

MACE TELESCOPE

Mirror Alignment Control System

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The Active Mirror Alignment Control System (AMACS) is a major subsystem of MACE Telescope and is required because the mirror support dish deforms under gravity loads and mirror panels need re-orientation corrections to achieve good focusing of optical system. In MACE, this is achieved by equipping each of the 356 individual mirror panels with linear actuators and servo motors, controlled by dedicated electronics while Optical feedback is provided by a CCD camera viewing the camera lid. AMACS is designed to realign all the 356 mirror panels in an automated manner.

A servo system helps point the telescope at any direction in the sky and track a celestial source to an accuracy of ~ 1arc-minute. When the dish is steered in elevation it deflects due to gravity loading of the camera boom as well as mirror panels. This deflection shifts the camera from the focus.

The focus is realigned by moving the mirror panels. With this, it is possible to design and manage the telescope structure with medium rigidity, leading to a worse case deflection of about 50mm at camera plane and to provide an on-line correction system for this gravity induced deflection.

AMACS System

The heart of the AMACS is a Central Basket Controller (CBC) which commands the mirror actuators through multiple RS-485 network segments to position the mirror panels at required orientation. The CBC also has interfaces with four other external systems viz., TCU (Telescope Control Unit), CBC Console, IS (Imaging System) and OC (Main Operator's Console). It receives current elevation angle from TCU. The console of CBC supports Human-Machine interface for testing and monitoring the AMACS. Imaging system issues commands to CBC in the calibration mode and assists in populating the look-up table. The Main Operators' console displays alignment status information of all mirror panels.

All the above systems are connected to CBC through UDP/IP over Ethernet.

Hardware Layout and Topology

Each of the 356 mirror panels have two Actuator Controller Units with RS-485 bus interface, for aligning the mirror panel at the designated position corresponding to a particular El

angle, with the accuracy of ~10 microns. Each mirror panels are supported on three ball joint pivots; one is fixed and two of these supports have linear actuators (Actuator-X, Actuator-Y) with a travel of 50mm which corresponds to tilt of about $\pm 2^\circ$ in focal plane. In AMACS each actuator is a node on a RS-485 segment.

Linear Actuator Unit (LAU)

Each mirror panel has two LAUs. It comprises of a power jack screw assembly coupled to a 250:1 gearbox driven by a three phase BLDC motor. Mounted right on to the gearbox is the actuator CBC maintains look-up tables holding corrections for all mirror panels for various EL angle position. CBC uses elevation angle information published by TCU to command all LAUs in the Correction Mode. The gearbox assembly has three spindle mounted radially magnetized 6mm dia. magnets; one on motor, one on lead screw axis and one on a small 50:1 gearbox output axis.

The small gearbox is connected to the lead screw axis. Once mounted on the gearbox, the control card pairs with the magnets to make a compound rotary encoder accessible on SPI bus. Each actuator controller card is based on AT90PWM3B micro-controller. It implements three phase BLDC motor drive with 10A drive capability. External command interface is an asynchronous serial RS-485 link.

There are two 12-bit magnetic encoders (As5045) - one coarse and the other fine - with a turns ratio of 50:1, which on combining, provide absolute position of the actuator with a resolution of 2 micron in a span of 50mm. Phase voltages are controlled to change motor speed and torque is limited by limiting current to ~ 5A. The voltage control is exercised by the PWM control of the three phase bridge.

PWM switching frequency is set to 20kHz. Actuator Software has built in features that lend itself to seamless calibration and production time testing and validation of the resources.

AMACS Central Basket Controller (CBC)

CBC controls the entire cluster of actuators. CBC is hosted on a PC104 SBC based embedded platform.



THE ACTIVE MIRROR ALIGNMENT CONTROL SYSTEM OF MACE is designed to realign all 356 mirror panels in an automated manner.

This hardware connects all 356x2 LAU on a RS-485 network. AMACS is used in two distinct modes of operation viz. (a) Calibration Mode to generate look-up table and (b) Correction Mode to align mirror panels during operation. During calibration operation AMACS interacts with imaging system which captures images at focal plane and provides position information. The look-up table calibration is done using laser mounted on panel or high intensity light source fixed or natural source such as stars.

The actuator position at which image produced by panel is at center of focal plane is taken for look-up table entry. The elevation range (0° - 90°) is divided into number of slots. A single look-up table is prepared for each slot. This calibration need to be done during initial commissioning and later at periodic intervals (e.g. once in a year).

AMACS is set in Correction Mode during normal observational campaigns. In this mode, AMACS receives EL angles from TCU and commands all mirror actuators to move to look-up table designated positions - thus correcting for gravity induced deflections.

AMACS Installation & Performance Evaluation

The installation of 356 mirror panels, 712 linear actuators, CBC etc. on mirror basket at site has been carried out successfully.

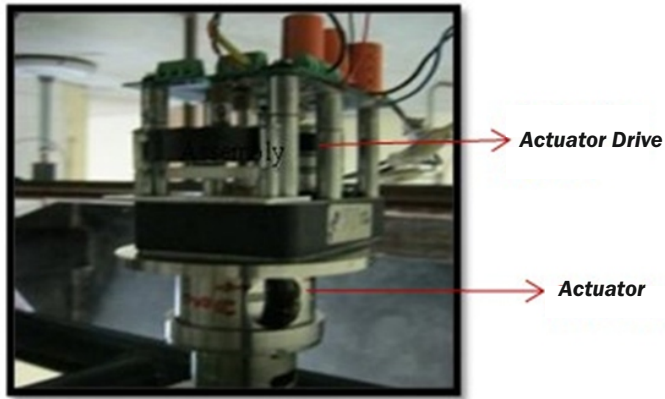
Source Images Captured after Aligning Mirror Panels

Image of source ARI-553 at 68° elevation angle without and with correction has been evaluated. Polaris image has been captured after aligning all the 356 mirror panels .

Conclusions

356 mirror panels with 712 motorised actuators are installed and tested successfully on the MACE basket at Hanle site. Images of Polaris and other astronomical sources are captured using the MACE telescope after aligning all the 356 mirror panels. Point spread function (D80) of the aligned reflector surface is $\sim 46.5\text{mm}$ which is well within the requirement of less than 1-pixel size i.e. 55mm. AMACS look-up table data is prepared for three elevation angle ranges $EI < 50^{\circ}$, $50^{\circ} \leq EI \leq 60^{\circ}$ and $EI > 60^{\circ}$. Active mirror alignment system automatically aligns the mirror panels with change in the telescope elevation angles.

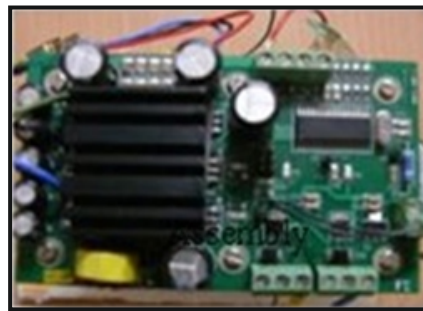
LAU (Linear Actuator Unit)



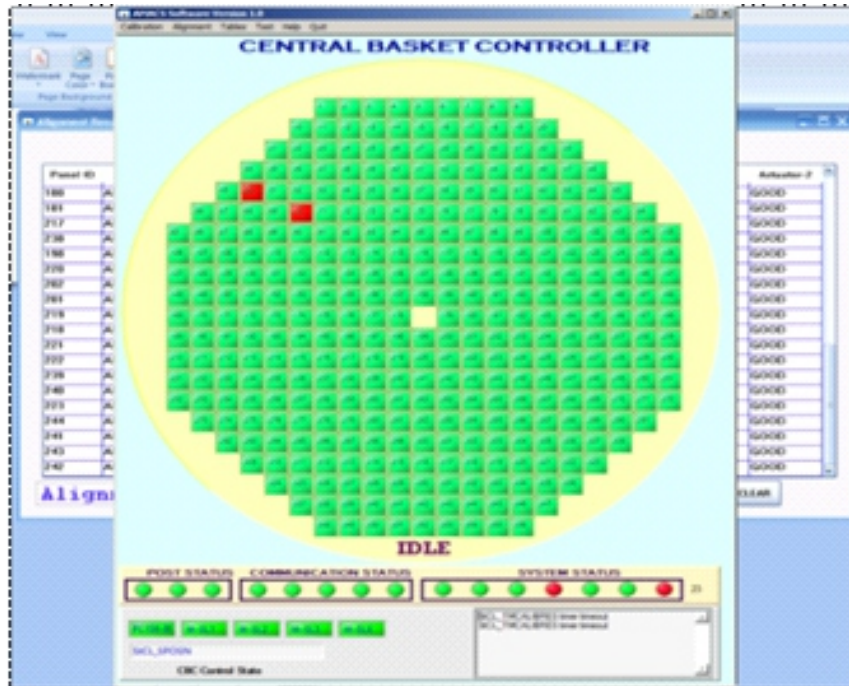
Actuator mechanism



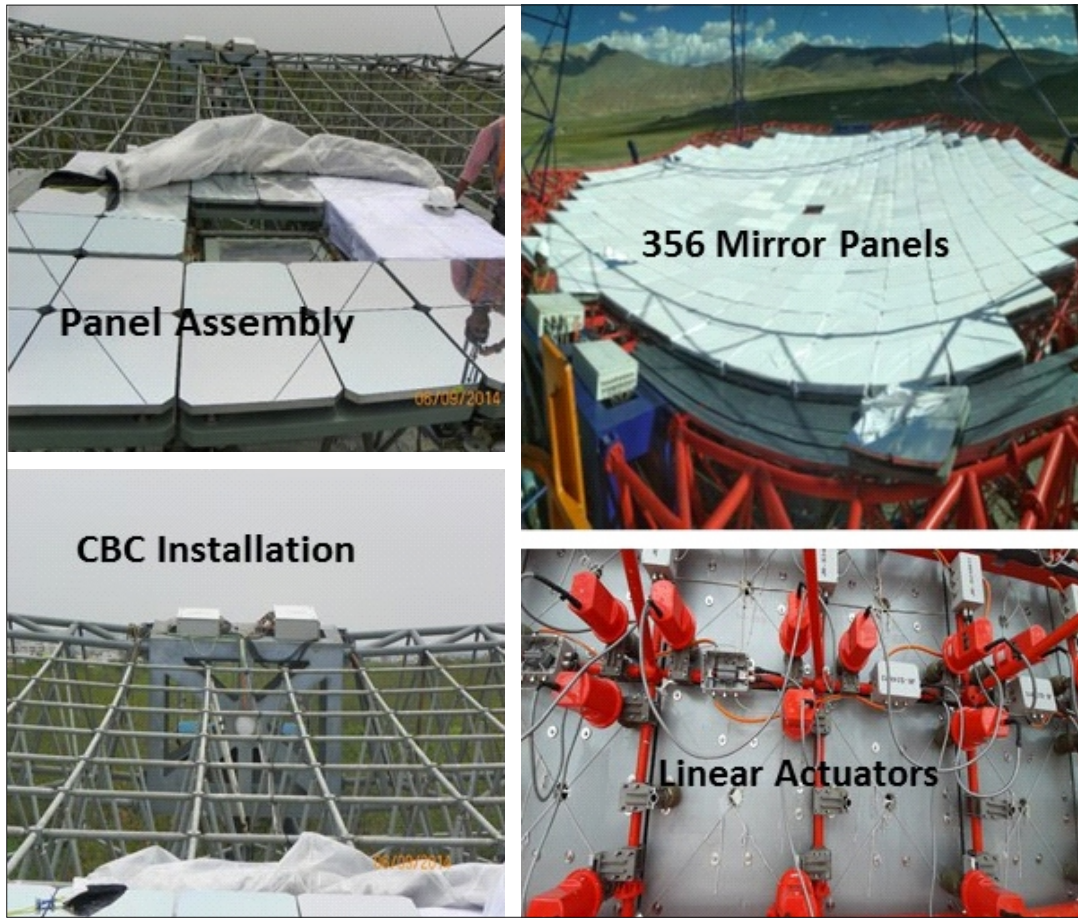
ACC (Actuator Controller Card)



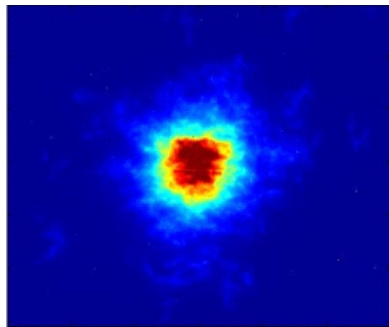
▲ LINEAR Actuator Unit for single Actuator.



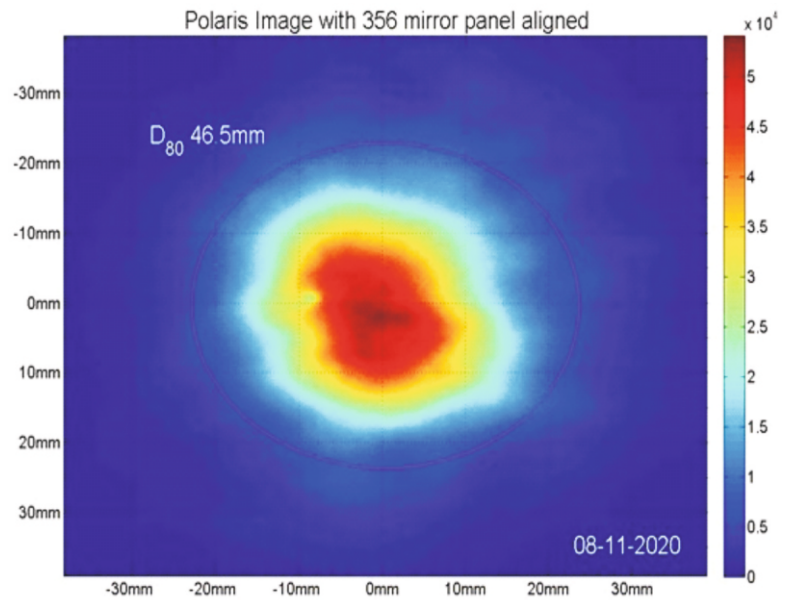
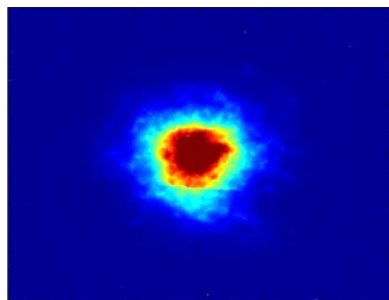
▲ CENTRAL Basket Controller.



▲ AMACS installation underway at the site.



◆ ARI-553 source images at focal plane.



▲ IMAGE of the pole star on a focal plane.

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