

# PRIMARY AND SECONDARY MIRROR REMOVAL AND RE-INSTALLATION MANUAL

*(1.3m Devasthal Optical Telescope)*



*Prepared By*

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*(With the help of DFM manual and self understanding)*

***Note: Read this section completely before performing any mirror maintenance or adjustments.***

***Note: When servicing both primary and secondary mirrors, the secondary mirror assembly should be removed first to avoid a dangerous top-heavy condition***

***List of tools required for removal and reinstallation of mirror:***

- 1)** Primary mirror insert tool (dwg. 621-189-1).
- 2)** 2ea. 12ft long pieces of 3" steel channel for guide rails.
- 3)** Focus stand (dwg.621-191).
- 4)** Primary mirror crate.
- 5)** Primary mirror lifting strap (stored in the primary mirror crate).
- 6)** Secondary mirror crate.
- 7)** Secondary mirror lifting strap (stored in the secondary mirror crate).
- 8)** Ball driver Allen wrench set.
- 9)** "L" ball end Allen wrench set
- 10)** 4 Mirror insertion guides (dwg. 621-155-2).
- 11)** Straight bladed screwdriver with a 15cm long shank.
- 12)** 3 axial and 2 radial dial indicators with extensions and mounting blocks.
- 13)** MCLA (Mirror Cell Lifting Assemblies) dwg. G48-086. These tools are stored in a wooden crate supplied by DFM.
- 14)** 2 threaded 1/4" guide pins.
- 15)** 2 threaded 3/8" guide pins.
- 16)** Wide base depth micrometer with 5"-6" rod.
- 17)** Axial hardpoint wrench (dwg 621-155-1)
- 18)** .003" feeler gage and handle
- 19)** 24" webbing loop.
- 20)** 5/8" combination wrench.
- 21)** 1/2" combination wrench.
- 22)** 6" dial caliper.
- 23)** Feeler-gage set.
- 24)** 3/8" nut driver.

**25)** DFM Engineering maintenance drawing package.

***List of drawings required:***

621-011 Primary Mirror Cell Assembly.

621-155-1 Front Defining Bracket Assemblies.

621-156 Mirror Support Assemblies.

621-186 Mirror Cell Lifting Assembly.

## PRIMARY MIRROR:

### Primary Mirror Removal:

***Note: When servicing both primary and secondary mirrors the secondary mirror assembly should be removed first to avoid a dangerous top-heavy condition.***

- 1) Use a 3/16" Allen wrench to reach through the slot in the 16 radial counterweight assembly covers and check the radial counterweights. Gently push each of the 16 radial counterweights outboard to verify that none of the radial counterweights will contact the mirror cell or cover. If any radial counterweights are at their travel limits adjust them for mid travel as described in "Collimation".
- 2) Drive the telescope to the zenith and install the lock pins.
- 3) Close the mirror doors.
- 4) Remove the instrument, SAG, and mirror cell weights from the primary mirror cell.
- 5) Remove the field corrector assembly and primary light shield.
- 6) Verify that the 3 axial and 2 radial dial indicator assemblies are installed, active and set to zero. Note that the dial indicator assemblies are stamped to define their position on the cell: "N"= North, "W"= West, "NEB"= Northeast bottom, "WB"= West bottom and "SB"= South bottom.
- 7) Remove the 4 Invar rod bolts, 3 mirror retainer anti-rotation arm screws, 3 retainer covers, retainer nuts, and (slotted) washers from the bottom of the mirror cell.
- 8) Remove the 4 earthquake guard port covers from the mirror cell side and set the 4 earthquake guards at the maximum height above the edge of the mirror.
- 9) Gently tighten the 4 primary mirror radial supports while watching the radial dial indicator assemblies. Do not translate the primary mirror in the cell.
- 10) Raise the 3 axial hardpoint screws until they just contact the bottom of the mirror. Watch the 3 axial dial indicators to see mirror motion when the hard points contact the mirror but do not raise the mirror more than .002 inches..
- 11) Unscrew the 36 back support counterweight screws 3 turns each to de-activate them. The primary mirror should now be resting on the 3 axial hardpoint screws and secured by the earthquake guards and radial supports.
- 12) Remove the north and west radial dial indicator assemblies.
- 13) Install both MCLA's onto the center section and mirror cell. Use the 1/4" guide pins to help install the upper MCLA pad first.
- 14) Take some load with the MCLA's.
- 15) Remove the 12 mirror cell flange bolts.
- 16) Lower the cell with the MCLA's. 2 persons should turn the MCLA handles, counting turns to keep the mirror cell level.

- 17) Lower the mirror cell onto the mirror insert tool so that the bottom of the cell is resting centered on the 3 posts of the mirror insert tool.  
DO NOT insert the legs of the tool into the holes in the cell yet.
- 18) Remove the earthquake guards.
- 19) Unscrew the 4 radial support push screws 6 turns each.
- 20) Disconnect the 16 radial counterweight assemblies by removing the clevis pins from the mirror blocks.
- 21) Use the 3 axial hardpoint screws to raise the mirror height 0.1". Be careful not to adjust any one hardpoint screw more than .025" (1/2 turn) each iteration to avoid tipping the mirror and damaging the back support counterweight assemblies.
- 22) With a straight screwdriver, reach through the access ports on the bottom of the mirror cell and loosen the 3 spring plungers that keep the front defining bracket assemblies clamped on the mirror.
- 23) Remove the 3 front defining bracket assemblies by lifting on each assembly, gently pulling the top outward away from the mirror and rotating it 90 degrees to disengage it from the mirror. Do not lose the spring and 2 washers as each assembly is removed.
- 24) Remove the 3 axial dial indicator assemblies.
- 25) Install the 4 primary mirror guides evenly spaced around the flange of the primary mirror cell.
- 26) Use the MCLA's to raise the mirror cell 1/2" above the mirror insert tool, position the steel channel guide rails on the floor so the mirror cell can roll to the north and slightly west of the center section.
- 27) Position the mirror insert tool such that the 3 posts will go through the large holes in the bottom of the mirror cell.
- 28) Carefully lower the mirror cell with the MCLA's so that the mirror insert tool posts enter the 3 large holes in the bottom of the cell and contact the primary mirror. Continue to lower the cell around the mirror until there is no load in the MCLA's and the primary mirror is resting on the mirror insert tool above the mirror cell.
- 29) Protect the mirror as needed, then disconnect the MCLA's from the mirror cell and remove the north MCLA from the center section.
- 30) Roll the mirror insert tool, mirror, and cell to a position to the north of the center section under the hoist.
- 31) Sling the mirror with its lifting straps (in the primary mirror crate) and attach them to the hoist.
- 32) Lift the mirror and set it on 3 blocks in the north east corner of the room.
- 33) Move the mirror cell and insert tool back into position under the telescope center section.
- 34) Use the ¼" threaded guide pins to help install the north MCLA on to the center section, then attach both MCLA's to the mirror cell.
- 35) Position the open mirror crate below the hatch nearest to the north wall.
- 36) Raise the mirror cell slightly with the MCLA's to remove the steel channel guide rail to allow the removal of the hatch nearest the north wall.
- 37) Lift the mirror with the hoist and lower the mirror into the crate. Disconnect the mirror straps and leave the mirror straps under the primary mirror in the crate.
- 38) Protect the mirror surface as needed and close the crate.
- 39) Clean the cell and cover it while it is out of service.

### **Primary Mirror Re-installation:**

- 1) Inventory the mirror cell parts: 12 stainless steel mirror cell bolts 3/8-24 x 1 1/2" long, primary light shield and flange, field corrector and corrector cell. 4 mirror insertion guides, 3 front defining bracket assemblies, 3 axial dial indicator assemblies, 2 radial dial indicator assemblies, 16 radial counterweight clevis pins, and safety rings.
- 2) Verify that the primary mirror cell is positioned below the center section, sitting on the mirror insertion tool and attached to the MCLA's.
- 3) Screw the threaded 3/8-24 guide pins into 2 holes 180 degrees apart on the mirror cell bolt pattern on the center section. Do not tighten the guide pins.
- 4) Disassemble the primary light shield from the light shield flange, then install the field corrector cell into the light shield flange. Protect the field corrector with tissue paper taped to the edge of the cell. Set the field corrector aside.
- 5) Remove the hatch in the observing floor nearest to the wall and position the hoist above the hatch.
- 6) Position the primary mirror and crate under the hoist.
- 7) Open the mirror crate, use the "X" mirror straps under the primary mirror to rig the primary mirror for lifting with the hoist.
- 8) Lift the primary mirror up to the observing floor and set it on 3 wood blocks in the northeast corner of the room.
- 9) Close the hatch in the observing floor.
- 10) Use the MCLA's to raise the mirror cell enough to allow the steel channel guide rails to be positioned such that the primary mirror cell and mirror insert tool will easily roll from a position under the center section to a position to the north and slightly west under the hoist. Place the mirror cell on mirror insert tool using MCLA. Rotate the cell if necessary to match the north of the cell with that of the centre piece section.



Figure 1: Fixing the sling on to the hook of the Crain (left) lifting the mirror cell using ratchet of MCLA(right)



Figure2: mirror cell placed on top of mirror inserting tool and free to move on guiding rails; below centre section (left) at north west position (right)

- 11)** Detach the MCLA's from the mirror cell and from the center section and move the mirror cell and mirror insertion tool to the northwest to a position to receive the mirror from the hoist.
- 12)** Prepare the primary mirror cell to receive the mirror: Set the top face of the 3 axial hardpoint screws to 1.75" above the inside surface of the mirror cell.
- 13)** Placing the radial counter weight system along the periphery of the cell and then place the axial counter weight system at the base of the mirror cell. (Make sure about the orientation of the axial support system).
- 14)** Place three axial set up supports and 4 radial defining supports.
- 15)** Insert tap pins on each of the axial supports. Do this very carefully.
- 16)** Put covers on each of the radial counter weights support system.
- 17)** Prepare the mirror cell to receive the mirror.
- 18)** The height of all three axial set up supports should be  $> 1.75''$  (check using the tool)
- 19)** The height of all 36 axial supports should be  $< 1.55''$  (check using a tool). All tap pins should be free to move (make sure).



Figure 3: checking the height of all 36 axial supports and making sure that all tap pins are free



- 20)** Make sure that all four radial defining supports has been retracted i.e. none of them is being pushed by the screw (all should be loose for the clean landing of the mirror).



Figure 4: retracting all 4 radial defining supports

- 21)** Make sure that all radial rods are at their minimum length (has a threaded arrangement so can be moved back and forth).

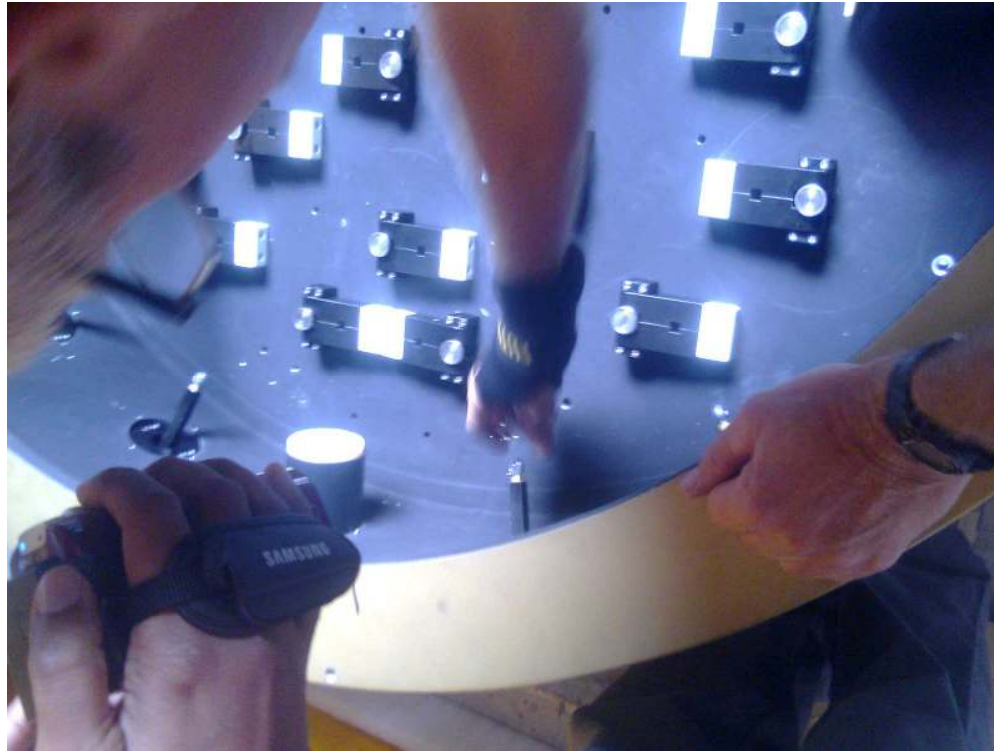


Figure 5: moving back the radial rods

**22)** Clean the mirror cell and the house using a vacuum cleaner.



Figure 6: cleaning the mirror cell using vacuum cleaner

- 23)** Using the Crain place the mirror on top of the mirror inserting tools (three in no's at  $120^\circ$ ).
- 24)** Gently rotate the mirror so as to match the north mark of the mirror to the north mark of the cell. Rotation can be done by just having a slight of the mirror on the inserting tools and rest on Crain and then 4-5 persons holding the mirror and rotating gently.



Figure 7: north marking of both mirror and cell should be aligned.

**25)** Move the mirror inserting trolley with mirror on top of it below the centre section.

**26)** Fix the north MCLA (remember south one is already fixed to the center piece).



Figure 8: fixing the north MCLA (use two guide pins to fix this) \*guide pins are pins used to fix in the holes provided for MCLA before putting MCLA and it allows you to have a comfort of easy hole matching.

- 27)** Install four insertion guide supports at the 4 corners to guide the mirror when inserting into the cell (protects it from hitting to the edge of the wall).



Figure 9: insertion guide support fixed at the mirror cell.

- 28)** Use the ratchets to lift the mirror cell. While lifting caution has to be taken to lift is symmetrically so better one person counts loudly and the other one follows. While this lifting 2-3 persons should hold the cell preventing it to float. At the same time after lifting say a considerable amount one should check whether nothing is going wrong and mirror is going in the cell without any obstacle. If any centering is required (though should be done at the time of putting the mirror on top of the inserting tool) then can be done right now to allow the mirror go safely inside the cell and leave the three inserting tools.
- 29)** Now lift the cell using MCLA and place the mirror on to the three axial set up supports. At this point Ratchets will feel the load so leave the ratchet at this point.
- 30)** 4 radial defining supports should be used to centre the mirror.
- 31)** For centering put the corrector into the corrector flange and then in to the mirror from the bottom of the mirror cell.





Figure 10: fixing the corrector in to the cell

**32)** Now take the measurement using a dial gauge and measure the distance between OD of corrector and the ID of the mirror.



Figure 11: using a dial gauge from OD of corrector to ID of mirror.

- 33)** Take the measurements at the four cardinal points (at the position of the radial defining supports). All should give the same readings if not than can be adjusted by using the radial defining supports. There is a screw at the radial defining position and tightening it will push the support inside which eventually pushes the mirror to the opposite direction. Once a screw is tightened and we want to tighten the opposite screw then first to lose this screw first and then tight the opposite one. This way centering can be achieved.
- 34)** Three dial gauges are inserted from the bottom of the cell.





Figure 12: bottom central hole having two small holes both side is the position where we insert the dial gauges.

**35)** Now we are all set to do the leveling of the mirror with respect to the cell. So peel off the spray paint form the regions where we are going to use depth micrometers (at three axial defining supports position).



Figure 13: peeling off the spray paint

- 36)** Check all tap pins from the bottom of the cell using an Allen key moving each one about  $\frac{1}{4}$ " and checking whether all pin are free and rotating freely. It's better to mark all of them from bottom and then check to make sure that all are safe.



Figure 14: checking all the pins using Allen (left) marking the pins (right)

- 37)** We need to reach to the figure of 5.92" ( from the top of the mirror cell to the edge of the mirror) for this we will use depth micrometer and measure the depth and lower down the mirror by using a wrench at the axial set up support position noting down the reading in the dial gauge (drawing 621-011).
- 38)** Then again measure the depth from the micrometer and lower down the corresponding amount (this can be different for all three dial gauges). This is to make sure that mirror is lowering on top of the axial set up supports in a uniform position and should not damage any of the tap pins which can damage in case of a large tip in the mirror.
- 39)** Lower the dial gauges say by 50 div each (max.) to make all approx at the same level. (Calibrating the dial gauges). Reach to a figure close to 5.92" say 5.75 " and then can lower 25 div each. (Note lowering one particular gauge will change the readings of the other two gauges also so need not to worry and let the mirror settle down first and then measure with the micrometer and lower down the mirror accordingly through the gauges).
- 40)** When close to the 5.90 mark then can lower by the amount of 10 div. then 5 div and then depending upon the reading of the depth micrometers we have to set each of the dial gauges by moving 2 – 3 div (can be more or less).
- 41)** While doing this one person can go in to the hole of the cell from the bottom and can ensure that all the pins are safe and at sufficient distances from the mirror.

- 42)** Set the 3 axial dial indicator assemblies to zero. These assemblies can now be used as a reference for the primary mirror location along the optical axis.

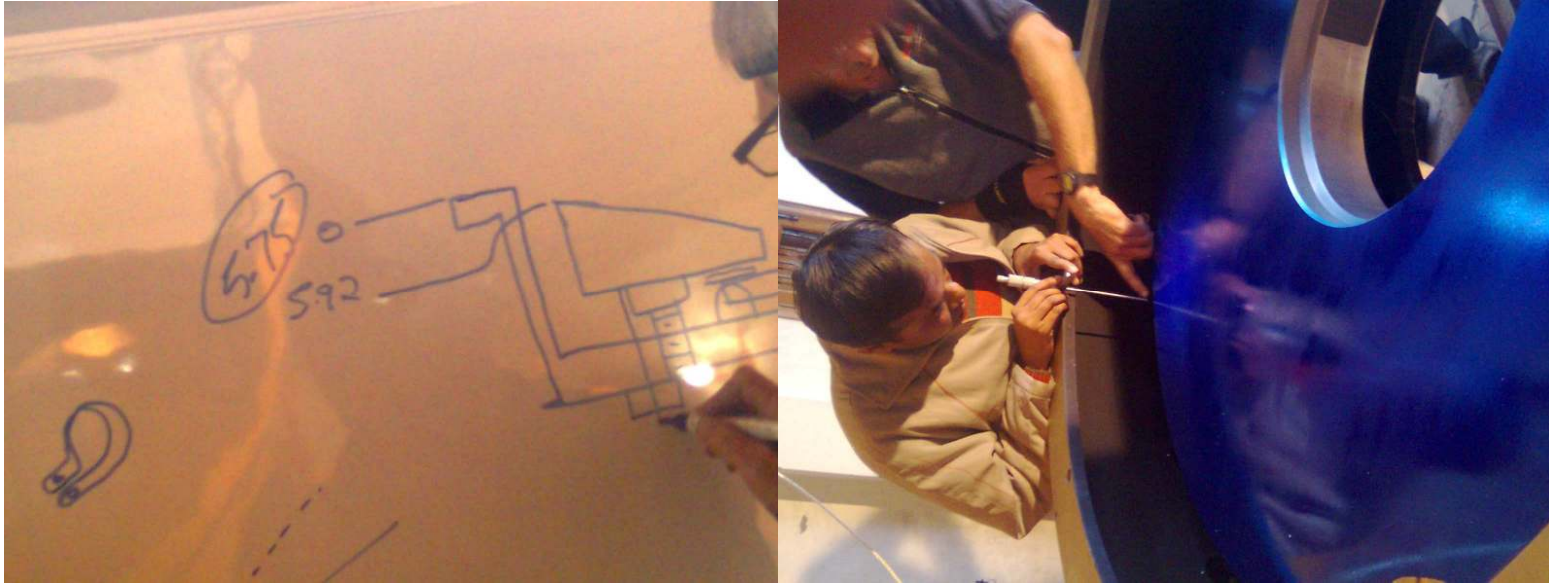


Figure 15: desired height to be achieved explained by Ian (left), using depth micrometer to measure the mirror height (right)

- 43)** Now the mirror is placed on top of the three axial set up supports and we are ready to fix the radial supports. The rod end of the radial supports is need to be fixed with the invar blocks that are already glued in to the mirror along the circumference at fixed distances with the help of the clevis pins.



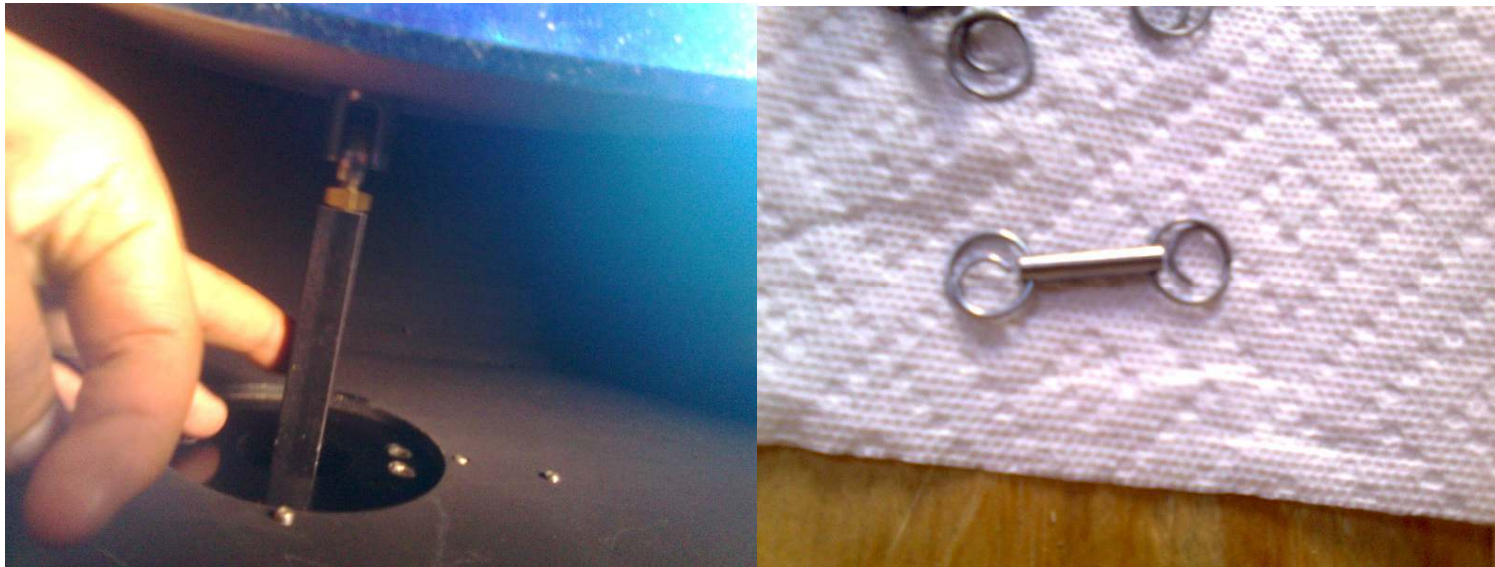


Figure 16: radial support rod positioned inside the invar block (left) the clevis pins need to fix the rod end to the invar block (right)

- 44)** At the top of the radial support rod we are having a brass nut and the rod end threaded inside the nut and both can be adjusted to practically provide infinite adjustment.

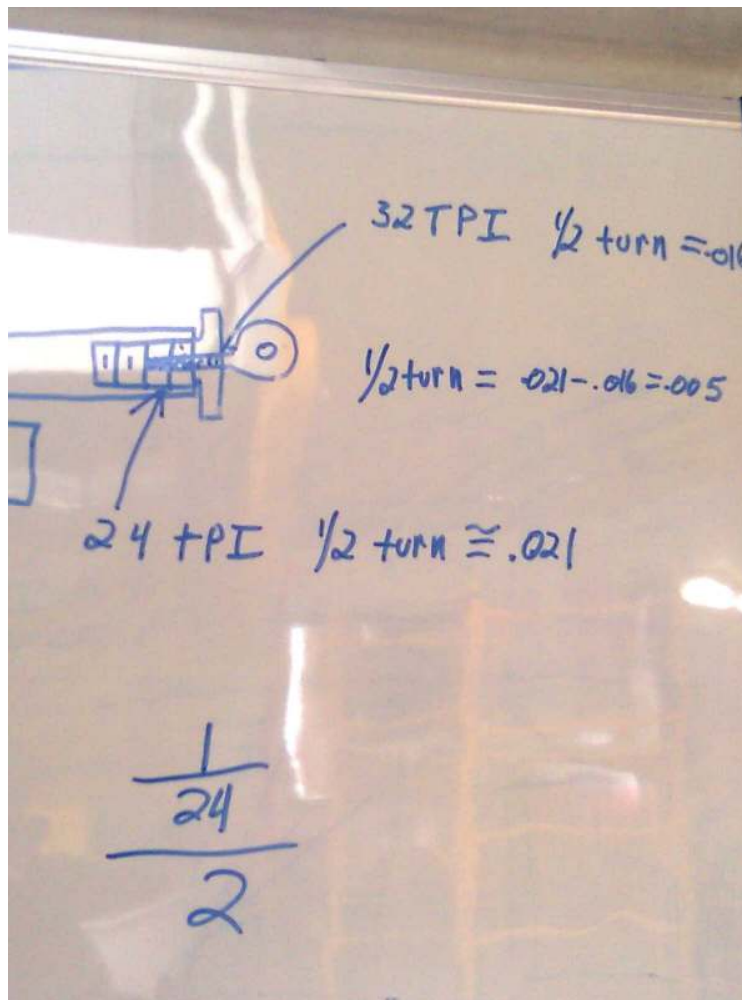


Figure17: showing the adjustment available with the radial rods

- 45) At this point we may need to rotate the mirror just to ensure that all the radial rods are going smoothly in to the invar blocks. For this purpose lift the mirror cell with MCLA until it is slightly above the mirror insert tool. Turn the mirror insert tool until the mirror insert tool post are aligned with the large holes in the mirror cell.

- 46)** Watch the 3 axial dial indicators and use the MCLA assemblies to slowly and evenly lower the mirror cell until the mirror insert tool posts just contact the mirror.
- 47)** Watch the 3 axial dial indicators and lower the cell until the mirror is a maximum of 0.010 inches (10 div) above the zero reference position. Now the cell may rotate independently of the mirror to allow alignment of the radial counterweight connecting rods and primary mirror blocks.
- 48)** Gently rotate the mirror cell as required to insert the 16 clevis pins and safety rings to link the radial counterweight assemblies to the primary mirror blocks.
- 49)** Use the MCLA assemblies to lift the mirror cell slightly above the mirror insert tool.
- 50)** Move the mirror insert tool to a convenient orientation so that the cell will sit centered on top of the mirror insert tool, and then lower the cell onto the mirror insert tool. Check the 3 axial dial indicator assemblies to see that the mirror position has returned to zero.
- 51)** Adjust the length of the 16 connecting rod ends and adjusting nuts as required to set the radial counterweight assemblies at mid travel when the clevis pins are installed.
- 52)** First ensure the brass nut and the rod end (the one with the aluminum and bearing) are at the minimum length i.e. all threads are in. Then rotate brass nut and rod end  $\frac{1}{2}$  turn one by one to make sure that both of them are going forward by equal amount and we have the maximum range available to adjust. Match the hole of the invar blocks and the rod end and insert the clevis pin to tie them up. Insert an Allen key in the corresponding counter weight cover and make sure that the location of counter weight is in the middle of the cell and the cover. If not then adjust its location using the brass nut (if brass nut range is over then can remove the pin and then can adjust by the rod ends for coarse adjustments). Then reinstall the clevis pins and safety ring.
- 53)** If some rods are not smoothly going into the blocks which can be the case as it was this time then better to remove the counter weight assembly, fix the problem e.g. put shims to tip it a little bit at one end and allow it to insert in the blocks. A little wiggling can also be done but very gently.
- 54)** Gently and uniformly tighten the 4 radial supports.



Figure 18: removing the counter weight assembly (left) putting a shim to fix the problem (right)

***Note: All counters weights should be covered while doing this exercise.***

- 55)** Put four earthquake guard supports at the four cardinal points (N, S, E, W). They have the adjusting system to vary its distance from the mirror. Keep the guards at the maximum distance possible from the mirror.



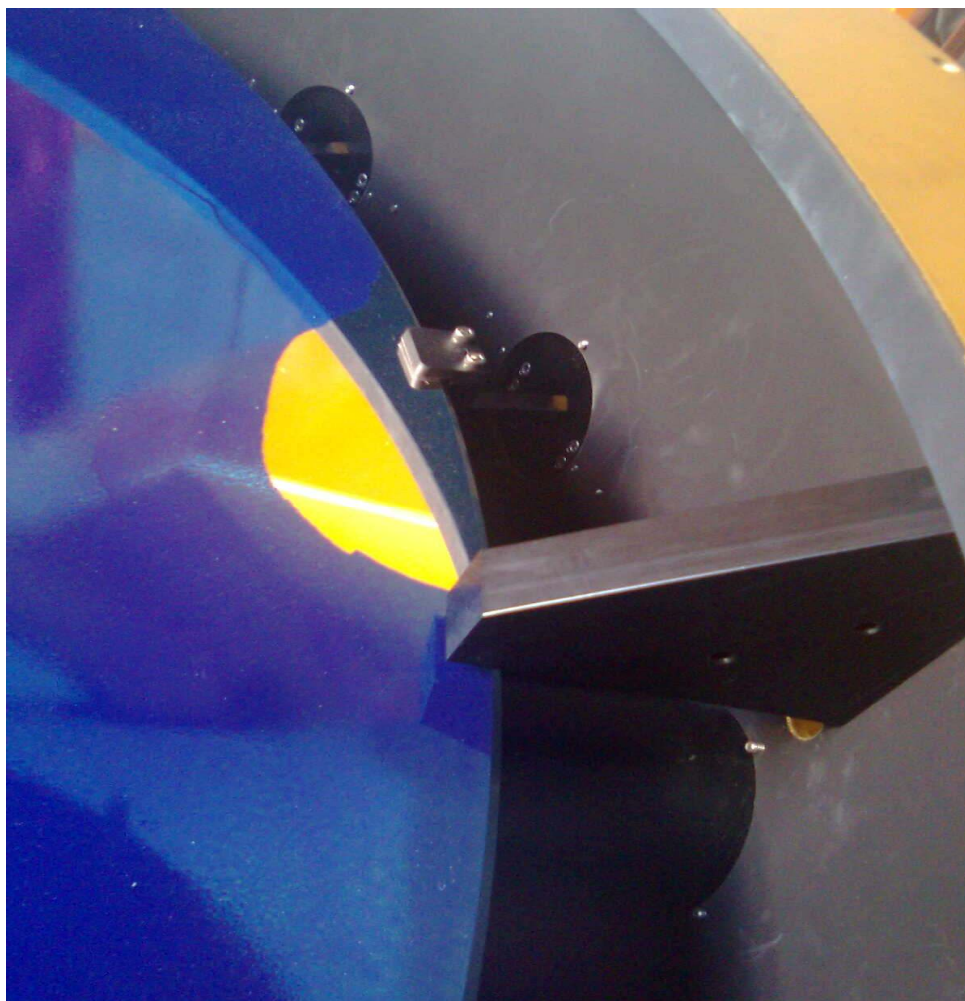


Figure 19: earthquake guards at four cardinal locations.

- 56)** For placing these guards at the North and south locations we need to remove the MCLA ratchet from the cell end. Then place the guards and put MCLA back to the cell.



Figure 20: removing MCLA for placing earthquake guards.

**57)** Now axial defining supports can be placed.



Figure 21: axial bracket assembly (defining clamp)

- 58)** Loose the plungers of the axial defining clamp and fix it at the three positions (already defined) on the mirror. Use a pin to tighten the arm of the clamp at the bottom of the cell, so that while tightening the screw it doesn't rotate.
- 59)** Once the front defining bracket assemblies are seated on the edge of the primary mirror, use a straight screwdriver from below to carefully tighten the spring plungers until they stop, then back the spring plungers off 1/2 turn.
- 60)** See drawing # 621-155-3. On the bottom of the mirror cell, install the 3 slotted washers and 3 (brass) retainer nuts onto the studs of the 3 front defining bracket assemblies. Leave the brass retainer nuts 2 turns loose.



Figure22: tightening the screw (bottom brass nut, other two screw and a arm lock pin) of the axial definers



- 61)** Now mirror cell is prepared to lift. Check once again that all radial supports are fixed to the invar blocks. All gauges are set to their position. Counter weights are in the centre of their travel. Earthquake guards are fixed and ok. Axial defining supports are ok at their position.
- 62)** Now lift the cell using the ratchet of MCLA the same way one person counts and the other one follows. Lift it gently; 2-3 persons should hold the cell to prevent any wiggling. While lifting make sure that everything is fine.
- 63)** Now first guide the four invar rods and then guide pins into the mirror cell.



Figure 23: lifting the cell and invar rods inserts into the mirror cell.



Figure 24: guide pin helping the cell to achieve best fit to the centre piece. Cell attached to the centre piece

**64)** Tight all the bolts of centre piece and mirror cell.

- 65) Remove the MCLA assemblies and install 4 lower invar rod bolts. Install the 2 radial dial indicator assemblies and set them to zero. Loosen the 4 radial support screws 1/4 turn. Check that the 3 axial dial indicator assemblies still read zero.



Figure 25: tightening the bolts joining the mirror cell and the centre piece

**Note:** Follow a systematic approach to adjusting the back supports so as not to overlook individual assemblies. Start adjusting the inner ring of 6 assemblies, then the middle ring of 12, then the outer ring of 18.

- 66) Now mirror can be placed over the 36 back supports system. For this take an Allen rotate the bolts at the bottom of the axial support until a slight increase in the load is felt as the counter weight lift up off the bottom of the cell. After 1/2 turn wrench will stop as the counter weight will contact the bottom of the mirror. Now unscrew the bolt just 1/4 turn so that all counter weight remains in the mid of their travel.
- 67) As the back support assemblies become active the primary mirror will float up off the axial hardpoint screws approximately .010" as shown by the axial indicator assemblies.



Figure26: placing the mirror on the 36 axial supports.



**68)** Lower down all the three axial set up supports 1 turn each. Tighten the 3 retainer nuts evenly until primary mirror floats down 0.005" as shown in the dial indicators.

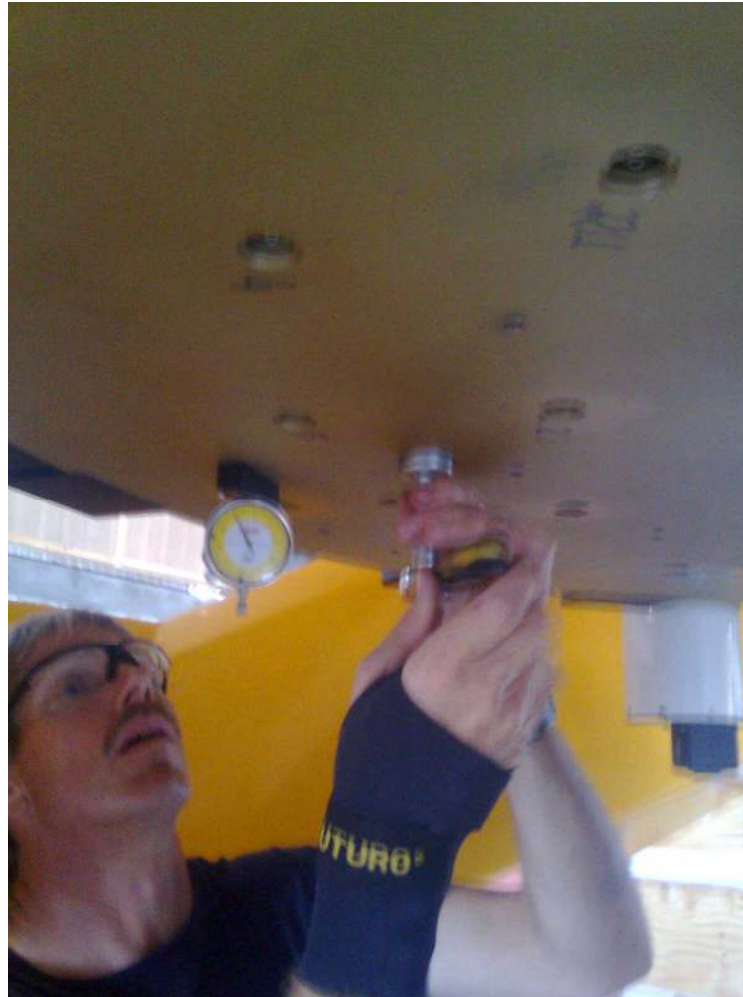


Figure 27: lowering the axial set up supports

***Note: While the back support counterweight assemblies are active, never adjust the height of the primary mirror more than .005 inches without re-adjusting all 36 back support counterweight assemblies.***

- 69) Check all the 36 axial supports, radial counter weight system and reading of all the gauges.
- 70) Tighten the 4 radial support screws, take care not to translate the primary mirror more than .001" (as shown by the 2 radial dial indicator assemblies).
- 71) Carefully raise (tighten) the 3 axial hardpoint screws until the 3 axial dial indicator assemblies show the hardpoints contacting the primary mirror, then lower (unscrew) each hardpoint until the wrench starts to turn freely.
- 72) Set the 4 earthquake guards .003" above the edge of the mirror. Use the .003 feeler gage (through the port below each earthquake guard) to insure the guards are not touching the primary mirror.



Figure28: checking the 16 radial counter weights (left) and 36 axial counter weights (right)

***Note: The primary mirror should now have its weight distributed equally between the 36 back support assemblies while pointing at the zenith. The 16 radial counterweight assemblies and 4 radial supports control the primary mirror when the telescope is pointing near the***

*horizon. When adjusted properly, the axial hardpoint screws, earthquake guards and radial supports work together to constrain the primary mirror during earthquakes or overturning events but not distort the primary mirror during normal operation.*

- 73)** Place the corrector into the baffle and insert it in the primary hole from the bottom. Put the instrument mounting flange.



Figure 29: placing the corrector with primary baffle (left) putting the instrument flange (right)

- 74)** Now park the telescope in the north position and install RA and DEC lock pins.
- 75)** Use a 3/16" Allen wrench to reach through the slots in the 16 radial counterweight assembly covers and check the travel of the radial counterweights. Gently push each of the 16 radial counterweights outboard to verify that none of the radial counterweights will contact the mirror cell or cover. If any radial counterweights are at their travel limits adjust them for mid travel. If coarse adjustment of the radial counterweight assemblies is needed, remove the clevis pins and adjust the threads of the rod ends or nuts as required, then re-install the clevis pins and safety rings. Access the radial adjustment screws from the top of the center section after opening the mirror doors.
- 76)** Close the mirror doors, remove the RA & DEC lock pins and return the tube to the zenith.





Figure 30: lock pin of the DEC axis (left) pulling the telescope to the north position manually (right).

## **SECONDARY MIRROR:**

### **Secondary Mirror Removal:**

Refer to the Secondary mirror assembly drawing 621-018.

***Note: To avoid a dangerous top heavy condition, the focus housing assembly should only be installed or removed when the primary mirror and cell are on the telescope.***

- 1) Remove the 4 invar rod bolts on the bottom of the primary mirror cell.
- 2) Install the RA and DEC lock pins to secure the telescope at the North service position.
- 3) Disconnect the focus housing cables at the truss ring.
- 4) Position the hoist above the spyder ring. Rig the spyder ring to the hoist with the nylon webbing sling provided.
- 5) Carefully raise the hoist to take a load on the secondary assembly.
- 6) Loosen the 4 flex-link bolts one turn each. Note: As the flex-link bolts are loosened and removed be prepared to adjust the hoist to minimize the strain on the flex-links.
- 7) Remove the flex link bolts and unscrew the 4 invar rods from the spyder vanes.
- 8) The focus assembly should now be free from the telescope and hanging from the hoist. Use the overhead hoist to pull the secondary assembly away from the telescope (to the north) until the light shield clears the truss ring.
- 9) Lower the secondary assembly onto the focus stand.
- 10) Use the strut on the focus stand to lock the spyder ring with the mirror facing up.
- 11) Open the secondary mirror crate to find the secondary mirror sling. Prepare the crate and sling to accept the mirror.
- 12) Remove the secondary light shield.
- 13) Remove the secondary mirror hub cover and mirror hub, carefully slip the secondary mirror sling under the secondary mirror.
- 14) Rig the secondary mirror and sling onto the hoist, and then lift the secondary mirror. Replace the secondary service stand with the secondary mirror crate and lower the secondary mirror into the crate.

- 15) Protect the mirror surface as needed and close the crate.
- 16) Clean the focus housing with glass cleaner and clean towels. Cover it while it is out of service.

#### **Secondary Mirror Re-installation:**

Refer to the Secondary mirror assembly drawing 621-018.

***Note: To service the focus housing the telescope RA and DEC lock pins must be installed to lock the telescope in the north service position.***

- 1) Remove the 4 Invar rod bolts from the bottom of the primary mirror cell.
- 2) Inventory the secondary mirror assembly parts, note that some parts may be stored in the secondary mirror crate: secondary mirror hub, 6ea.10-32 x 4" long stainless soc cap screws, wave spring washer, laser collimation tool and mounting screws, mirror hub cover, secondary light shield and mounting screws, 4 flex links and screws.
- 3) Check that the focus assembly is locked on the secondary service stand with the mirror back plate up. Set the wave spring washer in place on the mirror back plate.
- 4) Check the condition of the Teflon tape on the secondary mirror hub. The secondary mirror hub flange should have a uniform, wrinkle-free layer of .003-.005 Teflon tape where it contacts the mirror. The 2.840" diameter of the secondary mirror hub should have 3, equally spaced, 3/4" squares of .003-.005 Teflon tape set 1" from the contact flange.



Figure 31: mounting the M2 plate in the spyder (left) M2 in its crate (right)

- 5) Open the secondary mirror crate and prepare the secondary mirror for lifting. The secondary mirror sling should be in the crate under the secondary mirror. Rig the mirror for lifting.

- 6) Lift the secondary mirror from the crate.
- 7) Swap the secondary mirror crate for the secondary service stand and set the secondary mirror on to the focus housing.
- 8) Unhook the mirror sling from the hoist and, by gently tipping the mirror, slide the mirror sling out from under the mirror and centering hub. Put the secondary mirror sling in the secondary mirror crate, close the crate and set it aside.
- 9) Install the secondary mirror hub.



Figure 32: lifting the secondary mirror with Crain (left) fixing the secondary mirror hub to hold the M2 (right)



- 10)** Install the 6 #10-32 x 4" long screws that secure the secondary mirror hub to the mirror back plate. Make sure the wave spring is seated properly. Torque the screws as tight as possible *by hand with the short leg of an "L" shaped Allen wrench*.
- 11)** Rotate the secondary mirror to align the north marks on the mirror and focus housing.
- 12)** Use a feeler-gage set to measure the gap between the focus housing back plate and mirror back plate. Adjust the gap, when measured near each adjusting screw, to be uniform to within .002". To pre-load the back plates, reduce the thickness of the feeler gage stack .020" and tighten the 4 adjusting screws to reduce the gap to this value.
- 13)** Install the secondary light shield. Cover the shield to protect the mirror until installation.
- 14)** Rig the spyder ring to the hoist with the nylon webbing sling. Be sure to hoist the focus housing with the south side up.
- 15)** Hoist the spyder ring into a position north the telescope truss ring.
- 16)** Adjust the hoist to move the focus assembly south into position to start the Invar rods.



Figure 33: putting M2 baffle (light shield) (left) lifting the arrangement by Crain (right)

- 17)** Start the threaded studs on the ends of the 4 Invar rods into the corresponding threaded holes in the spyder vanes. Tighten the 4 Invar rods and then back them off 1 turn.
- 18)** Install the 4 flex links between the truss ring and spyder ring.

- 19) Make sure the nylon sling will not get pinched between the spyder ring and truss bolts.
- 20) Install the 4 Invar rod bolts in the bottom of the mirror cell but do not tighten them yet.



Figure 34: fixing the spyder ring to the telescope truss (left) loosening the invar rod bolts from the bottom of the M1 cell to fix it in the hexapod structure.

- 21) Tighten the 4 Invar rods against the spyder vanes, 4 flex link screws and 4 invar rod bolts in the mirror cell.
- 22) Disconnect the hoist and nylon webbing sling.
- 23) Connect the 8 focus control cables.
- 24) Remove the lock pins and balance the telescope.