E-ELT Optomechanics

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

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

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

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

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

**LGSU**
- (Laser Guide Star Units)
- Laser Sources + Laser Beacons shaping and emitting
M1 Unit

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

<table>
<thead>
<tr>
<th>M1 Mirror</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer diameter (mm)</td>
<td>39146.0</td>
</tr>
<tr>
<td>Inner diameter (mm)</td>
<td>9418.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M1 Optical Prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of curvature (mm)</td>
</tr>
<tr>
<td>Conic constant</td>
</tr>
</tbody>
</table>
M1 Unit
M1 Unit

Segment Assembly

931 x M1 Segments
931 x Blanks + 19 x Spare Blanks
931 x Segments Polishing

4530 x M1 Edge Sensors
4530 x Sensors + 813 x Electronics + Spares
(100 sensors – 15 x controllers)

931 x M1 Segment Supports
& SA Auxiliary Equipment
[SA Handling Tools, SA Transport Containers, SA AIV Tools]

2394 x M1 Position Actuators
2394 x Actuators + 798 x Electronics + Spares (16 x PACT – 6 x Controllers)

M1 Auxiliary Equipment
Aux. Sensors, Mass Dummies. Carts, Stands, Manipulator, Phasing Gun, Alignment Tools

Including glass, mechanics, electronics:
⇒ more than 10 000 components
M1 Unit – Segment Supports

- 931 x M1 Segment Supports
- 798 x M1 Fixed Frames
- 3 x M1 SA Handling Tools
- 798 x M1 SA Transport Containers
- 1 x M1 SA AIV Tools

Segment Support

Fixed Frame

Prototype Segment Support

Prototype Fixed Frame

Prototype Transport Container

AIV Tooling

Handling Tool

Extraction & Handling
M1 Unit - Segment Supports

M1 Segment Support – Procurement

**Contract: Final design and Qualification**

- Final Design Seg. Support & Aux. Equip. (Shipping, Handling, AIV tooling)
- Engineering and Qualification Models
- Manufacturing and testing

**Contract: fabrication**

- Complementary Tests at ESO
- Pre-set manuf. and testing

- Fixed Frames Manufacturing Ex-works
  - Delivery to site [ESO]
- Segment Supports Manufacturing Ex-works
  - Delivery to Polisher [ESO]
- Aux Tools Manufacturing Ex-works
  - Delivery to Polisher [ESO]
M1 Unit - Segment Supports

M1 Segment Support – Procurement
Final Design and qualification: awarded, 2 contracts ongoing.

VDL/TNO Eindhoven/Delft (The Netherlands)
◆ Kick Off: 26.01.15

CESA Madrid (Spain)
◆ Kick Off: 10.02.15
M1 Unit - Segment Supports

M1 Segment Support – Procurement

Final Production:
CfT: planned in May 2017
Contract start: June 2018
Production plan: 2.5 years

Required Skills:
• Precision Mechanical Manufacturing and Integration
• Mass Production

<table>
<thead>
<tr>
<th>Activity Desc.</th>
<th>Duration</th>
<th>Early Start</th>
<th>Early Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 Segment Support Qualification Units</td>
<td>1163d</td>
<td>03Mar2014</td>
<td>20Aug2018</td>
</tr>
<tr>
<td>M1 Segment Support Production Units</td>
<td>1036d</td>
<td>05Jan2017</td>
<td>30Dec2020</td>
</tr>
<tr>
<td>M1 Segment Support Proc. Units - Procurement</td>
<td>351d</td>
<td>05Jan2017</td>
<td>11May2018</td>
</tr>
<tr>
<td>M1 Segment Supports - Tech. and Managerial Reqs. (CTT Package) - Production</td>
<td>100d</td>
<td>05Jan2017</td>
<td>24May2017</td>
</tr>
<tr>
<td>M1 Segment Supports - Tendering</td>
<td>120d</td>
<td>25May2017</td>
<td>06Nov2017</td>
</tr>
<tr>
<td>M1 Segment Support Prod-Units - Selection</td>
<td>60d</td>
<td>09Nov2017</td>
<td>31Jan2018</td>
</tr>
<tr>
<td>Contract award committee</td>
<td>30d</td>
<td>01Feb2018</td>
<td>14Mar2018</td>
</tr>
<tr>
<td>Preparation of FC Documentation</td>
<td>20d</td>
<td>15Mar2018</td>
<td>11Apr2018</td>
</tr>
<tr>
<td>M1 Segment Supports - FC Approval</td>
<td>0</td>
<td>11May2018</td>
<td>11May2018</td>
</tr>
<tr>
<td>M1 Segment Supports - Manufacture Contact</td>
<td>685d</td>
<td>07Jun2018</td>
<td>30Dec2020</td>
</tr>
</tbody>
</table>
M1 Unit – Blanks and Polishing

- 931 x Grind & Pre-Polish Segment Roundels
- 931 x Bound interfaces
- 931 x Cut to hexagonal shape
- 931 x Integrate with Segment Support
- 931 x Finish figure and Test Segment Assemblies
M1 Unit - Blanks and Polishing

- RFI for blanks procurement: ongoing.
- RFI for Polishing: completed.
- PI for Polishing: July 2015.
- CfT for Polishing: planned Nov 2015
M1 Unit – Blanks and Polishing

M1 Segments Polishing – Procurement

CfT: planned in Nov 2015
Contract start: Jan 2017
Contract plan: 7 years

Required Skills:
• High Performance optomechanical components manufacturing, integration, and testing
• Mass Production
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 – Edge Sensors

M1 Edge Sensors – Procurement


Pre-set manufacturing and qualification testing

Sensor & Electronics Manufacturing
Ex-works

Delivery to site [ESO]

Sensor I/F and Dummy masses Manufacturing
Ex-works

Delivery to Polisher / Site [ESO]
M1 Unit – Edge Sensors

M1 Edge Sensors – Procurement

CfT: planned in Jan 2016
Contract start: Jan 2017
Production plan: 5 years

Required Skills:
- Precision non-contact sensors (inductive, nm precision)
- A/D electronics, mechanics
- Control
- Mass Production
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 Position Actuators – Procurement

- Design PACT & test equip.
- Pre-set manufacturing and qualification testing
- Actuators & Electronics Manufacturing Ex-works
- Delivery to site [ESO]
M1 Unit – Position Actuators

M1 PACTs – Procurement

CfT: planned in Apr 2016
Contract start: Jun 2017
Production plan: 6.5 years

Required Skills:
- High precision actuators (nm)
- Electro-Mechanics, Electronics
- Control
- Mass Production
M2 Unit

Passive 4-m f/1.1 convex mirror, highly aspheric (+ warping harness provision)
Axial support: 18 points whiffletree + tripods
Lateral support: 12 tangential struts + fixed lateral and clocking
Positioning system: hexapod with sub-micron accuracy
Earthquake protection: mirror restrainers + load limiters
Active 4-m f/2.6 concave mirror, mild aspheric (warping harness shape control)
Axial support: 18 points whiffletree + tripods
Lateral support: 12 tangential struts + fixed lateral and clocking
Positioning system: hexapod with sub-micron accuracy
Earthquake protection: mirror restrainers + load limiters
M2 and M3 Units are very similar ones!

⇒ Same size, same support concept
⇒ Same mass, same stiffness
⇒ Same shaping system (warping harness: provision on M2, required on M3)
⇒ Same positioning system
⇒ Common auxiliary equipment (handling, transport, …)

Main difference: the mirrors.

Hence, ESO is willing to contract:

• The M2 Mirror
• The M3 Mirror
• The M2+M3 Cells
**M2 Mirror – Procurement**

- **Design – Mirror and Aux. Equipment**
  - Mirror & Blank specs
  - Interfaces (pads, tripods, targets)
  - Mirror Aux. Equip. (Container, Stand, Handling tool, Dummy Mirror)

- **Design & Manufacturing Metrology**

- **Design & Manufacturing Production tooling**

- **Pick-up and transport blank**

- **Bond interface pads**

- **Grinding Polishing**

- **Technical Acceptance Testing**

- **Integration with Cell**

- **Testing with Cell**

- **Dummy Mirror Shipment to Cell manufacturer**

- **Cell delivery to polisher**

- **Provisional Acceptance Delivery Ex-works**

---

*E-ELT – Belgian ESO Industry Day*
M3 Mirror – Procurement

Design – Mirror and Aux. Equipment
- Mirror & Blank specs
- Interfaces (pads, tripods, targets)
- Mirror Aux. Equip.
- (Container, Stand, Handling tool, Dummy Mirror)

Design & Manufacturing Metrology

Design & Manufacturing Production tooling

- Dummy Mirror Shipment to Cell manufacturer

Pick-up and transport blank
- Bond interface pads
- Grinding Polishing
- Technical Acceptance Testing
- Integration with Cell
- Testing with Cell

Cell delivery to polisher
- Provisional Acceptance Delivery Ex-works

Dummy Mirror Shipment to Cell manufacturer
M2 & M3 Cells – Procurement

- Design M2 & M3 Cell & Aux. Equip. (Shipping, Handling, AIV tooling)
- Critical Components Qualification Testing [Strength/Ageing / MTBF]
- M2&M3 Cells Subsystems Manufacturing
- Local Control System development
- M2&M3 Cells AIV With M2&M3 dummy mirrors
- M2&M3 Cells Tech. Acc. Testing With dummy mirrors
- Shipment to Polishers [ESO task]
- Integration with actual Mirrors & Testing
- Provisional Acceptance & Delivery (Ex-works)
M2 Mirror – Procurement

CfT: planned in Oct 2015
Contract start: Jun 2016
Production plan: 5.5 years

Required Skills:
- High performance large optics manuf. & testing
- Optics, Mechanics, Metrology, Adhesive bonding, …
M3 Mirror – Procurement

CfT: planned in Feb 2016
Contract start: Jan 2017
Production plan: 4.5 years

Required Skills:
- High performance large optics manuf. & testing
- Optics, Mechanics, Metrology, Adhesive bonding, …
M2&M3 Cells – Procurement

CfT: planned in Feb 2016
Contract start: Jan 2017
Production plan: 4.5 years
(schedule shall read M2 and/or M3)

Required Skills:
• Optomechanics, Mechanics (for large high performance optics)
• Electromechanics (warping harness)
• Mechanical & optomechanics integration and testing
• 2.4-m flat adaptive mirror – 6 petals
• Preliminary Design Study contract completed
• Contract for Final Design and Manufacturing being awarded
• Contract for Optics being awarded
• Contracts start: July 2015

⇒ Check ESO Web site to know contractors
M5 Mirror – Procurement

Design – Mirror and Aux. Equipment
- Mirror & Blank specs
- Interfaces (pads, targets)
- Mirror Aux. Equip.
  (Container, Stand, Handling tool)

Design & Manufacturing
- Metrology
  Variable gravity orientation. Compatible with integrated M5 Unit
- Production
  Production tooling

Blank fabrication
  Technology: tbd

Interface bonding
  Grinding
  Polishing

Mirror acceptance testing
  with metrology support

Mirror Tests & Qualification
  integrated M5 Unit

Mirror and Aux. shipment to site

Mirror site inspection and acceptance
**M5 Unit**

### M5 EMU – Procurement

- **Design M5 EMU & Aux. Equip.**
  - (Shipping, Handling, AIV tooling, Dummy Mirror)

- **Critical Components Qualification Testing**
  - [Strength/Ageing / MTBF]

- **M5 EMU Subsystems Manufacturing**

- **M5 Local Control System development**

- **M5 EMU AIV**
  - With dummy mirror

- **M5 Electromechanical Unit transport to M5 Mirror contractor**

- **M5 EMU integration with mirror, and qualification testing (variable gravity orientation)**

- **M5 Electromechanical Unit shipment to site, on site AIV, with dummy mirror**

- **M5 Electromechanical Unit acceptance tests with dummy. Provisional Acceptance**
**M5 Mirror – Procurement**

CfT: planned in July 2017

Contract start: July 2018

Production plan: 4 years

**Required Skills:**
- High performance large optics manuf. & testing
- Optics, Mechanics, Metrology, Adhesive bonding, …

---

<table>
<thead>
<tr>
<th>Activity Desc.</th>
<th>Duration</th>
<th>Early Start</th>
<th>Early Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>M5 Mirror</td>
<td>1160d</td>
<td>07Jul2017</td>
<td>22Dec2021</td>
</tr>
<tr>
<td>M5 Mirror - Procurement</td>
<td>220d</td>
<td>07Jul2017</td>
<td>11May2018</td>
</tr>
<tr>
<td>M5 Mirror - Tendering</td>
<td>120d</td>
<td>07Jul2017</td>
<td>21Dec2017</td>
</tr>
<tr>
<td>M5 Mirror - Selection</td>
<td>60d</td>
<td>22Dec2017</td>
<td>15Mar2018</td>
</tr>
<tr>
<td>M5 Mirror - Prepare FC Documentation</td>
<td>20d</td>
<td>16Mar2018</td>
<td>12Apr2018</td>
</tr>
<tr>
<td>M5 Mirror - FC Approval</td>
<td>0</td>
<td>11May2018</td>
<td>11May2018</td>
</tr>
<tr>
<td>Phase 1 - Design M5 Mirror</td>
<td>160d</td>
<td>05Jul2018</td>
<td>15Feb2019</td>
</tr>
<tr>
<td>Phase 2 - Manufacture M5 Blank</td>
<td>640d</td>
<td>27Sep2018</td>
<td>17Mar2021</td>
</tr>
<tr>
<td>Phase 3 - Mirror Finishing</td>
<td>500d</td>
<td>21Jan2020</td>
<td>22Dec2021</td>
</tr>
<tr>
<td>M5 Delivery (Stays at polisher facilities)</td>
<td>0</td>
<td>22Dec2021</td>
<td>22Dec2021</td>
</tr>
</tbody>
</table>
M5 EMU – Procurement

CfT: planned in Jan 2018
Contract start: Jan 2019
Production plan: 3.5 years

Required Skills:
- Optomechanics, Mechanics (for large high performance optics)
- Electromechanics
- Mechanical & optomechanics integration and testing
- Control
Prefocal Stations

Interface with Telescope have changed.

⇒ Under development…

⇒ See Roberto’s presentation
Laser Guide Star Units

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

6 Laser Beam Projection Subunits
- Mechanical Structure & enclosure
- Beam relay and diagnostics
  - Launch Telescope
  - Baffle towers
  - Cooling
- Control Electronics

Local Electronics and Control System

Auxiliary Equipment
(AIV, handling, shipping, testing)

Toptica 20W VLT AOF Laser Source

Laser Source Control Electronics

TNO 20W VLT AOF Launch Telescope

E-ELT – Belgian ESO Industry Day
Laser Guide Star Units

Laser Sources – Procurement

Risk Reduction: Studies of alternative laser components/technologies

Risk Reduction: On-sky guide star experiments and numerical modeling

Tech. Specs and SOW, CfT and Laser Technology selection

Laser Source Design

Pre-production Unit MAIT and Final Design Update (Test with LBPS)

Laser Sources manufacturing and tests. Acceptance and Delivery Ex-Works

Delivery to site [ESO]
Laser Guide Star Units

Laser Beam Projection Subunits – Procurement

1. LBPS and Auxiliary Equipment Design
2. LBPS Prototype build and Test (With Laser Source)
3. Procurements and AIV
4. Acceptance tests
5. Delivery to site – Assembly and Provisional Acceptance [Contractor]
Lasers – Procurement

CfT: planned in Jan 2018
Contract start: Jan 2019
Production plan: 4 years

Required Skills:
• High power lasers 589 nm
Laser Guide Star Units

LBPS – Procurement

CfT: planned in Jan 2018
Contract start: Jan 2019
Production plan: 4 years

Required Skills:
• Optomechanics, Mechanics
• Electromechanics
• Mechanical & optomechanics integration and testing
• Control

<table>
<thead>
<tr>
<th>Activity Desc.</th>
<th>Duration</th>
<th>Early Start</th>
<th>Early Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Beam Projection Subunits</td>
<td>1460d</td>
<td>23Jun2017</td>
<td>02Feb2023</td>
</tr>
<tr>
<td>Laser Beam Projection Subunits - Procurement</td>
<td>360d</td>
<td>23Jun2017</td>
<td>09Nov2018</td>
</tr>
<tr>
<td>Laser Beam Projection Subunits - Technical and Managerial</td>
<td>120d</td>
<td>23Jun2017</td>
<td>07Dec2017</td>
</tr>
<tr>
<td>Laser Beam Projection Subunits - Tendering</td>
<td>120d</td>
<td>08Dec2017</td>
<td>24May2018</td>
</tr>
<tr>
<td>Laser Beam Projection SubUnits - Selection</td>
<td>60d</td>
<td>22Jun2018</td>
<td>13Sep2018</td>
</tr>
<tr>
<td>Laser Beam Projection SubUnits - Prepare FC Documentation</td>
<td>20d</td>
<td>14Sep2018</td>
<td>11Oct2018</td>
</tr>
<tr>
<td>Laser Beam Projection SubUnits - FC Approval</td>
<td>0</td>
<td>09Nov2018</td>
<td>09Nov2018</td>
</tr>
<tr>
<td>Laser Beam Projection Subunits (LGSU) - Manufacture (Phase 1)</td>
<td>11000d</td>
<td>09Nov2018</td>
<td>02Feb2023</td>
</tr>
</tbody>
</table>
WE ARE DOING IT NOW !!!

PLEASE JOIN 😊 !!!