IIA Technical Report Series, No.8, pp.1-16, 2011 Report No: IIA-TRS-0811

Re-aluminization of 2M Himalayan Chandra Telescope Primary Mirror

P.M.M.Kemkar*, A.K.Saxena, P.K. Nirmal Kumar,
R. Ismail & K. Sagayanathan
Indian Institute of Astrophysics, Bangalore, India.
*Corresponding Author : pmmk@iiap.res.in

Abstract:

The purpose of this document is to establish the general requirements for handling and coating of the primary and secondary mirror of 2M Himalayan Chandra Telescope (HCT) at the observatory Mirror Coating facility, Hanle. The optics of the telescope represents the major investment in project time & cost and also must be protected from damage during handling. Safe lifting equipment and procedures for maneuvering the mirror out of the telescope are mandatory. The complete scope of study for aluminization includes, removal of mirror from the telescope, transportation and unloading, mirror preparation (stripping and cleaning), interface with the coating chamber and putting back the mirror into the telescope with the necessary alignment, performance verification tests and tuning the correct warping harness. This report limits the discussions to mechanical handling issues during aluminization.

Introduction

The coating plant facility has been installed and is functional at the observatory located at Hanle. This in- house facility at the observatory site is built for re-aluminising the telescope mirrors. The mirrors of 2M HCT Telescope have not been coated since they were originally installed in the telescope in Sept 2000. The low temperature, low aerosol and dry conditions at the site are favorable for preservation of the bare aluminum without protective coating. The two distilled water washes undertaken using an improvised method by IIA photonics lab. It is planned to re aluminize the primary mirror during the next working season of 2012. This coating plant has a facility to coat different layers of different materials through electron beam gun and thermal evaporation. The technical details of the coating plant are available in the operation manual.

The re-aluminization is an important event, considering the thickness of the mirror with an aspect ratio of 1:20 and complexities involved in primary support system which needs utmost care in handling such a thin mirror.

The steel dummy mirror (proof load) has been designed and fabricated in house satisfactorily to establish the integrity of a structure with tilt mechanism and to ensure the smooth sequence of operations during handling the proof load before the original mirror is loaded into the chamber. The washing cart has also been designed and fabricated in house for removal of old aluminum coating and cleaning the surface in readiness for vacuum coating of aluminum on the front surface (i.e. aluminization).

Several auxiliary facilities such as mirror handling facility, mirror washing facility, mirror cell trolley and mirror coating chamber are located in the VCP building which are required for aluminization of telescope mirror. These are described in the following sections.

2M Telescope Mirror Physical configuration

HCT Primary Mirror has a largest diameter of 2032mm with a uniform thickness meniscus substrate of 101.1mm and the cassegrain central hole of diameter 380mm. The top and bottom radius of curvatures of the primary mirror are 7000mm and 7101.1mm. It has been fabricated from Corning ULE 7971 material which weighs around 694kgs.

Mirror Support System of HCT Mirror

The support system used for the 2M HCT is of whiffle tree configuration, provides support for the mirror on the back at 18 points on two different PCD's. These support points are grouped by three's and then connected to the three overall support points via levers forming a whiffle tree. The rear surface of the Mirror is bonded with pucks on two different PCD which inserts into the support system during integration with the cell. The whiffle tree support system configuration picture is shown as Fig1.

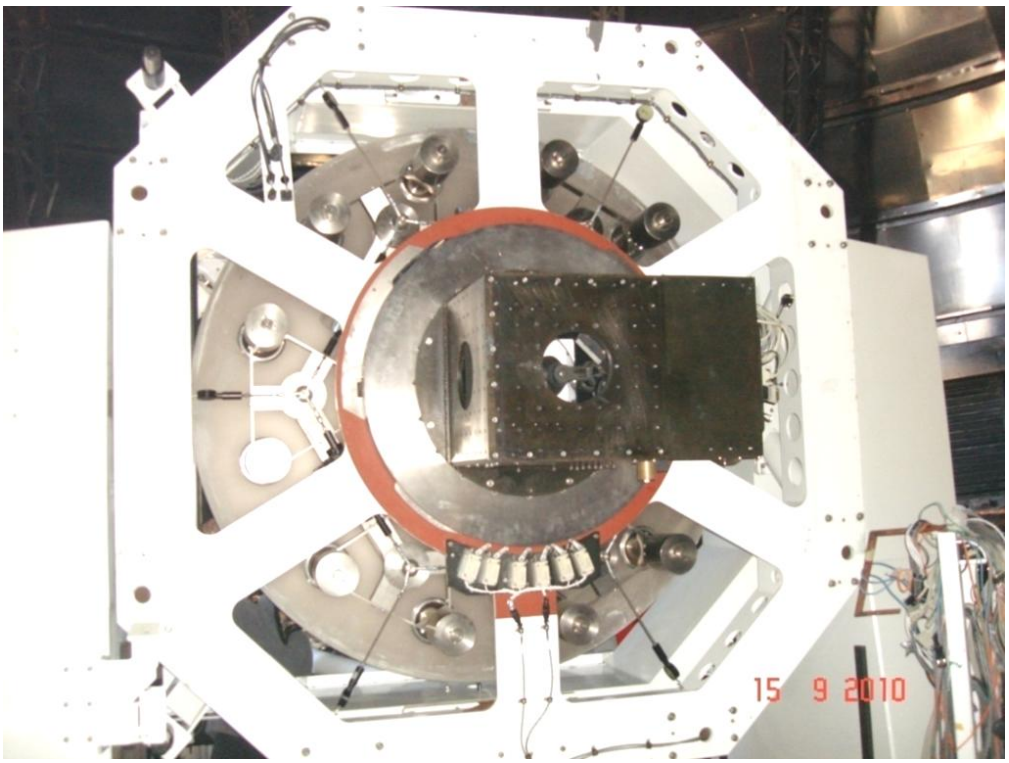

Fig 1. : Whiffle tree mirror support system.

2M mirror front & rear surface forms a meniscus in shape. The mirror attached to a push pull support structure via adjustable warping harnesses which is shown below as fig 2. Push pull is provided with 18nos of pucks stuck to the mirror back using a glue. Utmost care is needed that the pucks are not disturbed during mirror removal and aluminization.

A dummy mirror is built with same dimensions, weight and puck provision for exercise purpose, details of the dummy mirror is given in the following section.

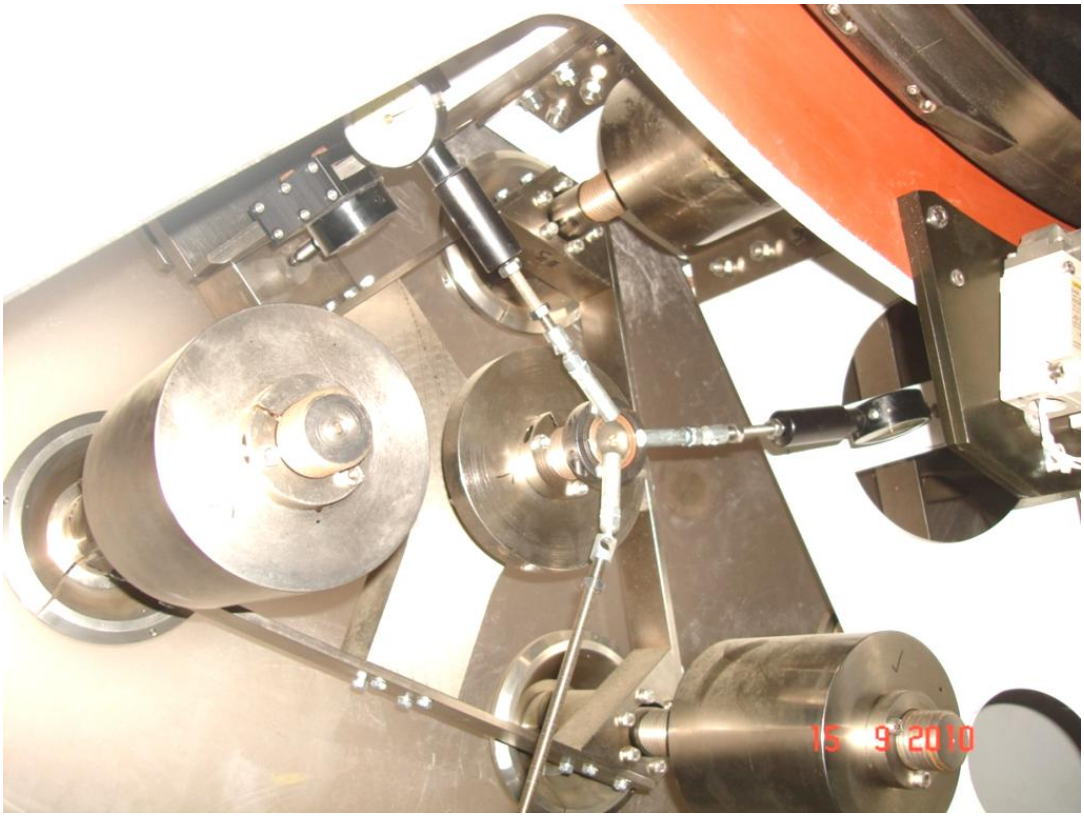

Fig 2 : Warping harness of support system.

Dummy Mirror

Dummy mirror is proof load, similar in dimensions and weight to the original HCT mirror, designed and fabricated to establish the integrity of a structure or tilt mechanism and to ensure the smooth sequence of operations during handling the proof load before the original mirror is loaded into the chamber. This proof load handling & integrity test shall ensure the performance of the hoist crane during handling of dummy mirror, the mirror would fit inside the tilting mechanism and to ensure the pucks are locating onto the supports and also it ensures the trial test of shifting and positioning the assembly of dummy mirror integrated with tilting mechanism with mirror looking upside down into the rotary drive of the coating chamber.

The fabricated dummy mirror is a replica of original mirror of 2M HCT. Dummy mirror is made from three segments namely top profile, central structure and bottom profile.

Fig 3 : Dummy Mirror

Fig 3 shows the configuration of dummy steel mirror. Lightness of weight and low inertia are the essential factors considered during design of this steel mirror, since the mirror has the thickness to diameter ratio of 1:20, the central structure of steel mirror was lightened by scooping the material as open pockets from a solid blank. The total weight of the mirror was 694kgs representing a 70% reduction from a solid. The top and bottom profile of steel mirror are concave parabolic optical surface created by pressing a 5mm thick CRCA sheet to the desired radius in a hydraulic press. Bottom profile has pucks on two pitch circle diameters, both top and bottom profile plates are welded to the central structure. The finished dummy mirror was weighing 700kgs. Picture below shows the lifting & integration of dummy mirror with tilting mechanism as in Fig3a.

Fig 3a: Integration of dummy mirror with tilting mechanism

The complete process of aluminization includes,

Vacuum Coating Plant

The vacuum coating plant as shown in fig 4, consists of a vacuum chamber, a vacuum pumping system, an evaporation unit and ion discharge unit for substrate cleaning. The vacuum chamber is composed of fixed main chamber and a movable lid constructed of stainless steel.

Thin films are prepared by depositing materials which are thermally stable on clean substrates by thermal evaporation/electron beam deposition under high vacuum thickness in the range of few tens of angstroms to few microns.

Fig 4: 2.5M diameter vacuum coating plant.

2M coating plant technical features and specifications are given below.

Large area coating unit is specially designed for optical coating of large diameter substrates like astronomical reflectors with enhanced reflectivity coating techniques.

The 2.6m diameter coating plant can take up to 2m diameter mirror to coat the surface. This coating plant is provided with a specially designed vacuum chamber of 2600mm diameter and a height of 2100mm size fabricated of non magnetic steel AISI 304L with top lid end door which will achieve vacuum sealing with the chamber flange by means of Viton 'o' rings. Top lid is lifted and lowered by hydraulic lift arrangements with a facility of swiveling.

The system is provided with necessary chamber gadgets like electron beam gun, evaporation grid source, deposition controller, ion bombardment gadgetry, substrate holder with rotary drive to rotate the substrate and shutter mechanism to achieve the required coating thickness and uniformity.

A high speed diffusion vacuum pumping system consists of two numbers of diffusion pumps with an airspeed of 12,000 liters/sec each, rotary and roots combination pump, high vacuum valves, vacuum measuring gauges (two nos), all integrated with necessary piping and are operated automatically.

All the necessary instrumentation like programmable logic controller, vacuum measuring gauges, deposition controller, EB gun controls, ion bombardment controls are housed in control cubicle are provided for operating the system by auto and manual mode facility.

We have also provided a supervisory control and data acquisition (SCADA) software for machine interface to communicate PLC with PC to operate the total system automatically.

Achievable coating performance is

1. Coating thickness uniformity less than 5% of coating thickness
2. Reflectivity with high purity aluminum is in the order of 92%.

Removal of Mirror from Telescope

The primary mirror will be removed from the telescope to allow thorough cleaning or re-aluminizing at a remote location. The telescope and support system have been designed to facilitate easy removal of the primary mirror by the end user. The primary mirror support system is mounted to a cell structure which in turn mounts to the lower telescope truss system. By disconnecting the cell from the lower truss as shown below the mirror cell and supports can be lowered onto a transport cart and removed from the telescope. The primary mirror can then be disconnected from its support system and packed for transportation. The following sections deal with this process in detail.

The method suggested by M/s EOST (EOS Technologies Inc., Tucson, Arizona) for removal / reinstallation of primary mirror has described briefly as an appendix A.

The 2M diameter primary mirror integrated with mirror cell of the telescope are attached to the lower truss engaged with the center section that separates from the telescope for mirror removal.

Mirror cell removal involves first removal of instrument cube and detaching the cell from the telescope, lowering the mirror and the mirror support system weighing around 4100lbs into a specially-designed cart of EOST with an vertical travel of 48 inches by means of elevator screw jacks located on either ends of the telescope yoke base as shown in the fig 5b and which is then rolled along two rail tracks to the observational floor, where the mirror can be disintegrated from the support system and lifted out of the cell by dome hoist and positioned inside the shipping box at observational floor. The observing floor is designed to carry the live load of the mirror cell assembly with special attachment points for the rails. The mirror is then transported and unloaded at the VCP building.

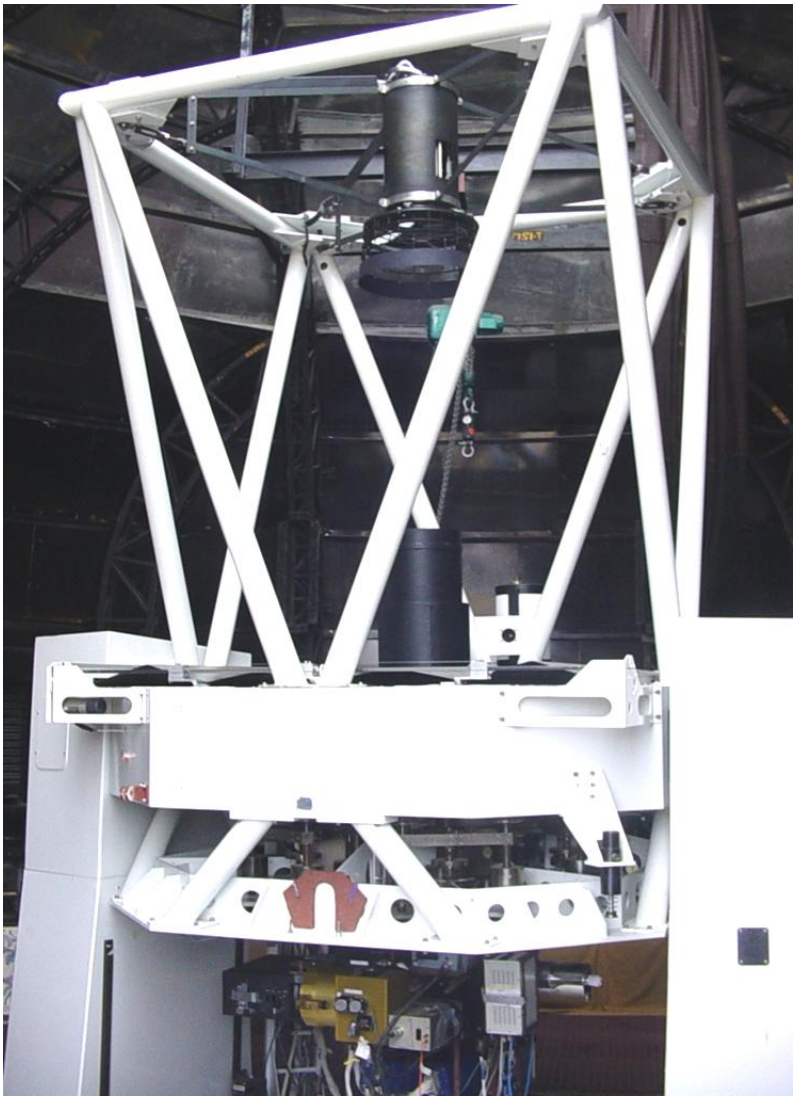

Fig 5a. – 2M Himalayan Chandra Telescope (HCT)

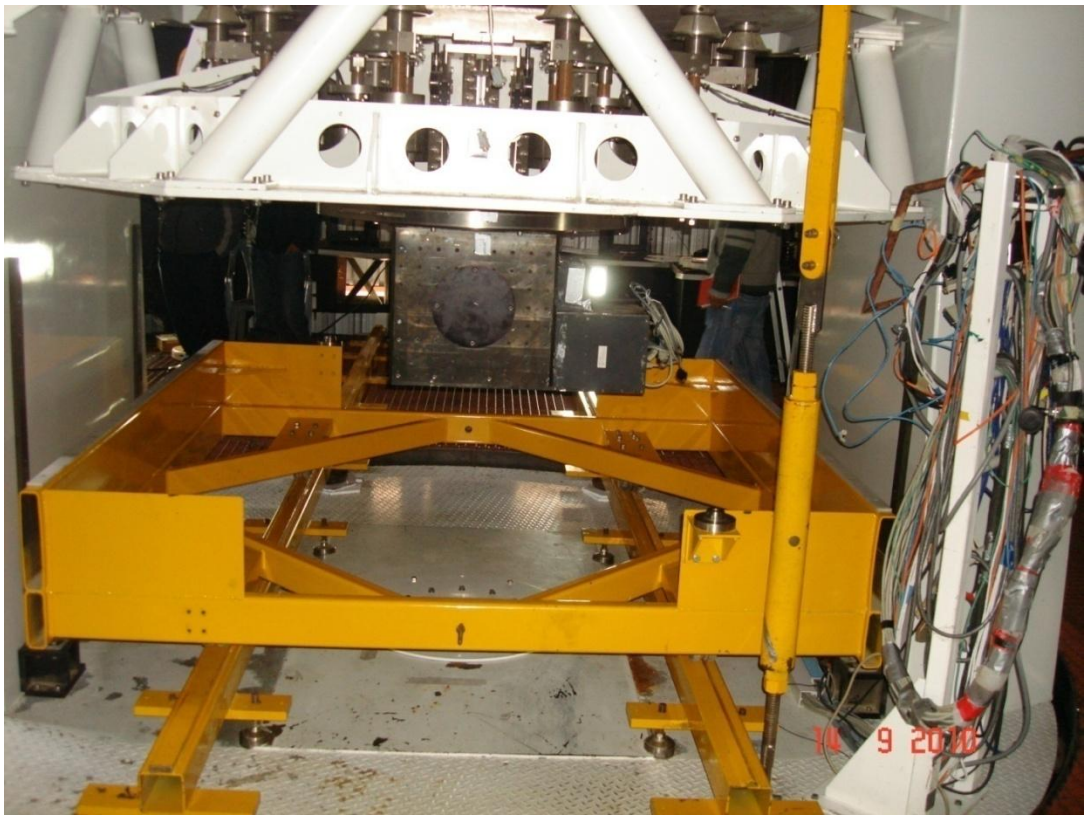

Fig 5b. Mirror cell lowering over EOST cart.

Mirror Preparation (Stripping & Cleaning):

The old aluminum coating shall be removed by swabbing method using alkali and acids. A thorough cleaning of the mirror shall be done to ensure contamination free surface.

Mirror Washing Cart

After checking the original mirror in the tilting fixture, the mirror has to be removed and placed onto the washing cart for washing. Mirror will be lowered on to the washing cart as shown in fig 6, which is specifically designed and fabricated in-house to position six inner PCD pucks located on 828mm diameter of whiffle-tree support system, whereas the outer 12 supports located on 1603mm diameter shall provide support and balances the weight of the mirror.

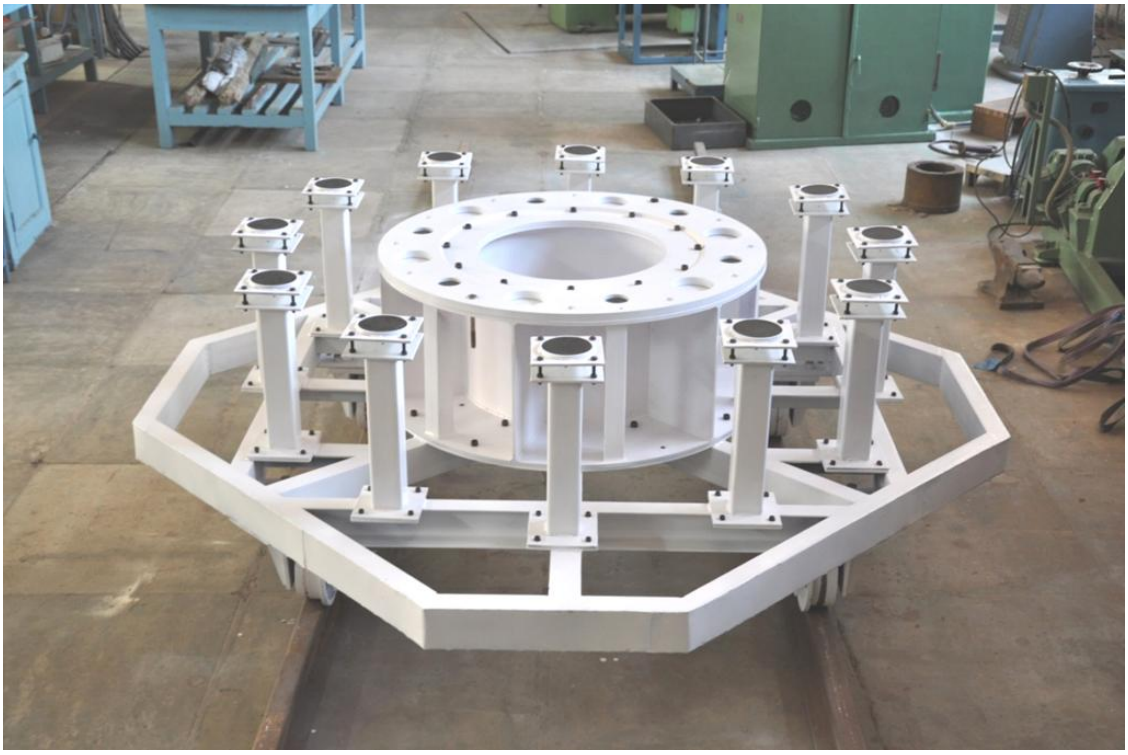

Fig 6 : Washing cart

Loading of the mirror in the coating Plant.

The mirror is unloaded from the truck and placed on the floor of the VCP building. Later mirror is lifted by engaging the lifting mechanism at the cassegrain hole and placed onto the tilting fixture to check the fixture dimensions compatibility with the original mirror. The tilting fixture is shown below as Fig 7. Tilting fixture is a circular holder for mirror, fabricated from stainless steel of SS304 grade having a diameter of 2100mm diameter. This circular holder fixture is supported on a vertical bearing to facilitate rotation of the fixture, since the mirror has to be loaded into the chamber with the mirror rotated inverted for coating.

Fig 7: Tilting Fixture & Rotation Mechanism

Fixing the mirror back in the telescope.

After aluminization process is complete, measurements of the coating quality shall ensure the coating has been of the required quality. The telescope mirror then successfully transported back to observation floor, reintegrated with its cell and active support system as per the optical specifications.

The necessary alignment, performance verification tests and tuning the correct warping harness need to be carried out with great precision. The overall efficiency of the telescope depends on the re-alignment of all the subsystems.

Alignment of the Telescope Optics

Adjacent to the HCT location, a nearby mountain top is available and could be used to place a light source at a distance 20f (20 times the effective focal length) from the telescope for the purpose of alignment. An alignment telescope already procured for the purpose can be placed at the back focal point of the telescope for alignment purpose. Fig.8 Standard procedure of alignment using distant stationary light source and alignment telescope can be easily adopted for the HCT. A detailed procedure with very specific details will be presented as a separate technical report.

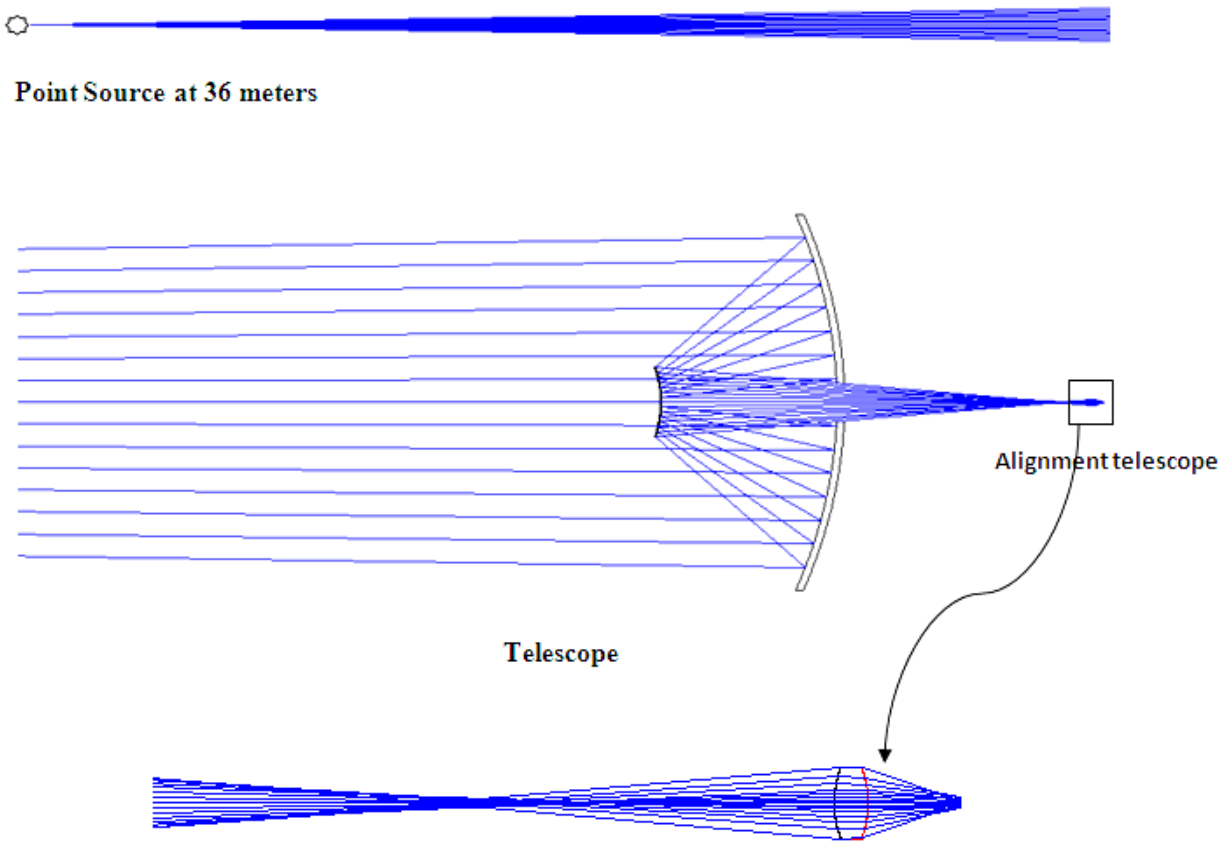

Fig: 8: Alignment of the Telescope Optics

Useful parameters for alignment

Aperture	2.01 meters
Mirror Material	ULE
Optics	Ritchey-Chretien
Focus	Cassegrain; provision for Nasmyth
F-ratio	f/1.75 primary; f/9 Cassegrain
Primary Secondary Separation	2849 mm
Image Scale	11.5 arcsec/mm
Field of View	7 arc min; 30arcmin with corrector
Image quality (zenith)	80% power < 0.33 arc sec dia; 90% power < 0.73 arcsec dia
Jitter & periodic errors	< 0.25 arcsec on each axis
Pointing accuracy	< 0.45 arcsec over 17 arcsec move; < 1.5 arcsec for > 10 deg move

Acknowledgement

The authors gratefully acknowledge the help and support from various members of the institute.

We have great pleasure in acknowledging Prof. T.P.Prabhu for his timely support in providing the valuable information and also Dr. J.P.Lancelot to his involvement in preparation for the coating operations.

We also thank Mr. Periyanayagam,(IIA, Machine shop), Tsewang Dorge, (Engineer of IAO, Hanle) and P.U.Kamath, (Engineer of Mechanical Design section) for their valuable support.

‘Appendix A’

Primary Mirror Removal /Re installation Procedure
(Ref: EOST, 2M Telescope Assembly and Maintenance Manual)

1. Move telescope to horizon pointing position and lock in place with stay bar.
2. Open primary mirror covers using control system or using manual crank handle.
3. Remove M1 Baffle from telescope.
4. Move telescope to zenith pointing position.
5. Secure elevation axis with stay bar. Tape stay bar pins to avoid accidental removal.
6. Position the telescope azimuth axis to the pre-defined mirror removal position and insert azimuth-locking pin.
7. Remove all loose items from telescope rotating floor.
8. Rotate instrument de-rotator to convenient position.
9. Remove instrument cube from telescope instrument de-rotator. De-rotator face must be clear before proceeding.
10. Remove all instrument related objects from mirror cell and surrounding areas.
11. Turn off telescope control system
12. Disconnect wiring from de-rotator limit switch assembly completely back to mirror cell cable access hole.
13. Note cable-labeling to ensure connectors are replaced correctly.
14. Disconnect wiring from de-rotator motor drive and encoder panel located on the underside of the mirror cell. Disconnect cables completely back to cell cable access hole. Note cable-labeling to ensure connectors are replaced correctly.
15. Gently feed cable bundles through cell access holes and lower truss legs bringing the cable bundles up into the telescope center sections outer cavity. Secure cables in this cavity.
16. Carefully check for extra cables and other obstructions that may prevent the mirror cell from being lowered from the telescope lower truss legs.
17. Remove the static elevation stop bracket from its location on the telescope fork tine. This bracket must be removed to allow the mirror cell to lower without obstruction.
18. Place both mirror cart guide rails into their location pucks (if fitted) on the telescope floor. The "V" rail should be placed on the non-drive side of the telescope (This is the side next to the instrument cable ladder that protrudes from the telescope floor.). Check guide rails for level and adjust them as required.

19. Attach the guide rail extensions to the two telescope mounted rails. Align the rails at the flange interface to minimize profile change at the flange joint. Level the rail extensions and ensure that all rail adjustable feet are in contact with the static telescope enclosure floor. Measure the distance between the rails and adjust to achieve parallelism.

20. Finally, inspect the guide rail system for secure mounting. These rails must support the full load of the primary mirror and its support system.

21. Using a suitable crane, place the primary mirror cart in position on the guide rail extensions. Note the cart can be placed facing either of two directions, however it may be more convenient to have the cart brake facing out in the direction of the guide rails.

22. Test the operation of the cart by moving it along the guide rail to both limits of travel. Once satisfactory operations is verified move the cart under the telescope mirror cell and engage the four cart lifting blocks with the four lugs mounted to the cart by operating the two crank handles mounted to the front edge of the telescope floor.

23. A stop device should be placed close to the ends of the rails to stop the cart at a predetermined point along the track and to prevent the cart from running over the end of the rails.

24. Make sure that the four circular protrusions found on the cart lugs fully engage with the four holes in the tops of the cart lifting blocks. Note the cart must be well centered with respect to the telescope centerline to allow the cart to properly align with the lifting blocks. Lock the cart brake.

25. Place a magnetically mounted spirit level on the front crossbeam of the mirror cart. Use this level to ensure the cart stays relatively level during its vertical travel.

26. Place a person at each crank handle position. Turn both cranks in unison to raise cart vertically. It may be helpful to count the number of turns as the vertical motion progresses.

27. Raise the cart vertically until it contacts the underside of the mirror cell. Note that the two steel pins mounted to the cart should engage with two corresponding holes in the mirror cell. Check that both sides of the cart are contacting the cell. Note it may be necessary to adjust the elevation stay bar to allow the telescope cell to be parallel with the cart.

28. Remove three (3) of the four- (4) M12 bolts from each of the eight (8) lower truss legs where they contact the mirror cell flange.

    DO NOT ATTEMPT TO REMOVE THE LOWER TRUSS BOLTS WHERE THEY

CONTACT THE TELESCOPE CENTER SECTION. THIS WOULD DESTROY CRITICAL TELESCOPE ALIGNMENT.

29. Remove the remaining eight (8) M12 bolts from the lower truss legs allowing the full weight of the primary mirror and cell to be taken by the lifting cart.

30. Lower the cart using the two crank handles until the cart rests fully on the cart guide rails. Keep the cart levels during this process using the magnetic level. Ensure that the cart lugs are free of the lifting blocks.

31. Unlock the cart brake. If the rails have been leveled the cart will remain stationary. Push the cart and its load out from under the telescope. Three people are required for this operation. Continue to push the cart and its load along the rails until the mirror is accessible using an overhead crane.

32. Lock the cart brake.

33. The primary mirror is now fully exposed; EXERCISE EXTREME CARE

34. Do not pass objects over the exposed top surface of the mirror. Wear facemasks to prevent contamination of the mirror surface by personnel. Wear gloves to prevent personnel from inadvertently touching the coated mirror surface.

35. The earthquake restraint must now be removed. Undo the restraint retaining bolts from the underside of the mirror support system that attach to the central support hub. This requires that someone crawl under the cart to access and remove the fasteners from inside the hub.

36. Attach the specially designed lifting fixture to the top of the earthquake restraint using two fasteners. Support the lifting fixture on the crane during this procedure .DO NOT PASS AN UNSECURED LIFTING FIXTURE ACROSS THE TOP FACE OF THE MIRROR.

37. Carefully lift the earthquake restraint out of the mirror hole and move it clear of the telescope.

38. To free the mirror from its support structure, loosen the M6 screws by several turns that secure the primary mirror pucks to the mirror support structure. Fully loosen all eighteen (18) screws, one from each support point.

    IT IS IMPERATIVE THAT ALL MIRROR PUCKS ARE FREE BEFORE THE MIRROR IS LIFTED. Failure to do this will result in mirror damage.

39. Place the mirror-lifting fixture under the mirror and cart. Locate the fixture directly under the central hole in the primary mirror.

40. Attach a fiber sling to the crane hook and position the crane over the primary mirror hole keeping the end of the sling well above and clear of the mirror surface.

41. Lower the crane to bring the end of the sling in proximity to the top of the mirror-lifting fixture.

42. Attach the sling to the fixture eye bolt using a suitable shackle. Slowly raise the crane to bring the lifting fixture into contact with the bonded Invar ring on the underside of the primary mirror. Note the lifting fixture and mirror have mating tapered features that must be lined up before any load is taken by the crane.

43. Gently lower the mirror into the box

44. With the mirror load taken by the foam lined box, continue to lower the crane until the mirror-lifting fixture comes to rest in the bottom of the box.

45. Disconnect the crane from the mirror-lifting fixture and remove the eyebolt from the top of the lifting fixture. Great care should be taken when reaching over the mirror surface; remove all loose items from pockets etc.

46. Insert packing to prevent the mirror-lifting fixture from moving in the box during shipment.

47. Pack all remaining foam padding into storage box and replace lid.

48. Secure lid to box using lag-bolts provided

Note: brackets located on box lid are for lifting the box lid only; they do not have the capacity to lift the entire box.

Mirror transport box should be handled gently. Striking the box sides with a forklift truck may result in mirror damage.