The ESO’s Extremely Large Telescope (ELT)

- Largest optical/infrared telescope in the world
  - 39m diameter, primary mirror, 798 high precision segments
  - Science: exo-earth, deep universe, resolved populations, open window to the unknowns
  - System Design complete – Construction on going on Cerro Armazones
    - As integral part of the Paranal Observatory (‘one more telescope’)
  - Timeline 2014-2024
  - ESO cost:
    - Capital cost: ~1175 MEUR incl. manpower, instruments and contingency
    - Operation cost: ~50 MEUR / year
Science drivers

- Planets in other stellar systems
  - Imaging and spectroscopy
  - *The quest for Earth-like exo-planets*

- Stellar populations
  - In galaxies inaccessible today
  - 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

Hubble Space Telescope

VLT+AO

E-ELT

ELT Programme status and opportunities, Sept 2018
Required resolution

10 cm
Required resolution

200 km
To put it in perspective…
How does it optically work?

- **Powered mirrors** collect and focus the light.
- **Flat mirrors** redirect the light towards the focal plane.

**Primary Mirror (M1)**
- 39-m diameter, 798 near-hexagonal segments re-aligned to ~ 0.0001 mm in real-time.

**Focal plane is fed to science instruments**

Light is precious – light waves must be preserved to a small fraction of their wavelength (0.0005 mm) and their direction preserved to a small fraction of one arc second.
How does it work?

Main Structure holds the opto-mechanical units

Alt-Az mount points and tracks to compensate for target motion (earth rotation)

Focal plane (on-sky) and embedded metrology systems measure the state of the telescope and of external perturbations (e.g. atmosphere); control system derives the commands sent to the units

Environment: gravity, wind, thermal, atmospheric turbulence, earthquakes

Opto-mechanical units are jointly capable of re-aligning themselves, refocusing, stabilising the image, and compensating for external perturbations
ELT Optomechanics

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

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

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

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

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

LGSU
(Laser Guide Star Units)
Laser Sources + Laser Beacons
shaping and emitting
ELT Programme status and opportunities
Armazones and Paranal

25km

Seen through clean atmosphere
(distance: 200 km)

ELT

VLT
## ELT – On-Going Contracts

<table>
<thead>
<tr>
<th>Concluded/Ongoing Contracts</th>
<th>Description of Work</th>
<th>Contract Signature Date</th>
<th>Contractor</th>
<th>Forecast Completion Date (w/o Options)</th>
<th>Status</th>
<th>Status Date</th>
</tr>
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<tbody>
<tr>
<td>PJ42.01 Project Office</td>
<td>PA Consultancy Services</td>
<td>Jan-16</td>
<td>ISQ</td>
<td>Dec-18</td>
<td>On-going</td>
<td></td>
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<tr>
<td></td>
<td>ISVV Consultancy Services</td>
<td>Jan-16</td>
<td>Critical Software</td>
<td>Dec-18</td>
<td>On-going</td>
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<td></td>
<td>Construction All Risks Insurance</td>
<td>Mar-18</td>
<td>SCOR</td>
<td>Mar-26</td>
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<td></td>
<td>ISVV Consultancy Services</td>
<td>Jan-16</td>
<td>Critical Software</td>
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<td>Mar-18</td>
<td>SCOR</td>
<td>Mar-26</td>
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</table>

### PJ42.02 DM&S Design and Construction Contract
- Consultancy Support
- DM&S Design and Construction Contract

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Signature Date</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Ramboll</td>
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</tr>
<tr>
<td>ACe</td>
<td>May-23</td>
<td>On-going</td>
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</table>

### PJ42.03 Optomechanics
- M4 Phase 1 Preliminary Design
- M4 Unit Final Design and Manufacturing
- M1 Segment Supports - Qual. Units
- M4 Mirror Shells Supply
- M2 Mirror and Auxiliary Equipment Supply
- M2 Blank Supply
- M3 Blank Supply
- M3 Mirror and Auxiliary Equipment Supply
- M2 and M3 Cell Design and Manufacturing
- M1 Edge Sensors Design and Manufacturing
- M1 Mirrors Polishing
- M1 Blanks Supply
- M1 Position Actuators
- Laser Sources
- M1 Segment supports - Production

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Signature Date</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>VDL</td>
<td>Jan-15</td>
<td>On-going</td>
</tr>
<tr>
<td>Safran Reosc</td>
<td>Jan-23</td>
<td>On-going</td>
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<tr>
<td>Sener</td>
<td>Jul-22</td>
<td>On-going</td>
</tr>
<tr>
<td>FAMES</td>
<td>May-22</td>
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<td>Safran Reosc</td>
<td>Jun-23</td>
<td>On-going</td>
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<tr>
<td>Schott</td>
<td>Jul-19</td>
<td>On-going</td>
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<tr>
<td>Safran Reosc</td>
<td>Sep-23</td>
<td>On-going</td>
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<td>Sener</td>
<td>Jul-22</td>
<td>On-going</td>
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<tr>
<td>FAMES</td>
<td>May-22</td>
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<td>Safran Reosc</td>
<td>Jun-23</td>
<td>On-going</td>
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<td>Schott</td>
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<td>On-going</td>
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<tr>
<td>PI</td>
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<tr>
<td>Toptica</td>
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<td>On-going</td>
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<tr>
<td>VDL</td>
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### PJ42.04 Control Core Integration Infrastructure
- Core Integration Infrastructure

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<tr>
<th>Contractor</th>
<th>Signature Date</th>
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<td>Cosylab AB</td>
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### PJ42.05 Civil Infrastructure
- Paranal ELT Technical Facility Design and Construction

<table>
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<tr>
<th>Contractor</th>
<th>Signature Date</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Abengoa</td>
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<td>On-going</td>
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</tbody>
</table>

### PJ42.06 Support Infrastructure Supply, and installation of ABC Power Substations (23kV + 0.4 kV)
- M1 Coating Plants Supply

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Signature Date</th>
<th>Date</th>
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<tbody>
<tr>
<td>AGC</td>
<td>Nov-21</td>
<td>On-going</td>
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</tbody>
</table>

### PJ18.10 Instrumentation
- MICADO Construction
- HARMONI Construction
- METIS Construction
- MAORY Construction
- IR Detectors for HARMONI, MICADO, METIS
- C-RED Cameras for MAORY

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Signature Date</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>STFC</td>
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<td>NOVA</td>
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<td>INAF</td>
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<td>Teledyne</td>
<td>Jul-18</td>
<td>On-going</td>
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<tr>
<td>FLI</td>
<td>Jul-18</td>
<td>On-going</td>
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### PJ42.11 Optical Control
- PFS-A Main system Design and Manufacture

<table>
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<th>Contractor</th>
<th>Signature Date</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>IDOM</td>
<td>Apr-18</td>
<td>On-going</td>
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</table>

### ELT Programme status and opportunities, Sept 2018

2018 Q1
- PJ42.01 Project Office
- PJ42.02 DM&S Design and Construction Contract
- PJ42.03 Optomechanics
- PJ42.04 Control Core Integration Infrastructure
- PJ42.05 Civil Infrastructure
- PJ42.06 Support Infrastructure Supply, and installation of ABC Power Substations (23kV + 0.4 kV)

2018 Q2
- PJ18.10 Instrumentation
- PJ42.11 Optical Control

2018 Q3
- PJ42.01 Project Office
- PJ42.02 DM&S Design and Construction Contract
- PJ42.03 Optomechanics
- PJ42.04 Control Core Integration Infrastructure
- PJ42.05 Civil Infrastructure
- PJ42.06 Support Infrastructure Supply, and installation of ABC Power Substations (23kV + 0.4 kV)

2018 Q4
Recent Accomplishments

- Completion of the 50km long extension of national grid overhead line by Grupo SAESA
- Delivery and installation of the substations (SIEMENS)
- Connection to the grid and start of supply:
  - Paranal (Dec ‘17)
  - Armazones (Mar’18)
Recent Accomplishments

- Dome and Telescope Main Structure (DMS)
  - Follow-up of Dome PDR actions
  - Main Structure PDR (Feb’18)
  - Completion of Base Camp installation
  - Start pouring concrete for foundation

ELT Programme status and opportunities, Sept 2018
Recent Accomplishments

- ACe started pouring concrete at Armazones!
Recent Accomplishments

- ACe started pouring concrete at Armazones!
Recent Accomplishments

ELT Technical Facility (ETF) at Paranal

- Contract signed with Abengoa (Chile) in Mar’18
- Successful Final Design Review in Aug’18
- Construction started in Aug’18
Recent Accomplishments

- ELT Technical Facility at Paranal
  - Contract signed with Abengoa (Chile) in Mar'18
  - Successful Final Design Review in Aug'18
  - Construction started in Aug'18
Recent Accomplishments

ELT Technical Facility (ETF) at Paranal
- Contract signed with Abengoa (Chile) in Mar’18
- Successful Final Design Review in Aug’18
- Construction started in Aug’18

M1 Coating Unit
- Call for Tender concluded for the coating units for M1 Segments
- Contract award approved FC May’18
- Contract signed and kick off in June Jun’18
Recent Accomplishments

- **M1 test Bench**
  - Structure delivered by ACe
  - Testing of M1 Segment control on-going at ESO

- **M1 Segment Support**
  - Design & Qual. contracts completed
  - Serie production contract awarded to VDL
Recent Accomplishments

M1 Segment Blanks

- First blank ready to be delivered from SCHOTT to REOSC
- Testing of M1 Segment control on-going at ESO
Recent Accomplishments

- M1 Segment polishing
  - design of facilities, production and metrology equipment

4000 m² production facilities in Poitiers
Recent Accomplishments

**M1 Edge Sensors**
- Qualification Models delivery in Q4 2018
- Total to be produced: 4566 pcs.

**M1 Position Actuators**
- Interim Design Review Feb ’18
- Total to be produced: 2418 pcs.
Recent Accomplishments

M3 blank
- Cast (May), Annealed, Inspected
- Ceramization ongoing ➔ June ‘18.

M2 blank
- Cast (Aug ‘17), in machining process

M2 polishing
- Adhesive characterization complete
- Fatigue tests completed
- Metrology design review
- Metrology Matrix blank finished and in figuring
- Auxiliaries final design done.
- Building fitting completed.

M3 Mirror Polishing
- Production facilities, metrology
Recent Accomplishments

- M2 blank inspection after annealing
Recent Accomplishments

- M2 Dummy Mirror (Aluminium), Handling Tools and Transport Container
Recent Accomplishments

M2 & M3 Cell

- Preliminary Design Review (PDR) in Jan’18 and Jun’18
■ M4 Shells
  ➢ All blanks delivered
  ➢ First three polished (front face)
  ➢ First two petals **completed** (Feb’18, Sep’18)
Recent Accomplishments

- **M4 Unit**
  - First 4 SiC petals for reference body manufactured by BOOSTEC
  - Test Tower & M4 Unit Final Design Reviews
  - Manufacturing on-going
Optical Control Project (OCP) – Pre-Focal Station

Functions:
- Optical Sensing for Telescope Optics Control and for Diagnostics
- Send Science Light to Nasmyth Instruments

Conceptual Design developed in house to derive technical specifications

Contract for PFS-A Main System kicked-off on Apr ’18 with IDOM (ES)
- 5x5x12 metres
- 34 Tonnes

Design on-going:
- Iteration on optical design of wave front sensor arm
- Trade-offs for drive and bearings
- Vibration analysis
Recent Accomplishments

Telescope Control System

- **M1 LCS Final Design review successful**
- CII Contract on-track with Cosylab AB
- CfT released for RTC Real-Time Core (Jan 2018 KO).
- WH Controller prototype done, project defined, **FDR successful**
- RFI for M1 Electronics Cabinets done
- RFI for Networking Infrastructure concluded: single source.
**Recent Accomplishments**

**MICADO (NIR Imager & Slit Spectograph)**
- PI: Ric Davies, MPE, MPIA, USM, NOVA, IAG, CNRS, INAF, A*, ESO
- Sys. Requirements Rev. (Apr’17)
- ➔ PDR scheduled for Nov’18

**MAORY (MCAO module)**
- PI: Emiliano Diolaiti, INAF (OAS Bologna, OA Arcetri, OA Brera, OA Capodimonte, OA Padova, OA Abruzzo - Teramo) INSU/CNRS-IPAG
- Sys. Requirements Rev. (Dec’16)
- ➔ PDR in May 2019
Recent Accomplishments

**HARMONI (IFU optical/NIR)**
- PI N. Thatte (Univ Oxford), UK ATC, IAC, CSIC-CAB, CRAL, LAM, + ESO
- PDR (Nov & Dec’17)
- On track

**METIS (Im./Sp. Th. & mid-IR)**
- Sys. Requirements Rev. (Jul’17)
- ➔ PDR in May 2019
ELT Programme – Commitment Evolution

ELT Commitment Evolution

- Contracts - Amount (EUR)
- Contracts - Cumulative Amount (EUR)

Year 2012 to 2025

- Contracts - Amount (EUR)
- Contracts - Cumulative Amount (EUR)

EUR (Mixed e.c.)

- 0
- 100,000,000
- 200,000,000
- 300,000,000
- 400,000,000
- 500,000,000
- 600,000,000
- 700,000,000
- 800,000,000

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

ELT Programme status and opportunities, Sept 2018
ELT Top Level Schedule

Today: ARM Site Preparation (Platform, Road, Trenches)

- **2014**
  - DMS - Design Phase

- **2015**
  - DMS - Manufacturing and Pre-Assembly
  - DMS - On-site Erection and Commissioning

- **2016**
  - M1 Segment Assemblies - Design and Production
  - M2 Unit - Design and Production

- **2017**
  - M3 Unit - Design and Production
  - M4 Unit - Design and Production
  - M5 Unit - Design and Production

- **2018**
  - Optical Control Units (PFS, Calibration Coarse Metrology, Test Camera)
  - Telescope Control

- **2019**
  - AIV

- **2020**
  - HARMONI - Available on-site
  - METIS - Available on-site
  - MAORY - Available on-site
  - MICADO - Available on-site

- **2024**
  - DMS Provisional Acceptance

- **2025**
  - Telescope First Light
On-going Procurement
## Annual Turn-over Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Annual Turn-over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt;3 M€</td>
</tr>
<tr>
<td>Medium</td>
<td>3 to 15 M€</td>
</tr>
<tr>
<td>Large</td>
<td>&gt;15 M€</td>
</tr>
</tbody>
</table>
M5 Mirror

Scope:
- Design and manufacturing of ultra-light 2.7m flat M5.
  - Possible technologies: ultra light weighted ULE, SiC, Zerodur
- Polishing and testing of 3m-class high performance optics (flat)

Expected Contract Duration:
- ~ 4 years

Turn-over: Large

Timeline:
- Request for Information: Jul 2017
- Preliminary Inquiry: Oct 2017
- Release Call for Tender: Dec 2017
- Closing date: Mar 2018
- FC Approval: Nov 2018 (TBC)
Scope:
- Design, manufacture & testing of the fast tip-tilt stage for M5

Expected Contract Duration:
- ~ 3 years

Turn-over: Medium

Timeline:
- Release Call for Tender: Oct 2018
- Closing date: Jan 2019
- FC Approval: May 2019
Specialties for potential (sub)contractor:

- Design, manufacture & testing of fast tip-tilt actuators
- Fast nanometer-precision frictionless actuators and tip-tilt mechanism (Piezo, Flex pivot, stiff structure)
- Cutting-edge dynamic control system technology
Washing & Stripping Unit (M1)

■ Scope:
  ➢ Design, manufacturing and installation on-site of the washing-stripping units for M1 Segments

■ Expected Contract Duration:
  ➢ ~ 2-4 years

■ Turn-over: Medium

■ Timeline:

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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<tbody>
<tr>
<td>RFI</td>
<td>Mar – Jul 2018</td>
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<tr>
<td>PI</td>
<td>Dec 2018</td>
</tr>
<tr>
<td>CfT</td>
<td>Feb-Jul 2019</td>
</tr>
<tr>
<td>FC Approval</td>
<td>Nov 2019</td>
</tr>
</tbody>
</table>
Specialties for potential (sub)contractors:

- Design, manufacturing and installation on-site of the washing-stripping units for M1 Segments
- Chemical coating removal
- Process automation
- Safety standards
M1 Segment Assembly - Manipulator

Scope:
- Design, construction and testing of high-precision, 4-axis, fail-safe handling tool with gripper to remove the M1 segment assembly from the telescope

Expected Contract Duration:
- ~ 1.5 years

Turn-over: Low

Timeline:
- Release Call for Tender: Q4 2018 (TBC)
- Closing date: Q2 2019 (TBC)
- FC Approval: Sep 2019 (TBC)
Specialties for potential (sub)contractors:
- Design, construction and testing of robotics arm
- Mechatronics,
- Automation engineering,
- Industrial handling
Scope:
- Design, manufacturing and testing of a prototype optical sensing tool to perform local segment phasing/alignment and offer for a fixed price offer for production of 6 units

Expected Contract Duration:
- ~ 1 + 1 years
  - 1 year for prototyping, (6 months ESO testing), 1 year for production of 6 units

Turn-over: Medium

Timeline:
- Release Call for Tender: Q4 2018 (TBC)
- Closing date: Q2 2019 (TBC)
- FC Approval: Sep 2019 (TBC)
Specialties for potential (sub)contractors:

- mechatronics,
- automation engineering,
- non-contact nanometer-accuracy
- optical sensing in industrial environment
M1 LCS Cabinets Procurement

- **Scope:**
  - Production of 132 electronic cabinets equipped with cooling heat exchanger, low power supply consumption, front-end electronics for Edge Sensors, PACTS, Warping Harness, COTS components.

- **Expected Contract Duration:**
  - ~ 2 years

- **Turn-over: Medium**

- **Timeline:**
  - Release Call for Tender: Beginning 2019
  - Closing date: Q2-2019
  - FC Approval: Sept. 2019
CCD/CMOS Detectors Procurement

Scope:
- CCD/CMOS detectors

Expected Contract Duration:
- ~ 2 years

Turn-over: Medium

Timeline:
- Release Call for Tender: Oct. 2019
- Closing date: Dec. 2019
- FC Approval: Sept. 2019
Coarse Metrology and Alignment System

- **Scope:**
  - Procurement of standard tools and design, fabrication of high-accuracy long-range metrology network to monitor relative positions of telescope mirrors [long-range (tens of m) non-contact, micron-accuracy optical sensing in industrial environment]

- **Expected Contract Duration:**
  - ~ 3 years

- **Turn-over: Low**

- **Timeline:**
  - Start procurement process: Q2/Q3 2018 (TBC)
  - Closing date: Q4 2018 (TBC)
  - FC Approval: TBD
## Procurement Plan for 2018

<table>
<thead>
<tr>
<th>Description of Work</th>
<th>Forecast FC Approval Date</th>
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<tbody>
<tr>
<td>ELT Programme All Risks Insurance</td>
<td>Feb-18</td>
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<tr>
<td>M1 Segment Supports Production</td>
<td>Feb-18</td>
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<tr>
<td>PFS-A Main System</td>
<td>Feb-18</td>
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<tr>
<td>ELT Technical facility at Paranal</td>
<td>Feb-18</td>
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<tr>
<td>M1 Coating Unit</td>
<td>May-18</td>
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<tr>
<td>IR Detectors</td>
<td>May-18</td>
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<tr>
<td>C-Red Cameras</td>
<td>May-18</td>
</tr>
<tr>
<td>M5 Mirror</td>
<td>Nov-18 (TBC)</td>
</tr>
<tr>
<td>Coarse Metrology and Alignment</td>
<td>Nov-18 (TBC)</td>
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<tr>
<td>Data Flow Development SE and Mgmt Services</td>
<td>Nov-18</td>
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# Procurement Plan for 2019

<table>
<thead>
<tr>
<th>Description of Work</th>
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<tbody>
<tr>
<td>MUSE type detectors</td>
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<tr>
<td>Transportation Service Contract</td>
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<tr>
<td>CCD220 Detectors</td>
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<tr>
<td>M5 Cell</td>
<td>May-19</td>
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<tr>
<td>Laser Beam Projection Subunits</td>
<td>May-19</td>
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<tr>
<td>M1 Segment Assembly - Manipulator</td>
<td>September-19</td>
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<tr>
<td>M1 Segment Assembly - Local Optical Phasing Sensor</td>
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<td>M1 LCS Cabinet Procurement</td>
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<tr>
<td>RTC infrastructure</td>
<td>November-19</td>
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<tr>
<td>Armazones Comms Fibre</td>
<td>November-19</td>
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<tr>
<td>M1LCS - Network infrastructure Equipment</td>
<td>November-19</td>
</tr>
<tr>
<td>M1LCS - Power Distribution and Control</td>
<td>November-19</td>
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<tr>
<td>M1 Washing and Stripping plant</td>
<td>November-19</td>
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</table>
Future Procurements
Real Time Control (RTC) Infrastructure

Scope:
- Design & development of high performance computing cluster for reliable & deterministic computation of Adaptive Optics corrections to M4 and M5
- Delivery: High Performance computing cluster
- HW, SW & network infrastructure

Expected Contract Duration:
- ~ 3 years

Turn-over: Low

Timeline:
- Release Call for Tender: TBD
- Closing date: TBD
- FC Approval: Nov ‘19
M1 LCS Network Infrastructure

Scope:
- The network infrastructure (HW) needed to distribute and coordinate signals of the M1 electronic items

Expected Contract Duration:
- ~ 3 years

Turn-over: Low

Timeline:
- Release Call for Tender: TBD
- Closing date: TBD
- FC Approval: Nov ‘19
Laser Beam Projection Subunits

Scope:
- Design, fabrication, testing of ~400mm diameter telescope, relay optics, beam steering & focus mechanism

Expected Contract Duration:
- ~ 3.5 years

Turn-over: Medium

Timeline:
- Release Call for Tender: Q1’2019
- Closing date: Q3’19
- FC Approval: Late’19 (TBC)
Specialties for potential (sub)contractors:

- Design, fabrication, testing of ~400mm diameter telescope
- Precision opto-mechanics and control
- Relay optics
- Beam steering & focus mechanism
- Lens polishing and laser coating
Washing-Coating-Stripping Unit (5m)

■ Scope:
  ➢ Design, manufacturing and installation on-site of the washing-stripping-coating units for the large mirrors (M2, M3, M5, M6)

■ Expected Contract Duration:
  ➢ ~ 2 years

■ Turn-over: Medium

■ Timeline:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release Call for Tender</td>
<td>Q2 2020</td>
</tr>
<tr>
<td>Closing date</td>
<td>Q3 2020</td>
</tr>
<tr>
<td>FC Approval</td>
<td>Nov. 2020</td>
</tr>
</tbody>
</table>
Washing-Coating-Stripping Unit (4m mirrors)

Specialties for potential (sub)contractors:

- Design, manufacturing and installation on-site of the washing-stripping-coating units for 4m class mirrors
- Control systems
- Thin-film coating technologies,
- Vacuum system (pumps),
- Chemical coating removal
Overview of Specialities involved in Main Procurements
### Specialities for potential (sub)contractors

<table>
<thead>
<tr>
<th>Procurement</th>
<th>Planned FC Approval</th>
<th>Specialities</th>
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</thead>
<tbody>
<tr>
<td>M5 Mirror</td>
<td>Nov-18</td>
<td>• High-performance (lightweight, stiff, low-CTE) substrate</td>
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<td>• Polishing and testing of 3m-class high performance optics (flat)</td>
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<tr>
<td>M1 - Manipulator</td>
<td>May-19</td>
<td>• mechatronics, automation engineering, industrial handling</td>
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<tr>
<td>M1 – Local Optical Phasing Sensor</td>
<td>May-19</td>
<td>• mechatronics, automation engineering, non-contact nanometer- accuracy optical sensing in industrial environment</td>
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<tr>
<td>M5 Cell</td>
<td>May-19</td>
<td>• Fast nanometer-precision frictionless actuators and tip-tilt mechanism (Piezo, Flex pivot, stiff structure)</td>
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<td></td>
<td></td>
<td>• Cutting-edge dynamic control system technology</td>
</tr>
<tr>
<td>Laser Beam Projection Subunits</td>
<td>May-19</td>
<td>• Precision opto-mechanics and control,</td>
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<td></td>
<td>• Lens polishing and laser coating</td>
</tr>
<tr>
<td>M1 LCS Cabinets Procurement</td>
<td>Sep-19</td>
<td>• Low-power consumption electronics, power supply, cabinet cooling (heat exchanger), COTS components</td>
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<tr>
<td>RTC Infrastructure</td>
<td>Nov-19</td>
<td>• high performance computing cluster (HW, SW, network infrastructure)</td>
</tr>
<tr>
<td>Coarse Metrology and Alignment System</td>
<td>TBC-19</td>
<td>• Long-range (tens of m) non-contact, micron-accuracy optical sensing in industrial environment</td>
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