### E-ELT Programme status

Roberto Tamai Programme Manager 29 June 2016

# **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



# The Organization

### Mission

Develop and operate world-class observing facilities for astronomical research

Organize collaborations in astronomy

### This is achieved by

- Highly-skilled staff carrying out a multi-project program
  - ~390 staff in Garching at Headquarters
  - ~300 staff in Chile at Observatory sites and Vitacura Office
- In-house science, engineering and support activities
  - Without these ESO becomes a management agency, quality of the program will suffer and support by the MS will decline

Matched by additional effort in the Member States

- In industry and in technical and scientific institutions
- In good coordination with ESO

# The ESO Model

Intergovernmental structure provides Support at highest government levels Ministerial level and above in Member States and in Chile Budget stability and long-term planning ability Partnership with community is key to support Joint instrumentation development Public surveys, advanced data products Student and Fellowship programme Small telescope and experiments hosted on La Silla Multi-project programme is cost-effective Re-use engineering skills, apply lessons learned Experience in working effectively with industry





Credit: Google Maps



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# Why the ESO Observatories are in Chile?

- Excellent conditions in the Atacama Desert
  - Extremely dry
  - ➢ 90% clean sky
  - Low turbulence
  - Very limited light pollution





# Excellent vision to the Southern Hemisphere







### ...and we are in very dark zone

Chajnantor

### Sarching bei München

Paranal La Silla Santiago

Earth at Night More information available at: http://antwrp.gsfc.nasa.gov/apod/ap001127.html

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Astronomy Picture of the Day 2000 November 27 http://antwrp.gsfc.nasa.gov/apod/astropix.html

# La Silla, where everything started



3.6m

3.5m NTT







### As seen from the space

Telescopi

60 000 litri di acqua consumati ogni giorno 2 autocisterne consegnano l'acqua ogni giorno da Antofagasta (2+2 ore di viaggio)

Image © 2008 DigitalGlobe

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Residenza

Campo base



### Residence



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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<sup>+</sup> 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











Largest optical/infrared telescope in the world

> 39m segmented primary mirror: transformational step

Science: <u>exo-earths</u>, 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: ~1143 MEUR incl. instruments and contingency

Operation cost: ~50 MEUR / year



# The E-ELT and its competitors

Giant Magellan Telescope (24m)

Carnegie, US univs, Australia, South Korea

> First Light 2022⁺, ≈ 700 MUSD

Las Campanas, Chile

Thirty Meter Telescope (30m)

Caltech, UC, Canada, Japan, China, India

➢ First Light ≈ 2027, ≈1000 MUSD

> Mauna Kea, Hawaii

E-ELT (39m)

- ESO (15 Member States)
- First Light 2024, 1100 MEUR
- > Armazones, Chile









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.





### Requested Resolution





### **Requested Resolution**



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# To put it in perspective...





# To put it in perspective...





### To put it in perspective...



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## **Huge Collecting Area**





# **E-ELT Overview**





# **E-ELT Organigram**

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



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# **Armazones and Paranal**



### Site Environment

Particularities: Altitude: 3046 m (Platform) c.a. 360 nights clear sky Very stable atmospheric and weather conditions with rare (typ. 1-2/year) and short-duration storms in Winter associated with low temperature (down to typ. -10C), unusual rain or snow fall and possibly high winds **Dryness and UV radiation** Active seismic area



### Telescope design

- Altitude-Azimuth mount
- Main Structure about 3400 tons including 700 tons of optomechanics and electronics
- Hydrostatic bearings, driven by electrical direct drive motors
- Precision of 0.3 arcsec under the maximum wind disturbance.
- Two Nasmyth Platforms and one Coude Room for instruments
- Laser launch from M1 edges



# 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 (segmented): 39.1 m



### **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

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:  $\Rightarrow$  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



## 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





Prototype Segment Support

Prototype Transport Container



Fixed Frame



Prototype Fixed Frame



AIV Tooling





Extraction & Handling








### 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 and clocking
  - Positioning system: hexapod with sub-micron accuracy
  - Earthquake protection: mirror restrainers + load limiters





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### 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
- Contracts for Final Design and Manufacturing is running







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## **Adaptive Optics principle**



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### 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
- Contracts for Final Design and Manufacturing is running







### M5 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

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#### **Prefocal Station**





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### **Laser Guide Star Units**



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



Laser Source Control Electronics



TNO 20W VLT AOF Launch Telescope

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## **E-ELT Full Programme Schedule**



## E-ELT Full Programme Schedule



# **E-ELT Full Programme Schedule**





## **Status of Procurements**

Request for Information (RFI) Preliminary Inquiry (PI) Call for Tender (CfT)

## **ESO Procurement Process**



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## The 'Launch Year' 2016

#### Massive advance in procurement processes for Optomechanics

- > M1 Polishing ( $\rightarrow$  CfT on-going)
- M2 Polishing (pending signature)
- M3 Polishing (negotiation on-going)
- M1, M2, M3 Blanks (negotiation on-going)
- ➢ Edge Sensors (→ CfT on-going)
- M1 Position Actuators (PACT) (RFI closed)
- ➢ M2 & M3 Cells (→ CfT on-going)
- **.**... + ...
  - M1 Washing & Coating (RFI closed)
  - ➢ MV prefab. Subst.s for connection VLT and E-ELT to Chilean grid (→ CfT on-going)





## M1 Polishing Call for Tender

#### Scope:

Figuring, mounting of interfaces, polishing, verification, integration, testing, packing, and delivery of the M1 Segment Assemblies and Segment Auxiliary Equipment

Expected Contract Duration:

≻ ~ 7 years

Timeline:

- ✓ Release Call for Tender
- Closing date
- FC Approval



11 December 2015

8 → 22 June 2016

November 2016

#### +ES+ 0 +

## M2 & M3 Cells Call for Tender

#### Scope:

- design, manufacturing, assembling, factory Integration, verification, optional system testing, packing, and delivery of the M2 Cell and of the M3 Cell, together with their associated auxiliary equipment and local control units
- Expected Contract Duration:
  - ≻ ~ 6 years

#### Timeline:

- ✓ Release Call for Tender
- Closing date
- FC Approval



7 March 2016

 $9 \rightarrow 30$  June 2016

November 2016

## **Edge Sensors Call for Tender**

#### Scope:

Idesign, manufacturing, production, packing, and delivery of ≈4500 sensors, together with their associated Controllers and Electronics

- Expected Contract Duration:
  - ➤ ~ 5.5 years
- Timeline:





<ul> <li>Release Call for Tender</li> </ul>	13 May 2016
Closing date	19 July 2016
FC Approval	November 2016



### Near Term Procurements (Optomechanics)

#### Position Actuators for M1

- Design, manufacture and deliver Electro-mechanical precision actuators (φ1≈1800, φ2 ≈ 600) and electronic controllers (φ1 ≈ 600, φ2 ≈ 200) to be mounted on each M1 Cell
- > Procurement start 2016 (May 2017 FC) contract to run for ~5 y ( $\varphi$ 1)
- Suitable for medium size to large suppliers in MS and Chile with track record in high precision position actuators design and manufacturing



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### Near Term Procurements (Optomechanics)

Segment Supports for M1 (serial production)

- Contract (s) for the production of segment precision mechanical supports (φ1 ≈ 600, φ2 ≈ 350) and fixed frames (φ1 ≈ 600, φ2 ≈ 200), tooling and transport containers.
- > Procurement start in 2017 (Feb 2018 FC) to run for 4-5 years ( $\varphi$ 1)
- Looking for medium to large size suppliers in MS and Chile with track record in precision mechanics manufacturing and integration







#### Near Term Procurements (Optomechanics)

#### Prefocal Station (PFS) A

- Design and production of the PFS including its large structure (>6m high) and precise optomechanics (sensor arms, adapter, cable wrap, phasing station), excluding cameras
- Contact to run from 2018 to 2022 (Nov 2017 FC)
- Looking for medium/large size suppliers in MS and Chile with track record in large opto-mechanical systems design and manufacturing





## E-ELT Control System Procurements



### Near Term Procurements (Control System)

Infrastructure telescope control

- SW design and development of the core integration infrastructure for the Telescope Control System (TCS)
- Possible procurement end 2016 / beginning 2017 (May 2017 FC)
- Looking for suppliers in MS and Chile
- 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.)



## **Control System Introduction**

#### System of Systems:

- Local Control System(s) fully responsible for subsytem function and safety.
- Central Control System: integrated control and telescope level safety.



- Principals: ٠
  - Separation of control and safety functions
  - Physical separation between computing units and field devices.
  - Usage of mainstream industrial standards.
  - Usage of mainstream COTS components.
  - Sub-systems contracted with corresponding LCS.



- Central <u>software</u> component for integration of all local control systems into the Central Control System.
- Generic control system services: messages, alarms, logging.
- CfT: Q3/2016.
- Value: ~1-2mEUR
- Three year contract (2017-2020) with optional maintenance.

## **Instrument Control Framework**

- Standard software framework for construction of Instrument Control System
- Real-Time GUI Displays, software templates, software interfaces to field electronics, etc.
- CfT: 2018 (TBD)
- Value: ~500kEUR





## **SCAO Telescope RTC**

- Real-time Computer (RTC), hardware and software for Adaptive Optics.
- Low latency, high performance cluster computing framework construction.





### **MCAO RTC Demonstrator**

- High performance, low latency computation cluster (hardware and software) for demonstration of suitability of CPU based COTS servers for application in Adaptive Optics.
- 2 Contract related to MCAO RTC:
  - 2016/2017: Demonstrator/pathfinder
  - 2019/2020: Production version
- CfT: 2016/2017 (TBC)
- Total Value for both: ~500kEUR





#### In case of specific question, please get in touch with Nick Kornweibel E-ELT Control System Project manager Tel.: +49-(0)89-3200 6117 nkornwei@eso.org

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### Near Term Procurements (Supporting Systems)

- Mirror Washing units
  - > 4 meter mirrors and M1 washing units
  - Procurement late 2016/early 2017 (Nov 2017 FC)
  - Looking for medium size 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 2016/early 2017 (Nov 2017 FC)
    - Looking for medium size suppliers in MS and Chile with track record in design and manufacturing of coating/vacuum thin film deposit equipment





### **Near Term Procurements** (Supporting Systems)

- 5m Mirror Coating unit
  - Coating units used to coat the M2, M3, M5, M6 on site
  - As above for M1 coating unit.



Figure 3. M3 coating/cleaning positions



#### Summary of 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 Date by ESO Finance Committee

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## **Contracts (>500k) coming next**

Year	Month	Item
2018	May	Segment Assembly – Manipulator
	May	M5 Mirror
	May	M2 In-situ cleaning device
	May	M1 Segment Supports
	May	M1 Segment Blanks
	May	Paranal Technical Buildings and Offices
	May	Control Building
	May	M3 Blank
	May	Software development contract #1
	May	Segment Assembly - M1 Phasing Gun
	Nov	M5 Electrom. Unit
	Nov	Laser Sources
	Nov	Laser Beam Projection Sub-units
	Nov	OPC Metrology and Alignment System
	Nov	Instruments Lab and Clean room buildings
	Nov	AIV building
	Nov	M1LCS - Cabinet Procurement
	Nov	M1LCS - Control infrastructure
2019	May	Data Flow Development SE and Mgmt Services
	Nov	Armazones Comms (Fibre) Infrastructure
2020	Nov	OCP Test Camera
	May	Armazones Network Room
	May	Software development contract #2
	Nov	Siemens/CISCO
	Nov	Network Infrastructure
2021	May	Cryo-Plant

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## **Programme Status**

**Running Contracts**
#### Site Preparatory Work; Access Road & Platform completed



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# Minor additional work on-going

#### Contract Amendment with ICAFAL

- > Scope:
  - Construction of the Dry-Cooler Platform & Storage Areas,
  - Installation of additional rock-retaining meshes
  - Improvement of the guard rails along the road
  - Upgrade of ESO offices





## Connection to the Chilean Electricity Grid

- **DIA approved** (25<sup>th</sup> Febr '16)
- Construction by SAESA started on 27<sup>th</sup>
- Grid connection inauguration expected







## **Running Service Contracts**

- Managerial and DMS Consultancy (Ramboll):
  - on-going (e.g. M1 logistics)
- Data Distribution System (DDS) middleware
  - Contract awarded, License started Jan. 2016
- QA Services (ISQ)
  - Kicked-off early 2016
  - Collaboration processes and tools defined in details AUTHORISED (JIRA, PDM, etc.)
  - First tasks committed (all on-going)
    - M4 Shell MRR (May)
    - List of allowed consumables
    - Review the Plan of one of our contractors for Accelerated Lifetime Testing
    - Support for Acceptance Sampling Plan definition for large serial production (e.g ES, PACT,...)
- ISVV (Critical Software)
  - Kicked-off early 2016
  - Collaboration processes and tools defined in details (JIRA, PDM, etc.)
  - First tasks committed
    - M4 Interim Review support (done)
    - Plan the ISVV activities across the Programme (on-going)





## M1 Segment Support Design & Qualification contract

- Two parallel contracts: VDL (NL) and CESA (ES):
  - Design to FDR and delivery of 4 qualification mod
  - FDR VDL held 31 Mar
  - FDR CESA planned 22 Jun





T Dummy segment for force tests

← VDL FDR Design

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#### M4 shell & M4 Unit (Cell) - Design and Construction -

- 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 Status

- M4 Cell (AdOptica)
  - Interim design review meeting held early April
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### M4 Unit

- 6 thin shells 1.95 mm thick. Thickness homogeneity < 3  $\mu$ m rms
- 12 shells manufactured = full spare set for re-coating and maintenance
- High spatial frequency errors < 15 nm RMS WFE</li>



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#### Instruments Construction Agreements

MICADO, HARMONI, METIS, MAORY: all kicked-off, making first progress

MOS & HIRES: <u>Phase A Study</u> Contract signed (March). Need 2<sup>nd</sup> PFS



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#### **The E-ELT: overview**



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