AN OVERVIEW OF THE ACTIVE OPTICS CONTROL STRATEGY FOR THE THIRTY METER TELESCOPE

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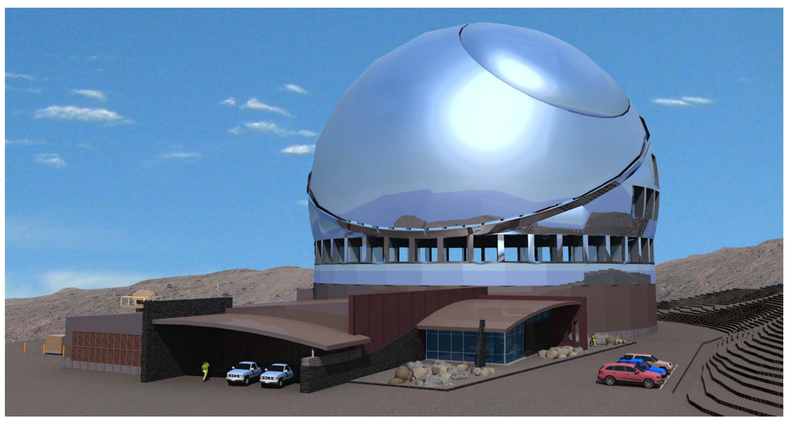
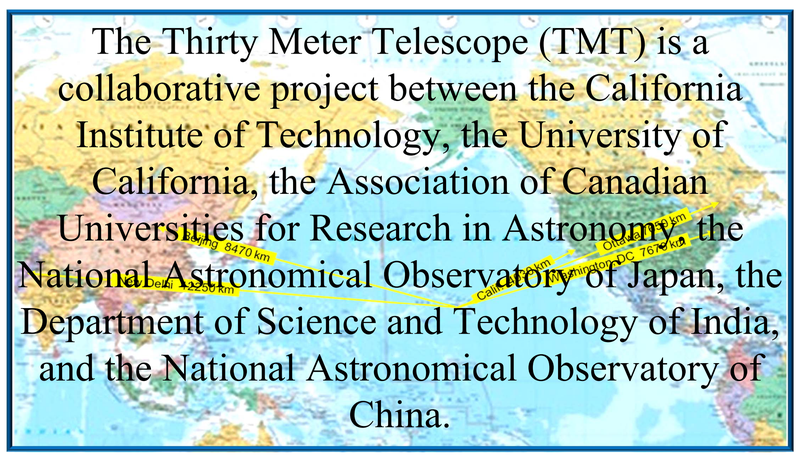
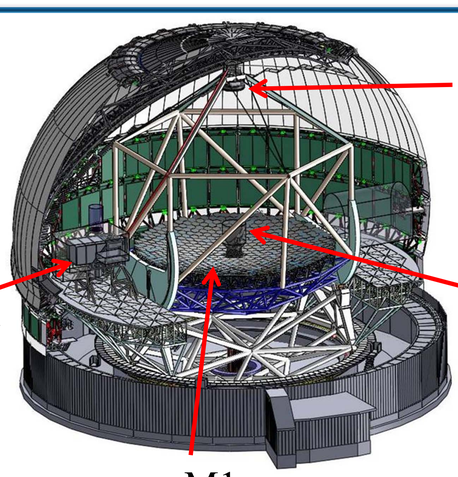


TMT will be sited at Mauna Kea, Hawaii
Construction on-site is to begin in 2014
First light with 492 segments in 2021



The Thirty Meter Telescope (TMT) is a collaborative project between the California Institute of Technology, the University of California, the Association of Canadian Universities for Research in Astronomy, the National Astronomical Observatory of Japan, the Department of Science and Technology of India, and the National Astronomical Observatory of China.

Ritchey-Chrétien Optical Design
f/15 final focal ratio

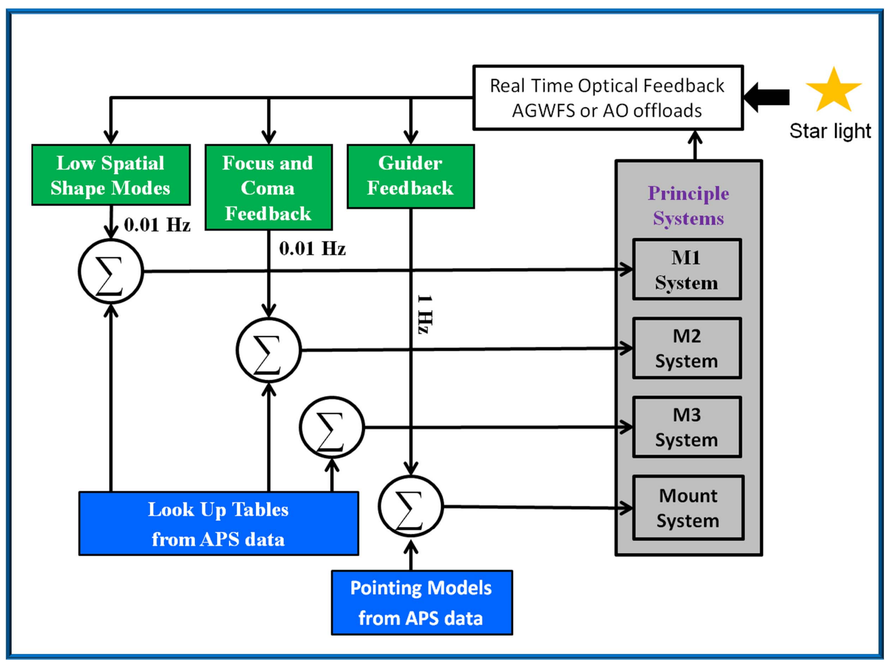


30m f/1, 492 1.4 m Hexagonal Segments

Four Principle Local Control Systems

1. Mount Control System (MCS)
   - Azimuth and Elevation Drives
2. Primary Mirror Control System (M1CS)
   - Three actuators per segment (1476 total)
   - Twenty one shape actuators (warping harnesses) per segment (10,332 total)
3. Secondary Mirror Control System (M2CS)
   - Five degrees of freedom
   - Hexapod, (θ_x, θ_y, δ_x, δ_y, δ_z)
4. Tertiary Control System (M3CS)
   - Two degrees of freedom
   - Rotation and Tilt

Active Optics Simplified Block Diagram



Real Time Feedback via On-Sky Measurements

Real time corrections based on on-sky optical measurements can come from one of three sources.

1. *Alignment and Phasing System (APS). --*

Used on-sky after segment exchanges to;

- measure and correct the global and segment shapes of M1.
- align M2 to M1
- calibrate the M1 edge sensors

2. *AGWFS -Acquisition, Guider and Wavefront Sensor*

Used with seeing limited instruments to;

- provide corrections to the Mount Control System (azimuth and elevation positions)
- Provide position corrections to the M2
- Provide low spatial frequency shape corrections to the M1

3. *Adaptive Optics (AO) System offloads*

Used with the TMT AO system NFIRAOS in conjunction with the near infrared instrument suite. Functionally similar to the AGWFS (No. 2 above)

M1CS

1. Based on the design developed for the successful Keck telescopes.
2. M1CS maintains the overall shape of the primary mirror by attenuating the response due to gravity, temperature, wind, and vibration disturbances
3. The M1CS is aligned and phased using the Alignment and Phasing System (APS) every 4 weeks or after a segment exchange (2 weeks). Look up tables are used in between calibration runs
4. M1CS controls the global shape of the M1 using segment-mounted edge sensors and actuators
5. Real time on-sky measurements by the AGWFS or AO system offloads are used to complement the static look up tables built using APS data.

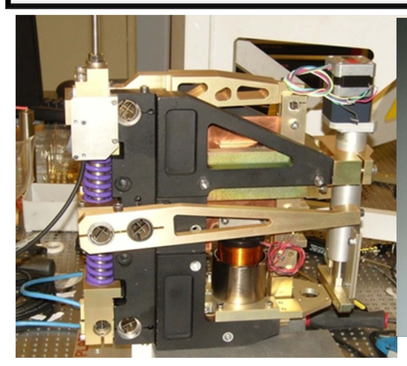
Principle Local Control Loops								Alignment and Calibration Loop		Operational Outer Loop	
	Name	Degrees of Freedom	Actuators	Sensors	Update Rate (Hz)	Loop BW (Hz)		Sensor	Refresh Rate	Sensor	Update Rate (Hz)
Mount	Azimuth & Elevation (Pointing and Guiding)	2	Direct Drive	Tape encoders	≥ 40	~ 1		APS camera (Pointing)	Monthly	AGWFS (Guider)	1
M1	Global Tip, Tilt, Piston	3	Segment actuators	Actuator sensors	≥ 10	~ 1		Surveying/ FEM	> 1 year	No outer control loop	
	Segment Tip, Tilt, Piston	1476	Segment actuators	Edge sensors	≥ 10	~ 1		APS	2 to 4 weeks	AGWFS (WFS)	0.003
	Warping Harness	10,332	Warping harness	Strain gauges	Set & Forget	na		APS	2 to 4 weeks	No outer control loop	
M2	Translation	2	Hexapod	Local encoders	≥ 10	< 1		APS	2 to 4 weeks	AGWFS (WFS)	0.003
	Tip/Tilt	2	Hexapod	Local encoder	≥ 10	< 1		Surveying	> 1 year	No outer control loop	
	Piston	1	Hexapod	Local encoder	≥ 10	< 1		APS	2 to 4 weeks	AGWFS (WFS)	0.003
M3	Tilt	1	DC drive	Local encoder	≥ 10	< 1		APS (Pupil Tracker)	> 1 year	No outer control loop	
	Rotation	1	DC drive	Local encoder	≥ 10	< 1		APS (Pupil Tracker)	> 1year	No outer control loop	

Characteristics of the Principle and Outer Control Loops

Alignment and Phasing System

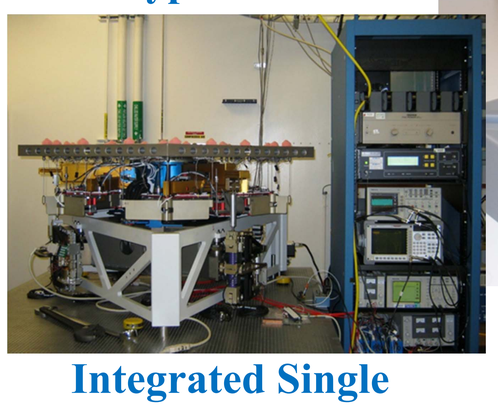
1. Based on the design developed for the successful Keck telescopes.
2. Shack-Hartmann wave-front sensor to measure and correct the shapes of individual segments and overall image quality
3. Phasing camera to phase segments (minimize height discontinuities between adjacent segments)
4. Measurement of shapes is parallelized and corrections via 21 actuator warping harness are automated.

M1CS Components and Integrated Testing



Prototype Actuator

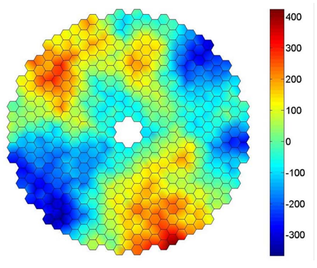
Prototype Sensor



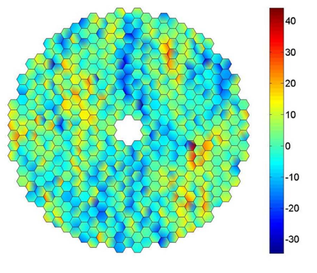
Integrated Single Segment Test Bed

Prototype Dust Boot

Wind Driven Segment Motion



M1CS loop open
Median wind conditions
127 nm RMS segment jitter



M1CS loop closed
Median wind conditions
7 nm RMS segment jitter

Phasing Concept