



Lick Automated Planet Finder

2.4 Meter Telescope

Primary Mirror Assembly

Installation/Removal Procedures

ASP-13952-1

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2.4 Meter Telescope

Primary Mirror Installation/Removal Procedures

1 INTRODUCTION

This document describes the procedure for installation and removal of the 2.4 Meter Primary Mirror to and from the telescope.

EOST and its related entities take no responsibility and shall not be liable for any injury, loss or damage (including death) which results from the operation, use or maintenance of the telescope and related systems, including the use of or reliance upon the contents of this manual. Such operation, use or maintenance of the telescope and related systems, including use of or reliance upon this manual is at the Customer's own risk.

Personnel operating, maintaining and performing work on or around the telescope and related systems should take all reasonable and necessary care for their safety, health and well-being and the directions, instructions and advice provided in this manual should not be followed as a substitute for observing safe work methods, or where injury, loss or damage may occur.

1.1 SCOPE

This document is for use with certain EOST 2.4 meter passive support telescopes only.

This document describes the procedure to be followed by qualified technicians or engineers to install or remove the Primary Mirror based on the following assumptions:

- An external crane will be used for the lifting.
- An adequate safety factor for conditions at the time of lift will be applied to all rigging, as well as using safe rigging practices.
- This procedure can only be executed in good weather. This is defined as having little or no wind and no precipitation.
- This procedure will require a minimum of four people in addition to the external crane operator in order to see all the way around the large objects that will be moved. These people will be allocated according to site conditions.
- When using this procedure, variations in site conditions and external equipment used must be taken into consideration.

1.2 CONFIGURATION

This document has been configured as **ASP-13952-1** and is a designated controlled document under the EOST Quality System.

1.3 REFERENCES

The following source documents may be used as reference materials for this document:

- [1] EOST drawing ASY-12194 M1 Mirror Crate, 2400MM Mirror
- [2] EOST drawing ASY-12362 EL Hard Stop Assy

- [3] EOST drawing ASY-5736 L SF Assembly
- [4] EOST drawing ASY-5888 L SF Counterweight Assembly
- [5] EOST drawing ASY-8555 M1 Cart Assembly
- [6] EOST drawing ASY-5760 M1 Support Assembly
- [7] EOST drawing ASY-5866 Seismic Restraint
- [8] EOST drawing ASY-11983 M1 Handling Fixture Assembly
- [9] EOST drawing ASY-5901 M1 Radial Position Sensor Assembly
- [10] EOST drawing ASY-5817 M3 Assembly
- [11] EOST drawing COM-5314 Loadspreader Assembly Counterbalance Rod
- [12] EOST drawing COM-5750 LSF Cover plate 1
- [13] EOST procedure MM-12920 "Lick APF Telescope Maintenance Manual"
- [14] EOST procedure PS-12964 "M1 Mirror Packing Procedure"
- [15] EOS procedure CI: AI-500879 "Mirror Installation & Removal Procedure"

1.4 ABBREVIATIONS AND ACRONYMS

Table 1 Abbreviations and Acronyms

Abbreviation or Acronym	Item
PMA	ASY-5760 Primary Mirror Assembly (complete assembly including mirror and cell or support)
PMC	Primary Mirror Cell (cell or support without mirror)
LSF	ASY-5297 Lateral Support Frame Assembly
AR	as required
SR	ASY-5866 Seismic Restraint
Primary Mirror	ASY-6782 2.4 Meter Primary Mirror Assembly (Primary Mirror with Axial Pucks and LSF Pucks permanently bonded to it)
Mirror Cart	ASY-8555 M1 Cart Assembly (M1 Cart)
OSS	Optical Support Structure or Optical Tube Assembly (OTA)
LSF/PMA/Mirror Cart assembly	LSF Assembly fastened to the Primary Mirror Assembly on Mirror Cart (includes mirror)
LSF/PMC/Mirror Cart assembly	LSF Assembly fastened to the Primary Mirror Cell on Mirror Cart (without mirror)

1.5 DEFINITIONS

- Tag Lines – rope used to control other movements of an object while being lifted by a crane. Tag lines are not used for lifting or load bearing.

2 SAFETY OF EQUIPMENT AND PERSONNEL

1. Read this entire procedure and review all referenced documents and drawings before beginning work.
2. Make sure all tools or items (such as drawings, procedures) are at the worksite and ready to use before starting.
3. Review this procedure with all personnel involved. Allocate specific responsibilities to staff before the crane arrives for lifting. Allow the crane crew to see the procedure and walk through the site while briefed on the procedure by the person in charge of the installation or removal.
4. A safety officer is to be allocated. Unauthorized personnel are to be warned that they should stay more than 10 meters away from any lifted load.
5. The dome, enclosure, and staging area are a restricted zone from first lift to last. The safety officer is to keep unauthorized personnel out of this space during this period. The person in charge of the installation or removal will decide who is authorized and who is not authorized.
6. At all times, only one pre-designated person is to give the crane operator instructions, unless an imminent hazard is apparent.
7. If there is a chance of rain, plastic drop cloths are to be secured over the primary mirror.
8. Do not install or remove the primary mirror if weather conditions are windy or rainy.

3 REMOVAL OF PRIMARY MIRROR

3.1 TERTIARY MIRROR REMOVAL

1. Use stay pin to hold telescope in horizon pointing position.
2. Remove the M3 Baffle and Mirror Assembly from the telescope according to the procedure provided in the Lick APF Telescope Maintenance Manual (MM-12920).
3. The M3 Tower should never need to be removed from the Primary Mirror Cell.

CAUTION: Removing the M3 Assembly and Baffle may leave the telescope slightly bottom heavy. When removing the Elevation Axis Pin, be careful to prevent the OSS from moving too quickly in this out of balance state.

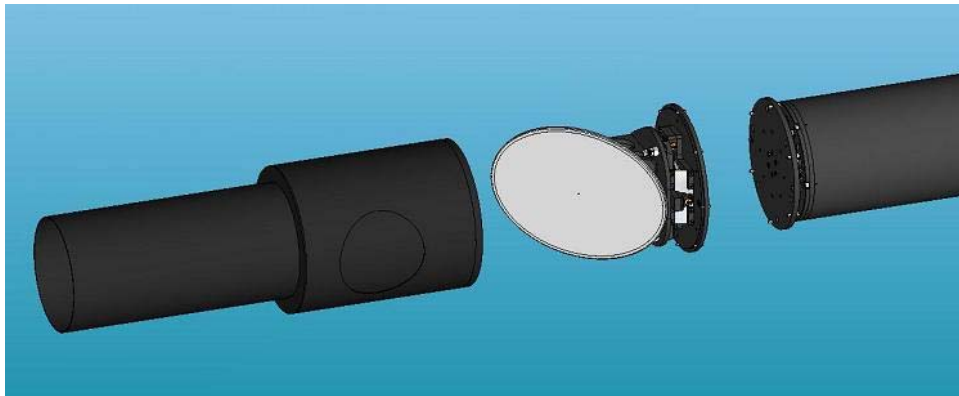


Figure 1 Tertiary Mirror Assembly

3.2 SET-UP

CAUTION: Do not lift if wind speed exceeds 15 mph or 24 km/h. If threat of rain, secure a new plastic drop cloth over Primary Mirror with the optical surface properly protected.

1. Prepare a work area or staging area outside the Dome that is within reach of the crane, roughly 30 square meters in total area.
2. Get the ASY-12194 “M1 Mirror Crate, 2400MM Mirror” (primary mirror crate) in the staging area ready for use. Use pallets or timber for holding pieces off the ground during intermediate staging to keep the shipping crate covers and lifting fixtures clean.
3. The telescope should be in the following condition:
 - It should be locked at the zenith position, with the staypin engaged and the ASY-12362 “EL Hard Stop Assy” fastened to one telescope Fork Tine restraining the Upper Truss from moving.
 - The M3 Baffle and M3 Mirror Assembly should be removed and stored in a secure location.

- The E-stop Switch nearest the telescope should be depressed. This E-stop switch may have to be reengaged later to move the Dome or for other reasons, but should be depressed when working directly on the telescope.

If any of these conditions are not present correct them at this time.

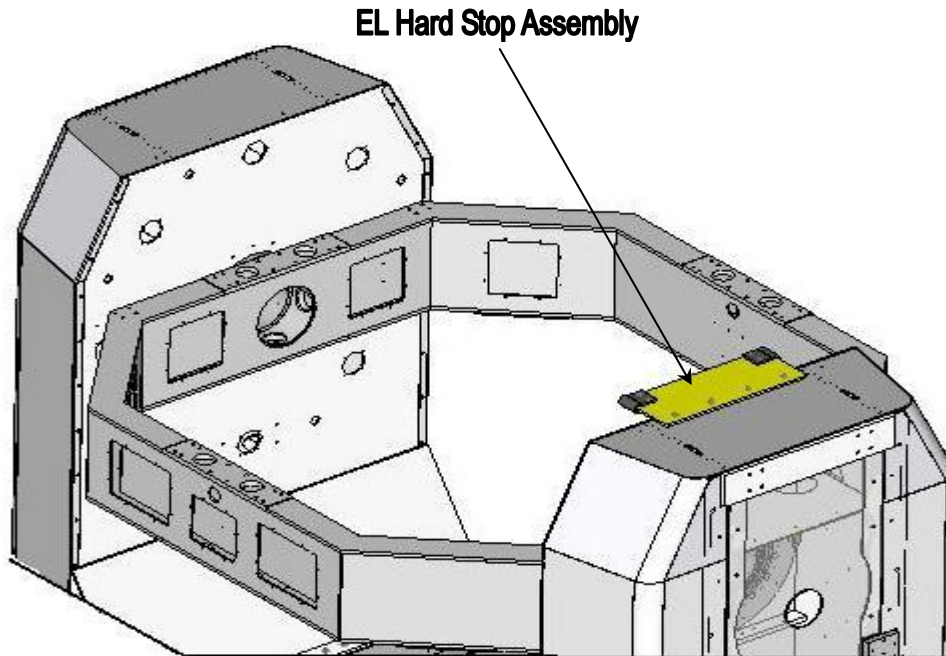


Figure 2 EL Hard Stop Assembly on right Tine

CAUTION: When the Primary Mirror Assembly is removed for any reason, the telescope must be left at the zenith position with the ASY-5797 “Elevation Staypin Bracket Assembly” engaged and ASY-12362 “EL Hard Stop Assy” fastened to the telescope Fork Tine to restrain the Upper Truss (in the zenith position) and handle the severe out-of-balance condition of the telescope.

The elevation staypin is not designed to prevent injury to personnel or damage to the telescope due to the imbalance of the OSS caused by the removal of the PMA.

4. Open the Dome.
5. Rotate the dome slit over the center of service balcony area.
6. Read EOS procedure CI: AI-500879 “Mirror Installation & Removal Procedure”.
7. Prepare the Dome according to the procedure for primary mirror removal.
8. Clean ASY-8555 “M1 Cart Assembly”.
9. Install and align M1 Cart Guide Rails, if not already done.

10. Rig, lift, and set the Mirror Cart onto M1 Cart Guide Rails. Casters on Mirror Cart must be turned facing inward or toward each other before setting the Mirror Cart on the rails. The mirror cart should be oriented such that the jacking crank is facing the rear of the dome.
11. Detach rigging from the Mirror Cart.
12. Roll the Mirror Cart under the PMA.
13. Center by eye the Mirror Cart under the PMA. Make sure the three counterweight rods protruding from the bottom of the M1 Support line up with the corresponding holes in the Mirror Cart.
14. Raise cart jacks using the ratcheting crank handle on the Mirror Cart to press up on the PMA with a slight amount of pressure.
15. Close the Dome, if you are not able to close the Dome make it as weather tight as reasonably possible.

3.3 PRIMARY MIRROR REMOVAL

1. Wear a dust mask and powder-free latex gloves when working above or around the surface of the mirror. Remove any jewelry and items from pockets that may fall onto the mirror surface.
2. At this point the LSF should be mounted to the PMA (the mirror is in the cell), the Mirror Cart is holding the LSF/PMA up in place in the telescope and the “CS to LSF Brackets” are bolted to the CS.

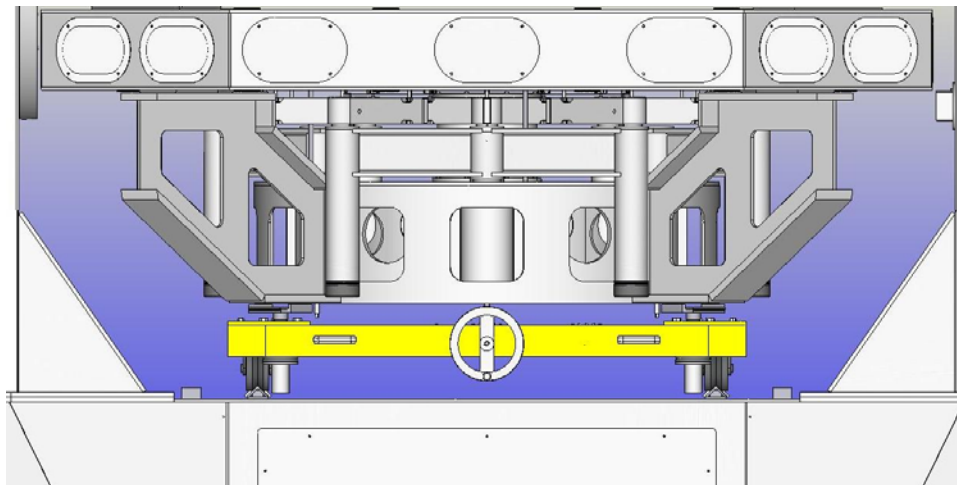


Figure 3 Telescope configuration at start of removal procedure

3. Note that the LSF/PMA/Mirror Cart assembly includes the four “CS to LSF Brackets”. The four “CS to LSF Brackets” should never be loosened or removed from the LSF.

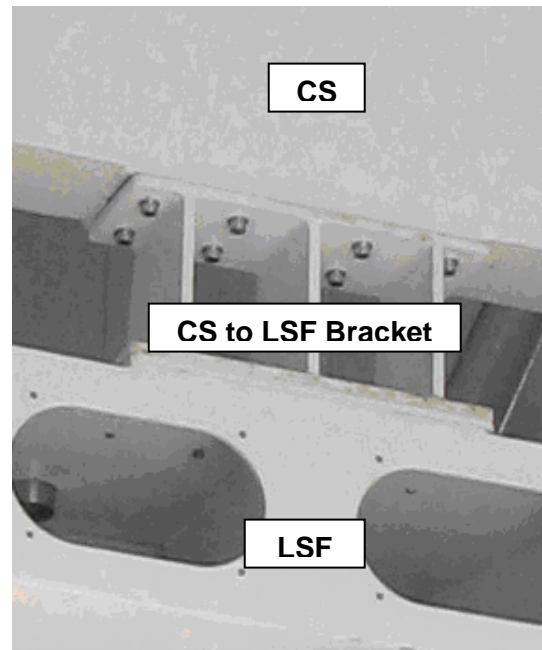


Figure 4 CS to FS Bracket on telescope

4. Take some weight off of the PMA by raising the cart jacks (using the ratcheting crank handle) on the Mirror Cart to press up on the PMA with a moderate amount of pressure.

WARNING: The Telescope is extremely top-heavy when the Primary Mirror Assembly is removed. DO NOT disengage the Elevation Staypin or remove the “EL Hard Stop Assy” without the Primary Mirror Assembly installed.

At this point you will be working very near and above the level of the Primary Mirror with tools.

5. Remove all the M12 cap screws that join the “CS to LSF Brackets” to the Center Section, if not already done. Move the fasteners away from the Primary Mirror and out of the way.
6. Check for lowering hazards. Clear all tools, fasteners, and loose hardware from the telescope. Make sure there is nothing in the downward path of the LSF/PMA assembly or the mirror cart jacks.
7. Lower LSF/PMA assembly down onto Mirror Cart by lowering the mirror cart jacks all the way down, until they bottom out.
8. Roll the Mirror Cart (with the LSF/PMA assembly on it) on the M1 Cart Guide Rails, slowly out from under the CS.

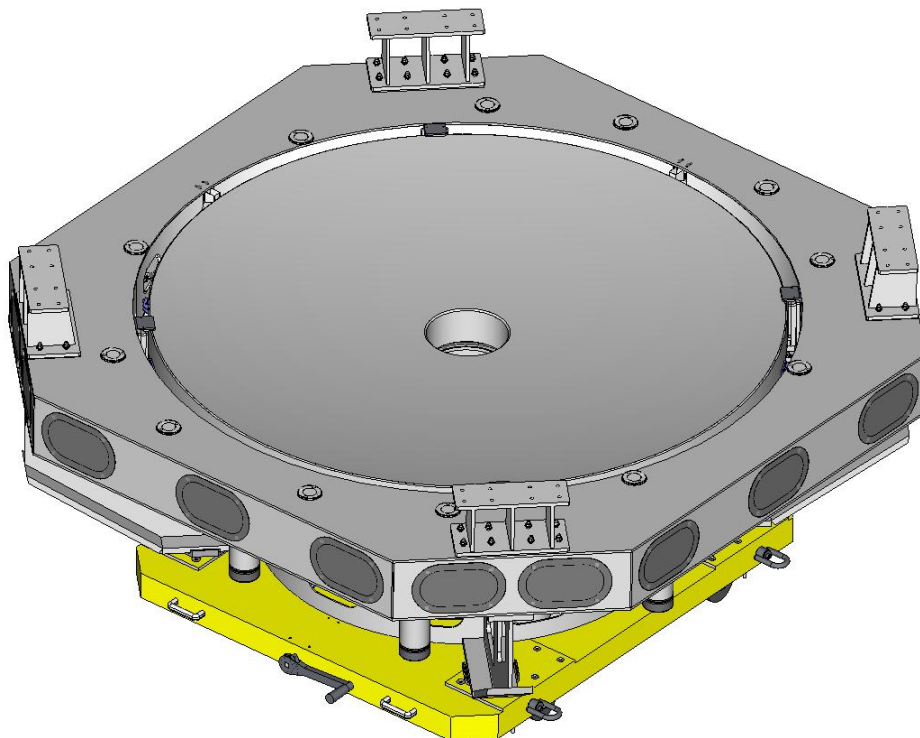


Figure 5 LSF/PMA/Mirror Cart Assembly

9. Roll the LSF/PMA/Mirror Cart assembly out until it clears the CS but is still inside the Dome. Stop at this point.

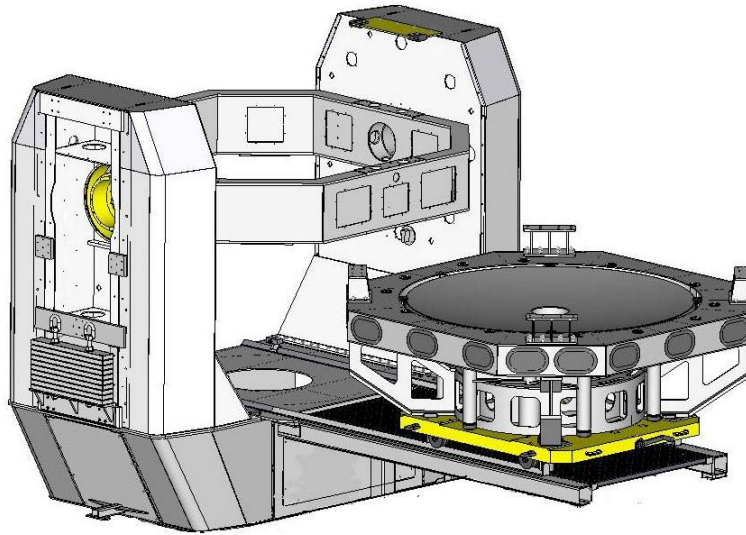


Figure 6 LSF/PMA/Mirror Cart assembly is inside the Dome on rails

10. Apply a protective coating product to the optical surface of the mirror and allow it to dry according to the manufacturers recommendations (i.e. Universal Photonics Pre-Cote #33 Blue). Applying multiple coats may simplify the removal process.

Caution: Extreme care is required to prevent contact with the optical surface if a protective coating is not used, as even incidental contact can damage the coating and/or surface of the mirror.

11. Move the ASY-5866 “Seismic Restraint” assemblies up against the side and bottom surface of the Primary Mirror. Only the neoprene pads COM-5871 “SR Pad 2” and COM-5870 “SR Pad 1” on COM-5868 “SR Bracket 2” should contact the mirror. There should be a visible gap between all four COM-5869 “SR Bracket 3” and the Primary Mirror and no part of this assembly should ever touch the optical surface. The purpose of this assembly (while PMA is in transit) is to minimize or stop lateral movement of the Primary Mirror; so placing the Seismic Restraints firmly against the sides of the mirror is critical, but if there is a small gap between COM-5870 “SR Pad 1” and the bottom of the Primary Mirror; it is acceptable.
12. Cover the Primary Mirror with a drop cloth or other additional protection if needed.
13. Roll the LSF/PMA/Mirror Cart assembly to the lift point on the M1 Cart Guide Rails.

Caution: Clearance must always be provided for the COM-5314 “Loadspreader Assembly Counterbalance Rod”. If the PMA or PMC is rested on the Counterbalance Rods severe damage to the PMA, PMC or Primary Mirror could result.

The Mirror Cart does provide clearance for the Loadspreader Assembly Counterbalance Rods on a flat and level surface such as a shop floor. When using this method in site conditions, care must be taken to make sure no debris or other matter invades this clearance space.

14. Remove the four COM-5869 “SR Bracket 3” and set them aside away from the PMA.



Figure 7 Seismic Restraint with COM-5869 “SR Bracket 3” removed

15. Disconnect the LSF linkages from the LSF Pucks on the mirror by executing the following steps:

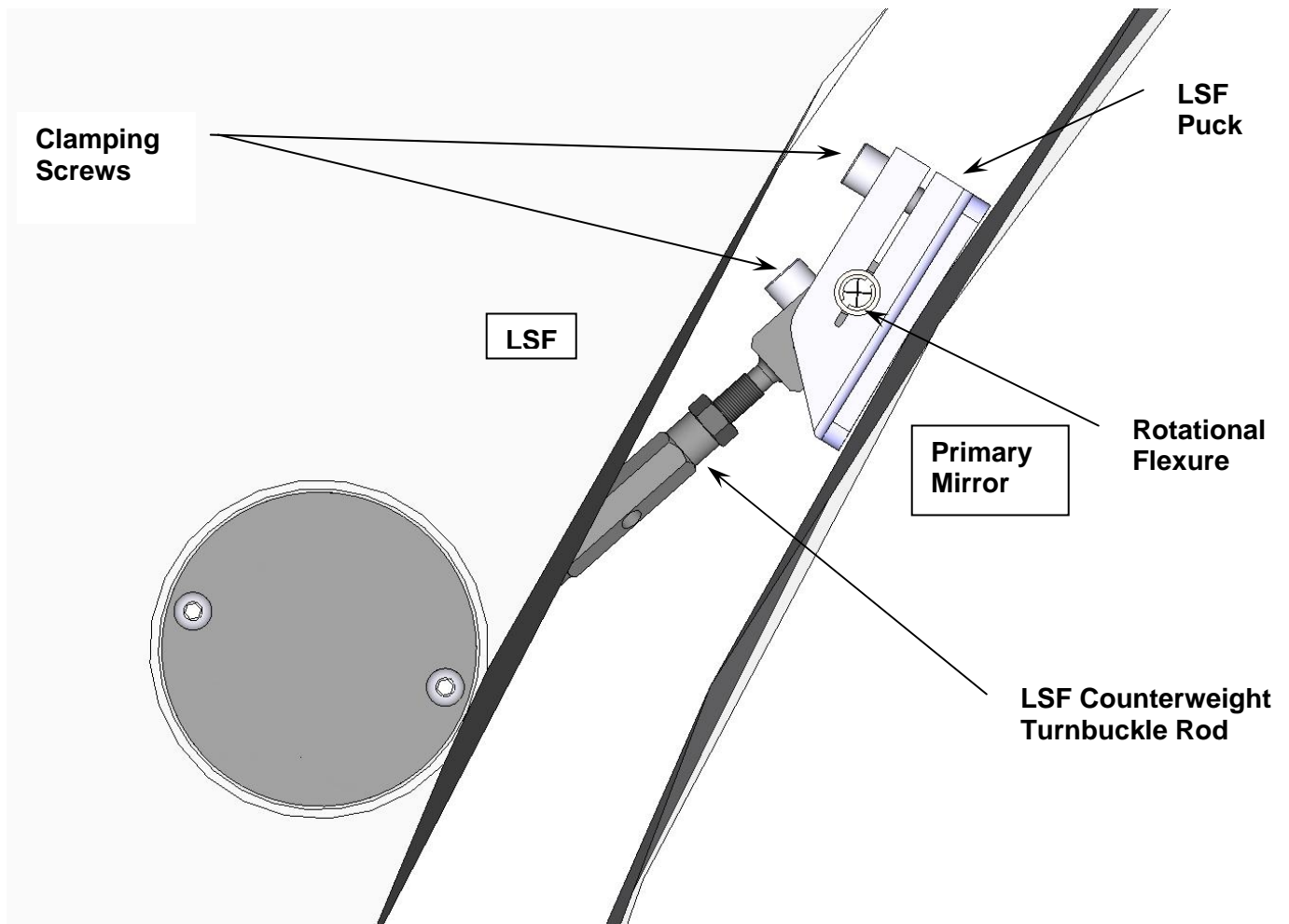


Figure 8 Counterweight Linkage connected to LSF Puck

16. If not already done remove all the COM-5750 "LSF Cover Plate 1".
17. Move the four Seismic Restraints inboard to contact the side of the Primary Mirror, if this has not already been done.
18. To disconnect LSF Counterweight Assembly linkages from LSF Pucks on the Primary Mirror loosen the clamping screws and remove rotational flexures. Store them in a clean dry place.
19. Restrain with tape or other device the LSF Counterweight Assembly linkages so they are held within the LSF by covering the LSF interior ports (openings). This is to prevent interference between the LSF Pucks and the Primary Mirror (or the Primary Mirror itself) during removal of the Primary Mirror. It may be necessary to shorten some of the LSF Counterweight Turnbuckle Rods during this process.
20. Place packing around the LSF Counterweight Assemblies inside the LSF to prevent counterweight assemblies from moving more than a few millimeters. This method is also used to prevent the brass counterweights from contacting the inside surface of the LSF during movement or storage.

Caution: For the safety of the Primary Mirror, the Lateral Support Frame linkages must be mechanically restrained out of the mirror opening.

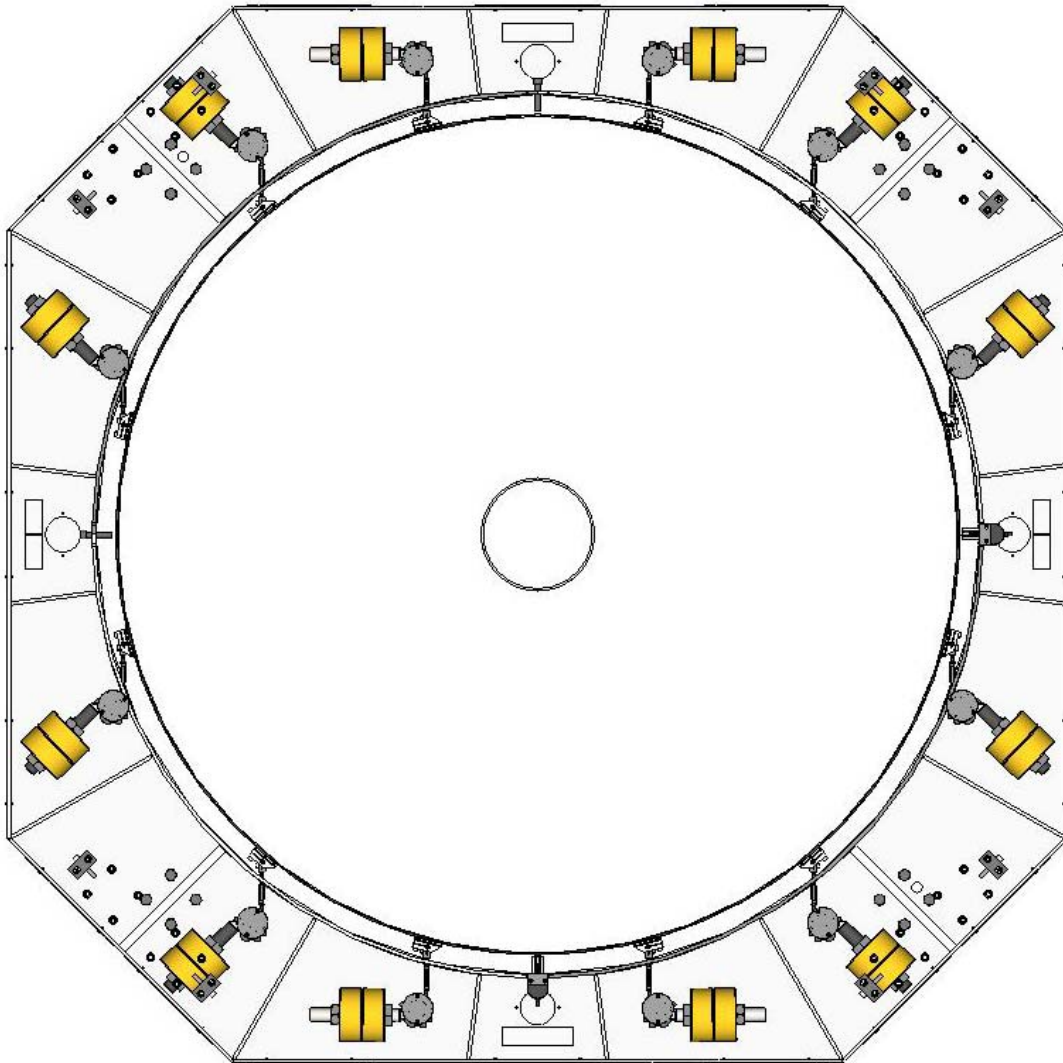


Figure 9 LSF and M1 top view

21. Remove the dial indicators in the LSF by removing the two M4 screws on ASY-5901 "M1 Radial Position Sensor Assembly".

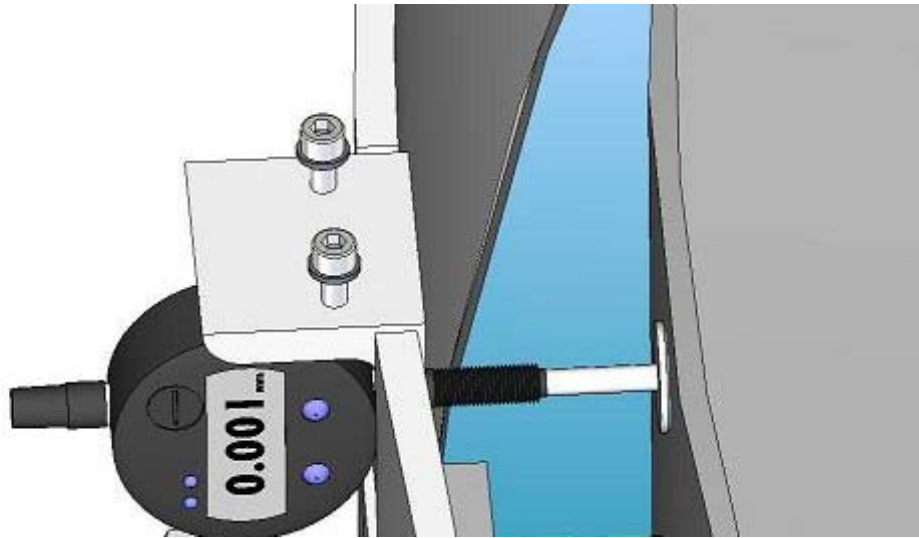


Figure 10 M1 Radial Position Sensor Assembly with top plate on LSF not shown

Caution: The M1 Radial Position Sensor Assembly must be removed from the path of the Primary Mirror before the Primary Mirror can be installed on the LSF/PMC Assembly. If this is not done, damage to the Primary Mirror and the M1 Radial Position Sensor Assembly will result.

22. Read the EOST procedure MPI-12923 "Mirror Removal/Installation Procedure" before moving onto the next step in this procedure. This procedure provides the detail needed to successfully mount or remove the Primary Mirror from its Mirror Cell in regards to the axial and rotational pucks.
23. Disconnect the Primary Mirror from the axial support per EOST procedure MPI-12923 "Mirror Removal /Installation Procedure".
24. Inspect and double check to make sure the Primary Mirror is completely disconnected from the cell.
25. Cover the protected M1 surface with a plastic drop cloth.
26. Place the closed cell foam and plywood cover on the protected M1 surface. Take care not to slide the cover on the surface.
27. Place thin foam around the M3 Tower to ensure that the Primary Mirror cannot contact the metal tower during removal.
28. Rig ASY-11983 "M1 Handling Fixture Assembly" to the crane.

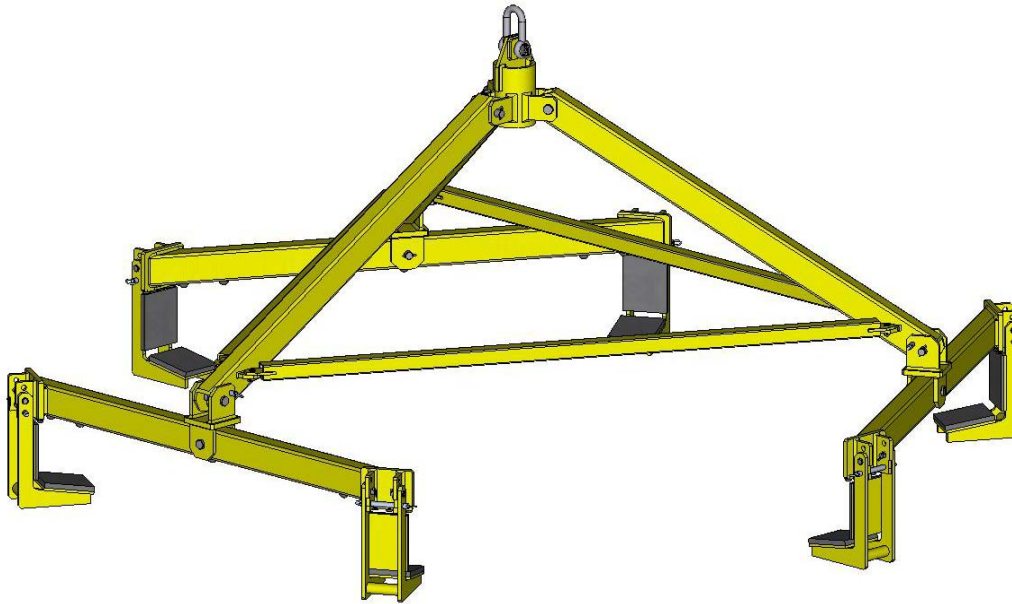


Figure 11 ASY-11983 “M1 Handling Fixture Assembly”

29. Lower the “M1 Handling Fixture Assembly” through the dome slit and remove the six “M1 Lifting Hooks” (COM-11988).
30. Lower the “M1 Handling Fixture Assembly” over the Primary Mirror and determine the proper orientation. The six Lifting Hooks must be clear of the LSF Pucks and any other parts of the M1 support. If this orientation is not already marked, mark it now.

Note: It is critical that the orientation of the M1 Handling Fixture be marked and used for all subsequent lifts. Failure to do so may make it difficult or impossible to reinstall the mirror through the LSF.

31. Insert the six M1 Lifting Hooks from below the Primary Mirror and attach them to the M1 Handling Fixture.
32. Lift the Primary Mirror carefully out through the center of the LSF assembly and attach 2 Tag Lines to the lifting fixture to assist with guiding the assembly during the lift. Make sure that these lines cannot fall onto the surface of the mirror. Toss these tag lines down to the people who will restrain the lateral motion of the assembly during the lift.
33. Lift the M1 Mirror out of the dome slit and set it into the ASY-12194 “M1 Mirror Crate, 2400MM Mirror”.
34. Disconnect and remove the M1 Handling Fixture Assembly from the Primary Mirror.

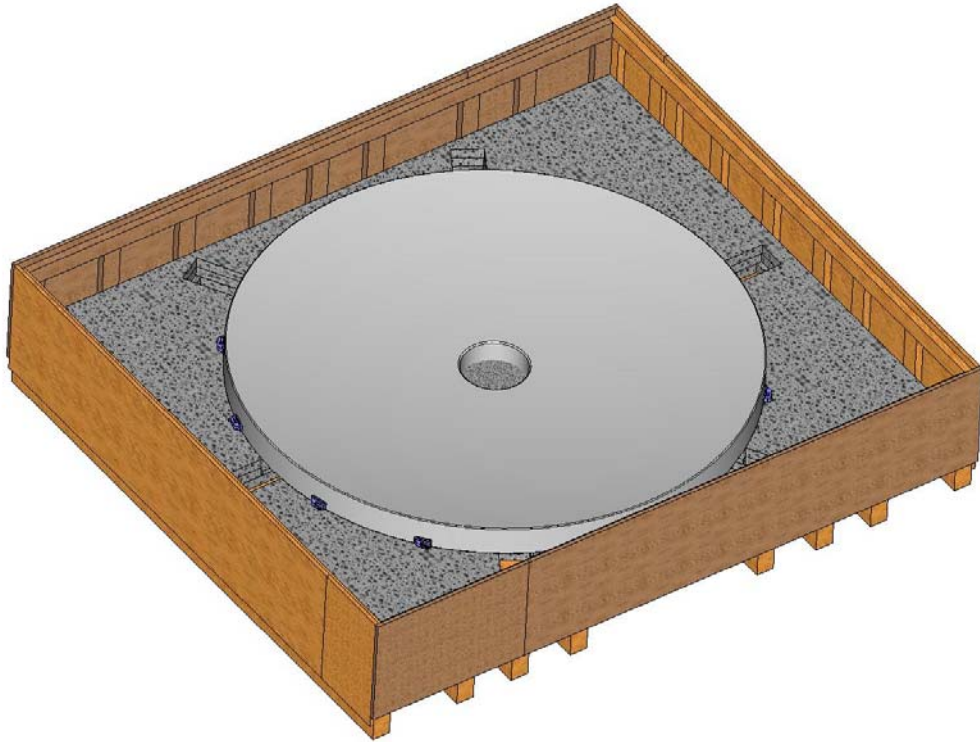


Figure 12 Primary Mirror in its Shipping Crate

35. Pack the Primary Mirror in its crate using EOST Procedure PS-12964 "M1 Mirror Packing Procedure"
36. While packing the Primary Mirror; add any additional protective coating, protective packing, and or desiccant necessary to insure the safety of the Primary Mirror during shipment and or storage. Move the securely packed and checked Primary Mirror from the work area to a safe, dry storage or loading location.

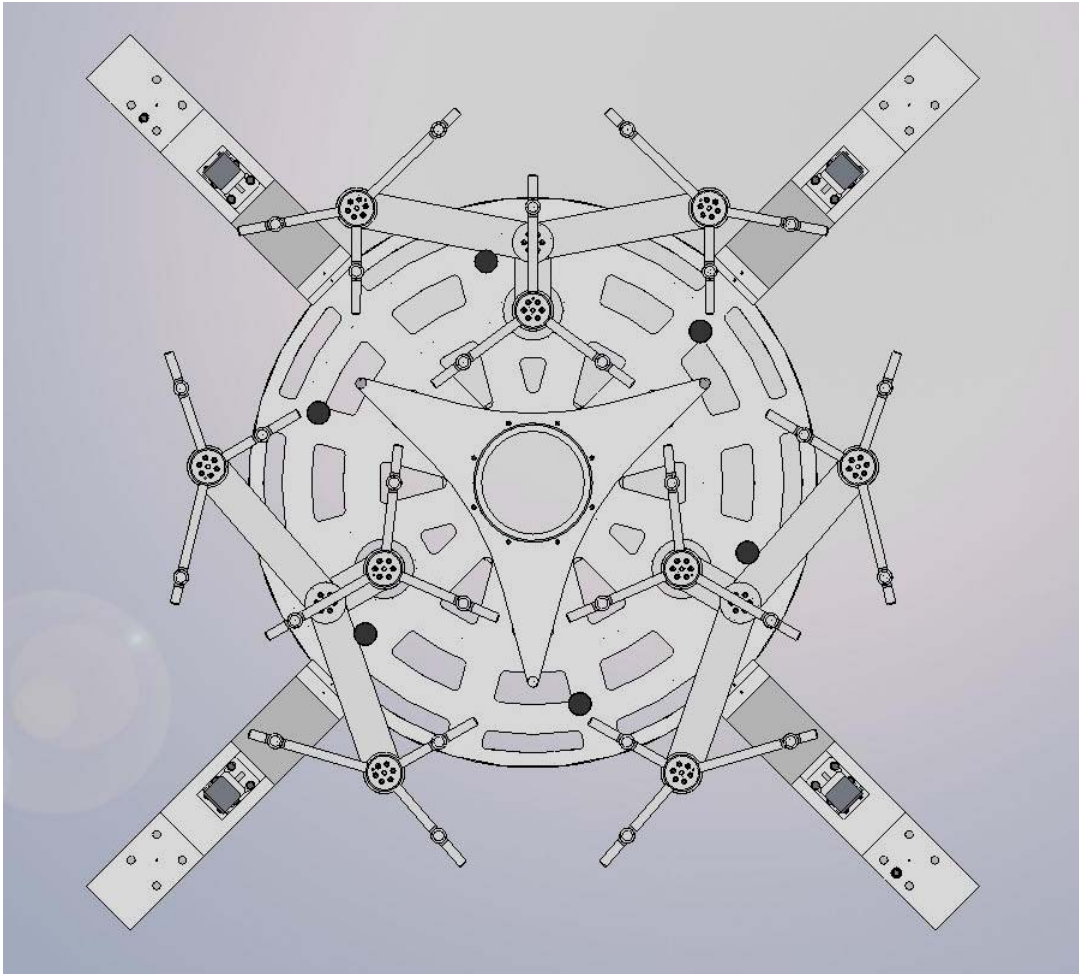


Figure 13 Top View of PMC only

37. Remove the two Dowel Pins from the bottom of the CS that fix the position of the “CS to LSF Brackets” to the CS.
38. Verify the mirror cart jacks are bottomed out.
39. Roll the LSF/PMC/Mirror Cart assembly slowly under the CS on the cart rails until the cart wheels are at or near the Track Stops (rail stops).
40. Align the LSF/PMC/Mirror Cart assembly to the CS as best as possible by eye, making sure all alignment pins are approximately where they need to be, by rolling the cart back and forth to the best overall position.
41. Check for any objects that will be in the way of lifting the LSF/PMC assembly vertically until the top of the COM-5730 “CS to LSF Brackets” contact the bottom of the Center Section. Take extra care to make sure nothing will be in the way of the mirror. If this vertical path is clear, proceed to the next step.
42. Turn the ratcheting crank handle on the Mirror Cart and raise the LSF/PMC assembly up on the mirror cart jacks until one “CS to LSF Bracket” just contacts the bottom of the CS. Stop jacking at this point.
43. Start all the M12 cap screws that join the “CS to LSF Brackets” to the Center Section.

44. Slowly and evenly tighten these fasteners until all four “CS to LSF Brackets” are pulled up tight to the Center Section. Torque these fasteners to 93 Newton-meters or 70 foot-pounds.
45. The Mirror Cart can be left in place with its jacks extended until it is time to install the Primary Mirror. It is obvious at this point that the telescope elevation axis cannot be moved or operated.
46. Prepare the Dome for operation per EOS procedure CI: AI-500879-01 “Mirror Installation & Removal Procedure”. Even though the Dome and telescope may not be operated while the Primary Mirror is removed it is important to restore the weather tightness and operational capability of the Dome.
47. Store lifting fixtures, crate, related hardware, and tooling in a clean, dry, and safe place.

4 INSTALLATION OF PRIMARY MIRROR ASSEMBLY

4.1 SET-UP

CAUTION: Do not lift if wind speed exceeds 15 mph or 24 km/h. If threat of rain, secure a new plastic drop cloth over Primary Mirror with the optical surface properly protected.

1. Prepare a work area or staging area outside the Dome that is within reach of the crane, roughly 30 square meters in total area.
2. Use pallets or timber for holding items off the ground during intermediate staging – to keep the shipping crate covers and lifting fixtures clean.
3. Remove and label (for reinstallation in the same location) all Tube End Trim Weights and Tube End Weights (upper truss trim or balancing weights) if not already done.
4. The telescope should be in the following condition:
 - It should be locked at the zenith position, with the stay pin engaged and the ASY-12362 “EL Hard Stop Assy” fastened to one telescope Fork Tine restraining the Upper Truss from moving.
 - The E-stop Switch nearest the telescope should be depressed. This E-stop switch may have to be reengaged later to move the Dome or for other reasons, but should be depressed when working directly on the telescope.

If any of these conditions are not present correct them at this time.

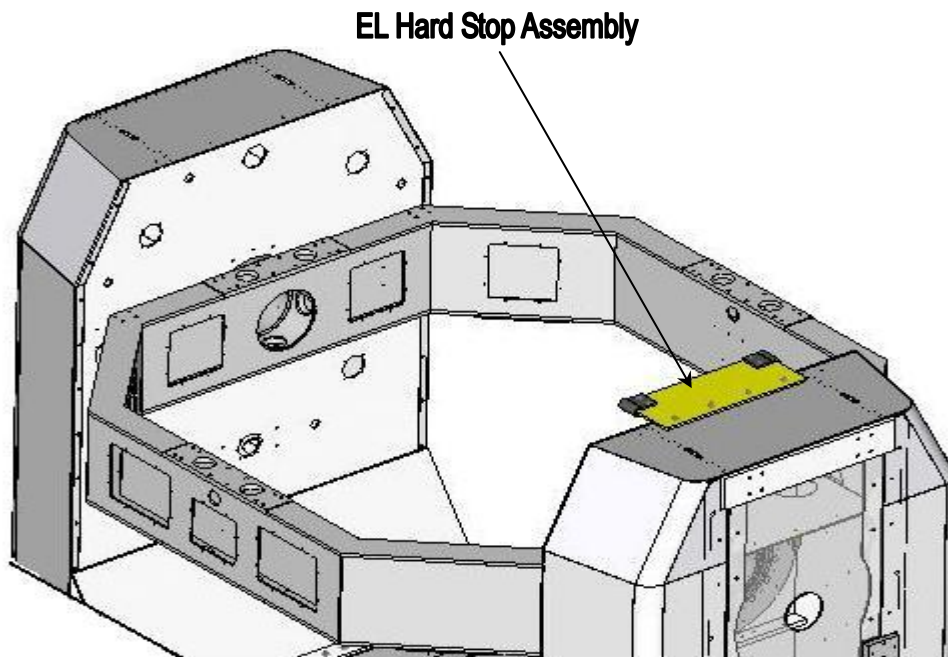


Figure 14 EL Hard Stop Assembly on right Tine

CAUTION: When the Primary Mirror Assembly is removed for any reason, the telescope must be left at the zenith position with the ASY-5797 “Elevation Staypin Bracket Assembly” engaged and ASY-12362 “EL Hard Stop Assy” fastened to the telescope Fork Tine to restrain the Upper Truss and handle the severe out-of-balance condition of the telescope.

The elevation staypin is not designed to prevent injury to personnel or damage to the telescope due to the imbalance of the OSS caused by the removal of the PMA.

5. Rotate the dome slit over the center of service balcony area.
6. Read EOS procedure CI: AI-500879-01 “Mirror Installation & Removal Procedure”.
7. Prepare Dome according to procedure for primary mirror installation.
8. Clean ASY-8555 “M1 Cart Assembly”. Make sure that the telescope is clean above the M1 zone.
9. Rig, lift, and set the Mirror Cart onto M1 Cart Guide Rails if it is not already installed. Casters on Mirror Cart must be turned facing inward or toward each other before setting the Mirror Cart on the rails.

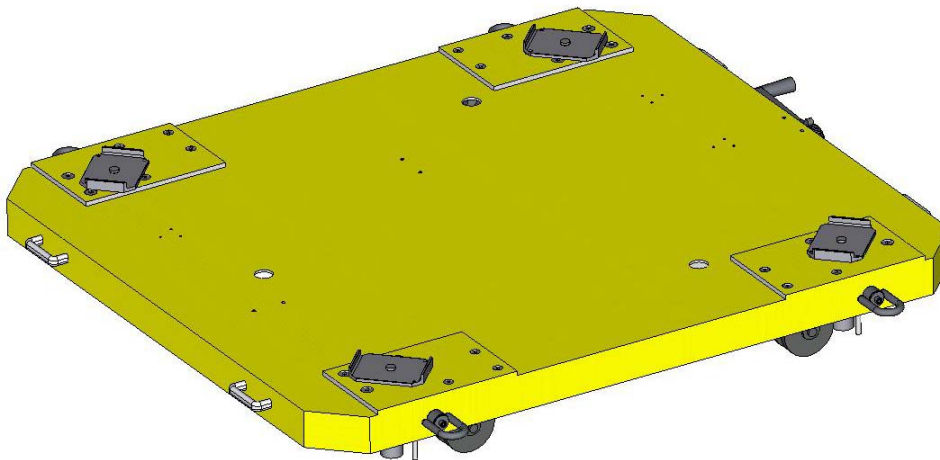


Figure 15 Mirror Cart

10. Install and align mirror cart rails, if not already done.

4.2 PRIMARY MIRROR INSTALLATION

1. Wear a dust mask and powder-free latex gloves when working above or around the surface of the mirror. Remove any jewelry and items from pockets that may fall onto the mirror surface.

2. At this point the LSF should be mounted to the PMC (the mirror is not in the cell) and the Mirror Cart is holding the LSF/PMC up in place in the telescope so that the “CS to LSF Brackets” are bolted to it.

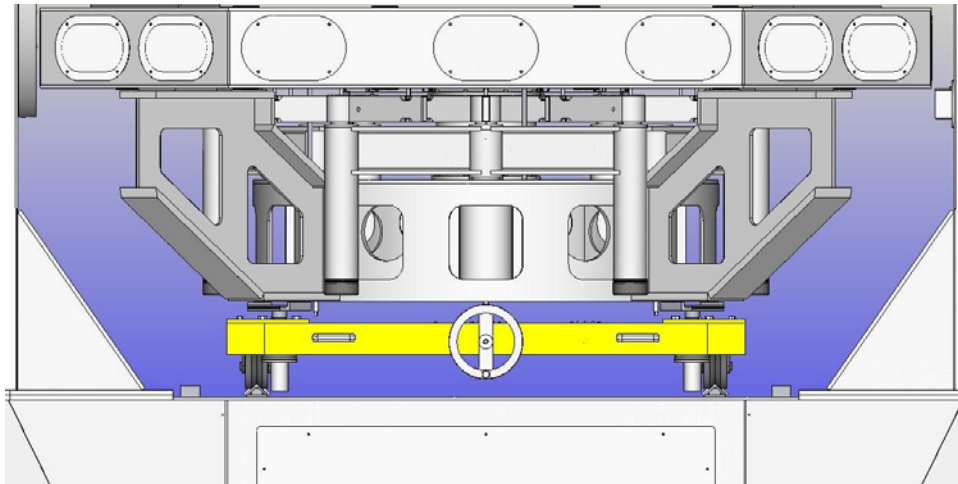


Figure 16 Telescope configuration at start of installation process

3. Note that the LSF/PMA/Mirror Cart assembly includes the four “CS to LSF Brackets”. The four “CS to LSF Brackets” should never be loosened or removed from the LSF.

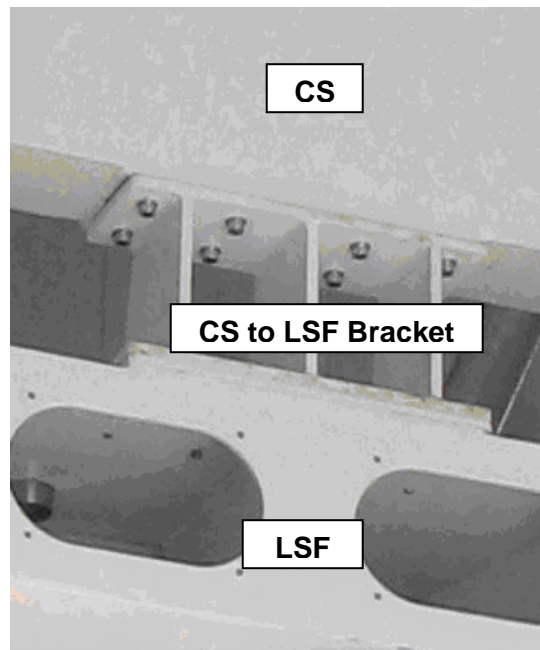


Figure 17 CS to FS Bracket on telescope

4. Remove all the M12 cap screws that join the “CS to LSF Brackets” to the Center Section, if this has not already been done. Move the fasteners away from the Primary Mirror Cell and out of the way.

5. Turn the ratcheting crank handle on the Mirror Cart to lower LSF/PMC assembly on the mirror cart jacks until the jacks bottom out. The jacks on the Mirror Cart must be fully retracted.
6. Roll the Mirror Cart, with the LSF/PMC assembly on, it out until it clears the CS.
7. Roll the LSF/PMC/Mirror Cart assembly to the lift point on the M1 Cart Guide Rails.

Caution: Clearance must always be provided for the COM-5314 “Loadspreader Assembly Counterbalance Rod”. If the PMA or PMC is rested on the Counterbalance Rods severe damage to the PMA, PMC or Primary Mirror could result.

The Mirror Cart does provide clearance for the Loadspreader Assembly Counterbalance Rods on a flat and level surface such as a shop floor. When using this method with site conditions care must be taken to make sure no debris or other matter invades this clearance space.

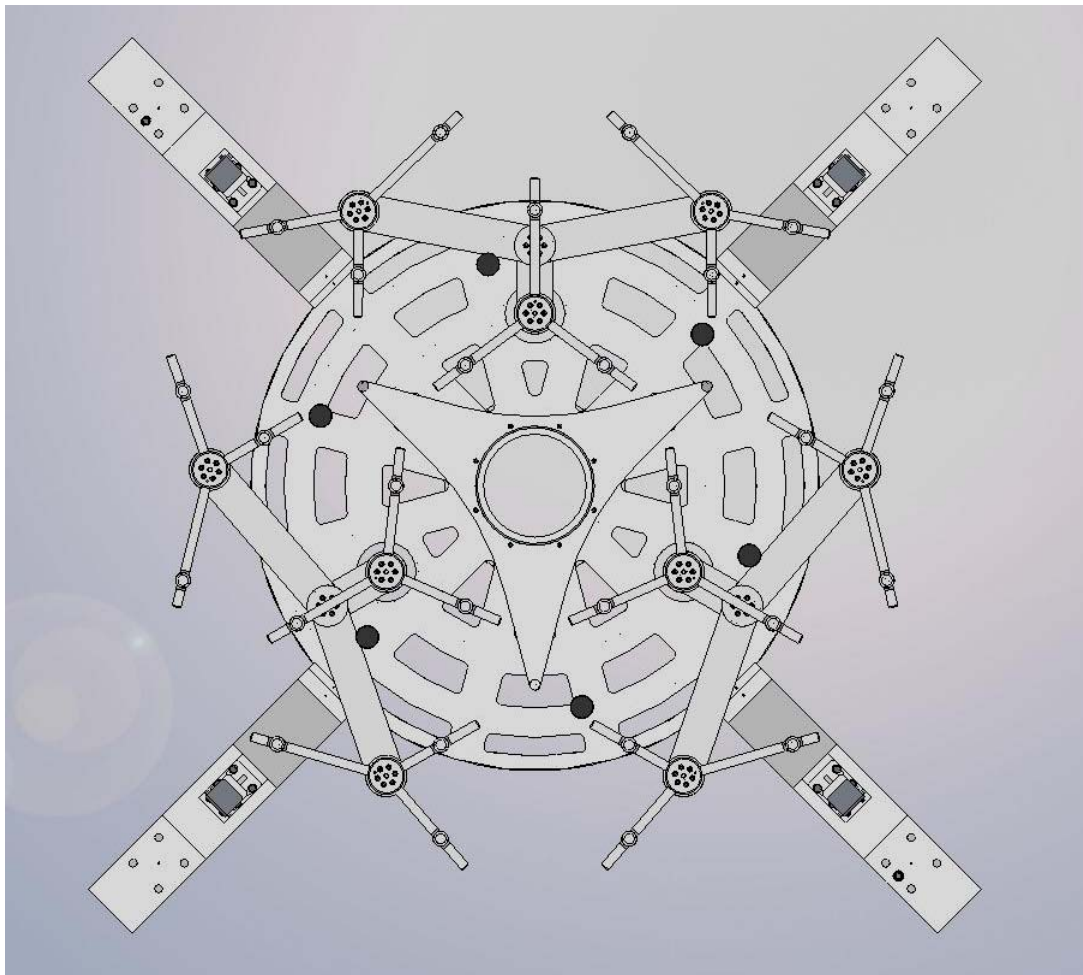


Figure 18 Top View of PMC only

8. Get the ASY-12194 “M1 Mirror Crate, 2400MM Mirror” (Primary Mirror Crate, with the mirror in it) ready for installation.
9. If not already done, remove all the COM-5750 “LSF Cover Plate 1” from the LSF assembly.
10. Make sure the linkages on the LSF Counter Weight Assemblies are restrained inside the LSF so they cannot contact the Primary Mirror or LSF Pucks.

Caution: For the safety of the Primary Mirror the Lateral Support Frame linkages must be mechanically restrained out of the mirror opening.

If this is not done correctly damage to the Primary Mirror and LSF Counter Weight Assemblies will result.

11. If not already done, remove the dial indicators in the LSF by removing the two M4 screws on ASY-5901 “M1 Radial Position Sensor Assembly”.

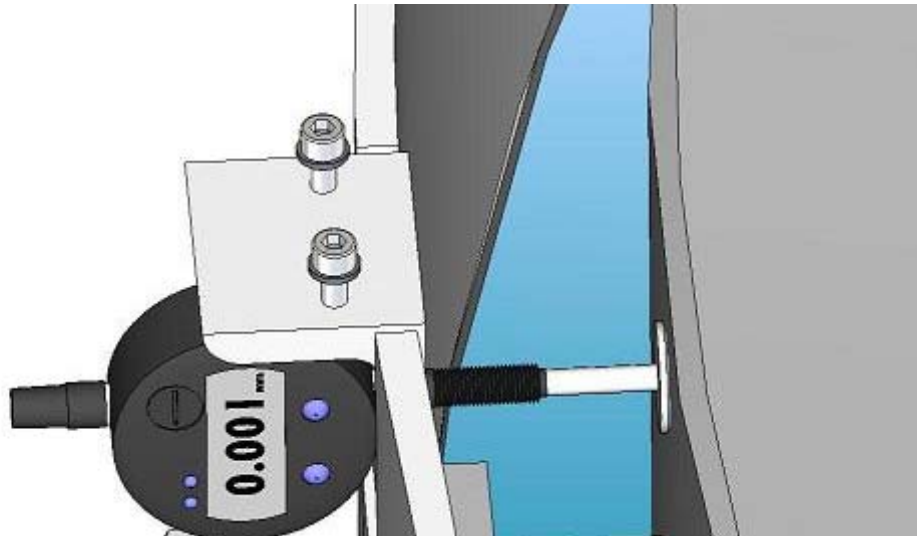


Figure 19 M1 Radial Position Sensor Assembly with top plate on LSF not shown

Caution: The M1 Radial Position Sensor Assembly must be removed from the path of the Primary Mirror before the Primary Mirror can be installed on the LSF/PMC Assembly. If this is not done, damage to the Primary Mirror and the M1 Radial Position Sensor Assembly will result.

12. Unpack the Primary Mirror.

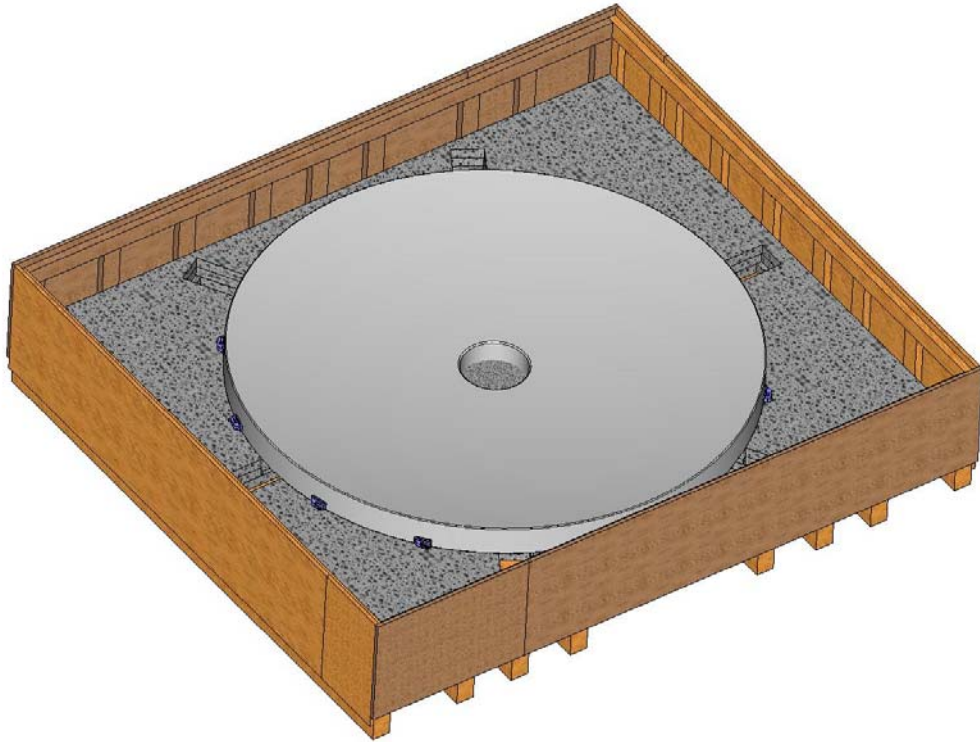


Figure 20 Primary Mirror in its Shipping Crate

13. Apply a protective coating product to the optical surface of the mirror and allow it to dry according to the manufacturers recommendations (i.e. Universal Photonics Pre-Cote #33 Blue). Applying multiple coats may simplify the removal process.
14. Check the orientation of the Primary Mirror to the PMC; temporarily mark the orientation to each other in a highly visible manner if needed.
15. Remove the four COM-5869 “SR Bracket 3” and set them aside away from the Primary Mirror and PMC.



Figure 21 Seismic Restraint with COM-5869 “SR Bracket 3” removed

16. If it is positively known that the Seismic Restraints have been specifically adjusted to assist in relocation of the Primary Mirror to the Primary Mirror Cell as in EOST procedure MPI-12923 "Mirror Removal /Installation Procedure" proceed to step 18 of this section. If there is any question as to the condition of the Seismic Restraints proceed to step 17 of this section.
17. Check that seismic restraint mounting fasteners have been loosened and slide the Seismic Restraints as far away from the mounted location of the Primary Mirror as possible (move them out away from center).
18. Read the EOST procedure MPI-12923 "Mirror Removal /Installation Procedure" before moving onto the next step in this procedure. This procedure provides the detail needed to successfully mount or remove the Primary Mirror from its Mirror Cell in regards to the axial and rotational pucks. Assembly and disassembly of the lateral support system from the Primary Mirror is covered later in this procedure.
19. Cover the protected M1 surface with a plastic drop cloth.
20. Place the closed cell foam and plywood cover on the protected M1 surface. Take care not to slide the cover on the surface.
21. Place thin foam around the M3 Tower to ensure that the Primary Mirror cannot contact the metal tower during installation.
22. Lift the Primary Mirror out of its crate with ASY-11983 "M1 Handling Fixture Assembly". Verify that the orientation of the M1 Handling Fixture to the Primary Mirror matches the alignment marks that were made during the removal process.
23. Attach 2 Tag Lines to the lifting fixture to assist with guiding the assembly during the lift. Make sure that these lines cannot fall onto the surface of the mirror.

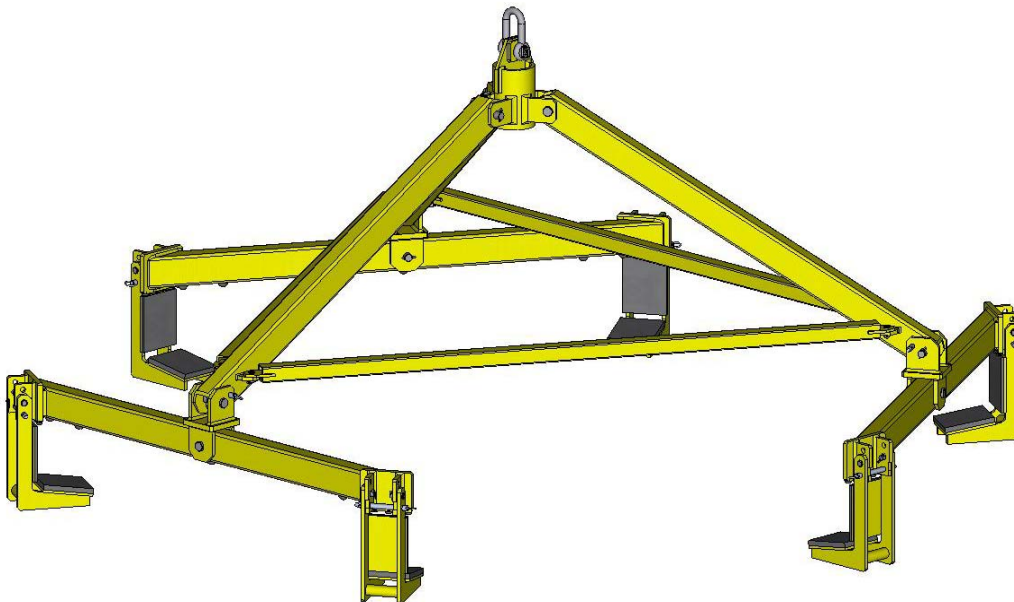


Figure 22 ASY-11983 "M1 Handling Fixture Assembly"

24. Using the tag lines to restrain the lateral motion of the assembly, lift the Primary Mirror through the dome slit and into position above the Mirror Support.
25. Lower the Primary Mirror carefully into the center of the LSF and onto the PMC. Use spotters to keep the Primary Mirror from bumping into anything.
26. Install and fasten the Primary Mirror onto the PMC per EOST procedure MPI-12923 "Mirror Removal /Installation Procedure".
27. After the Primary Mirror is installed carefully remove the six M1 Lifting Hooks from the "M1 Handling Fixture Assembly" and move it away from your work area.

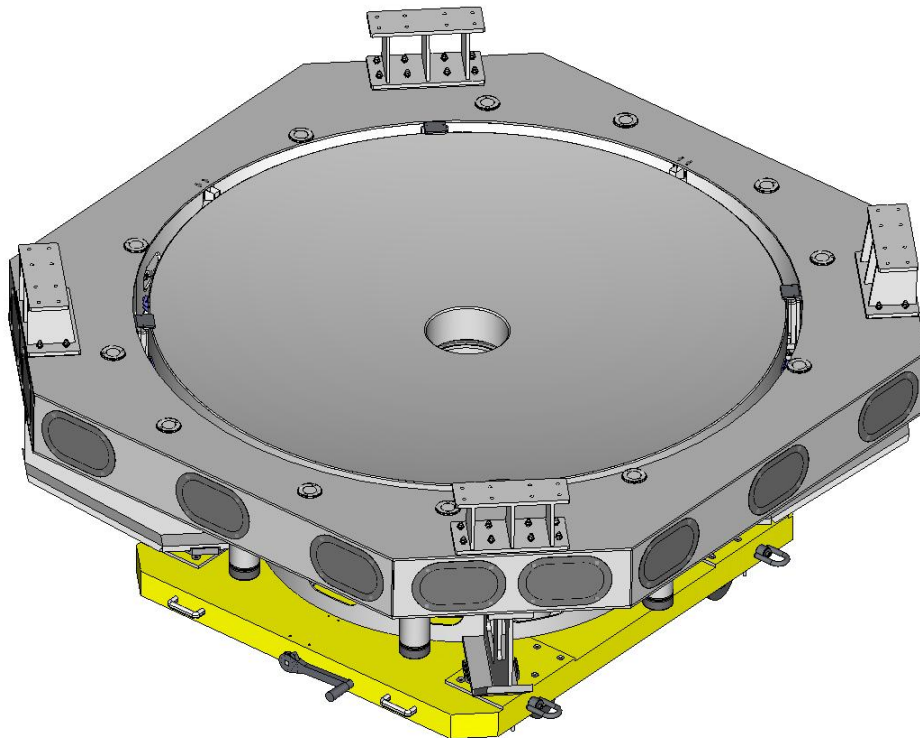


Figure 23 LSF/PMA/Mirror Cart Assembly

28. Check that Seismic Restraints are contacting the side of the Primary Mirror and their fasteners are tightened holding Seismic Restraints in place.
29. Connect the LSF Counterweight Assembly linkages to the LSF Pucks on the Primary Mirror by executing the following steps:

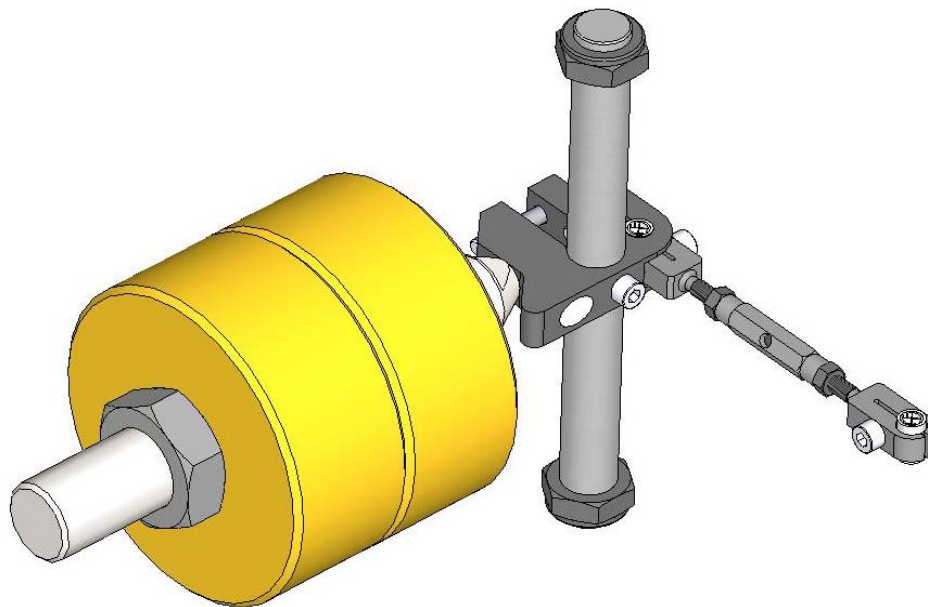


Figure 24 LSF Counterweight and Linkage Assembly

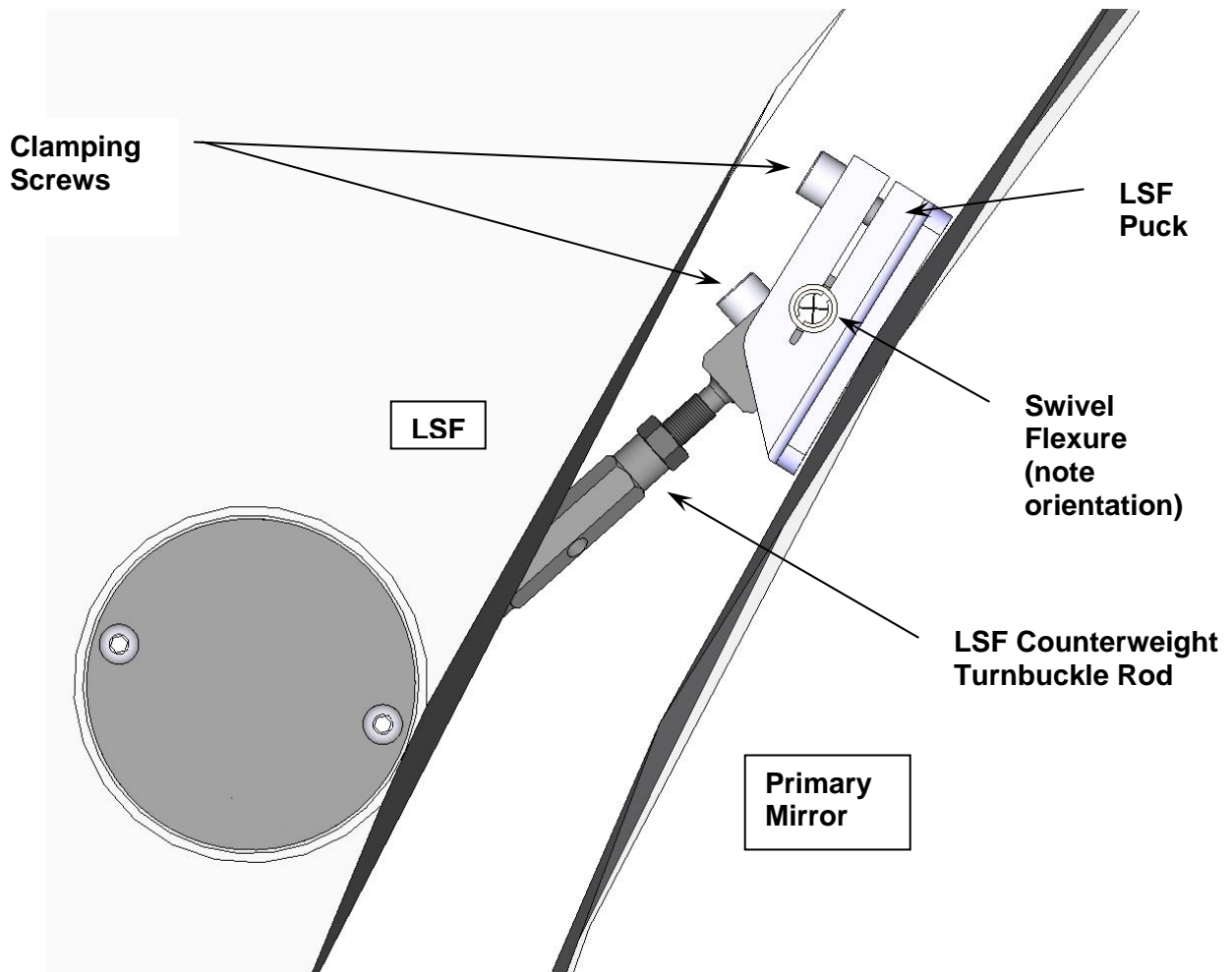


Figure 25 LSF Counterweight Assembly Linkage connected to LSF Puck

30. Remove any packing material inside LSF around counterweight assemblies, to allow free movement.
31. Remove any tape (or other device) holding LSF Counterweight Assembly linkages restrained inside the LSF.
32. Swing counterweight linkage arm out to align the hole in the “LSF Counterweight Pusher Rod Clamp” with the Swivel Flexure hole in the LSF Puck.

Caution: In the next steps you will be working very close to the Primary Mirror with tools. Keep all tools below the level of the optical surface of the mirror so that if dropped they fall onto the ground and not the Primary Mirror.

33. Insert Swivel Flexure into hole and tighten the clamping screws the minimum amount to keep the Swivel Flexure from falling out.
34. Orient the swivel flexure such that the internal flexures are each 45 degrees from the direction of the turnbuckle arm.

35. Using a T-Square (and 45 degree angle block where necessary) set the orientation of each brass counterweight relative to the outside of the LSF by adjusting the length of the differential turnbuckles. See Figure 26.

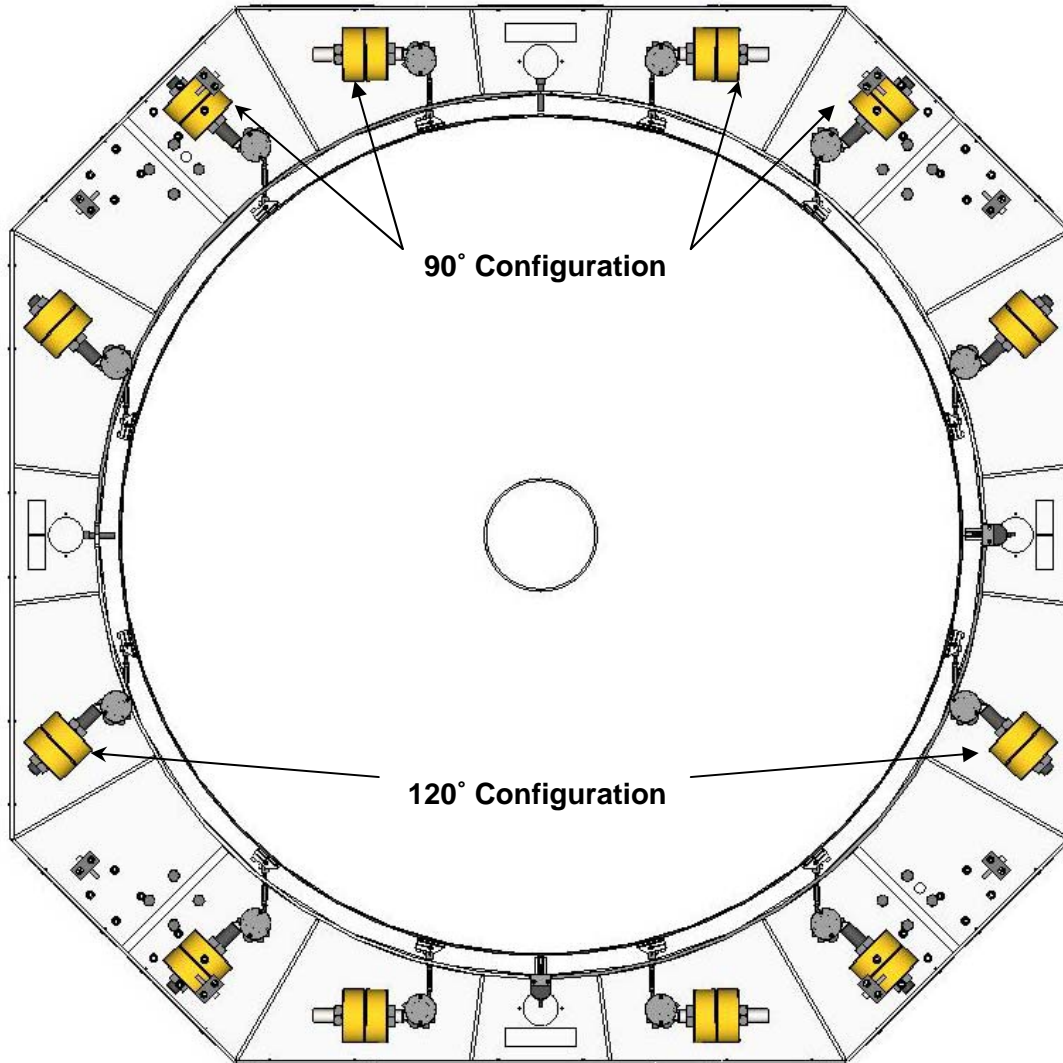


Figure 26 LSF Counterweight Configuration

36. Tighten the locking nuts on each side of the turnbuckle.
37. While resisting the torque with a 20 mm open-end wrench on the solid and inboard part or the LSF Puck; tighten clamping screws to 25 Nm or 18 ft-lbs.
38. Repeat steps 33 through 37 for each of the 12 lateral support points.
39. Re-install the four COM-5869 "SR Bracket 3" onto the ASY-5866 "Seismic Restraint" assemblies. There must be substantial clearance between the four COM-5869 "SR Bracket 3" and the Primary Mirror.
40. Move the ASY-5866 "Seismic Restraint" assemblies up against the side and bottom surface of the Primary Mirror. Only the neoprene pads COM-5871 "SR Pad 2" and COM-

5870 “SR Pad 1” on COM-5868 “SR Bracket 2” should contact the mirror. There should be a visible gap between all four COM-5869 “SR Bracket 3” and the Primary Mirror and no part of this assembly should ever touch the optical surface. The purpose of this assembly (while PMA is in transit) is to minimize or stop lateral movement of the Primary Mirror; so placing the Seismic Restraints firmly against the sides of the mirror is critical, but if there is a small gap between COM-5870 “SR Pad 1” and the bottom of the Primary Mirror; it is acceptable.

41. Note and mark if needed the LSF/PMA/Mirror Cart assembly based on the orientation the LSF/PMA and “CS to FS Brackets” needed to bolt up to the CS.
42. If necessary, or not already done install all the COM-5750 “LSF Cover Plate 1”.
43. Roll the LSF/PMA/Mirror Cart assembly on the M1 Cart Guide Rails slowly into the Dome. Stop when the LSF/PMA/Mirror Cart assembly is inside the Dome but not under (or very far under) the CS.

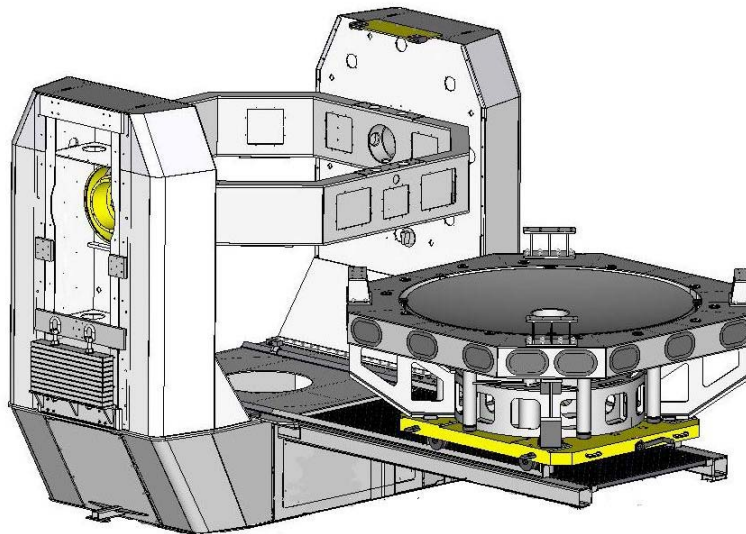


Figure 27 LSF/PMA/Mirror Cart assembly is inside the Dome on rails

44. Close the Dome, if you are not able to close the Dome make it as weather tight as reasonably possible.
45. Move the SR Brackets back and down so there is a 1/16 to 1/8 inch gap between them and the side of the mirror and the same size gap or larger is at the bottom of the mirror. There should also be space between the four COM-5869 “SR Bracket 3” and the Primary Mirror. The purpose of this assembly (during telescope operation) is to keep the Primary Mirror on the mount in the case of a Seismic or other catastrophic incident.

Note: Remember that Seismic Restraints are safety devices and cannot be touching the Primary Mirror for operation; but they must be touching (restraining) the Primary Mirror during shipment/installation/removal.

They are specifically designed not to touch the optical surface of the Primary Mirror.

46. Verify that the PMA, Seismic Restraints, and LSF assembly hardware is in proper position and properly tightened.
47. Remove the protective covering from the Primary Mirror. When removing the mirror protection, lift it straight up being careful not to drag it across the mirror.
48. Roll the Mirror Cart slowly under the CS on the car rails until the cart wheels are at or near the Track Stops (rail stops).
49. Align the LSF/PMA/Mirror Cart assembly to the CS as well as possible by eye making sure all alignment pins are approximately where they need to be, by rolling the cart back and forth to the best overall position.
50. Check for any objects that will be in the way of lifting the LSF/PMA assembly vertically until the top of the COM-5730 "CS to LSF Brackets" contact the bottom of the Center Section. Take extra care to make sure nothing will be in the way of the mirror.
51. Turn the ratcheting crank handle on the Mirror Cart and raise the LSF/PMA assembly up on the mirror cart jacks until one "CS to LSF Bracket" just contacts the bottom of the CS. Stop jacking at this point.
52. Note that at this point you will be working very close to and above the level of the Primary Mirror.
53. Start all the M12 cap screws that join the "CS to LSF Brackets" to the Center Section, if not already done.
54. Slowly and evenly tighten the M12 cap screws until all four "CS to LSF Brackets" are pulled up close to the Center Section. Insert the two Dowel Pins that fix the position of the "CS to LSF Brackets" to the Center Section.
55. Slowly and evenly tighten the M12 cap screws until all four "CS to LSF Brackets" are pulled up tight to the Center Section. Torque these fasteners to 93 Newton-meters or 70 foot-pounds.
56. Lower the jacks on the cart until they bottom out, and remove Mirror Cart from telescope. Remove the Mirror Cart from the Dome if needed.
57. Prepare the Dome for operation per EOS procedure CI: AI-500879-01 "Mirror Installation & Removal Procedure".
58. Balance the telescope using the procedure in the APF Telescope Maintenance Manual (MM-12920). Never assume the telescope is balanced or bottom heavy until it has been proven that is the case.
59. Re-assemble "M1 Mirror Crate, 2400MM Mirror" for storage.
60. Store Mirror Cart, lifting fixtures, crate, related hardware, and tooling in a clean, dry, and safe place.