PO-15P

[Project Status]
TMT Telescope Structure System Development

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on behalf of TMT Telescope Structure Team (NAOJ / Mitsubishi Electric Inc. / TMT International Observatory)

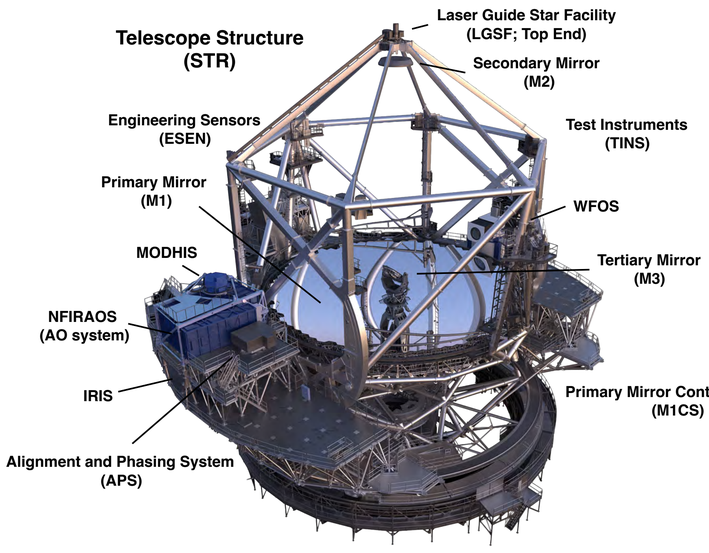
ABSTRACT

Telescope Structure System (STR) of the Thirty Meter Telescope (TMT) is the core of the telescope that houses a wide variety of the TMT subsystems including the main components of the TMT: the primary, secondary, and tertiary mirrors, laser guide star facility, adaptive optics system, and science instruments. It is a responsibility of National Astronomical Observatory of Japan (NAOJ) to provide this telescope main structure as well as its mount control system. These systems realize unprecedented high precision of the telescope tracking and high durability under harsh seismic environments. The TMT STR is equipped with a highly unique Segment Handling System (SHS) which enables to exchange the segmented primary mirror by the automation function of the segment handling robot.

The design study of the TMT STR began in 2011. After a series of the successful design reviews, the final design has been established in 2019. Of the six planned Production Readiness Reviews (PRRs), three have been completed so far for major structures and the remaining PRRs are currently in preparation. This presentation will discuss the expected basic performance of the TMT STR and the current project status.

High-Level Summary of TMT System

- ▣ Thirty Meter Telescope (TMT)
  - ➢ Next generation ground-based optical/infrared telescope with 30-m aperture
  - ➢ Realizes unprecedented sensitivity & spatial resolution
  - ➢ Promoted through international collaboration of US, Canada, India, and Japan (previously with China)
- ▣ Japan is responsible for a delivery of Primary Mirrors (M1), Science Instruments (INS) as well as Telescope Structure (STR).
  - ➢ STR basics (weight & size): 2650 metric ton & ~50m (in H/W/D)
  - ➢ STR provides very unique capabilities such as Segment Handling System (SHS) and Seismic Isolation System (SIS).
  - ➢ STR has ~20 TMT subsystems to be interfaced, which requires highly complicated systems engineering process (interface management & control).



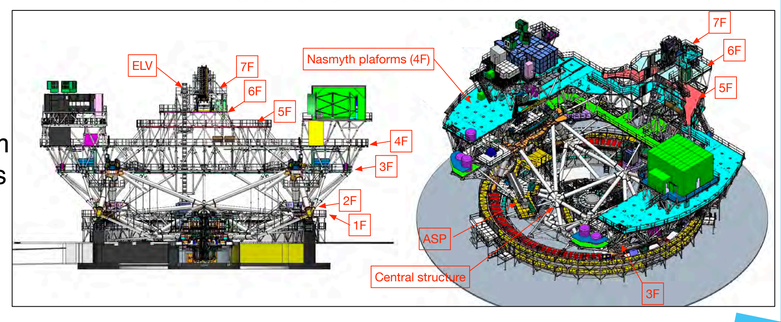


Telescope Structure System (STR) Decomposition & Key Features

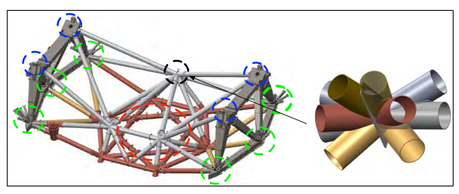
Azimuth Structure

Consists of:
- ▣ Central Structure
- ▣ Aerial Service Platform
- ▣ Seven-Level Platforms (including Nasmyth (4F))
- ▣ AZ Cable Wrap

Overview of Azimuth Structure

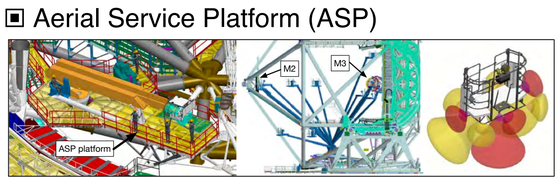


▣ Central Structure



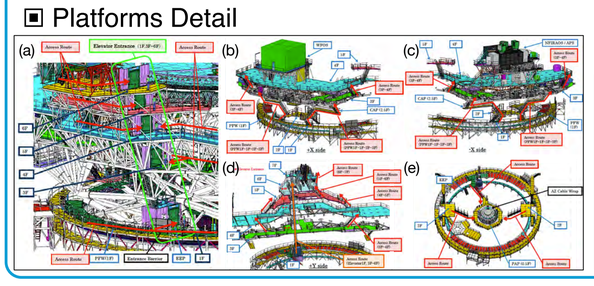
○: 6 AZ thrust Hydro Static Bearing (HSB) pads supporting the Az weight
○: 4 EL radial HSB pads supporting the EL weight (through EL Journal)
○: 6 AZ pintle HSB pads: contacting to the pintle bearing

▣ Aerial Service Platform (ASP)

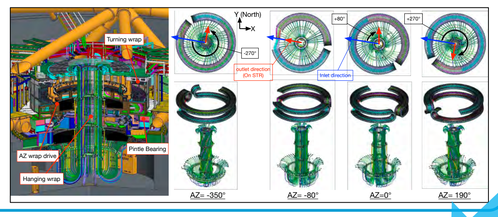


- ➢ For maintenance of M2 and M3 + etc
- ➢ Operated by single operator with 30m max reach, >220kg weight
- ➢ Collision avoidance sensors embedded

▣ Platforms Detail



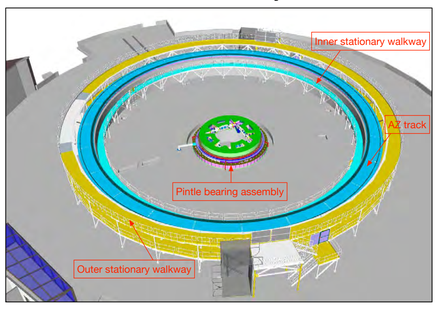
▣ AZ Cable Wrap
- ➢ Active Drive with ±270deg.

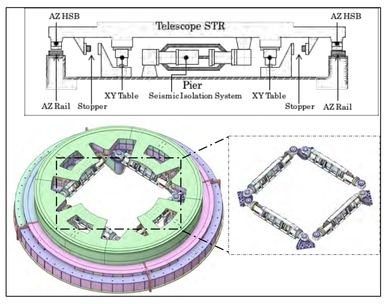


Stationary Structure

Consists of:
- ▣ AZ tracks: *24 pieces*
  - ➢ Located on concrete outer pier (D=36m) with ~30μm surface roughness
- ▣ Stationary Walkways: *Inner & Outer*
  - ➢ For access & maintainance for STR equipment
- ▣ Pintle Bearing Assembly + Seismic Isolation System (SIS)

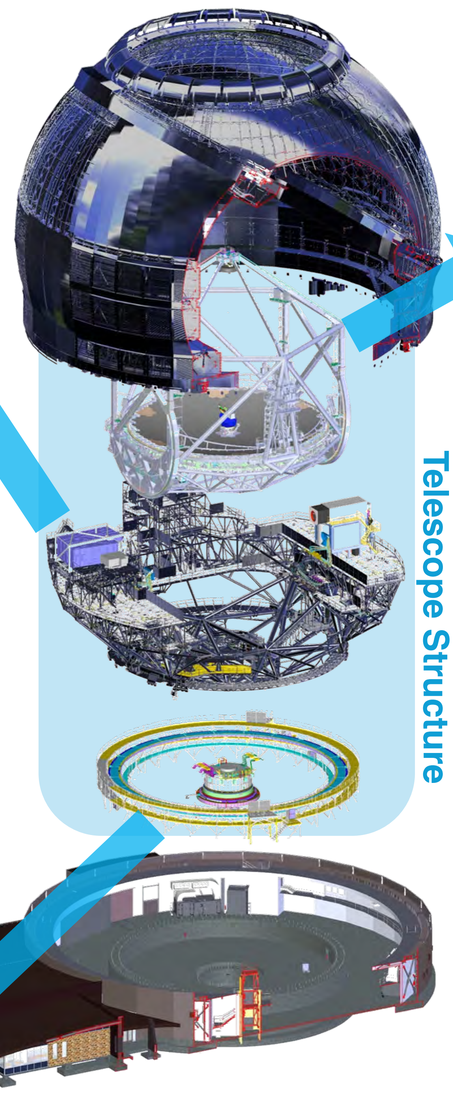
Overview of Stationary Structure





▣ Seismic Isolation System (SIS)
- ➢ TMT STR has horizontal SISs in the Pintle Bearing and Base
- ➢ Under normal telescope operations, SIS has high rigidity to avoid runout of the rotating Az axis.
- ➢ Under a seismic event above certain threshold, the dampers in SIS start absorbing the seismic energy by expansion and contraction.

Dome Enclosure

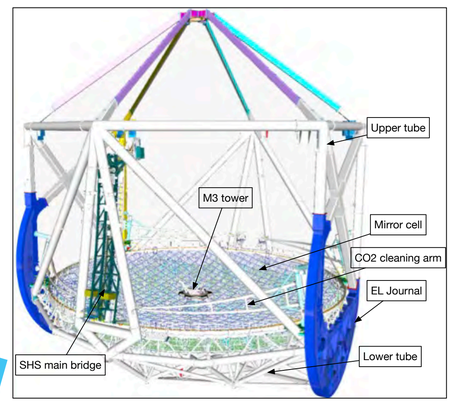


Telescope Structure

Summit Facility

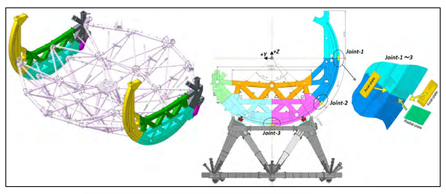
Elevation Structure

Overview of Elevation Structure

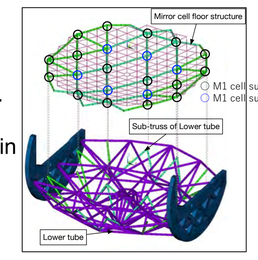


Consists of:
- ▣ Elevation (EL) Journal
- ▣ Lower Tube
- ▣ M1 mirror cell
- ▣ Upper Tube (supporting M2 / LGSF)
- ▣ Segment Handling System (SHS)
- ▣ CO_2 Cleaning (CLN) Arm

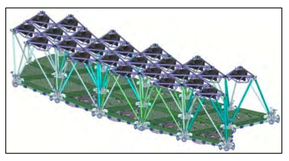
▣ EL Journal
- ➢ Consists of 6 Pieces, supported by HSB pads on Central structure
- ➢ R~10m±0.2mm, Roughness < 30μm rms (in pad size), **confirmed by prototypes.**



▣ Lower Tube
- ➢ Double lower tube structure: including an additional sub-truss mounted on the main truss.
- ➢ Soft stiffness provided by the sub-truss tubes avoids the mirror cell to be deformed by the main truss of the lower tube and the EL journals, minimizing gravity deformation of M1 cell.



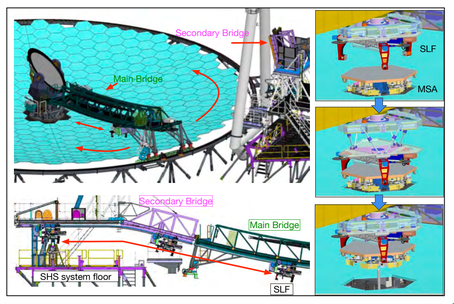
▣ Mirror cell (M1 cell)
- ➢ Diagonal truss structure (curved)
- ➢ Segment mirrors are installed to triangular spaces atop the mirror cell.
- ➢ Access from the M1 cell access floor for maintenance of M1 (and M3, etc)





▣ Segment Handling System (SHS)
- ➢ Regularly replace the segment
  - ✓ 10-mirror per 10-hour
- ➢ Compliance control technology with vision & tactile sensing to precisely position, grasp, and release the segments.

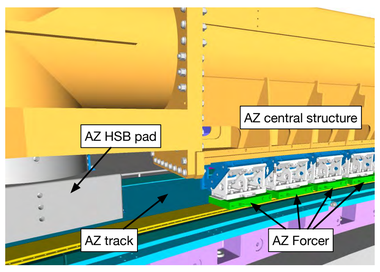


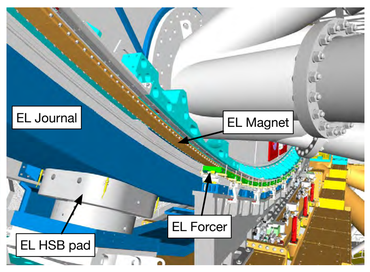


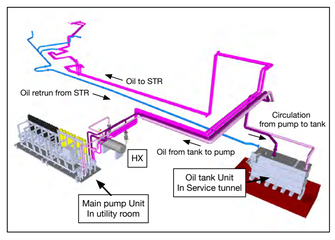
Other Subsystems

Consists of:
- ▣ Hydrostatic Bearing System (HBS)
- ▣ Mount Control System
- ▣ Telescope Utility Services (TUS)

▣ Hydrostatic Bearing System (HBS) & Direct Drive (DD) Motors
- ➢ HSB: 6 AZ thrust, 4 EL radial (6 AZ pintle, 8 EL thrust) HSB pads (total 24)
- ➢ 56 (32 for EL) Direct Drive motors (2--3kN maximum force per each)
  - ✓ Gap to magnet ~ 2mm nominal
  - ✓ Cogging force <1--10N, **confirmed by prototypes.**





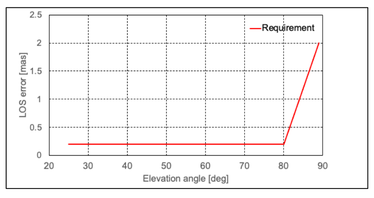


- ➢ Oil accumulators to keep oil pressure for approximately 70 seconds under stop of pumps due to power loss

STR Expected Performance

▣ Vibration Performance
- ➢ Stringent Requirement: Contribution on Wave Front Error (WFE) (Allocated to STR):**12nm rms**
- ➢ Vibration Sources: Cable wraps, Fans, pump, turbulence and pulsation of fluid in piping.

▣ Tracking Performance:
- ➢ Another Stringent Requirements:
  - ✓ Tracking Error **~0.2mas rms over 20sec** (EL=25--80deg, 0.2 to 2mas from EL=80--89deg)



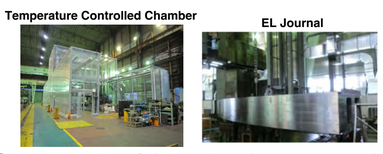
STR Prototyping Activities (example)

Complex Lower Tube Weldment | Plasma Arc Cutting | M1 Cell Subassembly



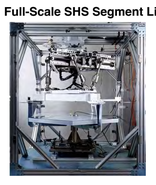
▣ High-precision manufacturing process for STR large components verified through these prototyping testing.

Temperature Controlled Chamber | EL Journal



▣ Super precise fabrication demonstrated by using the large (40m x 16m x 8m) temperature controlled chamber (±1.5°C).

Full-Scale SHS Segment Lifting Fixture



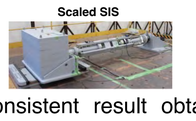
▣ Clearly demonstrated TMT segment exchange capability.

Scaled EL Cable Wrap



▣ Successfully evaluated micro-vibration caused by the Cable Wraps.

Scaled SIS



▣ Consistent result obtained between the simulation and the measurement for the SIS damper behavior.

STR Development Status

▣ Series of Production Readiness Reviews(PRRs) & Final Design Reviews (FDRs) successfully conducted since 2012, now finishing up the Production Readiness phase
- ➢ 2020-2023: **Passed PRRs (PRR1—3)**
  - ✓ **Major rotating mechanical structures of AZ and EL.**
  - ✓ **Ready for fabrication**
- ➢ Remaining PRRs (PRR4—6)
  - ✓ Fixed walkways, Az tracks, SHS/ASP/CLN Arm/Elevator, cable wraps, control/software.
  - ✓ **Preparation ongoing**.

▣ Significant programmatic studies completed:
- ➢ Construction, Assembly, Integration and Verification (CAIV)
  Construction sequence, material handling in done, staged analysis, etc
- ➢ Shipping and Transportation Plan
  Field survey for on-site transportation, routes with dimensional limited access area, storage areas, etc.

See Sugimoto et al., 2024, Proc. SPIE, 13094, 1309408 for all the technical details