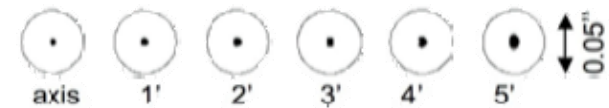
Telescope foundation and Azimuth tracks



The E-ELT: overview

Optical design

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

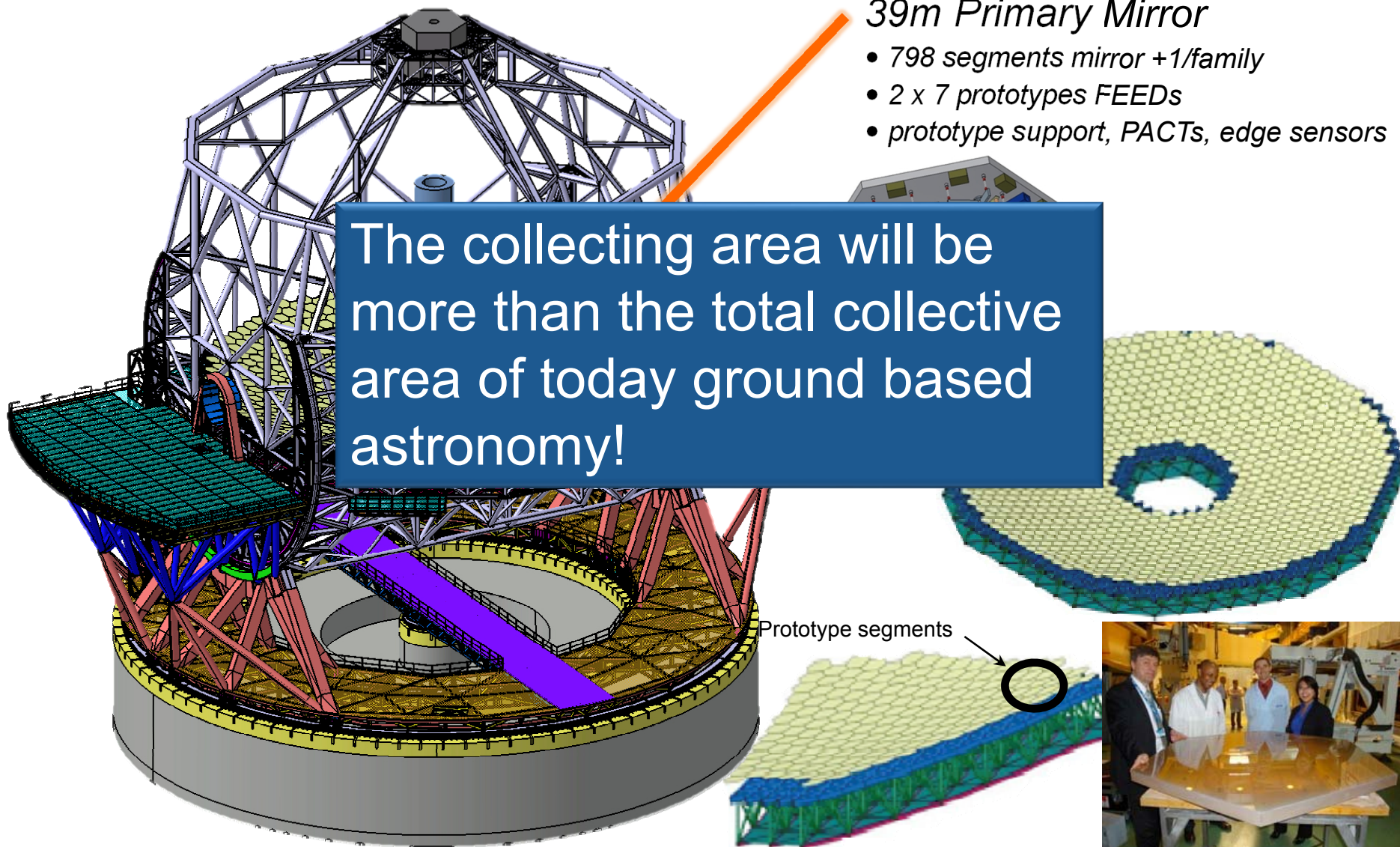


The E-ELT: overview

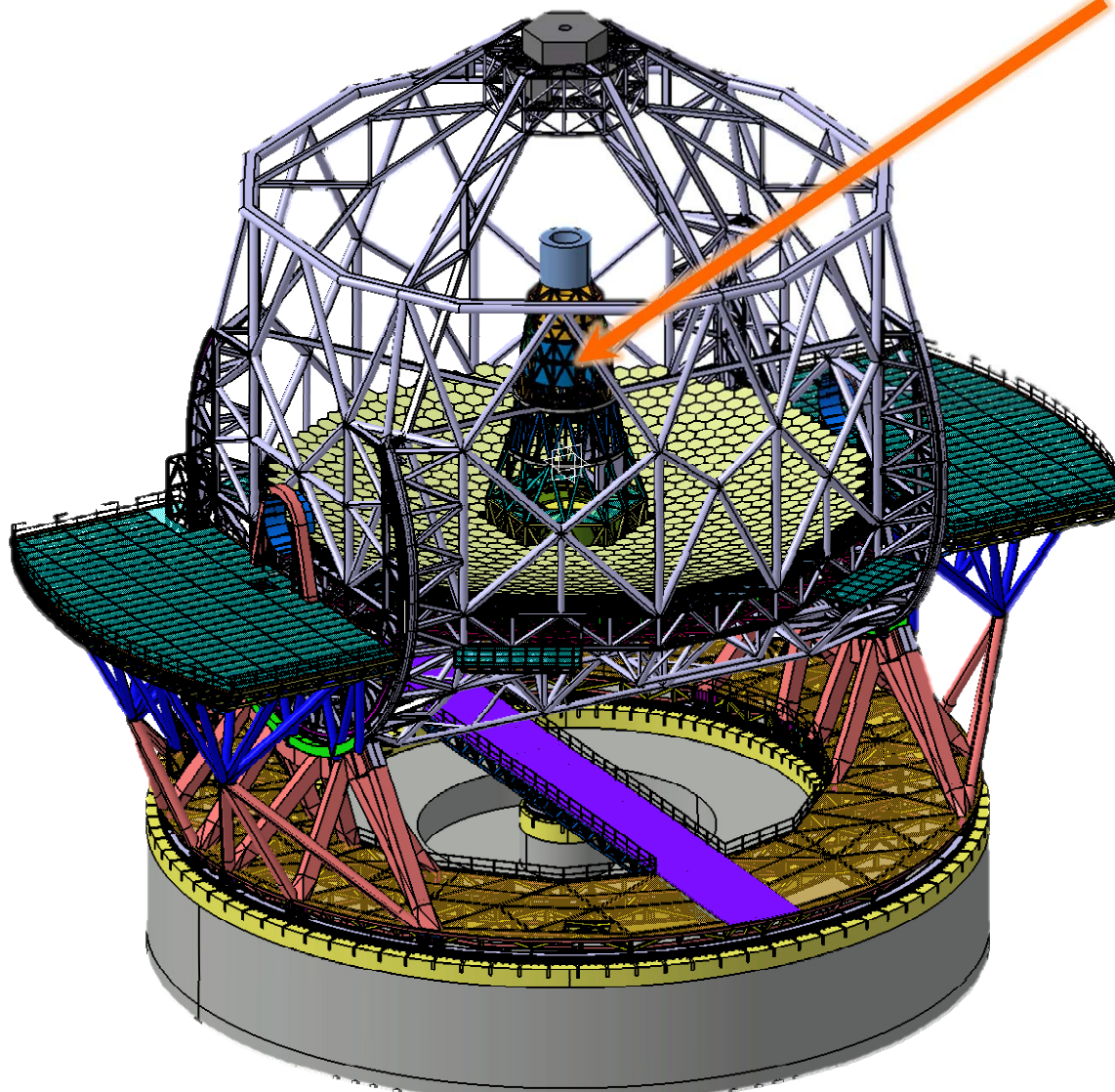
39m Primary Mirror

- 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!

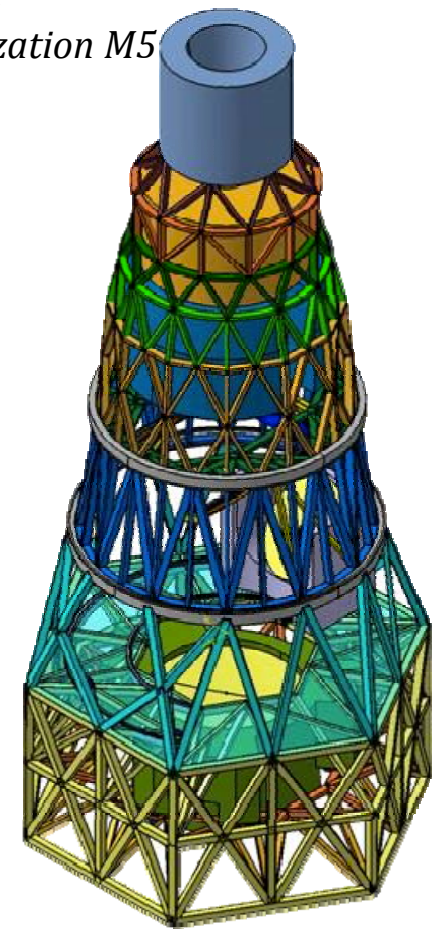


The E-ELT: overview

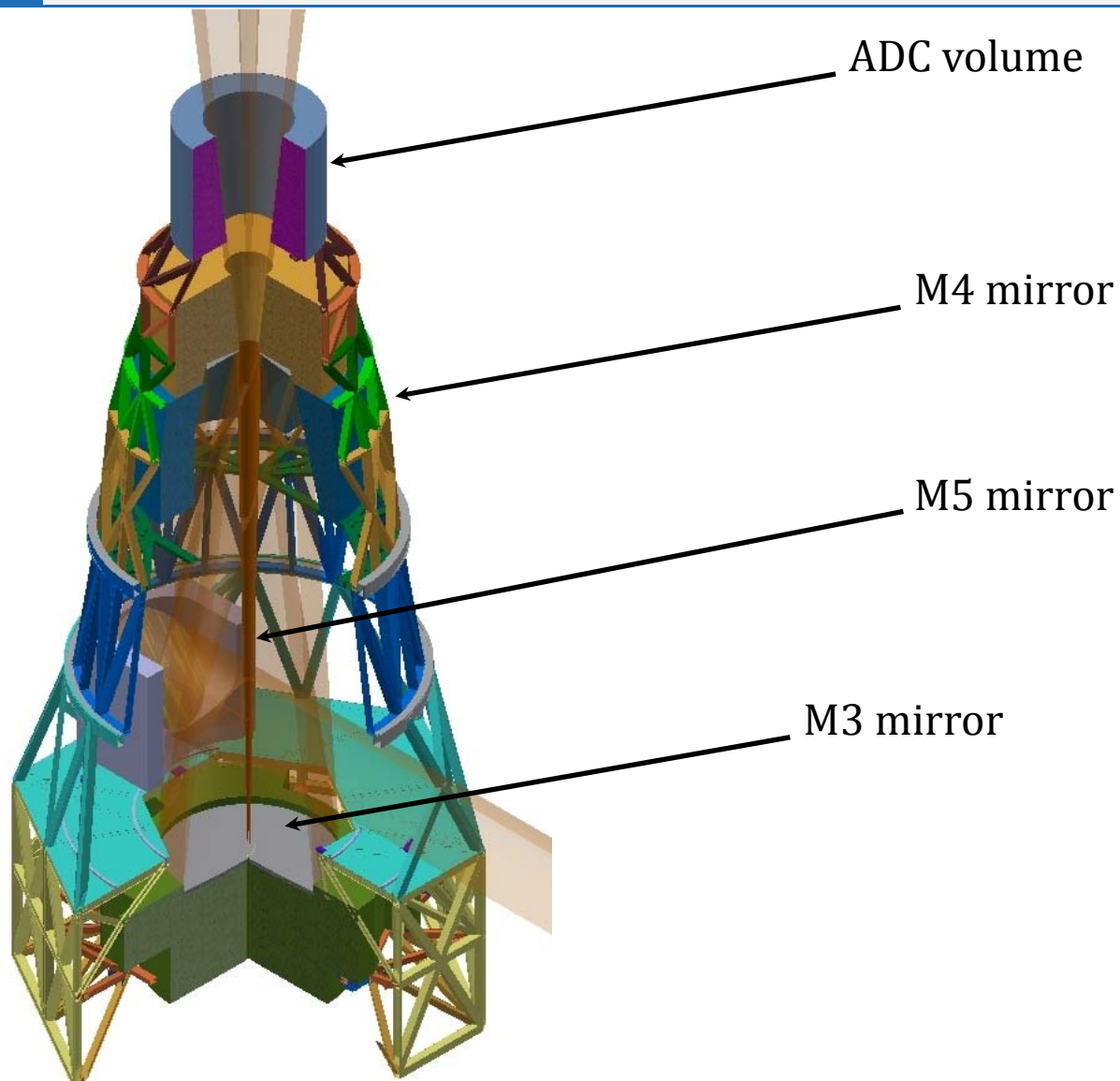


Central tower

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

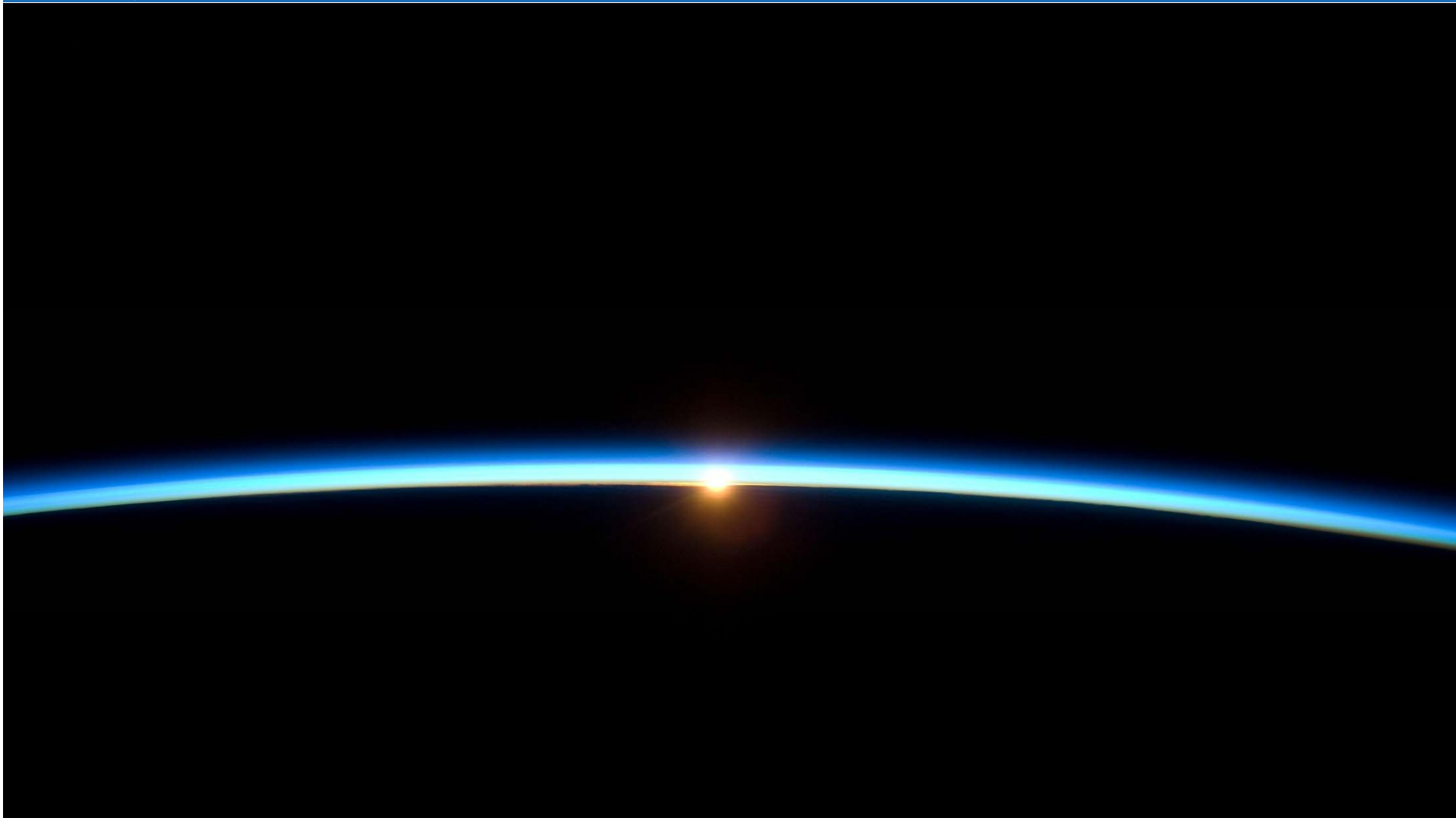


The E-ELT: overview





Our atmosphere



Credit: NASA

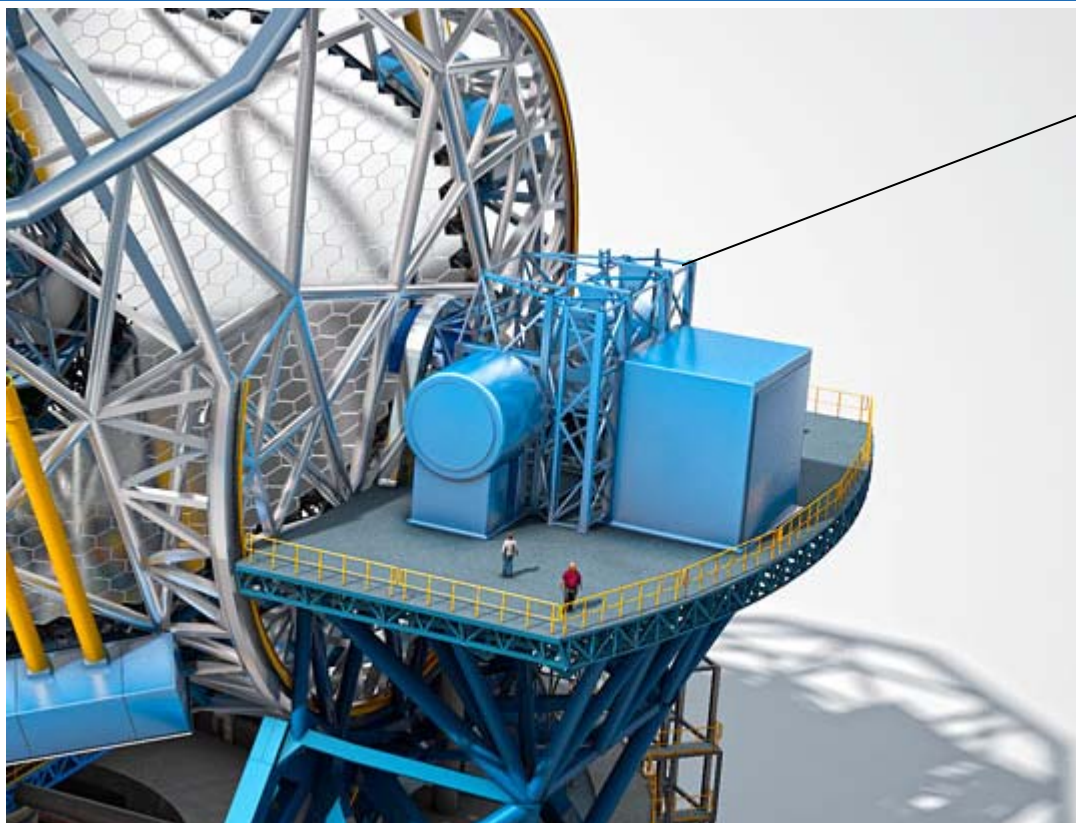
Adaptive Optics Principle







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



Prefocal Station Functional Requirements

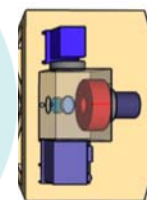
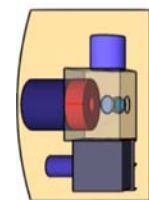
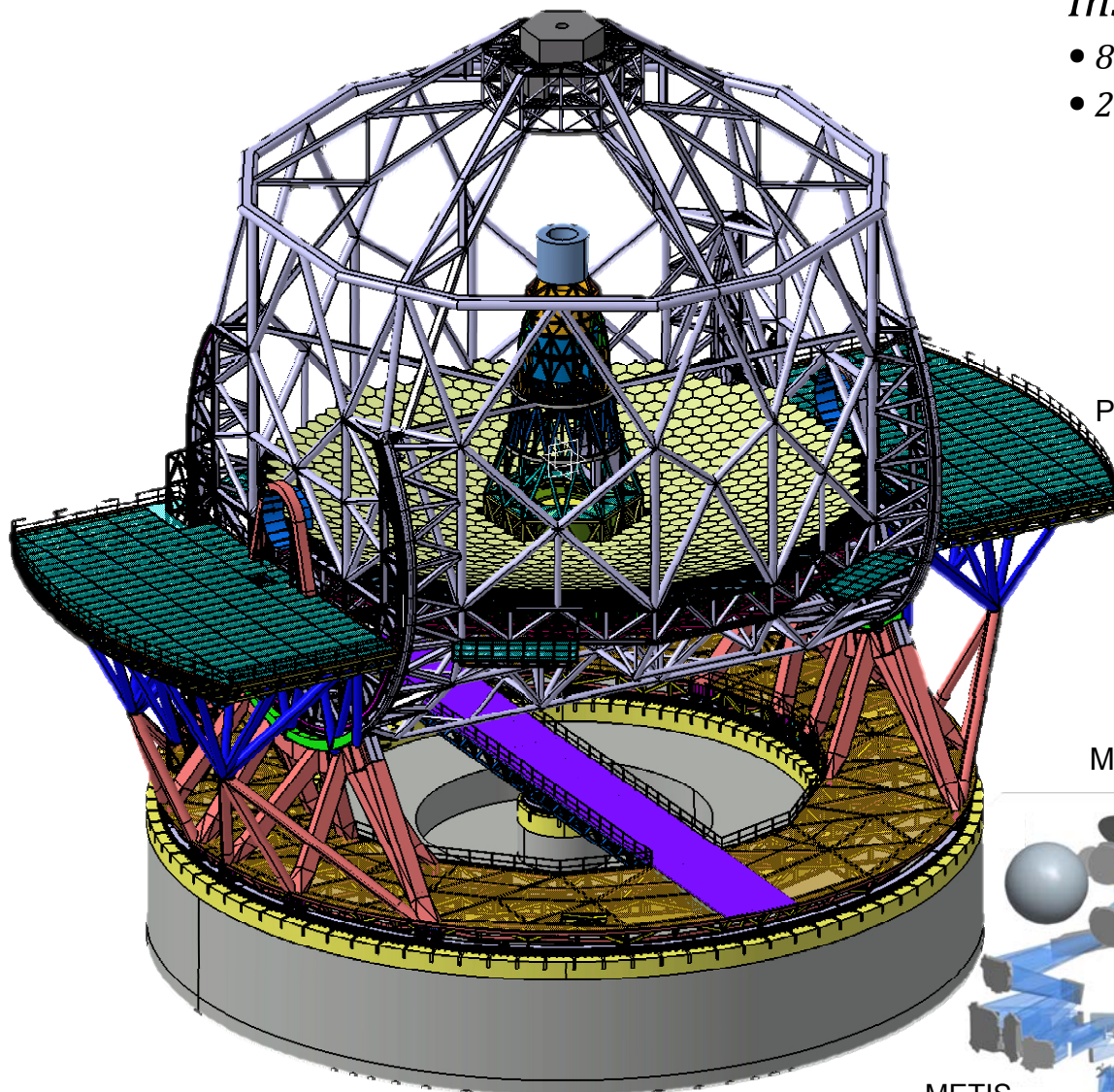
- Beam propagation and optical reconfiguration
- Optical sensing to support active optics (provision for up to a maximum of 3 independent natural guide stars wavefront sensor arms in telescope adapter)
- Phasing Sensor with imaging capability for calibration
- Serve the Coude Focus and Phasing Sensor (M6C mirror)
- Serve straight through focus with 10 arc minute field
- Serve two lateral foci with 4.5 arc minute field (M6N mirror)
- Structural Support and Stability
- Local Control



The E-ELT: instruments overview

Instrumentation

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



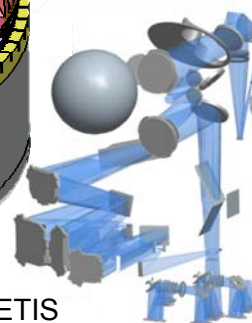
Possible instruments location



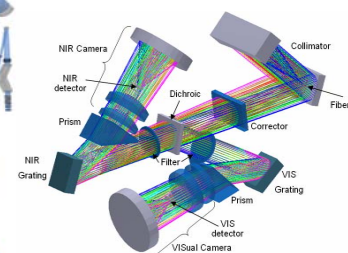
MICADO



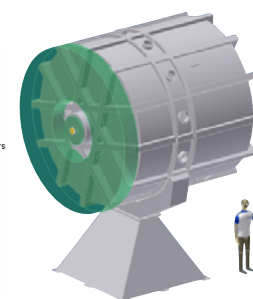
EAGLE



METIS



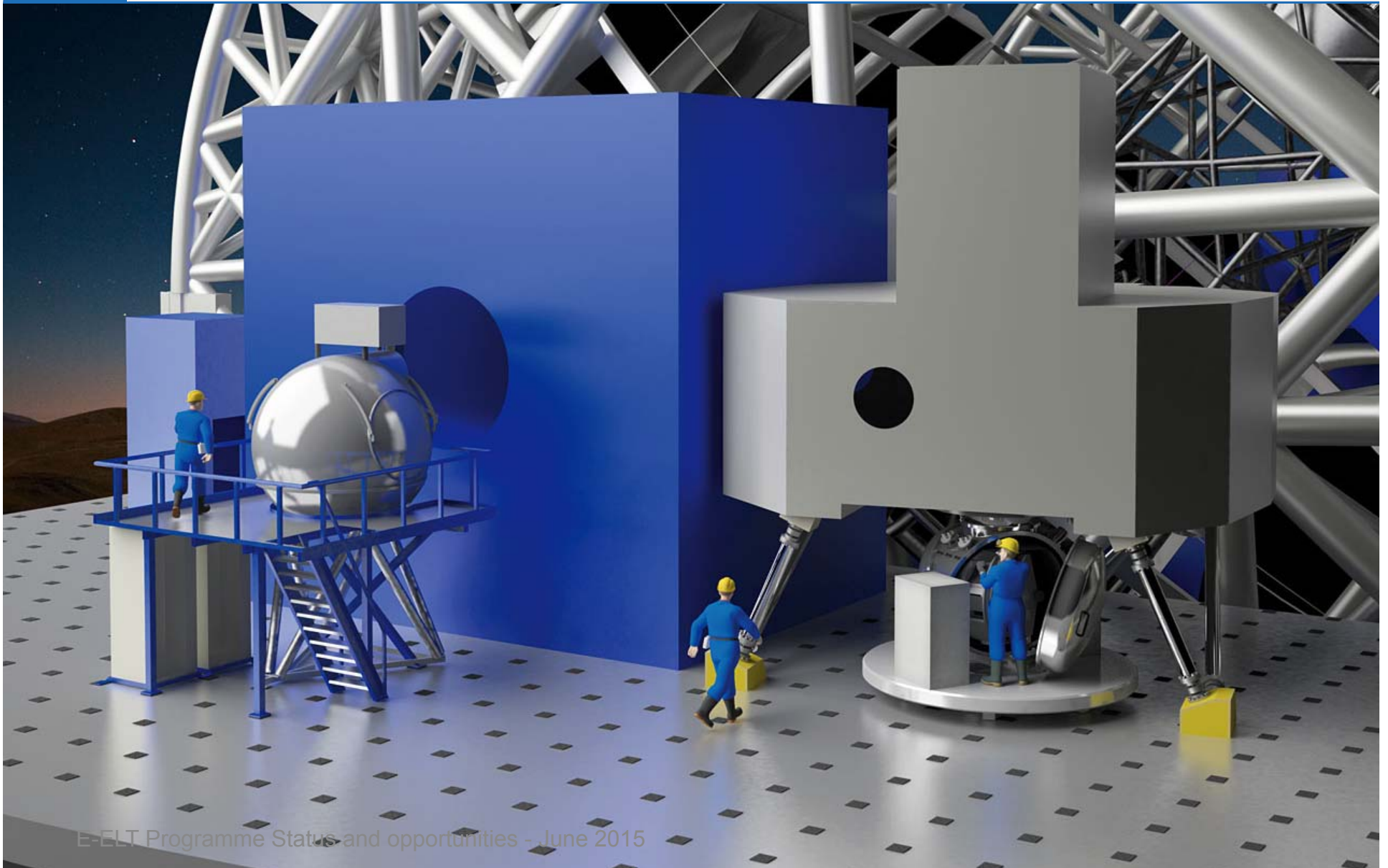
OPTIMOS/EVE



HARMONI



The Instruments





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 in December 2012, and
 - Brazil had/has not yet completed its accession,
- the approval was subjected 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.



Moving forward

- The achieved approval:
 - 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

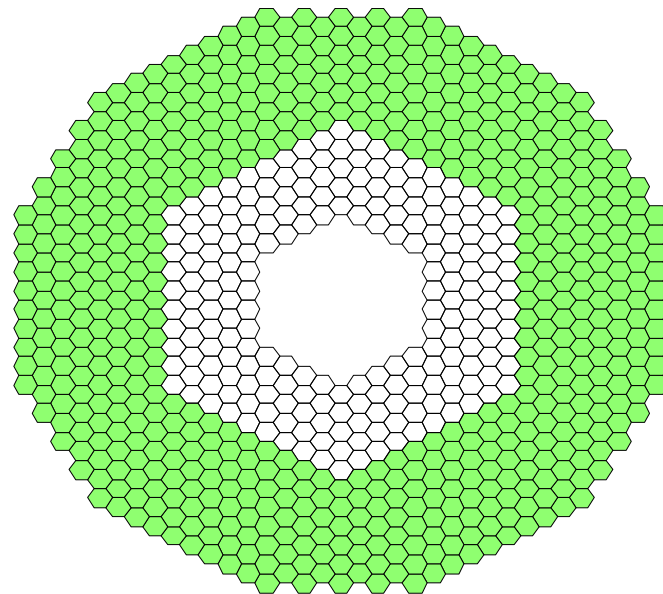


Deferred Items (Phase 2)

Item	Priority for restoration in Phase 2
LTAO	1
Atmospheric Monitoring	2
Inner 5 rings of M1 segments	3
7 th 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





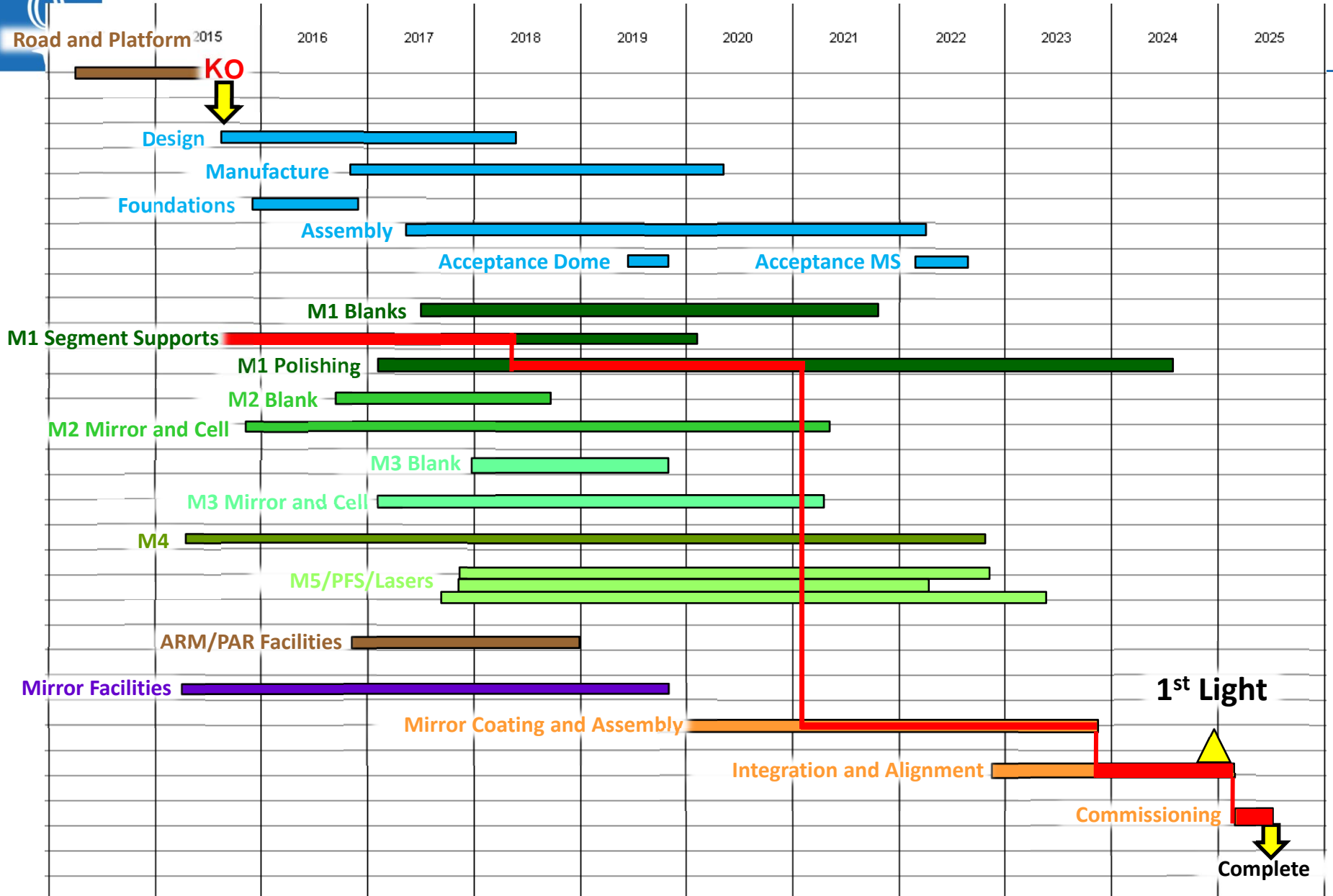
The start of a new Era!

- 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





E-ELT Construction Schedule & Critical Path





Executive Summary

- 'Green Light' for Phase 1 construction (Dec. 2014)
- Team has been working at full throttle with strict deadline commitment to allow May FC approval for:
 - Two industrial Contracts (M4)
 - Agreements for three Instruments and an AO Module study
- This sustained effort secured:
 - The momentum in the scientific community of ESO Member States
 - Our goal: *Achieve first light, ahead of the other ELTs and contemporaneously with JWST, with a full complement of instrumentation!!*

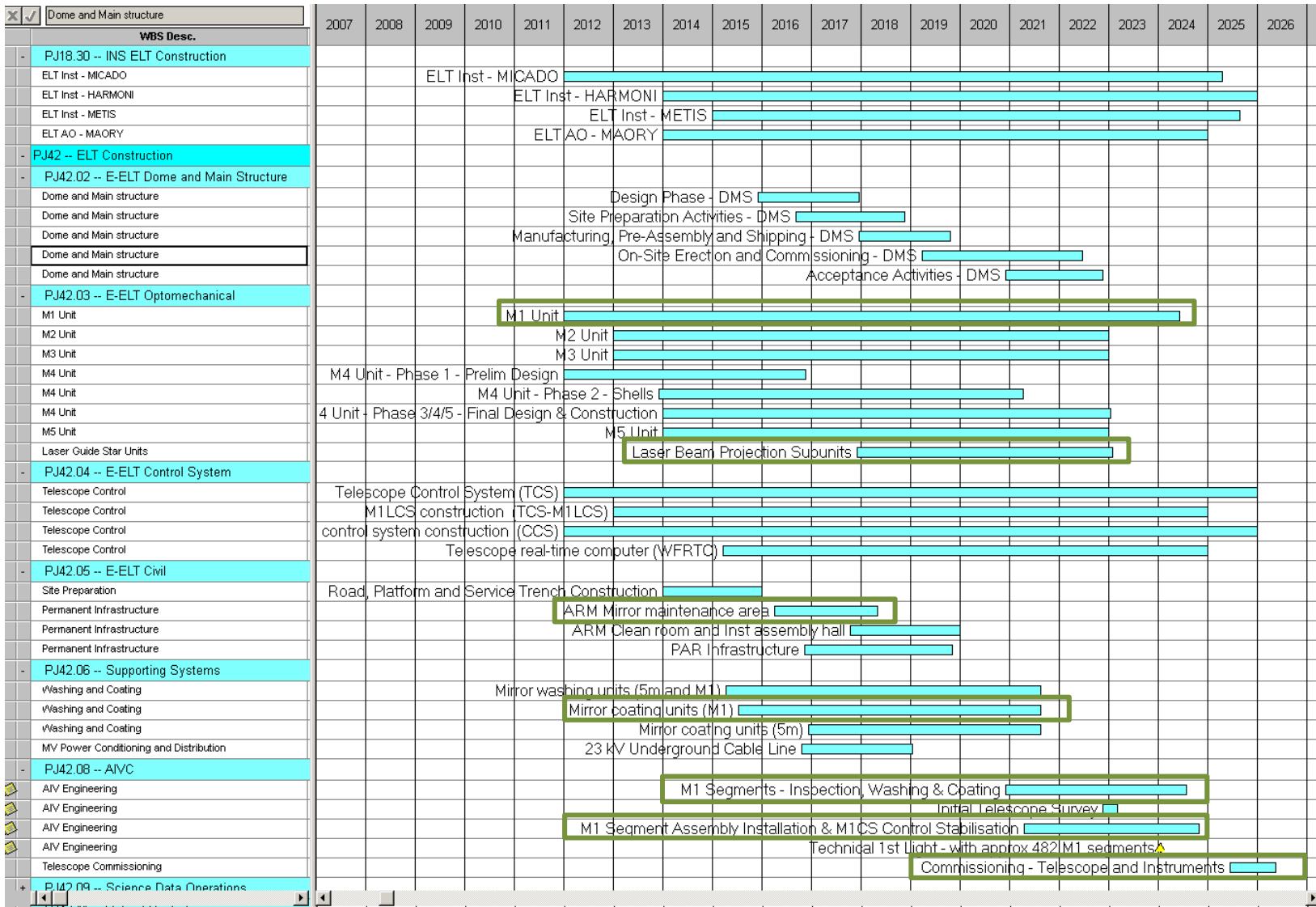


Programme Planning Update (Two-phases approach)

- 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

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



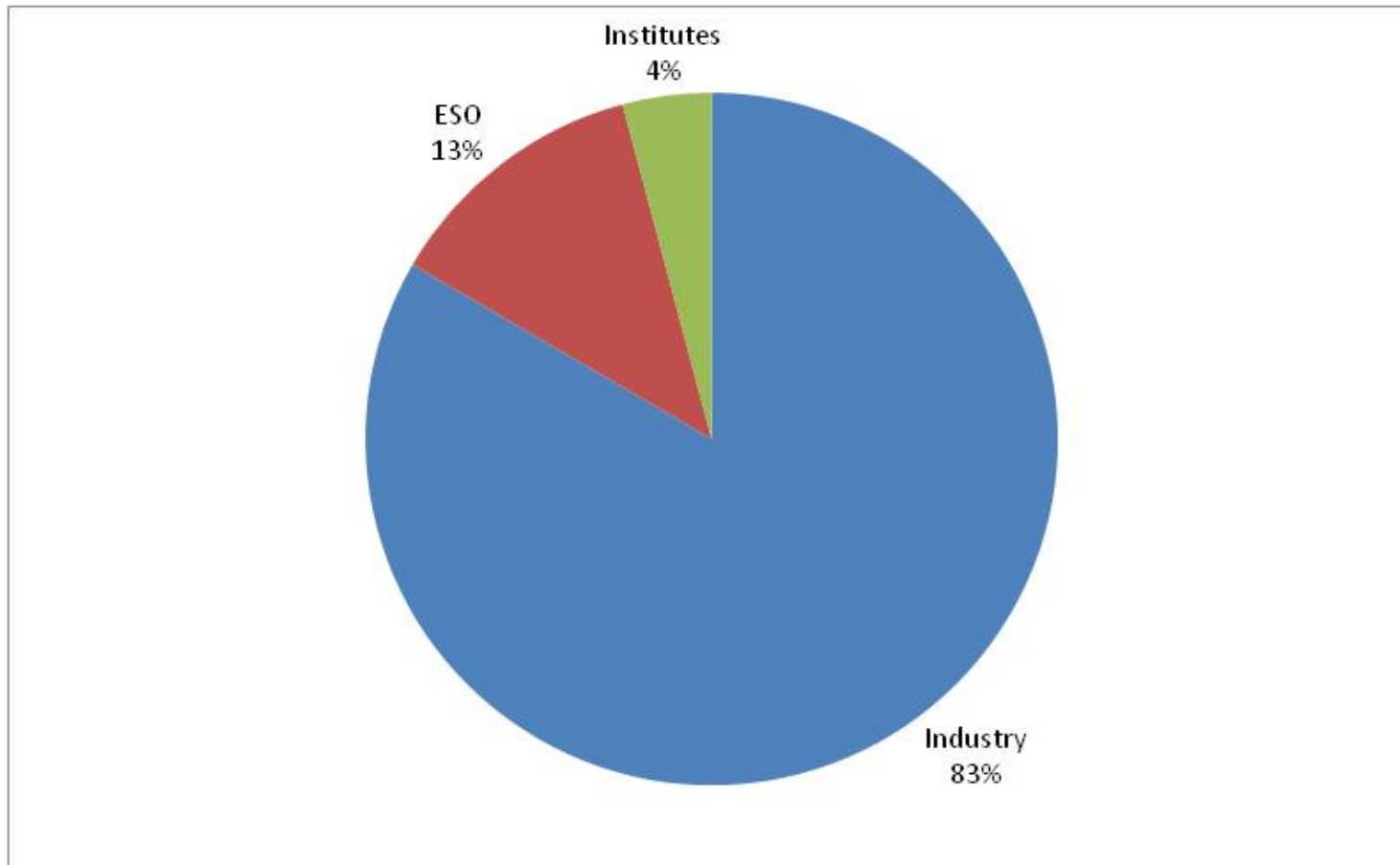


Procurement Strategy Principles

- Basic principle: outsource all what can be efficiently performed by outside partners (industry or institutes) while keeping inside ESO the tasks where ESO has a long and specific experience not readily available outside .
 - Examples of the first category are: detailed design, construction and integration of large structures (e.g. Dome, telescope Main Structure), high-precision optical mirror production, design, construction and integration of astronomical science instruments (by consortia of astronomical institutes).
 - Examples of the second category are: specification, design and implementation of telescope control systems, AIV of high-precision opto-mechanical units, coating of large mirrors.



E-ELT - Overall ESO/Industry share





Near Term Procurements (WBS 1)

- Independent Software Validation and Verification Service (ISVV)
 - Independent check to ensure quality of the control software development (requirements definition, traceability, testing)
 - Procurement start in 2015 (Nov 2015 FC) to run for 7 years
 - Looking for suppliers in MS and Chile with track record in ISVV

- Quality Assurance Services
 - Focused on Dome & Mainstructure and Optomechanics production to ensure projects are being carried out in accordance with contractual specifications. Includes: measurement of materials, parts and products, supervision of transport operations
 - Procurement start in 2015 (Nov 2015 FC) to run for 9 years
 - Looking for suppliers in MS and Chile with track record in QA/PA for large EPC contracts



Near Term Procurements (WBS 2)

■ 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): done in February this year
 - Step 2 (commercial offer): due date July 2015
- Procurement continues in 2015 (Feb 2016 FC) to run for 9 years



Still opportunities to become sub-contractor



Near Term Procurements (WBS 3)

- Polishing of the M1 Mirror Segments
(Phase 1: 588 segments, Phase 2: 343 additional)
 - Polishing and integration with segment supports. Delivery to site at Armazones
 - CfT planned for Q4 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 (φ 1: 1764, φ 2: +646) and electronic controllers (φ 1: 588, φ 2: +216) to be mounted on each M1 Cell
 - Procurement start 2017 (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



Near Term Procurements (WBS 3)

■ Edge Sensors for M1

- Contract(s) for the production of edge sensors (φ 1: 3318, φ 2: +1312) , controllers, tools and interfaces.
- Contract to start end 2016 (Nov 2016 FC) to run for 5 years
- Looking for medium large size (turnover 10-15 MEURO) suppliers in MS and Chile with track record in non contact nanometer accuracy displacement sensors

■ Segment Supports for M1 (serial production)

- Contract (s) for the production of segment precision mechanical supports (φ 1: 588, φ 2: +343) and fixed frames (φ 1: 588, φ 2: +210), tooling and transport containers.
- Procurement in 2018 (May 2018 FC) to run for 4 years
- Looking for medium to large size (turnover above 30-60 MEURO) suppliers in MS and Chile with track record in precision mechanics manufacturing and integration

2018



Near Term Procurements (WBS 3)

- M2 Cell and Mirror (jointly with M3 cell and mirror)
 - M2 Mirror design and production of polished mirror blank with mechanical supports, transport container and tools
 - M2 Cell design and production of whiffletree steel frame structure, mechanical supports and tools. Integration with dummy mirror (from mirror supplier)
 - Contract to run during 2016 to 2021 (Nov 2016 FC)
 - Looking for medium/large size (turnover > 20 MEURO) suppliers in MS and Chile with track record in large optics manufacturing, large opto-mechanical systems design and manufacturing

- M2 Mirror Blank (possibly jointly with M3 blank)
 - Contract to run during 2017/18 (Nov 2016 FC)
 - Looking for medium-large size (turnover > 20 MEURO) suppliers in MS and Chile with track record in large glass ceramic blanks manufacturing.

 - RFI to be released soon



Near Term Procurements (WBS 4)

■ Communication Middleware (DDS):

- Development licenses and tools for the Data Distribution Service (DDS) communication middleware software, for E-ELT distributed control system.
- Procurement process end 2015
- Looking for suppliers in -and outside MS (*in previous round no suitable suppliers were identified in MS*)
- Product sought is an off-the-shelf implementation of the DDS standard available from a financially stable supplier.

■ Infrastructure telescope control

- SW design and development of the core integration infrastructure for the Telescope Control System (TCS)
- Possible procurement end 2016 (Nov 2016 FC)
- Looking for suppliers in MS and Chile



Near Term Procurements (WBS 4)

■ Real time computer (RTC) infrastructure

- SW development environment, computer and network infrastructure
- Procurement during 2017 (Nov 2017 FC)
- Looking for in MS and Chile with track record in supply of SDE (SW Dev. Env.)

■ WaveFront Sensor (WFS) Detectors

- Procurement of wavefront sensors. Design and production of the detector and associated controller, it includes the optomechanical subassemblies that sample the wavefront (e.g. lenslet array)
- Procurement during 2016/17 (May 2017 FC)
- Looking for suppliers in/and outside MS and Chile with track record in of scientific optical mechanical systems

2017



Near Term Procurements (WBS 6)

- Design of Medium Voltage (MV) Power System (inc UPS)
 - Design of power system (connection between grid and power distribution with in Armazones). Function of the power system will be: Medium and low voltage transmission, UPS, back-up generation capability and power management
 - Procurement in summer 2014 (Nov 2014 FC)
 - Looking for suppliers in MS and Chile with track record in design of medium and low voltage power systems

Phase 2



Near Term Procurements (WBS 6)

■ Mirror Washing units

- 4 meter mirrors and M1 washing units
- Procurement late 2016 (Nov 2016 FC)
- Looking for medium size (turnover 5-10 MEURO) suppliers in MS and Chile with track record in design and manufacturing of cleaning/stripping equipment (chemical cleaning/stripping)

■ M1 Mirror Coating units

- Coating units used to coat the M1 segments on site
- Procurement late 2017 (Nov 2017 FC)
- Looking for medium size (turnover 10-15 MEURO) suppliers in MS and Chile with track record in design and manufacturing of coating/vacuum thin film deposit equipment

Near Term Procurements (WBS 6)

■ MV Distribution and UPS Construction

- See slide 15. EPC contract for hand over to ESO
- Procurement for supply and commissioning by end 2018 (November 2016 FC)
- Looking for medium size (turnover XXX MEURO) suppliers in MS and Chile with track record in supply and installation of MV power systems

■ Chillers

- HVAC 3.5 KW for provision of chilled medium to the Dome
- Implementation during 2017 and 2018 (November 2016 FC). Interface with Dome
- Looking for medium size (turnover 10-15 MEURO) suppliers in MS and Chile with track record in supply, installation and commissioning of HVAC systems



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 June)
 - 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)*
 - ISVV, Independent SW Validation and Verification Consultancy (done)
 - Quality Assurance and Quality Control Consultancy Service (done)
 - Edge Sensors (waiting for replies)
 - M1 segment polishing, M2 blank & polishing (in preparation for June)

- **One Call for tender running**
 - Dome and Main Structure (Phase 2 started)
 - See next slide



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 |



Instrument Procurement Process

- ✓ Council approval of Two-Phase approach (Dec 2014)
- ✓ Initial allocation to instrument teams (Dec 2014)
- ✓ Feedback from instrument teams (Feb 2015)
- ✓ Discussions with PST and ESC (Feb/March 2015)
- ✓ Proposed de-scopes considered excessive
- ✓ Extra funds required
- ✓ Cash contributions from consortia (special situation)
- ✓ Part of E-ELT contingency released (March 2015)
- ✓ Discussion and agreement on scope and cash for construction



Instruments Next steps

- ✓ Recommendation from STC (April)
 - To complete negotiations for construction
- ✓ Approval from FC (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



The Baseline Roadmap

Instrument	Status
MICADO	Approved by Committees – finalization of docs for contract signature
MAORY	Approved by Committees – finalization of docs for contract signature
HARMONI	Approved by Committees – finalization of docs for contract signature
METIS	Approved by Committees – finalization of docs for contract signature
ELT-MOS	Request for Information
ELT-HIRES	Request for information
ELT-6	Call for proposals in 2016
ELT-PCS	To proceed when technology is ready (2019)



MOS & HIRES (summary)

- ELT MOS & HIRES are funded to PDR as part of construction. Work post PDR is funded from Operations.
- Request for Information issued, received (April) and analysed. RFI instruments try to fulfill all the TLRs, rather than a subset, but will cost significantly more than the budget available to 2030 (even with Brazil). Information to be used for Call for Proposals (issued before August break).
- The call will
 - Specify the available budget and will *not* allow a significant distortions of the GTO with external cash contributions
 - Will include guidelines for consortia size and organization
 - TLRs non-compliance's may be traded-off as part of the Phase A study, but requires a scientifically compelling, affordable and feasible project



Status of procurement processes (approved new contracts)

- Two contract awards approved by May FC
 - M4 Shells (within budget)
 - M4 Unit final design and construction (within budget)

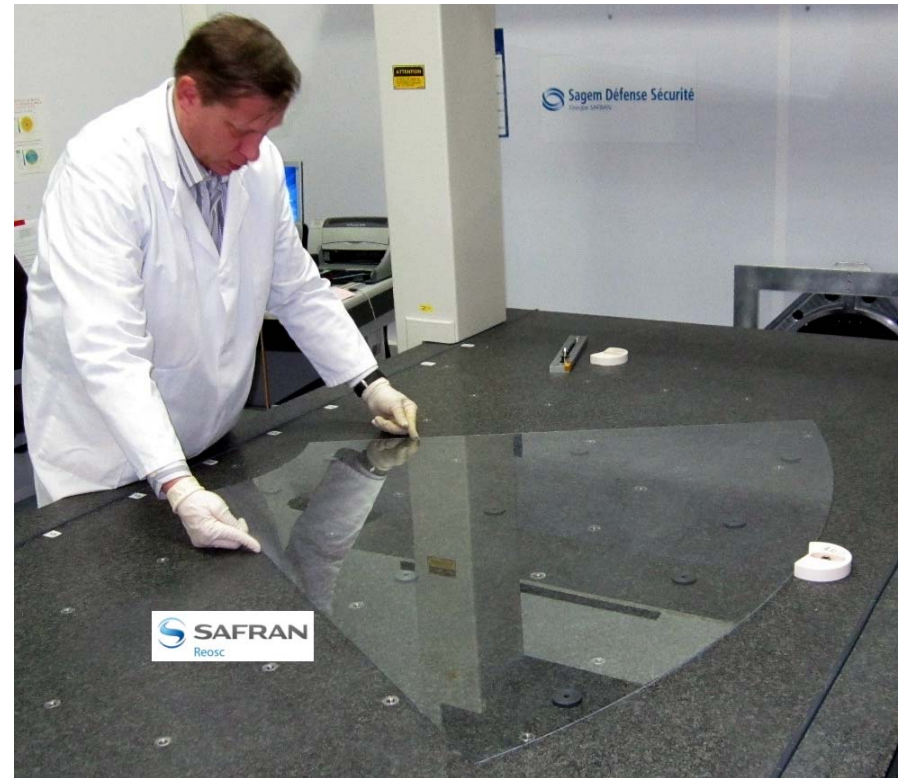
- Instruments procurements approved by May FC (contingency needed) and GTO approved by Council in June
 - MICADO
 - MAORY
 - HARMONI including LTAO study to PDR
 - METIS

- See details below



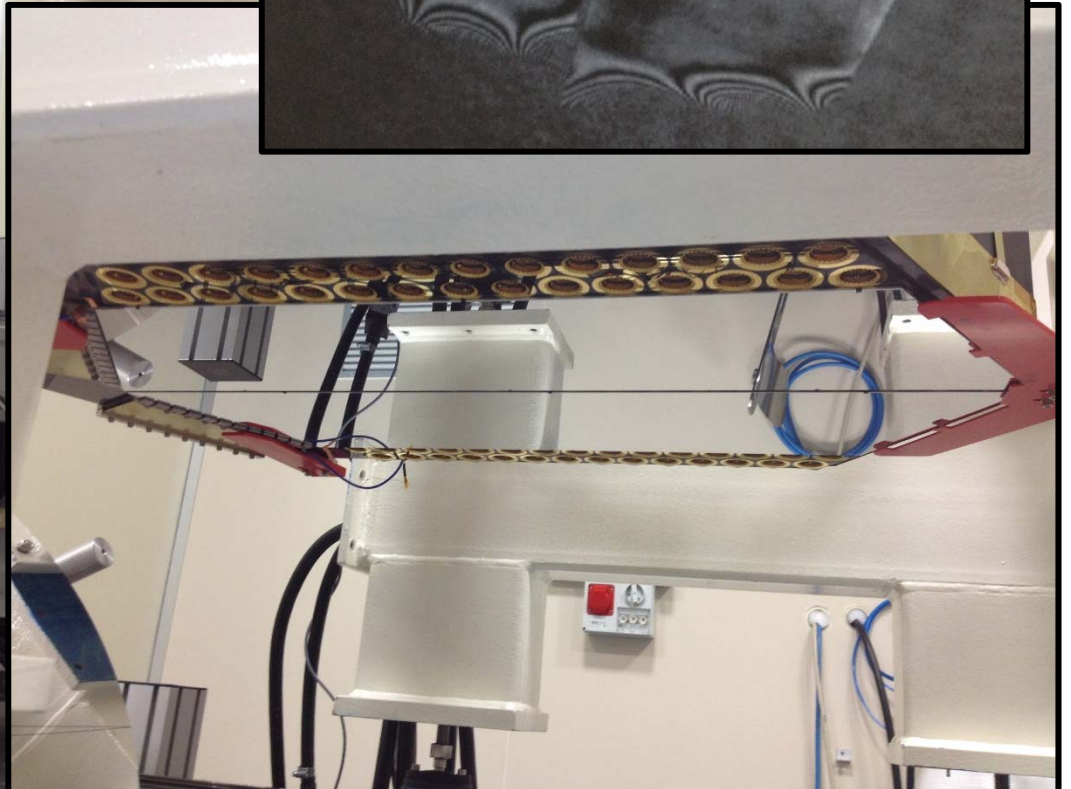
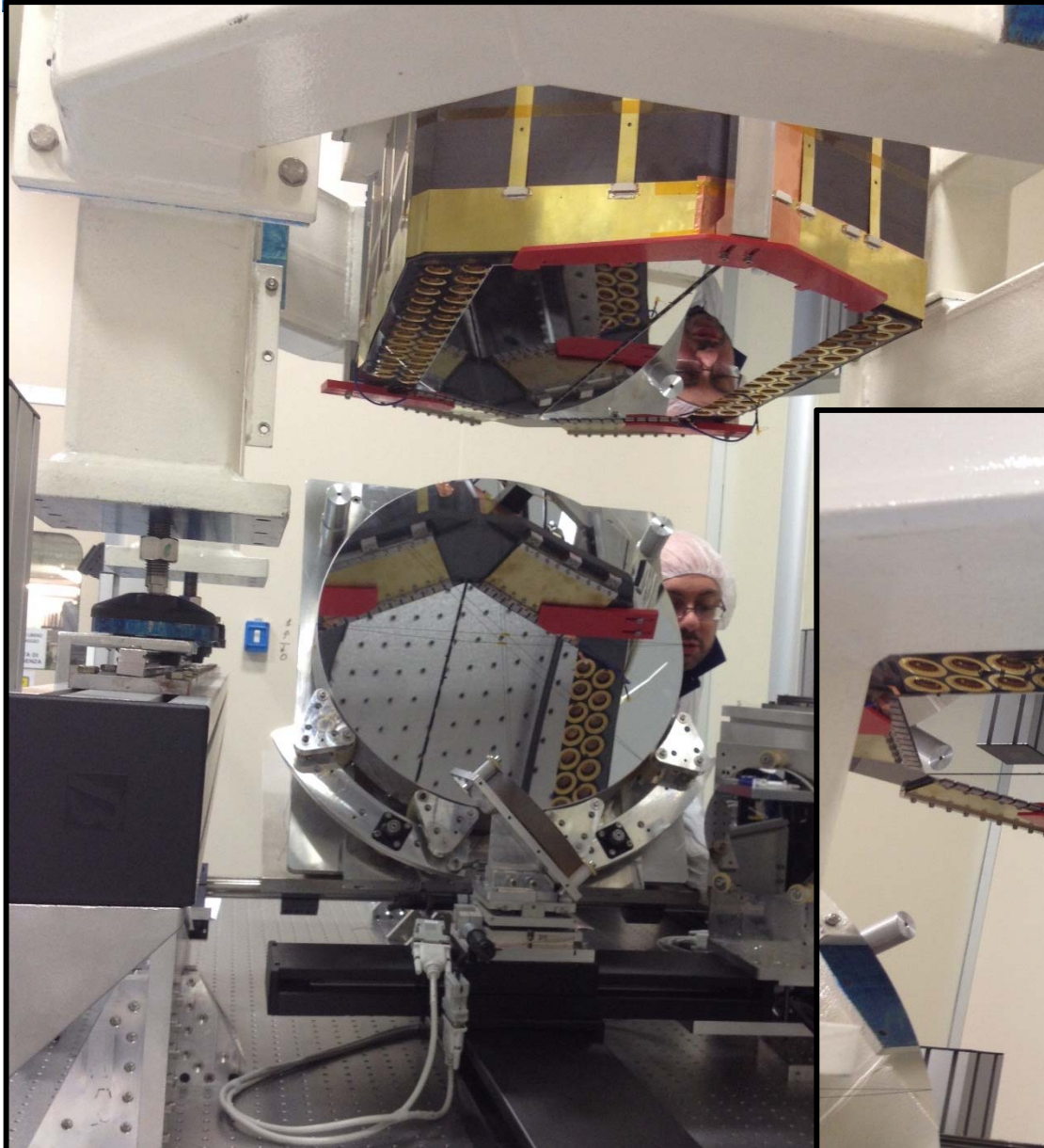
M4 Shell Contract

- Manufacturing of the shells (blank, polishing, testing)
- Diameter 2.4m, 1.95mm thick 10nm RMS figuring errors
- Completion in 8 years





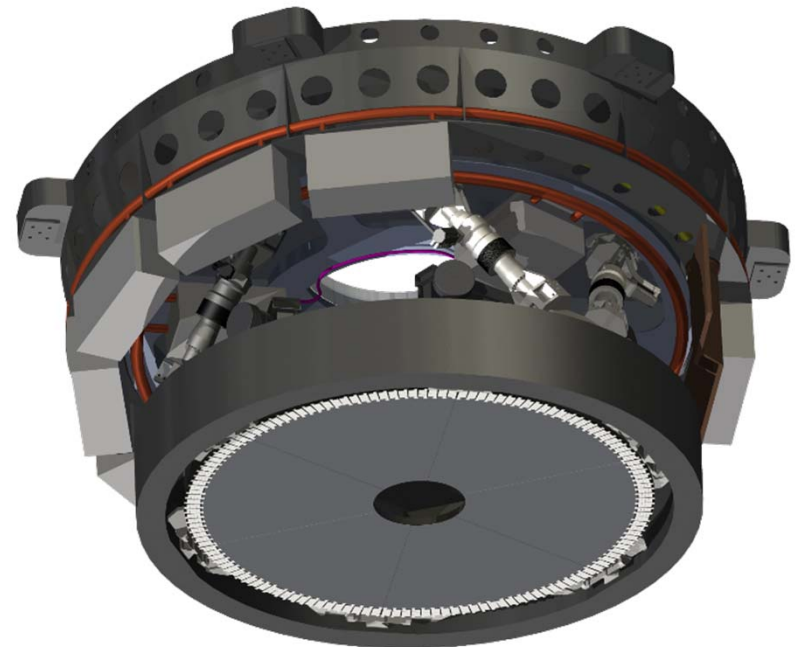
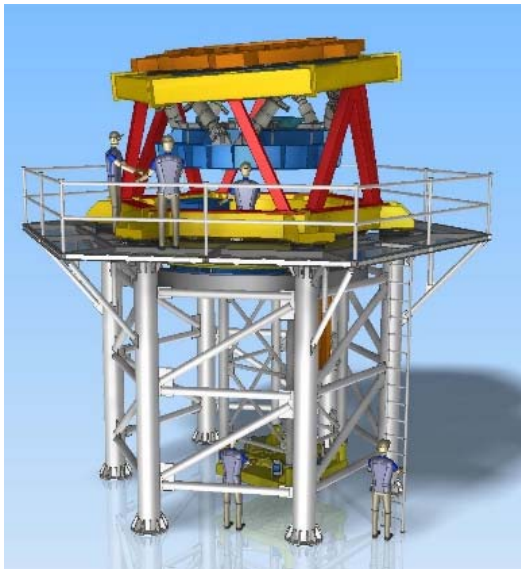
M4 Unit, Demonstration Prototype final optical tests (Q1 2015)





M4 Unit Design & Manuf. Contract

- M4 unit with c.a. 5600 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





Instruments Construction phases

- Preliminary design (2017)
 - Followed by cost/scope review
- Final design (2019)
- Preliminary acceptance – Europe (2024)
- Commissioning (2024)
- Provisional acceptance – Chile (2026)
 - Warranty period follows
- Final acceptance (2028)



Status of Running Contracts

Overview



Running contracts, and their status

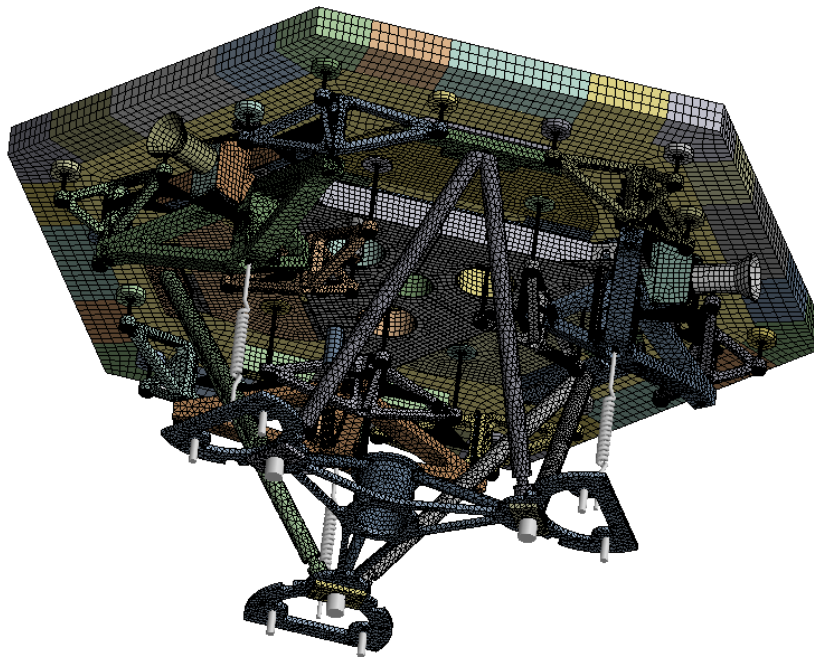
- M1 Segment Support (x2):
 - Design to FDR and delivery of 4 qualification models
- Ramboll – Managerial and DMS Consultancy: on-going
- ✓ M4 unit preliminary design: **completed**
- Road and Platform: Continuing progress



M1SS VDL/CESA Parallel Contracts Status

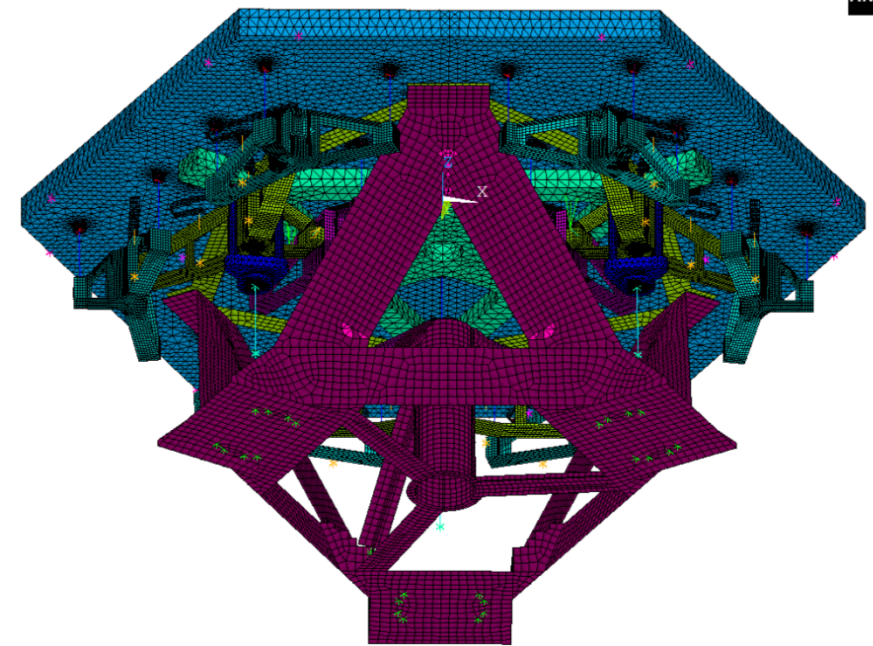
VDL/TNO Eindhoven/Delft (The Netherlands)

- Contract Signature: 14.12.14
- Kick Off: 26.01.15
- Last PM(5): 10.06.15
- PDR: 02.09.15 (T₀+8M) Confirmed



CESA Madrid (Spain)

- Contract Signature: 14.01.15
- Kick Off: 10.02.15
- Last PM(3): 13.05.15
- PDR: October 2015 (T₀+8M) Open



ANSYS



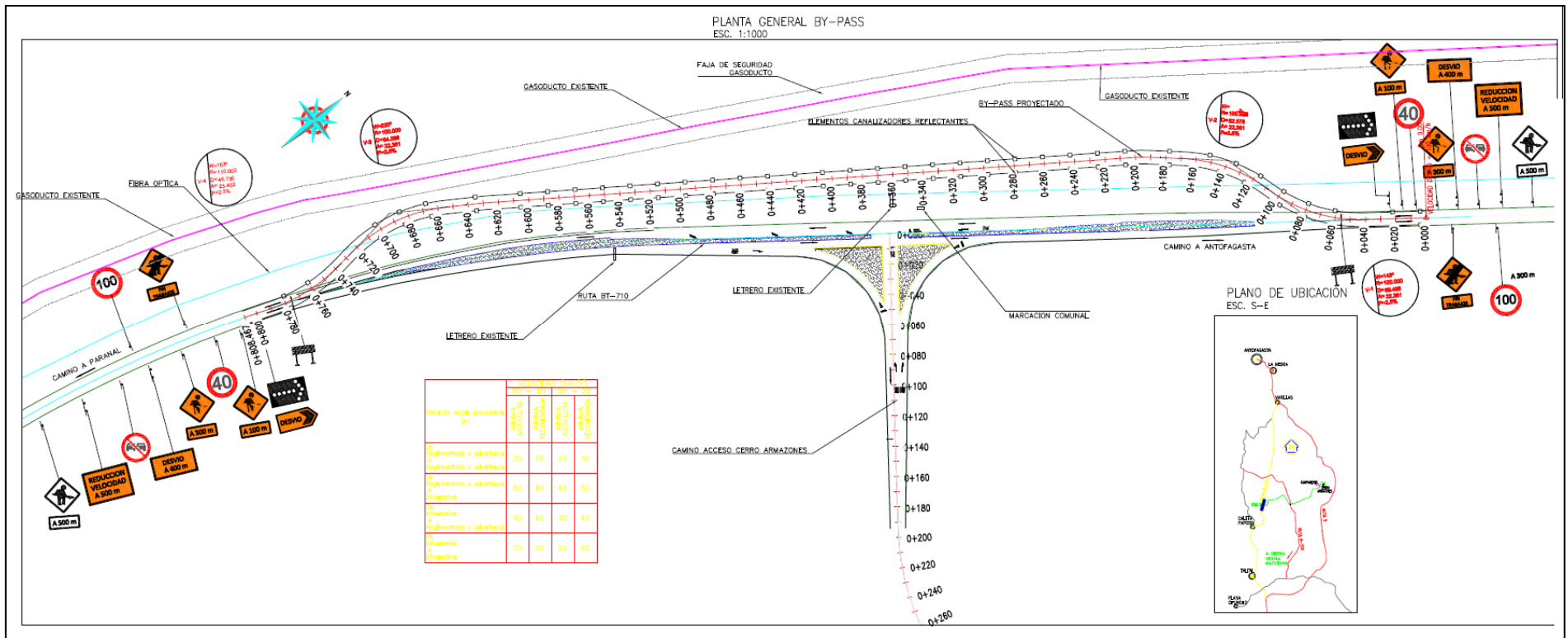
Most Recent Progress

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



Most Recent Progress

- Road By-pass at the connection of the new E-ELT Road with the B710 near Paranal
- Coordinated with the Chilean Dirección de Vialidad, MOP.
- Started on 20th of April, for 60 days





Most Recent Progress





Most Recent Progress





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





Most Recent Progress (20 May 2015)





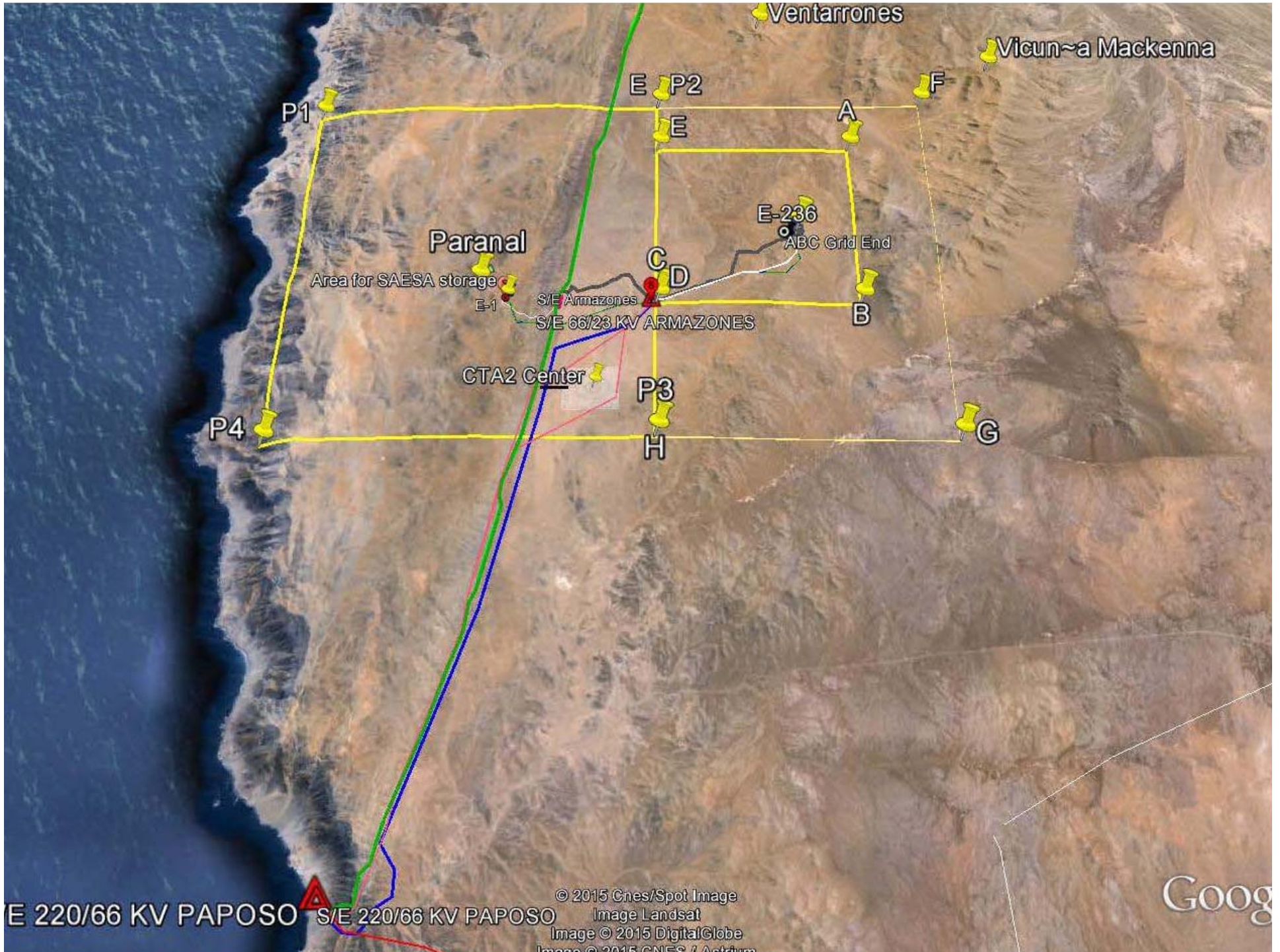
On-site work





Most Recent Progress







The E-ELT



