E-ELT Opportunities for Civil & Mechanical Engineering Companies

Alistair McPherson PM E-ELT

Main Structure Design

General Overview

The Main Structure is about 3350 tons of steel moving 755 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.
**E-ELT Primary Mirror**

**Segment Assembly (x1148)**
[Movable and exchangeable part]
- Segment
- Edge sensors
- Segment Support (& Warping Harness)

**Subcell (x984)**
[Permanently attached to Main Structure]
- Fixed Frame
- Extractor
- Position Actuators

*Note: Same design for all Segment families*

**Segment**
- Low CTE glass / glass ceramic
- 50 mm thick at center, back surface flat
- Back center hole Ø200 mm, h 36 mm
- 27 axial invar pads
- 6 lateral invar pads
- 3 azimuthal invar pads
- Invar Pads Ni plated
- 12 Edge Sensor interfaces (Boron Nitride)
- Adhesive: Structural Epoxy and/or RTV
E-ELT Programme

Segment Support - Alternative Design

M1 Position actuators

- Soft, 2 stage actuator
- Coarse Stage: brushless motor, gear box, lead screw
  2 axial guides - Micron precision encoder – 15 mm stroke
- Fine Stage: voice coil actuator, two leaf springs
  Nanometer precision encoder – +/- 5 micron stroke

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Unit</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>mm</td>
<td>15</td>
</tr>
<tr>
<td>Stiffness (in 0-4 Hz range)</td>
<td>N/micron</td>
<td>12</td>
</tr>
<tr>
<td>Positioning error, tracking</td>
<td>nm RMS</td>
<td>1.7</td>
</tr>
<tr>
<td>Tracking velocity</td>
<td>µm/s</td>
<td>+/- 10</td>
</tr>
<tr>
<td>Slewing velocity</td>
<td>µm/s</td>
<td>+/- 250</td>
</tr>
<tr>
<td>Power consumption, average</td>
<td>W</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Mass</td>
<td>kg</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Bandwidth, update rate</td>
<td>Hz</td>
<td>30, 1000</td>
</tr>
</tbody>
</table>
### E-ELT Programme

#### Edge Sensors
- 6 Emitters + 6 Receivers per Segment
- Inductive sensing technology:
  - Emitter & receiver Silver-palladium coils embedded in ceramic (Boron Nitride)
- Mechanics: casted low CTE Boron Nitride ceramic (metal free)
- Embedded low power (0.5W) front-end electronics for signal modulation, detection and digitization

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Piston</th>
<th>Gap &amp; Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>±1 mm</td>
<td>±200 μm</td>
</tr>
<tr>
<td>Linearity</td>
<td>1 ±10 %</td>
<td>1 ±1 % (over ±100 nm)</td>
</tr>
<tr>
<td>Noise</td>
<td>-</td>
<td>≤ 1 nm/√(Hz) (goal 0.2)</td>
</tr>
<tr>
<td>Drift</td>
<td>-</td>
<td>&lt; 10 μm/week (goal 2 μm)</td>
</tr>
<tr>
<td>Temperature sensitivity</td>
<td>ΔP/ΔT ≤ 5 mm/°C</td>
<td>ΔG/ΔT ≤ 5 μm/°C</td>
</tr>
<tr>
<td>Humidity sensitivity</td>
<td>-</td>
<td>ΔP/ΔRH ≤ 10 mm/50%</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>0.5 W / sensor max</td>
<td></td>
</tr>
</tbody>
</table>

#### M1 Edge Sensors

- **Files and Notes**

### E-ELT Programme

#### M2 unit

**F/1.2 Convex Mirror 6-m diameter**
- **Active positioning** – 5 DoF
  - Slewling
  - Step tracking
  - Δz 0.7 mm for Gravity Invariant (GI)
- **Active shaping**
  - Correction for optical surface errors
  - No shape change for GI > M3
- **Polishing spec**: 30 nm RMS WFE (in active mode)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of curvature</td>
<td>-14488 mm</td>
</tr>
<tr>
<td>Conic constant</td>
<td>-2.564187</td>
</tr>
<tr>
<td>Useful area, outer</td>
<td>5692 mm</td>
</tr>
<tr>
<td>Useful area, inner</td>
<td>1561 mm</td>
</tr>
<tr>
<td>Aspheric departure</td>
<td>2.06 mm</td>
</tr>
</tbody>
</table>
**M2 Mirror**
- Thin meniscus
- 6000 mm diameter
- 1700 mm center hole
- 100 mm thick
- Interface with tripods

**M2 Cell**
- Hexapod Support
- Steel Backbeam Structure
- CFRP Box type mirror backplate
- Mirror Support:
  - 162 Pneumatic + Voice Coil actuators
  - 24 + 8 pneumatic lateral support
  - 24 Safety restrainers

**M2 Mirror**
- Thin meniscus
- 6000 mm diameter
- 1700 mm center hole
- 100 mm thick
- Interface with tripods

**M2 Cell**
- Hexapod Support
- Steel Backbeam Structure
- CFRP Box type mirror backplate
- Mirror Support:
  - 162 Pneumatic + Voice Coil actuators
  - 24 + 8 pneumatic lateral support
  - 24 Safety restrainers

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**M3 unit**

**F/2.7 Concave Mirror 4-m diameter**

- **Active positioning** – 5 DoF
  - Slewing, Tracking, Telescope control
  - Δz 166 mm for Gravity Invariant (GI)
- **Active shaping**
  - Correction for optical surface errors & Telescope control
  - Change <20 μm PV for GI
- **Polishing spec**: 30 nm RMS WFE (in active mode)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of curvature</td>
<td>22120 mm</td>
</tr>
<tr>
<td>Conic constant</td>
<td>2 aspheric terms (r^4+r^6)</td>
</tr>
<tr>
<td>Useful area, outer</td>
<td>4032 mm</td>
</tr>
<tr>
<td>Useful area, inner</td>
<td>250 mm</td>
</tr>
<tr>
<td>Aspheric departure</td>
<td>0.04 mm</td>
</tr>
</tbody>
</table>
**M3 Mirror**
- Thin meniscus
- 4200 mm diameter
- 100 center hole
- 100 mm thick
- Interface with tripods

**M3 Cell**
- Hexapod Support
- Steel Box type mirror backplate
- Mirror Support:
  - 57 Pneumatic actuators
  - 24 lateral astatic levers
  - Fixed points (3axial, 3 lateral)
- 10 Safety restrainers – Radial & axial
  [Brackets, outer edge, 0.5 mm Gap]

**M4 - Design 1**
- 5928 contactless actuators in optical area
- 160 µm stroke
- 31.5 mm pitch, triangular pattern
- Segmented Zerodur 2mm thin shell (6 petals)
- External membrane frame
- Lightweighted CFRP Backplate
- Removable Actuator Brick design (228 bricks)
- On board M4 Adaptive Mirror electronics
- Remote M4 Control System electronics
- Flex joint hexapods for M4 Positioning System
- Large bearing + cable wrap for Nasmyth selector
- Mass: 9.9 tons
- Power: 8.4 kW
E-ELT Programme

M4 – Design 1

Tip/Tilt flat mirror 3.0 x 2.5 m
Incoming disturbance with 1” rms residual tip tilt
• Residual after M5 stabilisation, on sky tip-tilt:
  • < 0.07” rms (goal 0.06”) over entire frequency range
  • < 0.004” rms for [9Hz to ∞] all peaks < 2σ
Telescope main axes control

Telescope w/M2

Remaining tip tilt < 1” rms

Low frequency, high stroke

High frequency, low stroke

M5 Unit

Figure 11: HV voltage cables connected to the active actuators (back side of the mirror)
**E-ELT Programme**

**M5 Unit**

### Electromechanical Unit
3 axial PZT actuators 0.5 mm range – Membrane lateral support (membrane)

![Scale 1 demonstrator](image1)

**Lateral support**

**Mounting frame**

### Mirror

**Monolithic - Ultra lightweight 60 kg/m² – 300 Hz**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specified value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
</tr>
<tr>
<td>Dimensions (clear ap.)</td>
<td>2388 x 2978 mm</td>
</tr>
<tr>
<td>Central hole (clear ap.)</td>
<td>151 x 183 mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>300 mm (TBC wrt design)</td>
</tr>
<tr>
<td>Areal density</td>
<td>90 kg/m², 60 kg/m² goal</td>
</tr>
<tr>
<td>First Eigenfrequency</td>
<td>~ 300 Hz</td>
</tr>
<tr>
<td><strong>Optical (WFE)</strong></td>
<td></td>
</tr>
<tr>
<td>Optical quality (scale &gt; 40 mm)</td>
<td>&lt; 1 μm P-V</td>
</tr>
<tr>
<td>Static mode distortion (scale &gt; 40 mm) (Additional: thermal, gravity)</td>
<td>&lt; 500 nm RMS</td>
</tr>
<tr>
<td>Obs. mode distortion (scale &gt; 40 mm)</td>
<td>&lt; 200 nm RMS</td>
</tr>
<tr>
<td>Optical quality (scale &lt; 40 mm)</td>
<td>&lt;15 nm RMS</td>
</tr>
</tbody>
</table>

**Closed-back ULE® Mirror with Abrasive Water-Jet (AWJ) Lightweight Square Core – Low temperature fusion**

**SiC brazed petals with CVD SiC layer**

**Ultralightweight machined Zerodur® Substrate**
2 Prefocal Stations

- **Selection of focal station:**
  - Straight-through focus – 10 arcmin FoV
  - Gravity Invariant focus - 10 arcmin FoV
  - Lateral foci - 5 arcmin FoV
  - Coudé focus – 20 arcsec FoV

- **Wavefront sensing Natural Guide Stars:**
  - Fast high order WFS for adaptive optics, tracking, optical alignment & mirror shape control
  - Slow high order WFS Segment Phasing and shape measurement

- **Wavefront sensing Laser Guide Stars**

- **Rotation of Instruments with weight up to 5 tons (4m x Ø 4m)**

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**PFS Baseline**

- Steel frame structure
- Two concentric adapters:
  - One for NGS – 4 arms (1+3)
  - One for LGS – 4 arms
- Instrument rotator on each port
- A folding mirror elevator for focus selection [M6G-M6N]
- A small Coudé folding mirror arm [M6C]
- Mass: approx. 55 t
- Total height 10.5 m
- Back focale distance : 750 mm
**E-ELT Programme**

**Platforms and Instruments**

- EPICS: Exo-planet imaging camera and spectrograph
- MAORY: Multi-conjugate AO
- EAGLE: Wide-field multi-IFU AO assisted NIR spectrograph
- AO assisted NIR spectrograph
- ATLAS: Laser Tomography AO
- MICADO: Diffraction limited NIR Camera
- METIS: Mid-infrared ELT Imager and Spectrograph
- HARMONI: Single field, wide band IFU, NIR spectrometer
- CODEX: High stability, high resolution visible spectrograph
- SIMPLE: High resolution NIR spectrograph
- EPICS: Exo-planet imaging camera and spectrograph
- OPTIMOS-EVE: Optical Hband fibre MOS
- OPTIMOS-DIORAMAS: A wide field imaging multi-slit spectrograph

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**Coating Plants**

- Primary Mirror Segments
  - M2 – 6m
  - M3 – 4m
  - M5 2.5 * 3m
  - M4 Segments
  - M6…..
Coating Plants

Proposed Technical Solutions
E30 Preliminary Inquiry F32004980790/10C – E-ELT Mirror Coating Units
Mirror Coating Units for the European Extremely Large Telescope (E-ELT) for mirrors M1, M2, M3, M4.
E-ELT Programme

Chillers

Scope of chilled medium system study

Chiller unit 1
Chiller unit 2
Chiller unit 3
Chiller unit 4

Power distribution
Chilled medium system control unit

Telescope fan exchangers

Telescope cooling system

Oil cooling
Telescope drives
Instruments
PFS

DOM
M1
M2
ELGS

Al. cable wrap

Silo

Dome cooling system

Axils
Axial rotation
number
Windscreen drive

Cryogenic plant
Cooling plant
Integration hall

I/O signals to E-ELT control system
Electric power supply
Power System

- Power from Grid
- Stand-by Power
- Distribution within Site

Route of Road
E-ELT Programme

Questions

Alistair McPherson PM E-ELT