TMT Primary Mirror Control System (M1CS)
Segment Controller and Cables (SCC)
Concept Description

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This presentation is intended to provide additional reference background information only. The SCC Architectural Concept Document, TMT.CTR.10.010.DRF01, shall take precedence over any information provided in this presentation.
The intent of this presentation is to provide background material to potential suppliers of the M1CS Segment Controller and Cables (SCC).

Background material
- Thirty Meter Telescope overview
- The primary mirror (M1) and its control system (M1CS).
- Segment Control and Cabling (SCC)
Thirty Meter Telescope
Astronomy’s Next-generation Observatory
The Thirty Meter Telescope will give astronomers the clearest and deepest picture of the Universe. This telescope will push the frontier of technology, fully integrating the latest innovations in precision control, segmented mirror design, and adaptive optics to correct for the blurring effects of Earth’s atmosphere. When combined with the unprecedented light-collecting area of the primary mirror, TMT will be the most capable and sophisticated telescope ever constructed.
Telescope Optics

M1 System

M2 System

M3 System
The core technology of TMT is its 492-segment, 30-meter diameter primary mirror.

There are 492 mirror segments mounted to the mirror cell.

Each segment has 3 actuators, 6 edge sensors (2 per intersegment edge), and 21 warping harnesses (WHs).
Telescope & M1 Cell
Group of Segments From Above
Group of Segments From Below
TMT M1CS Components

- Segment 1.4 m
- Segment Support Assembly
- Actuators 3 per segment
- Sensor Control Bd. prototype
- Sensor Preamp prototype
- Drive half
- Sense half
M1 Control System
Man in Mirror Cell
M1CS Functions

- **M1CS maintains the shape of the segmented M1 mirror.**

- **M1CS minimizes global M1 distortions caused by:**
  - Tilting the telescope (gravity sag)
  - Temperature
  - Wind
  - Vibration
  - Fabrication and installation errors

- **M1CS has**
  - *Edge sensors and actuators* to correctly position segments relative to each other, and
  - *Warping harnesses*, to correctly shape individual segments.
Edge Sensors and Actuators

Edge sensors and actuators move the 492 mirror segments relative to each other.

- The edge sensors report displacement, tilt, and the gap between adjacent segments. The actuators move each segment in piston, tip, and tilt.
- The edge sensors are to have noise better than 5nm noise, drift better than 1nm/C and 1/nm week, to be linear over a 300 um range, and to be monotonic over a 5 mm range.
- The actuators each have a voice coil and a precision linear encoder operating in a local closed loop, at 5000 Hz update rate. Each actuator has a stepper motor that offloads the voice coil.
- The control laws connecting the 2772 sensors to the 1496 actuators are implemented in “Node Boxes” and in the “Global Loop Controller”.
- The update rate for positioning the segments is 20 Hz.
Warping Harnesses

- Warping harnesses (WHs) bend each segment to its optically perfect shape.
- There are 21 WHs per segment, each with a stepper motor and a strain gauge.
- There are 3 temperature sensors per each segment.
- Control of these is split across 3 WH Boxes, each handling 7 stepper/strain gauge pairs and a temperature sensor.
- The strain gauges just report applied force back to software. There is no local closed-loop control of the motor.
- WHs are adjusted no more than 10x per night, possibly much less frequent. The WHs are only powered up during these adjustments.
- Only one motor / strain gauge pair is powered up and addressed at a time, per WH Box. This means both the motor and strain gauge connections can be analog multiplexed to a single driver per WH Box.
M1 Control System
SCC Hierarchy

- The Global Loop Controller (GLC), in an environmentally controlled computer room, connects to a Power and Signal Unit (PSU) on the telescope.
- The PSU connects to six Sector Hubs.
- Each Sector Hub connects to 14 Node Boxes. There are 84 Node Boxes.
- Each Node Box connects to 5 or 6 segments. There are 492 segments.
- Each segment has 3 actuators. There are 1476 actuators.
- Each segment has 6 drive-half and 6 sense-half edge sensors. There are 2772 edge sensors pairs (drive plus sense).
- Each segment has 21 WHs. There are 13,284 WHs.
- Each segment has 3 temperature sensors. There are 1476 temperature sensors.
- There are 82 spare segments each with sensors, WHs, temperature sensors, and cabling.
Table 1. Quantities of SCC components.

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Total for telescope</th>
<th>Total including 7th sector</th>
<th>Total with spares</th>
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</thead>
<tbody>
<tr>
<td>Power and signal unit</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Power and signal cabling</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sector hub</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Sector hub cabling</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Node box</td>
<td>84</td>
<td>84</td>
<td>88</td>
</tr>
<tr>
<td>Node cabling</td>
<td>84</td>
<td>84</td>
<td>88</td>
</tr>
<tr>
<td>Segment lower box</td>
<td>492</td>
<td>492</td>
<td>517</td>
</tr>
<tr>
<td>Segment actuator box</td>
<td>1476</td>
<td>1476</td>
<td>1550</td>
</tr>
<tr>
<td>Segment lower cabling</td>
<td>492</td>
<td>492</td>
<td>517</td>
</tr>
<tr>
<td>Segment upper box</td>
<td>492</td>
<td>574</td>
<td>603</td>
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<tr>
<td>Segment warping harness box</td>
<td>1476</td>
<td>1722</td>
<td>1808</td>
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<tr>
<td>Segment sensor preamp</td>
<td>2772</td>
<td>3234</td>
<td>3396</td>
</tr>
<tr>
<td>Segment upper cabling</td>
<td>492</td>
<td>574</td>
<td>603</td>
</tr>
</tbody>
</table>

The SCC does not include segment actuators, edge sensors, WH motors or strain gauges.
# Cabling and Connectors Quantity

## Moving Frame Mounted - must be vacuum compatible

<table>
<thead>
<tr>
<th>Source</th>
<th>Destination</th>
<th>Number and type of conductors, per cable</th>
<th>Qty per segment</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seg Upper Box</td>
<td>Seg Sensor Drive</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
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<tr>
<td>Seg Sensor Preamp</td>
<td>Seg Upper Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>WH motor</td>
<td>WH Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>WH strain gauge</td>
<td>WH Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Temp Sensors</td>
<td>WH Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>WH Box</td>
<td>Seg Upper Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
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</tbody>
</table>

## Fixed Frame Mounted

<table>
<thead>
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<th>Source</th>
<th>Destination</th>
<th>Number and type of conductors, per cable</th>
<th>Qty per segment</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seg Upper Box</td>
<td>Seg Lower Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Segment Actuator</td>
<td>Seg Lower Box</td>
<td>shielded twisted pair 2,200,556</td>
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</table>

## Cell Floor Mounted

<table>
<thead>
<tr>
<th>Source</th>
<th>Destination</th>
<th>Number and type of conductors, per cable</th>
<th>Qty per segment</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seg Lower Box</td>
<td>Node Box</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Node Box</td>
<td>Sector Hub</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Sector Hub</td>
<td>Power &amp; Sig Unit</td>
<td>shielded twisted pair 2,200,556</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

## Notes

- * Most Segments have 6 Edge Sensors - some have fewer
- coax = coaxial cable
- (SCC Provided)
- Total Cables: 36,570
- Number of segments: 492
- Number of Node Boxes: 84
- Number of Edge Sensors: 2,772
- Total Copper Length (m): 92,782
- Total Connectors: 23,382

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Cables procured through SCC

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Cables procured elsewhere
Location of Sector Hubs and Power and Signal Unit

One of six Sector Hubs on back of mirror cell

Power and Signal Unit (1x)

One of six Sector Hubs on back of mirror cell

View from Sky
Node Box Locations

Node boxes (84x)
The primary mirror is comprised of 6 identical sectors. One sector is shown.

Each sector has 82 mirror segments, for 492 total segments.

Each sector has 14 Node Boxes, for 84 total Node Boxes.

In each sector—
12 Node Boxes control 6 segments
2 Node Boxes control 5 segments.

A possible mapping of segments to Node Boxes is shown by the color coding.

The Node Boxes are shown as red squares.
Design of D10 Upper Box and Sensor Preamp D12.1-6 provided by TMT
Primary Segment Assembly

- Mirror Segment
  - Axial Support Rod
  - 3 ea Whiffletree
- Diaphragm
- Guide Flexure
- Warping Harness
  - Actuators, 21 ea
- Tower
- Moving Frame
- Fixed Frame
- Mirror Cell
  - Cell floor is 6 ft below
- Edge sensor Drive/Sense Pair
- 3 ea Actuators
Location of SCC Components on Primary Segment Assembly

- Sensor Drive Side
- Sensor Sense Side
- Edge sensor Drive/Sense Pair
- Sensor Preamp/ADC
- Warping Harness
- Actuator Board (3)
- Actuator
- Warping Harness Box (3)
- Segment Upper Box
- Segment Lower Box
- To Node Box

TMT Confidential
Warping Harness Box Location

Warping Harness Boxes
Detail of Warping Harness

- Strain Gauge
- Stepper Motor
The mirror segments are aluminized (coated) in a vacuum, first on installation then every two years.

All components on the segment and moving frame must be vacuum compatible. These are

- Segment Sensor Preamp Assembly
- Warping Harness Boxes each with a Warping Harness Board
- Segment Upper Boxes each with an Segment Upper Board
- Temperature Sensors, with wires and connectors
- Cables
  - Segment Sensor Preamp Assembly to Segment Upper Box
  - Segment Sensor Drive Block to Segment Upper Box
  - Warping Harness Box to Segment Upper Box (3x492).

The Segment Upper Box to Segment Lower Box cable disconnects at the Segment Upper Box end for this coating procedure.
Segment Installation / Removal

Lifting Talon

Segment Upper Box
Stays with Segment Assembly

Segment Lower Box
Stays in Place in Mirror Cell

Segment Lifting Jack

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Primary Segment Assembly
Test Bed

Segment Upper Box goes here
Actuator