ESO and the ELT

Roberto Tamai
ESO’s ELT Programme Manager
• Intergovernmental Organisation
• International Convention (1962), between 5 countries
• Now 16 Member States
• Annual Budget: ~ 200 million €
The ESO Mission

Mission (Convention):
- Build and operate world-class ground-based astronomical facilities
- Foster collaboration in Astronomy

ESO enables:
- Scientific discoveries & understanding of the Universe
- Other: Development of new technologies, impact in economy, international cooperation

Complementing other ground & space facilities

In collaboration with scientists, institutes and industry
Study of all that is "beyond" the earth

Objects that are far away, therefore small and weak

- With limited information about their nature
- Need for large instruments: resolution and sensitivity

The combination of different types of observations is crucial

- Images / spectra / time-series

The field of visible, infrared and radio waves is accessible from land-based telescopes
Orion Nebula
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

![Image of Earth with ESO observatories highlighted]
ESO in Chile

- La Silla Observatory (1960's)
- Paranal Observatory (1998)
- ALMA Observatory (2013)
- Administration, Science & ALMA Offices and Guest House
- La Silla Observatory (1960's)
- Paranal Observatory (1998)
- ALMA Observatory (2013)
- Administration, Science & ALMA Offices and Guest House
- ... Armazones (ELT) (....2025)
The ESO’s Extremely Large Telescope (ELT)

- Largest optical/infrared telescope in the world
  - 39m diameter, primary mirror, 798 high precision segments
  - Science: exo-earths, 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 2014-2025
  - ESO cost:
    - Capital cost: ~1175 MEUR incl. manpower, instruments and contingency
    - Operation cost: ~50 MEUR / year
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
Required sensitivity
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.

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.

Primary Mirror (M1)
- 39-m diameter
- 798 near-hexagonal segments
- Re-aligned to ~ 0.0001 mm in real-time
Armazones and Paranal

Seen through clean atmosphere (distance: 200 km)

ELT

VLT

25km
How are we organised to build it

■ ESO as “Prime” or “System Architect”
  ➢ Defines the top-level scientific and technical requirements
  ➢ Develops the system (observatory) concept and subsystem requirements
  ➢ Subcontracts to (ESO Member States) industry for the construction
  ➢ Assembles the subsystems together on-site (AIV)

■ ESO Member States Industry
  ➢ Detailed design and manufacturing of the subsystems based on requirements following competitive Call-for-Tenders

■ Consortia of Scientific Institutes
  ➢ Detailed design and manufacturing of the scientific instruments based on (collaborative) agreements
Contract placed with ACe, Consortium of Cimolai and Astaldi

- PDR of the Dome done
- PDR of the Main Structure mostly completed
- Manufacturing started
- On site activities in progress
DMS manufacturing activities in Europe 1/3

Dome & Main Structure Manufacturing phase has started for:

- **Enclosure structure**
  - Part 3 (first ring in green in the picture here below) is manufactured, pending sand blasting and painting
  - Steel purchased and inspected by ESO, manufacturing on going (part 4)

- **Seismic Isolators of Dome and Aux. Building**
  - First units manufactured and tested. Waiting for Contractor confirmation
  - Interface plates for embedding in foundation shipped to site

- **Enclosure rotating mechanism design completed**
  - Production of first unit started
DMS manufacturing activities in Europe 2/3
Mirror Blanks

M1 Segment Blanks
- First M1 Segment Blank (tests) completed by SCHOTT end of August.
- Ready for delivery to REOSC as part of the first delivery set.

M2 Blank
- Technically accepted in Dec’18
- Delivered to Safran/Reosc Jan’19

M3 Blank
- Casted
- Checking the ceramization
M1 Segments Polishing

4000 m² production facilities in SAFRAN Poitiers (France)

About 1 segment/day after ramp-up

<table>
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<tr>
<th>Year</th>
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<td>2024</td>
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</table>
M2 blank from SCHOTT to ESO to SAFRAN-Reosc
M1 Segment Support (M1SS) Series production

- Since Kick-Off with VDL (May’18), nominal progress (until April’19)
- Held Manufacturing Readiness Review (MRR) for Pre-series (18 Supports)
- Design contract deliverables (5 QM segment support + handling tools) for Reosc are ready for shipment.
M1 Edge Sensors (Contract with FAMES, FR-DE)
- Design and performance are now under control
- Preliminary Design Review in Jan’19 was successful
- 42 Qualification Models (QMs) produced
- Total to be produced: 4566 pcs.

M1 Position Actuators (Contract with PI, DE)
- Qualification Test Review held (Jan’19),
- Preliminary Design Review in Mar’19
- 5 QM’s manufactured
- Total to be produced: 2418 pcs.
M1 Position Actuators

Tracking Error while following 50nm/sec ramp

Tracking Error while following a 5nm/sec ramp
M2 Cell and PFS

- M2/M3 Cell (SENER, ES)
  - Preliminary Design Review held in 2018
  - Qualification of Hexapod on-going

- Prefocal Station (IDOM, ES)
  - Design on-going, PDR held in Apr ’19
Adaptive Optics
Contract placed with Consortium AdOptica ADS and Microgate, IT
FDR passed
In advanced manufacturing stage
ESO is delivering the mirror shells
M4 Shells

- Four (out of twelve) thin Shells accepted, two delivered to Adoptica for integration into M4 Unit
- 3rd and 4th shells being delivered to ADS 12th June

M4 Adaptive Unit

- Final Design passed
- Manufacturing in progress
  - Most components for the adaptive mirror actuators (more than 5300 actuators!) ordered and many received (~ 50%)
  - All 6 SiC petals for reference body completed and brazed
  - M4 Test Tower, manufacturing in progress
Telescope Control System

- **Instrument Control System Framework SW** alpha release delivered to Consortia.
- **Time Reference System** technologies, verification and failure modes being studied.
- **Core Integration Infrastructure** software first release imminent (testing on-going).
- **M1 Electronics Cabinets** (final prototype) integrated and ready for thermal testing.
- First software release for **M1 Local Control System (LCS)**; on-track and comfortably exceeding performance requirements for baseline Edge Sensor control loop.
- **Central Control System (CCS)** requirements specification released.
- **M1 Warping Harness (WH) Controller** entered serial production.
- **RTC Toolkit**: WP commencing mid-2019 to provide SW for MIMO controller applications in the telescope (M1, TREx) and INS AO applications.
ELT First set of Instruments

- METIS
- HARMONI
- MAORY
- MICADO
ELT Top Level Schedule

**ARM Site Preparation (Platform, Road, Trenches)**

- **DMS - Design Phase**
- **DMS - Manufacturing and Pre-Assembly**
- **DMS - On-site Erection and Commissioning**

**M1 Segment Assemblies - Design and Production**

**M2 Unit - Design and Production**

**M3 Unit - Design and Production**

**M4 Unit - Design and Production**

**M5 Unit - Design and Production**

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

**Telescope Control**

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

**Telescope First Light**

- **5/24**
- **11/25**
ELT Programme – Commitment Evolution

Nr. of Contracts

ELT Commitment Evolution

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Cumulative nb. of Major Contract Approved

- Nr. Of Major Contracts (>= 0.5 MEUR)
- Contracts - Cumulative Amount (%)

EOO and the ELT, 6th June 2019
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<tr>
<th>Concluded/Ongoing Contracts</th>
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<th>Contract Signature Date</th>
<th>Contractor</th>
<th>Contract Responsible</th>
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<td>PJ42.06 Support Infrastructure</td>
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<td>S. Lewis</td>
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</table>
The Programme is in full construction!
- 33 large contracts plus agreements
- >90% of material cost committed
- On-site progress (e.g. Dome foundations at Armazones, Technical building at Paranal)

A fantastic endeavor with many technical challenges
- but all currently “under control”

Very tight Timeline
- All contracts signed for First Light 2024 (delays appearing at contractors level), new baseline foresee First Light in 2025.

Go to Details for next procurements
Go to movie
On-going Procurement
Next Procurements

1. M1 Manipulator

By Mitsubishi for TMT
Next Procurements

1. M1 Manipulator

2. M5 Cell
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
5. Cameras for detectors
1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
5. Cameras for detectors
6. Laser Beam Projection subunits
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
5. Cameras for detectors
6. Laser Beam Projection subunits
7. M1 LCS Cabinets
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
5. Cameras for detectors
6. Laser Beam Projection subunits
7. M1 LCS Cabinets
8. 5m Coating unit
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
5. Cameras for detectors
6. Laser Beam Projection subunits
7. M1 LCS Cabinets
8. 5m Coating unit
9. Network Infrastructure
Next Procurements

1. M1 Manipulator
2. M5 Cell
3. M1 Washing and Stripping
4. Coarse Metrology and alignment tools
5. Cameras for detectors
6. Laser Beam Projection subunits
7. M1 LCS Cabinets
8. 5m Coating unit
9. Network Infrastructure
10. RTC (Real Time Computing) Infrastructure
## Plan for 2019-2020

(Large Procurements)

<table>
<thead>
<tr>
<th>Description of Work</th>
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<td>M5 Mirror</td>
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<td>MUSE Type CCD for HARMONI</td>
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<td>CCD220 Detectors for MAORY, MICADO, HARMONI, PFS-A</td>
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<td>Telescope Test Unit</td>
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<td>Network Infrastructure*</td>
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<td>M1LCS Network infrastructure Equipment*</td>
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Go to movie

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## Annual Turn-over Categories

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<td>Medium</td>
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<td>Large</td>
<td>&gt;15 M€</td>
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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:
- Request for Information: Oct 2018
- Preliminary Inquiry: Jan 2019
- Release Call for Tender: May 2019
- Closing date: Sep 2019
- FC Approval: Nov 2019 (TBC)
Specialties for potential (sub)contractors:

- Design, construction and testing of robotics arm
- Mechatronics,
- Automation engineering,
- Industrial handling

By Mitsubishi for TMT
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:

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ESO and the ELT, 6th June 2019
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
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: Q4 2019 (TBC)
- Closing date: Q2 2020 (TBC)
- FC Approval: (TBC)
Cameras for LVSM and CCD220

Scope:
- Manufacture, Verification and Delivery of different types of Wavefront Sensing Cameras for Adaptive Optics applications at the ELT
- The cameras consist of the detector (ESO furnished) and its mount, read-out Front-End board, Main Control board, Power Regulator board, Peltier Controller/Cryostat, main structure and cooling system

Expected Contract Duration:
- ~ 2 years

Turn-over: Low

Timeline:

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Request For Information</td>
<td>Q4 2018</td>
</tr>
<tr>
<td>Release Preliminary Inquiry</td>
<td>Q3 2019</td>
</tr>
<tr>
<td>Release Call for Tender</td>
<td>Q4 2019 (TBC)</td>
</tr>
<tr>
<td>Closing date</td>
<td>TBD</td>
</tr>
<tr>
<td>FC Approval</td>
<td>May 2020 (TBC)</td>
</tr>
</tbody>
</table>
Cameras for LVSM and CCD220

Specialties for potential (sub)contractor:

- Manufacturing and testing of small mechanics
- Manufacturing and testing of low-noise electronics
- Minimum understanding of optics
Laser Beam Projection Subunits

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

Expected Contract Duration:
- ~ 4 years

Turn-over: Medium

Timeline:
- Request for Information: Q4 2019 (TBC)
- Preliminary Inquiry: Q4 2019 (TBC)
- Release Call for Tender: Q1 2020 (TBC)
- Closing date: Q2 2020 (TBC)
- FC Approval: Nov 2020 (TBC)
Specialties for potential (sub)contractors:

- Large precision optics and mechanisms and athermalisation
- Polarisation analysis
- Optical and mechanical alignment
- Performance verification of large precision opto-mechanical and electro-mechanical systems specified for varying environmental and operational loads (temperature, gravity vector, laser thermal load)
M1 LCS Cabinet 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: Q3 2019
  - Closing date: Q4 2019
  - FC Approval: May 2020
Scope:
- Design, manufacturing and installation on-site of the coating unit for the large mirrors (M2, M3, M5, M6)

Expected Contract Duration:
- ~ 2 years

Turn-over: Medium

Timeline:
- Release Call for Tender: Q2 2020
- Closing date: Q3 2020
- FC Approval: Nov 2020
Specialties for potential (sub)contractors:

- Design, manufacturing and installation on-site of coating units for 4m class mirrors
- Control systems
- Thin-film coating technologies
- Vacuum system (pumps)
Network Infrastructure

Scope:

- Supply of network devices hosted in Computer room (multilayer data center switches) and in the SCP-B cabinet (ruggedized industrial switches)

Expected Contract Duration:

- ~ 3 years (+2 years possible extension)

Turn-over: Low-Medium

Timeline:

- Release Call for Tender: Q1 2020
- Closing date: Q2 2020
- FC Approval: Nov 2020
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: May ‘21
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
# Plan for 2019-2020 (Large Procurements)

<table>
<thead>
<tr>
<th>Description of Work</th>
<th>Forecast FC Approval Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>M5 Mirror</td>
<td>February-19</td>
</tr>
<tr>
<td>MUSE Type CCD for HARMONI</td>
<td>February-19</td>
</tr>
<tr>
<td>CCD220 Detectors for MAORY, MICADO, HARMONI, PFS-A</td>
<td>February-19</td>
</tr>
<tr>
<td>M5 Cell</td>
<td>September-19 ✓</td>
</tr>
<tr>
<td>M1 Manipulator</td>
<td>November-19 (TBC) ✓</td>
</tr>
<tr>
<td>Mirror Washing Stripping unit</td>
<td>November-19 (TBC) ✓</td>
</tr>
<tr>
<td>Coarse Metrology and Alignment</td>
<td>November-19 (TBC)</td>
</tr>
<tr>
<td>Laser Beam Projection SubUnits</td>
<td>Feb-20 (TBC)</td>
</tr>
<tr>
<td>Cameras for LVSM, CCD220</td>
<td>May-20</td>
</tr>
<tr>
<td>Transportation Service Contract</td>
<td>May-20</td>
</tr>
<tr>
<td>M1LCS Cabinets Procurement</td>
<td>May-20</td>
</tr>
<tr>
<td>Mirror Coating Unit (5m)</td>
<td>November-20</td>
</tr>
<tr>
<td>Telescope Test Unit</td>
<td>November-20 (TBC)</td>
</tr>
<tr>
<td>Network Infrastructure*</td>
<td>November-20</td>
</tr>
<tr>
<td>M1LCS Network infrastructure Equipment*</td>
<td>November-20</td>
</tr>
</tbody>
</table>
## Plan for 2019-2020
(Small Procurements)

<table>
<thead>
<tr>
<th>JOB</th>
<th>Activity Desc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Lift., Handl. and Transp. Equipment</td>
<td>40ton truck heavy duty 6x6 with 100mt Palfinger type crane - Supply</td>
</tr>
<tr>
<td></td>
<td>10ton truck - Supply</td>
</tr>
<tr>
<td>Instrumentation Infrastructure</td>
<td>Procurement of lab. equipment for Inst lab - 2020</td>
</tr>
<tr>
<td></td>
<td>Procurement of handling equipment for Inst lab - 2019</td>
</tr>
<tr>
<td>M1 Unit</td>
<td>M1 Segment Assembly - Stands</td>
</tr>
<tr>
<td>Washing and Coating</td>
<td>Mirror Washing/Stripping unit (5m) Procurement</td>
</tr>
<tr>
<td>Supporting Equipment</td>
<td>PAR Supporting Equipment - ETF Chiller Manufacturing</td>
</tr>
<tr>
<td>Interlock and Safety</td>
<td>Purchase development environment (GAR) - (TCS-ILS)</td>
</tr>
<tr>
<td>ELT Laser Guide Star Units</td>
<td>LGS - Cooling System - Procurement</td>
</tr>
<tr>
<td>M1 In-Situ Cleaning Development</td>
<td>Segment Assembly - In situ cleaning Studies</td>
</tr>
</tbody>
</table>
# Plan for 2020-2021

**(Small Procurements)**

<table>
<thead>
<tr>
<th>JOB</th>
<th>Activity Desc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Lift., Handl. and Transp. Equipment</td>
<td>ELT Road transporters - 3ton Van - Supply</td>
</tr>
<tr>
<td></td>
<td>Forklifts - 2 ton (x2) - Supply</td>
</tr>
<tr>
<td></td>
<td>Forklifts - 5 ton - Supply</td>
</tr>
<tr>
<td></td>
<td>Forklifts - 10 ton - Supply</td>
</tr>
<tr>
<td></td>
<td>Forklifts - 1.5 ton (x2) - Supply</td>
</tr>
<tr>
<td>M1 Unit</td>
<td>M1 Cell Auxiliary Sensors</td>
</tr>
<tr>
<td>WFRTC</td>
<td>Purchase SW Development Environment - AO app SW</td>
</tr>
</tbody>
</table>
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>
</tr>
</thead>
</table>
| M5 Cell                                          | Sep’19              | • Fast nanometer-precision frictionless actuators and tip-tilt mechanism (Piezo, Flex pivot, stiff structure)  
• Cutting-edge dynamic control system technology |
| M1 Manipulator                                   | Sep/ Nov’19         | • mechatronics, automation engineering, industrial handling                   |
| Laser Beam Projection SubUnits                   | Nov’19              | • Precision opto-mechanics and control,  
• Lens polishing and laser coating            |
| Mirror Washing Stripping unit                    | Nov’19              | • Chemical coating removal,  
• Process automation,  
• Safety standards                                 |
| Coarse Metrology and Alignment                   | Nov’19 (TBC)        | • Long-range (tens of m) non-contact, micron-accuracy optical sensing in industrial environment |
## Specialities for potential (sub)contractors

<table>
<thead>
<tr>
<th>Procurement</th>
<th>Planned FC Approval</th>
<th>Specialities</th>
</tr>
</thead>
</table>
| Cameras for LVSM, CCD220                   | May’20              | • Manufacturing and testing of small mechanics  
• Manufacturing and testing of low-noise electronics                                          |
| M1LCS Cabinet Procurement                 | Nov’20              | • Low-power consumption electronics, power supply, cabinet cooling (heat exchanger), COTS components                                      |
| Mirror Coating Unit (5m)                  | Nov’20              | • Design, manufacturing and installation on-site of coating units for 4m class mirrors  
• Control systems  
• Thin-film coating technologies,  
• vacuum system (pumps), |
| Telescope Test Unit (TBC)                 | Nov’20 (TBC)        | • Opto-mechanical design and manufacture  
• Detectors                                                                                           |
| Network Infrastructure                    | Nov’20              | • Network components (Routers, Switches, Firewall, WLAN Controller, etc.)                                                                     |
| M1LCS Network infrastructure Equipment    | Nov’20              | • Network devices including multilayer data center switches  
• ruggedized industrial switches.                                                                 |

ESO and the ELT, 6th June 2019
Thanks for you attention!