MACE TELESCOPE

Hardware Components

*A. Kumar, R.K. Gupta, S. Ahmad, S.G. Thul,
V.K. Mishra, S. Bhatt and S.P. Srivastava

Many hardware components of the telescope are designed and developed at Centre for Design and Manufacture in BARC. These subsystems consist of Camera Housing, Camera Modules, Laser Alignment Device, Mirror Mount, Mirror Focusing mechanism for Active Mirror Control System, and subsystems to carry out maintenance related activities at the site.

Camera Housing

The Camera housing is an octagonal shaped enclosure fastened securely on a camera mounting bracket attached to four booms of the telescope. It has four lugs for rigidly fixing to Camera Mounting Bracket through four T-brackets to the 4 boom structure. These T-brackets have slotted holes on their two limbs with a provision of X, Y & Z adjustment so that the focal plane of camera can be maintained at 25m from mirrors of the telescope. When the telescope is in a vertical position, the camera will be at a height of 45m from the ground. The camera is provided with motorized dual shutters in the front and manually operated shutters in the rear. The PMTs in camera integrated module have compound parabolic concentrator (CPC) fixed in front of them to enhance their light collection. The camera is operational at site since 2020. Various components of the MACE camera are described below:

CPC Housing: It is the front part of the camera on which overlapping honeycomb shutters are hinged. The housing contains a panel on which all CPCs are pasted.

Camera Main Frame and Mounting Bracket: It is located behind the CPC housing and is extended to form rear side of the camera.

Camera front shutter and its drive mechanism: MACE Camera has two overlapping Shutters/doors having angle of opening 109°.

Camera Module: Each camera comprised 68 modules which are mounted on the camera frame. Each module comprises of 16 PMTs and VDN (Voltage Divider Networking) card with four high voltage cards, 3 PCB and a fan.

Back lid and side access hatch: Two back lids are used to cover the camera from rear side. These lids are hinged to camera main frame and can be bolted at middle after closure. All opening and gaps of the camera housing are pasted with silicon gaskets to stop exposure of light to PMTs during daytime in parking shelter. The inside metallic and non-metallic surfaces facing mirror are powder-coated with black color to restrict reflection of photons. The CPC plate handling fixture and customized battery operated scissor lift based aerial work platform were developed for handling CPC plate and delicate camera modules at site.

Development of Laser Alignment Device

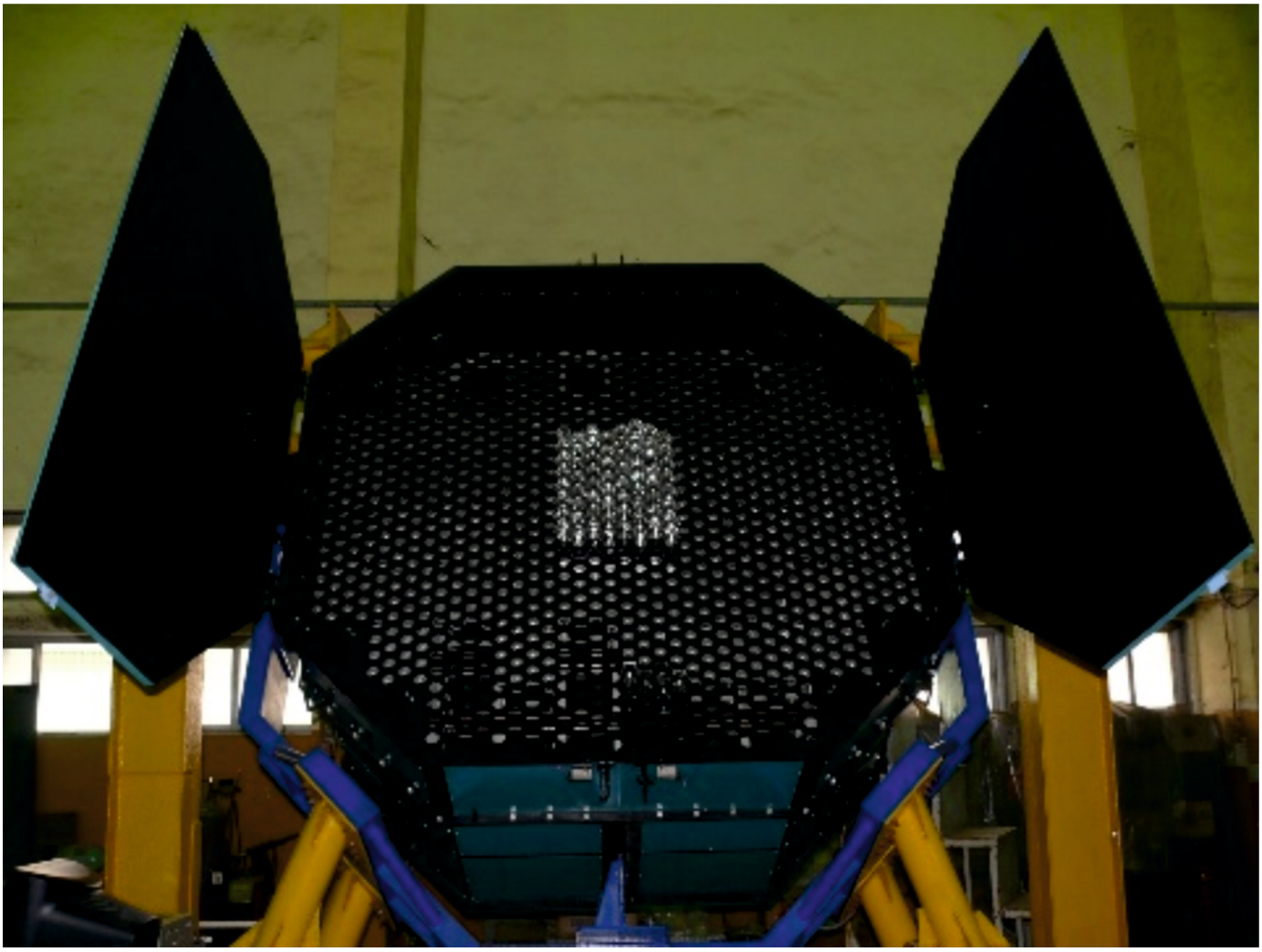
Laser device is used for (i) generation of transformation matrix table data for active mirror control system during initial optical alignment at laboratory, (ii) alignment of all laser spots formed by 356 mirror panels on camera lid with CCD camera mounted on telescope during installation, and (iii) periodic rechecking of alignment of mirror panels when telescope is operational. A laser alignment device is designed and manufactured at CDM, with diode laser fitted inside. The device has an angular range of 15° for laser fitted inside and it has been successfully tested with an accuracy of 16 arc-second (deviation of 2mm at 50m distance) during optical alignment and post vibration test. Each of 356 panels of the telescope has central laser alignment device fitted on it. The assembly is portable and light weight in design.

Mirror Focusing Mechanism for Active Mirror Control System

Mirror focusing mechanism is designed and developed to align the aluminium honeycomb panel of size 984mm x 984mm having four 488mm x 488mm mirrors mounted on it. In total 356 such panels, which are mounted on the MACE basket, are to be aligned to focus on a spot size of 45mm. The mechanism consists of three types of lower pairs to achieve tilting along three different axes.

Three types of combination of lower pairs are:

- Single Ball Joint without Actuator.
- Actuator with Double Ball Joint.
- Actuator with Ball Joint and LM Rail.



▲ CAMERA MODULE of MACE Telescope.

Design Parameters for the Tilting Mechanism

(i) Adjustment along 'Z' = ± 10 mm for Single Bal Joint
= ± 32 mm for Other Joints

(ii) Adjustment along 'X' = ± 10mm

(iii) Adjustment along 'θ' = ± 5°

(iv) Design load carrying capacity = 40 kg

(v) Design temperature = -30°C

Actuator with Single Ball Joint

Single ball joint consists of a standard ball joint mounted on a bracket. It facilitates one-time adjustment along 'Z, 'X' and 'θ'. The ball joint is fully covered by a flexible neoprene bellow clamped on the either side to prevent it from weathering due to rain and dust. Double joint consists of two numbers of co-linear ball joints. The ball joints are fully covered by a flexible neoprene bellow clamped on the either side to prevent it from weathering due to rain and dust. This joint can be actuated along the 'Z' direction by means of trapezoidal nut and screw arrangement which is operated by means of a geared motor. The mating surfaces of the movable parts are Ni plated to provide anti-seizing property. The bearings are pre-loaded to have minimum backlash along the direction of motion. Maximum components are made up of SS castings to minimize the overall weight. The complete assembly facilitates onetime adjustment along 'Z, 'X' & 'θ' for the initial alignment of the mirror panel and make it as 0-0 plane when operated in combination with other kinematic pairs.

Actuator with Ball Joint with LM Rail

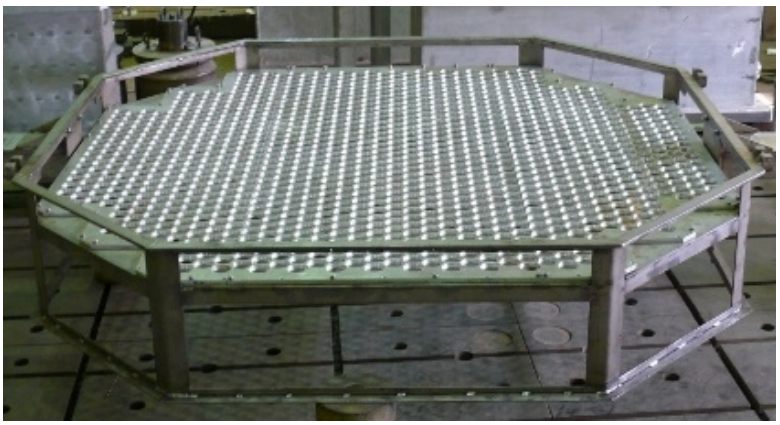
Single ball joint with linear pair consists of ball joint and a LM guide arranged along the 'Z' direction. These two pairs are encased inside the neoprene bellow for weathering protection. The joint configuration is similar as that of actuator with double ball joint. Degrees of Freedom of the mechanism is calculated using Spatial Mechanism by

EACH of the 356 panels of the telescope has been fitted with a central laser alignment device, and the entire assembly is portable and light weight.

Maximum size of camera	**2230mm X 2140 mm X 1350mm**
PMT panel size	**2000mm X 2000 mm**
No. of CIMs, PMTs, PMTs per CIM	**68, 1088,16**
Camera coverage angle	**4°**
Pixel pitch(triangular) and resolution	**55mm, 0.125°**
Max. Intra-CIM gap at front panel	**2mm**
Maximum Array of CIMs (at mid)	**10 X 8**
CIM insertion/removal design feature	**Modular Type design**
Front shutter/lid	**Overlapping honeycomb panel**
Front shutter/lid mechanism type	**4-bar mechanism motorised**
Gear box	**worm wheel , GR 25:1**
Motor	**BLDC motor**
Maximum open angle	**109°**
Limit switches for opening/closing of shutter	**Roller & plunger type**
Back lid	**Overlapping Honeycomb panel**
Back lid operation & locking	**Manual with door stays & positive clamp**
Protection of camera electronics	**From dust and ambient light**
Protection arrangement	**Inside black clothing, Silicon gasket sealing & manual latches**
Max. Weight of CIM (Populated)	**8.5 kg**
Max. Weight of camera	**1300 kg**

Materials employed in Camera Housing Structure

Al6061 T6, Ti Gr 2, SS 304,SS316, 17-4 PH Steel, Al Honeycomb, Phosphor Bronze, EN36A, Silicone Gasket, ABS Plastic, Cellular Silicone.



▲ CPC Housing Panel

Chebychev-Grubler-Kutzbach Criterion

M = 6(N-1) – (5 F1) – (4 F2) – (3 F3) – (2 F4) – F5

where

M = Total Mobility of Mechanism
N = Total No. of Links (including fixed link)
F1, F2, F3, F4, F5 = 1/2/3/4/5 DOF Pairs respectively

Kinematic Arrangement

The three types of lower pairs explained above are arranged in particular fashion satisfying the required mobility of 3-DOF to achieve the ultimate requirement of tilting about the 3-axes for plane adjustment of the honeycomb mirror panel. The lower pairs are arranged in a triangular fashion having ball joint at the vertex and the other two pairs with actuator mounted on the opposite edge. When the actuators are not actuated the kinematic arrangement will act as a rigid body. Likewise, for the adjacent panels, the ball joint will come in between the actuators of the previous panel and actuators will come by the side of ball joint. With the help of the actuators and the kinematic arrangement tilt along three axes can be achieved and also both the actuators can be operated simultaneously to get tilt about central axis. This way focusing of four mirror panels mounted on a single honeycomb panel can be achieved.

Panel Tilt Parameters for rotation about A2-A3 & A1-A3

Vertical travel of actuator A1 = ± 32 mm

Maximum angular tilt = ± 6°

Maximum linear movement of LM block = 0.752 mm

Linear motion of actuator per revolution of motor = 0.04 mm

Angular deflection of panel per revolution of motor = 13.5 arc-second (for gear box of 1:50)

Parameters for rotation about A4-A4

Vertical travel of actuator A1 & A2 = ± 32 mm

Maximum angular tilt = ± 4°

Maximum linear movement of LM block = 0.269 mm

Linear motion of actuator per rev. of motor = 0.04 mm

Angular deflection of panel per revolution of motor = 9 arc-second (for gear box of 1:50)

Tests Conducted on the Actuators

Functional testing of actuators has been carried out for different loads and panel mounting positions. Followings two tests were performed at CDM in BARC.

Test-1

Panel mounting position = Horizontal

Loading conditions = 26 kg for 10 hours
= 40 kg for 10 hours

Travel of actuators = ± 32 mm

Cycle time = 10 minutes

Sequence of operation = One actuator at a time

Result: Tests were successful in both cases.

Test-2

Mounting position = 12^0

Loading conditions = Under self-weight for 8 hours
= 40 kg for 8 hours

Travel of actuators = ± 32 mm

Cycle time = 10 minutes

Sequence of operation = One actuator at a time

Result: Successful tests in both the cases.

Mechanical Mounting of Actuators on Basket

Actuators are assembled on the basket with the help of fixture or jig to correctly locate the position of actuator on basket square pipes. Actuators are mounted on respective square according to the segment allocated to the respective actuators.

Mirror Mount for MACE Telescope

There are four spherical mirror facets which are mounted on each of 356 honey comb panels of the MACE telescope. The mirror mount is used for adjustment of individual mirror mounted on honey comb panel. All the four mirror facets resemble as spherical surface of a quasi-parabolic basket assembly of the telescope. Bottom clamping plate is fixed on honeycomb panel and mirror is fixed on top clamping plate. Spherical seat is provided between top & bottom clamping plate along with three levelling studs with retaining springs to set individual mirror. Once the four mirrors over the honey comb panel achieve a desired curvature according to its location on the frame structure, locking screws are used to lock the mirror in position.

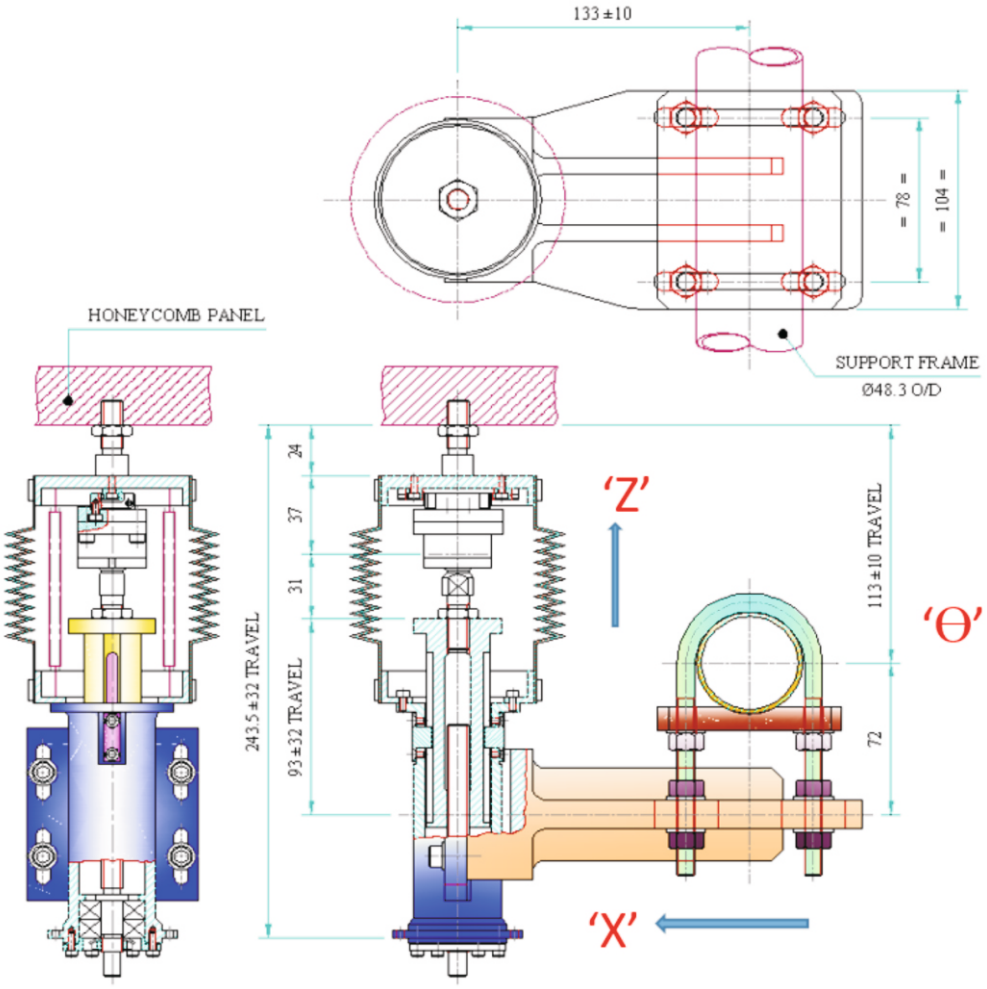
Conclusion

Design, manufacturing and testing of MACE Camera, which is heart of the telescope as it houses all camera electronics, is successfully completed. Major challenges addressed during design, development,

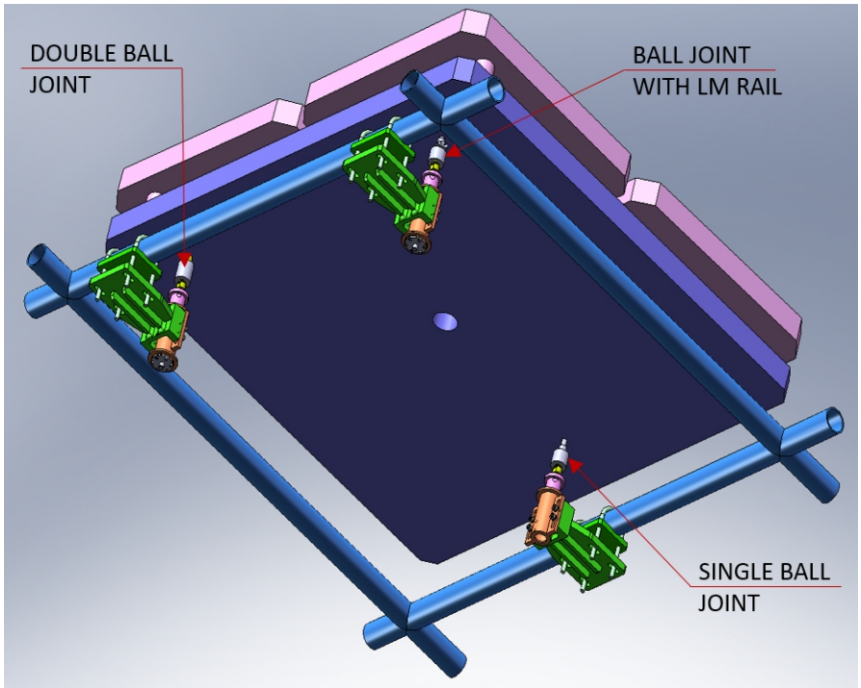
▲ MACHINING of CPC holes on CNC machine.

▲ AERIAL Work Platform for Camera module access.

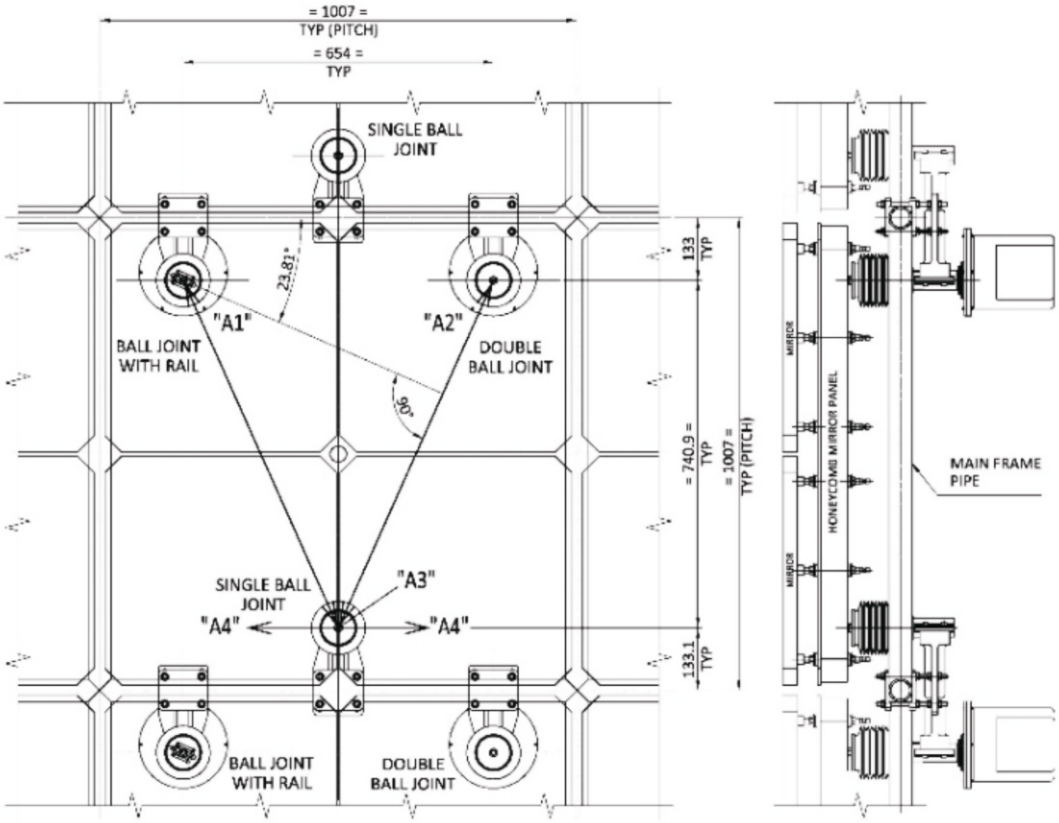
▲ LASER Alignment Device for Mirror panel.



▲ ACTUATOR with Ball Joint and LM rail.



▲ ACTUATOR Mounting Arrangement.



▲ KINEMATIC Arrangment of Actuators.

testing, installation & commissioning were rigidity of camera housing, light sealing requirement, optimization for light weight, optimum shadow region of camera on mirror basket, extreme adverse cold and windy weather conditions, handling of delicate electronics, CPC cups and photomultiplier tubes. Standard procedure for installation and maintenance was provided to site persons for all subsystems. All hardware subsystems are installed, working satisfactorily and in use at the Hanle site.

The authors are from Centre for Design and Manufacture of Bhabha Atomic Research Centre Trombay, Mumbai-400085.

*abhaycae@barc.gov.in**