



# Tertiary Mirror Handling Procedures

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## **Introduction**

This document describes procedures for handling the tertiary mirror. Three handling operations are covered:

- removal of the tertiary from the telescope
- removal of the mirror from its cell
- installation of the mirror into its cell.

Reinstallation of the cell into the telescope is the reverse of the removal operation.

## **Description**

The tertiary mirror is elliptical in shape, 110.1 by 77.6 by 10.2 cm thick (43.35 x 30.55 x 4"). The blank is made of Zerodur glass lightweighted by milling hexagonal pockets into the back of the glass. The blank weights 69 Kg (132 lb). The mirror is figured flat to 0.026 wave rms and 0.26 peak to valley over the useable elliptical 108 by 75.6 cm aperture. This leaves one cm of unused surface at the edge of the blank.

## **Mirror support**

The mirror is supported axially with an air bag. Lateral supports act at six points arranged in an elliptical pattern and located at the CG plane of the blank. Three of the lateral supports double as axial hard points. Strict lateral definition (as opposed to support) is not needed for a flat mirror. The lateral supports mechanism is a reed flexure - six steel rods that extend from the load cell to the CG plane of the mirror. Three of the rods terminate in flexures that act like spherical bearings which are axially stiff to provide the axial definition. The remaining three rods terminate in linear bearings to decouple axial forces. Lateral loads in the mirror are reacted by cantilever bending of the rods, and the lateral support forces are distributed by elastic averaging. The rod flexures also accommodate differential thermal expansion between the cell and the mirror.

The rod diameter, length, and material were chosen to balance several characteristics. The diameter and length were chosen to give a lateral spring rate of 900 lbs per inch for each flexure which set the lateral mode resonant frequency of the mirror at 20 Hz. Under the full mirror weight the flexures sag about 0.02". Snubbers incorporated into the supports stop the mirror at 0.06" travel where the steel in the rods is still well within its elastic range. For additional safety the rod is designed to yield at about 165 lbs

load - a load that is still safe for the glass.

## **Mirror cell**

The rods, load cells and air bag are supported by a welded steel mirror cell consisting of a skeletal framework and a thin shell to protect the mirror during handling. The mirror cell weighs 79 Kg (173 lb). Cell and mirror together weigh 139 Kg (305 lb).

The cell attaches to an A-shaped frame atop the tertiary rotator. The attachment is kinematic; the cell locates at three points in the classic cone - groove - flat combination. This allows removal and installation of the mirror with excellent registration. The three locator points are fitted with fine pitch (40 TPI) adjustment screws for collimation.

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## **Removal from the telescope**

This procedure takes two people and can be done in about one hour.

### **Equipment:**

- Them floor crane
- Secondary/tertiary handling cart (4' x 4' plywood cart)
- Four small shackles
- Two nylon straps
- Tertiary trunnion fixture
- Two 2x4's for cribbing (about 2' long)

## **Procedure**

1. Bring the floor crane up to the observing level. Set the mast and boom to their maximum extensions.
2. Point the telescope towards the east or south (away from the equipment and platform lifts). Park the tertiary facing the folded Cass position, and in the fold removed position.
3. Maneuver the crane into position between the "V" of the forward tube assembly while lowering the elevation axis to 5 degrees el. Engage the telescope stow pin and brakes.
4. Install the tertiary cover to protect the surface.
5. Detach air lines and the load cell signal line from the back of the cell. Remove the load cell preamp box and set aside.
6. Attach two straps with shackles to the four lifting points on the cell. Rig the straps to a single shackle in the crane hook. Once the rigging is in place, take up slack with the crane. Be sure there is enough hoist travel to lift the mirror cell clear of its frame. If not, adjust rigging as necessary.

7. Remove the tertiary attachment bolts There are six attachments between the cell and the "A" frame; four 1/4-20 cap screws in a bolt circle at the apex of the A-shaped support frame, and two 3/8-16 cap screws which attach at either foot of the A.
8. With one person operating the hoist, and another to "spot" the tertiary cell, carefully lift the cell above the A frame. This involves maneuvering approximately 300 pounds within inches of the primary, **USE EXTREME CAUTION.**
9. Roll the crane back to maneuver the mirror cell away from telescope. Bewar of the rear wheels rolling into the crack at the perimeter azimuth platform (this can't be avoided, only anticipated - it will make the hoist jump and give the mirror cell a jerk).
10. Turn the hoist so that the cell lifts over and clear of the V truss, attach the trunnion bracket to the back of the cell (four 1/4-20 bolts) and lower the cell onto cribbing set on the cart.
11. Once the cell has been placed on the dolly the rigging straps and shackles can be removed.

**This completes the mirror cell removal procedure**

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## **Mirror Removal from Cell**

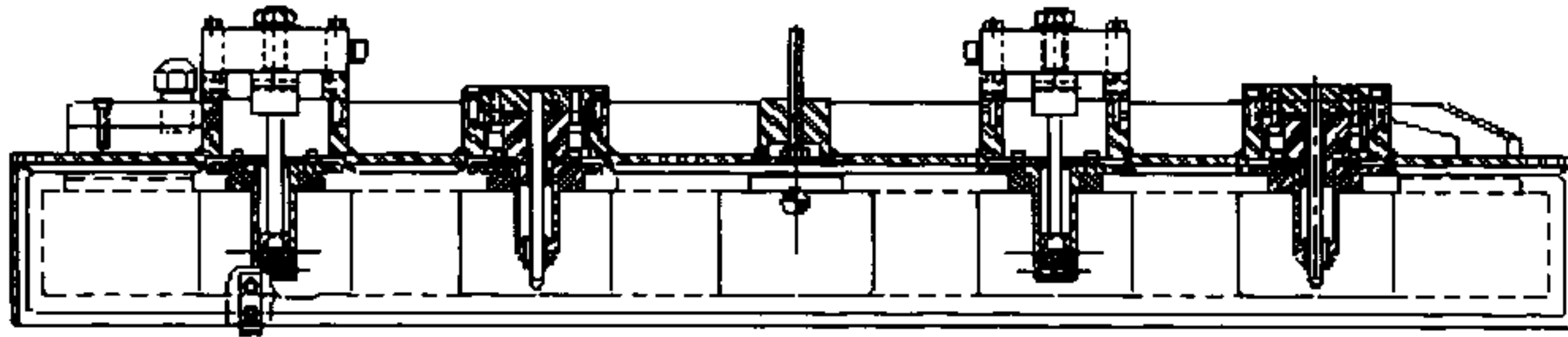
This procedure takes two people and can be done in about two hours.

### **Equipment:**

- Tertiary trunnion
- Overhead hoist
- WIYN spreader bar
- Tertiary removal fixture
- Tertiary lifting fixture (edge handling band)
- Tertiary removal tool kit
- Tertiary packing crate

### **Procedure**

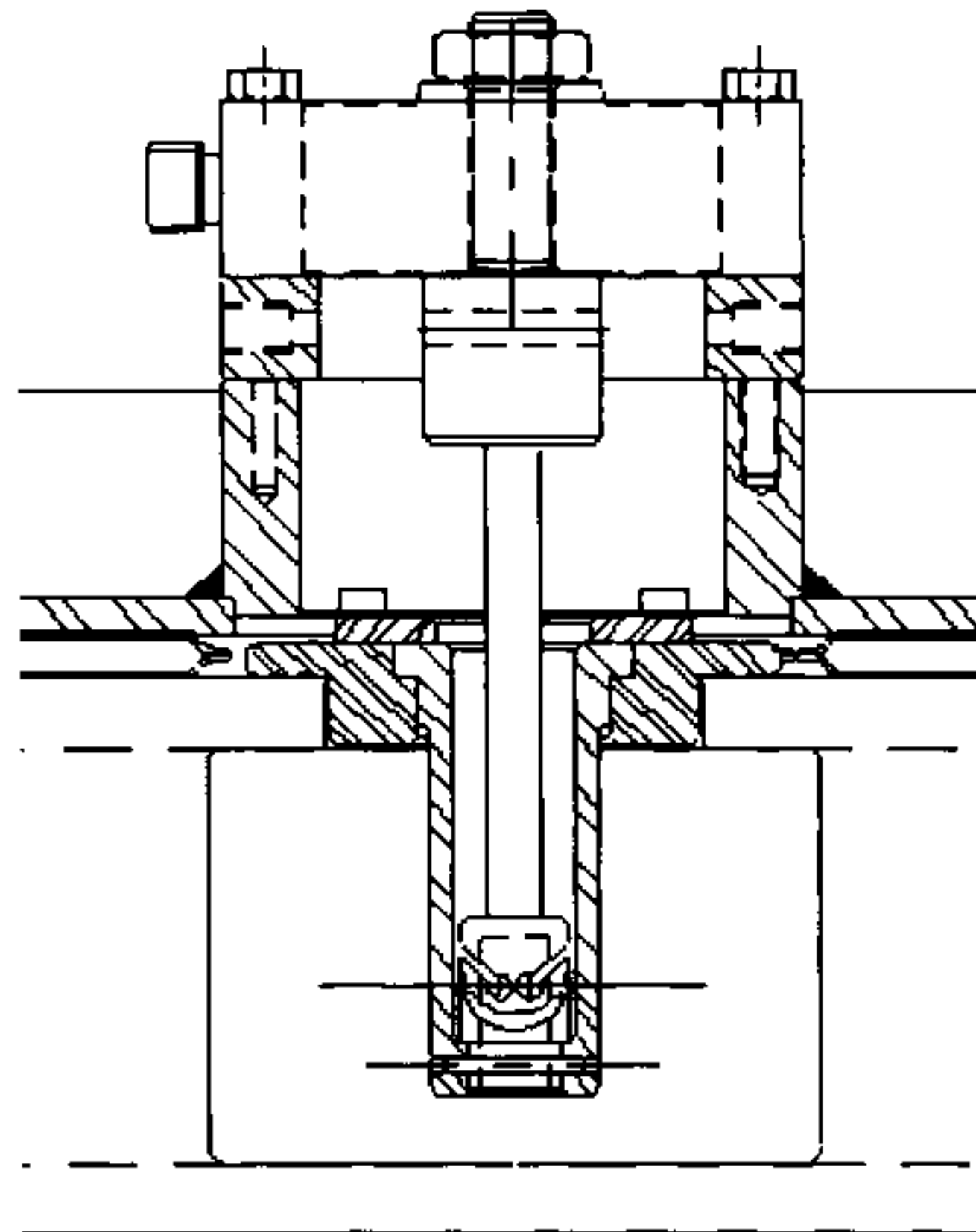
At the start of this procedure, the mirror cell assembly is face up on a cart. Basically, the procedure is to pick the mirror cell up with an overhead hoist, turn it over (mirror face down) and position it on the mirror removal stand where the mirror can be detached from the cell. The mirror removal stand is designed to support the cell and mirror separately. The mirror is supported on six delrin pads arranged around the edge of the mirror face. The cell rests on the stand at three points. The weight of the mirror is transferred to the pads before detaching the mirror support and removing the cell from the glass.



*Cross section through the mirror cell assembly.  
The mirror is face down supported on its removal stand (not shown).*

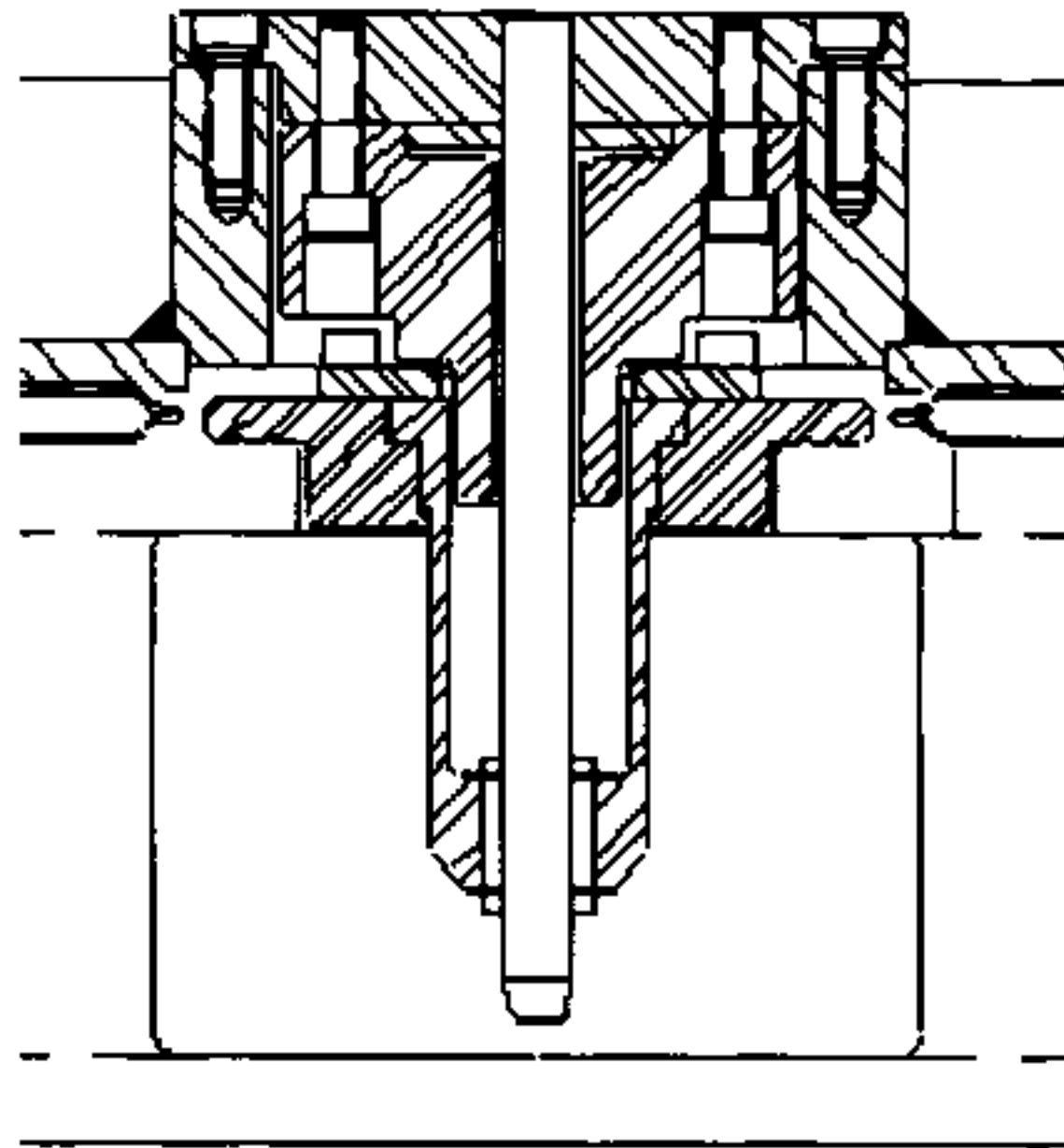
1. Place the removal fixture on the cart and back off the six delrin pad adjusting screws to low the pads.
2. Using the overhead davit hoist, pick up the mirror cell by its trunnion fixture, turn the cell over and maneuver it onto the removal fixture. The cell's weight will settle onto the fixture. At this point the glass is suspended from the cell.
3. Adjust the six delrin pads, advancing the screws till they **JUST TOUCH** the glass. Be careful not to advance the pads too far; doing so would transfer the weight of the cell onto the glass and could damage the support.

We are now ready to detach the mirror from its support. The mirror is attached through flexures to three load cells on the back of the cell. **These flexures are fragile, and particularly susceptible to failure in torsion.** Anti-rotation drift pins **MUST** be installed before removing load cells.



*Cross sections showing the axial supports*

In addition to the load cells, there are three assemblies which provide lateral support and provide safety bumpers for the glass. Remove the load cells FIRST, then the lateral support assemblies.



*Cross sections showing the lateral supports*

4. Remove the mirror safety clips.
5. Just beneath each load cell there are two set screws entering the side of the load cell spacer plate. Remove these set screws (six total). Insert a 1/4 inch x 5" long drift pin through the hole revealed under the set screws. Be sure the drift pin passes completely through the base of the flexure rod. This will prevent the flexure from rotating during the next step.
6. Remove the 5/8-16 lock nut from the top of the load cell.
7. Remove eight 1/4-20 bolts holding the load cell in place.
8. Remove the load cell by rotating it CCW off of the threaded end of the flexure. Check to be sure the loadcells are marked. Set the load cell aside.
9. Repeat for the other two load cells.
10. Removing the load cells reveals the flexure and retaining cup in the back of the mirror. The flexure rod is fragile and should be handled carefully. Insert the split aluminum retainers (kept in the tertiary removal tool kit) around each flexure rod and remove the drift pins.
11. Remove six #10 screws (careful not to drop them!) and remove the washer, cup, and flexure from the mirror. Repeat for the other two. Make sure the parts are identified. Set aside.
12. Remove eight 1/4-20 SCHS from each of the three lateral support assemblies. Remove the lateral support assemblies by lifting them straight out of the mirror cell. Set aside.

**The mirror has now been detached from the cell.**

13. Back off the set screw at the center of the cell. This loosens the air bag valve stem.
14. Rig the cell with 2 nylon straps and shackles at the four lift points. Using the overhead hoist, remove the cell from around the mirror by lifting straight up. The air bag will be left on top of the tertiary.
15. Position the tertiary mirror handling band around the mirror. One of the eight safety clips will interfere with the handling fixture and can only be installed after the mirror is raised.
16. Using the overhead hoist, lift the tertiary mirror. Rotate the mirror face up. Position the packing box under the mirror. Lower the mirror into its packing box.

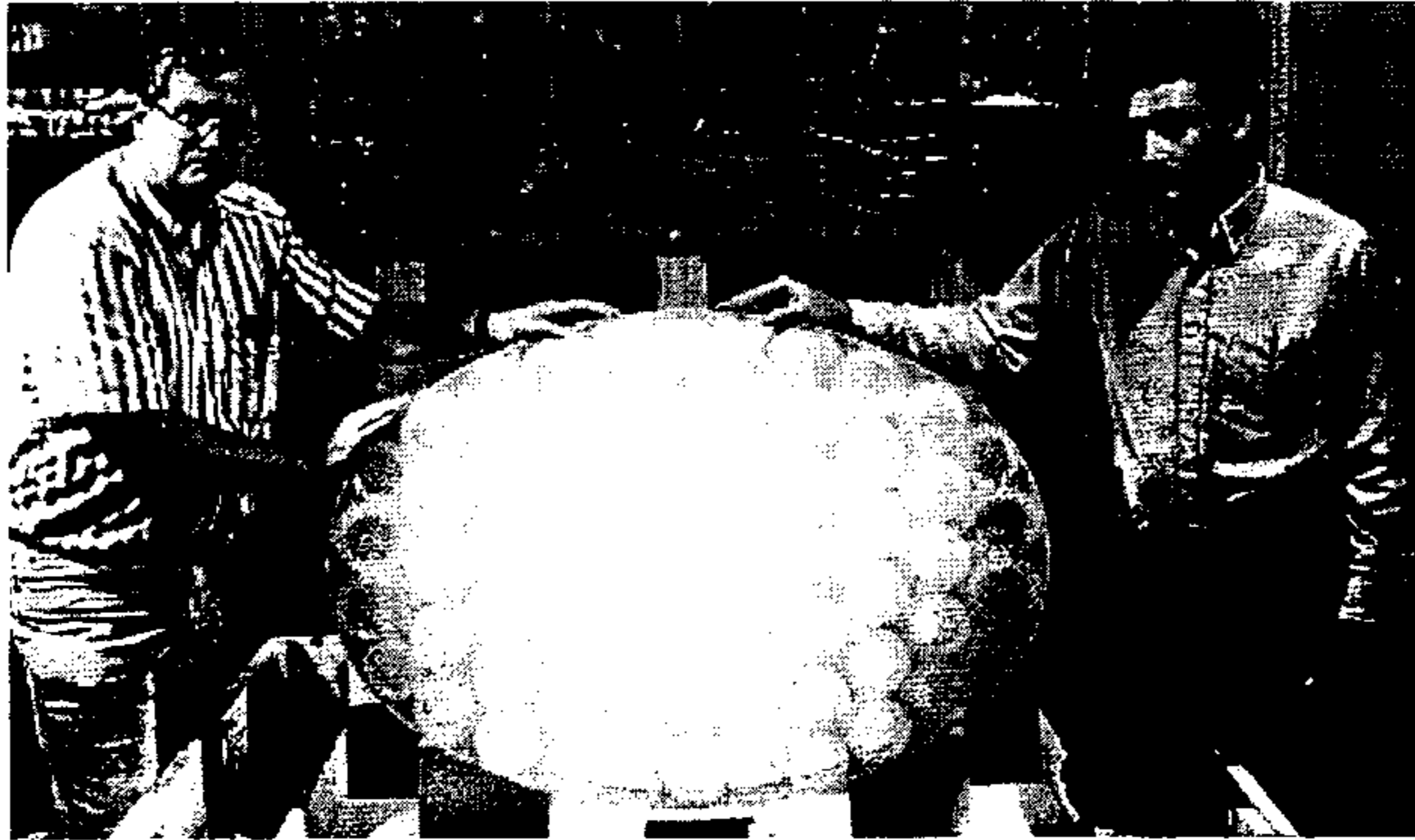
**NOTE: do not change the settings on the delrin pads.**

**This completes the mirror from cell removal procedure.**

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## **Mirror installation into its cell**

This is essentially the reverse of the removal procedure with a few cautionary notes. This procedure requires two people and can be done in about two hours.



*The tertiary mirror blank as it looked before polishing*

### **Equipment:**

- Tertiary trunnion
- Overhead hoist
- WIYN spreader bar
- Tertiary removal fixture
- Tertiary lifting fixture (edge handling band)

- Tertiary removal tool kit

## Procedure

1. Lift the mirror from its box using the edge band. Place the mirror onto the removal fixture.
2. Rig the cell with two nylon strap shackled to the four lift points and lift with the overhead hoist.
3. Lay out the air bag on the back of the mirror with the valve stem centered and pointing up.
4. Carefully lower the cell over the mirror. Use a 1/8" diameter plastic rod to guide the valve stem into the hole in the cell. This hole is stepped so use care in guiding the valve stem.
5. Lower the cell until it rests on the removal frame.

We are now ready to attach the mirror to the cell. In this mounting system the mirror is overconstrained to its cell. The load cells and rod flexure mounts were purposely made with loose fits to allow them to "float" during installation. Assembly must be done carefully to be sure there is minimum initial stress on the glass. Parts should be allowed to float into their neutral positions without binding.

6. Insert the cup, flexure and washer assemblies into their correct positions. Rotate the flexures to align the reference marks. Install the drift pins through the cell into the flexure rods. Install six #10 screws in each assembly and tighten to hand tightness.
7. Carefully thread the load cell onto the end of the rod. If the delrin pad adjust screws have not been changed the loadcell should seat in the proper orientation.
8. Bolt down the loadcells with 8 1/4-20 screws each allowing the load cell to float to a stress free position. Remove drift pins and replace the filler screws in the drift pin holes.
9. Back off each delrin pad adjust screw one full turn. This transfers the support of the glass to the cell.
10. Insert the three rod flexures into their labelled locations. Let the rod base float to a stress free position and bolt them in place.
11. Pull up on the air bag valve stem and tighten the set screw in the cell.
12. Inspect the overpressure blow off valve.
13. Install the mirror safety clips.
14. Attach the trunnion fixture and lift the mirror and cell from the removal frame. Turn the mirror over, install the cover and set the assembly, mirror side up, on cribbing.

**Installation into the telescope is the reverse of the removal procedure. This completes the mirror installation procedure.**

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