

Controlled Document
Confirm revision before using



2.4m Telescope

Passive Primary Mirror Assembly

Mirror Removal/Installation Procedure

MPI-12923-1

This document and enclosed information is the property of EOS Technologies, Inc. The information contained herein is confidential and cannot be used for commercial or any other purposes. This document may not be copied nor disclosed without prior written approval of EOS Technologies, Inc.

DOCUMENT CONTROL

© 2007 EOS Technologies, Inc., Tucson, AZ, USA

This document and enclosed information remains the property of EOS Technologies, Inc. Information herein may not be copied nor disclosed without written consent of EOST Management.

Issue: 1

Prepared:	Vincent Blair	Date:	11/8/2007
Checked:	Kerry Gonzales	Date:	11/8/2007
Approved:	Gordon J. Pentland	Date:	11/8/2007
Configured:	Edith Hatch	Date:	11/8/2007

Document Revisions

Issue	Date	Description	Prep	Chk	Appr
1	11/8/2007	Initial Release	VLB	KG	GJP

TABLE OF CONTENTS

1	INTRODUCTION	5
1.1	SCOPE.....	5
1.2	CONFIGURATION	5
1.3	REFERENCES.....	5
2	TOOL LIST	6
3	HANDLING PRECAUTIONS.....	7
4	MIRROR REMOVAL PROCEDURE	9
5	MIRROR INSTALLATION PROCEDURE	21

List of Figures

Figure 3-1	PMA, or Support with mirror.....	7
Figure 3-2	Top view of Support with mirror removed.....	8
Figure 4-1	Example of lifting device shown with tissue, foam and plywood for protecting mirror	9
Figure 4-2	Support with mirror and lifting device.....	9
Figure 4-3	Seismic Restraint with SR Bracket 3 removed	10
Figure 4-4	One of four Seismic Restraints with 3 mm gap from side of mirror	10
Figure 4-5	Foam Blocks	11
Figure 4-6	Foam Blocks installed under Main Loadspreader Assembly	11
Figure 4-7	location of a Noodle Flexure Clamp assembly labeled “L”	12
Figure 4-8	location of a Noodle Flexure Clamp assembly labeled “V”	12
Figure 4-9	Noodle Flexure Clamp assembly installed.....	12
Figure 4-10	Noodle Flexure Clamp assembly “H” removed and disassembled	13
Figure 4-11	temporary fiducial marks on the side of the mirror.....	13
Figure 4-12	notice temporary fiducial marks above Seismic Restraint on side of mirror .	13
Figure 4-13	1 of 3 Rotational Restraint Flexure assemblies	14
Figure 4-14	axial Invar Puck permanently bonded to mirror	14
Figure 4-15	M1 Rotational Restraint Puck Bonded to mirror.....	14
Figure 4-16	jacking screw with the swivel feet padded with neoprene rubber	15
Figure 4-17	jacking screw finger tight against mirror	15
Figure 4-18	Noodle Flexure Clamp assembly “H” disassembled.....	16
Figure 4-19	Disassembling Noodle Flexure Clamp assembly	16
Figure 4-20	arrow indicates 1 of 3 M1 Rotational Anchor Pucks	17
Figure 4-21	arrow indicates location of 1 of 3, M6 x 1.0 x 12 long stainless steel FHCS...	17
Figure 4-22	M1 Rotational Restraint Flexure Plate	17
Figure 4-23	shows 1 of 27 axial Invar Pucks mechanically disconnected from Noodle Flexure Assembly by removal of Noodle Flexure Clamp assembly.....	18
Figure 4-24	shows 1 of 3 M1 Rotational Restraint Flexure assemblies mechanically disconnected from M1 Rotational Restraint Flexure Plate by removal of M1 Rotational Restraint Anchor Puck	18

Figure 4-25 screw jack, with the swivel foot, padded with neoprene rubber	19
Figure 4-26 mirror ready to be lifted off of Support.....	19
Figure 4-27 temporary marks to show indexing of mirror or placement of lifting device..	20
Figure 4-28 arrow indicates 1 of 4 M4 x 0.7 x 10 mm long SHCS mounting M1 Rotational Restraint Puck Flexures to M1 Rotational Restraint Pucks	20
Figure 5-1 temporary fiducial marked on edge of mirror to mark a lifting device or Seismic Restraint location	21
Figure 5-2 temporary fiducial aligned with Seismic Restraint.....	21
Figure 5-3 Seismic Restraint with SR Bracket 3 removed	22
Figure 5-4 1 of 4, M4 x 0.7 x 10 mm long SHCS that mount the M1 Rotational Restraint Puck Flexures to the three M1 Rotational Restraint Pucks	22
Figure 5-5 mirror being set onto Support.....	23
Figure 5-6 temporary fiducials aligned with Seismic Restraint.....	23
Figure 5-7 mirror lowered onto screw jack.....	24
Figure 5-8 sphere of axial Noodle Flexure Assembly engaged into cone of axial Invar Puck, 1 of 27 places.....	25
Figure 5-9 1 of 3 M1 Rotational Restraint Anchor Pucks assembled to M1 Rotational Restraint Flexure Plate and M1 Rotational Restraint Puck Flexure	26
Figure 5-10 Noodle Flexure Clamp assembly stamped “H”	27
Figure 5-11 location of Noodle Flexure Clamp assembly marked “L” on Support.....	27
Figure 5-12 Noodle Flexure Clamp Pad	28
Figure 5-13 side section view of Noodle Flexure Assembly, fully assembled	28
Figure 5-14 gap on Flexure Clamp assembly is nearly symmetrical and in an acceptable condition	29
Figure 5-15 torquing Flexure Clamp assemblies	29
Figure 5-16 check for minimum clearance between arrows all the way around Noodle Flexures with 0.8 mm or larger diameter wire	30
Figure 5-17 mirror installed on Support	31
Figure 5-18 another view of mirror installed on Support	32

List of Tables

Table 1 Abbreviations.....	5
Table 2 Parts and Tools List	6
Table 3 Fastener Torque Table	29

2.4 M

PASSIVE PRIMARY MIRROR ASSEMBLY MIRROR REMOVAL/INSTALLATION PROCEDURE

1 INTRODUCTION

Please read and understand this entire document before beginning work. This process by its nature requires that it be done correctly the first time, and done only when necessary. It is a realistic expectation that this procedure will have to be modified by practice for different locations, lifting equipment, and working conditions.

1.1 SCOPE

This document describes the procedure that should be followed in order to remove and replace the 2.4-meter primary mirror from the primary mirror passive mount.

1.2 CONFIGURATION

This document has been configured as **MPI-12912-1** 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:

- Abbreviations and Nomenclature:

Table 1 Abbreviations

Abbreviation	Item
PMA	Primary Mirror Assembly (mirror and support or cell and related parts thereof)
Support	Primary Mirror Support
mirror	Primary Mirror, M1
SHCS	Socket Head Cap Screw
FHCS	Flat Head Cap Screw

2 TOOL LIST

Locate the components necessary to complete the bonding process, these are listed below.

Table 2 Parts and Tools List

Item	Quantity
protective mirror cover	1
level	1
ASY-9854 M1 Support Assembly – fully assembled w/mirror	1
hex wrench set, T-handle metric	1
hex wrench set, driver handle metric	1
hex wrench set, L - handle metric	1
3/8 inch drive ratchet	1
3/8 inch drive torque wrench (in inch pounds)	1
4 mm hex socket 3/8 drive	1
19 mm combination wrench	1
3/8 inch drive long extension	1
3/8 inch drive short extension	1
dust masks	as required
surgical gloves, latex, powder free	as required

3 HANDLING PRECAUTIONS

During the procedures detailed in this document, care must be exercised to avoid damage to Primary Mirror Assembly components. The following minimum guidelines should be followed to protect the optic and support hardware.

- (1) Remove all objects that could fall from pockets when working close to optics.
- (2) Wear gloves and a face mask when close to or when handling polished optical elements.
- (3) Secure the work area from main traffic areas, using caution tape or similar barrier.
- (4) Remove all tools not in use from the optics area.
- (5) Cover and protect optics when not in use.
- (6) Take extra care during any movement or lifting of mirror and or Support, even if damage to the Mirror is prevented or avoided, damage to the many flexures in the Support could occur.

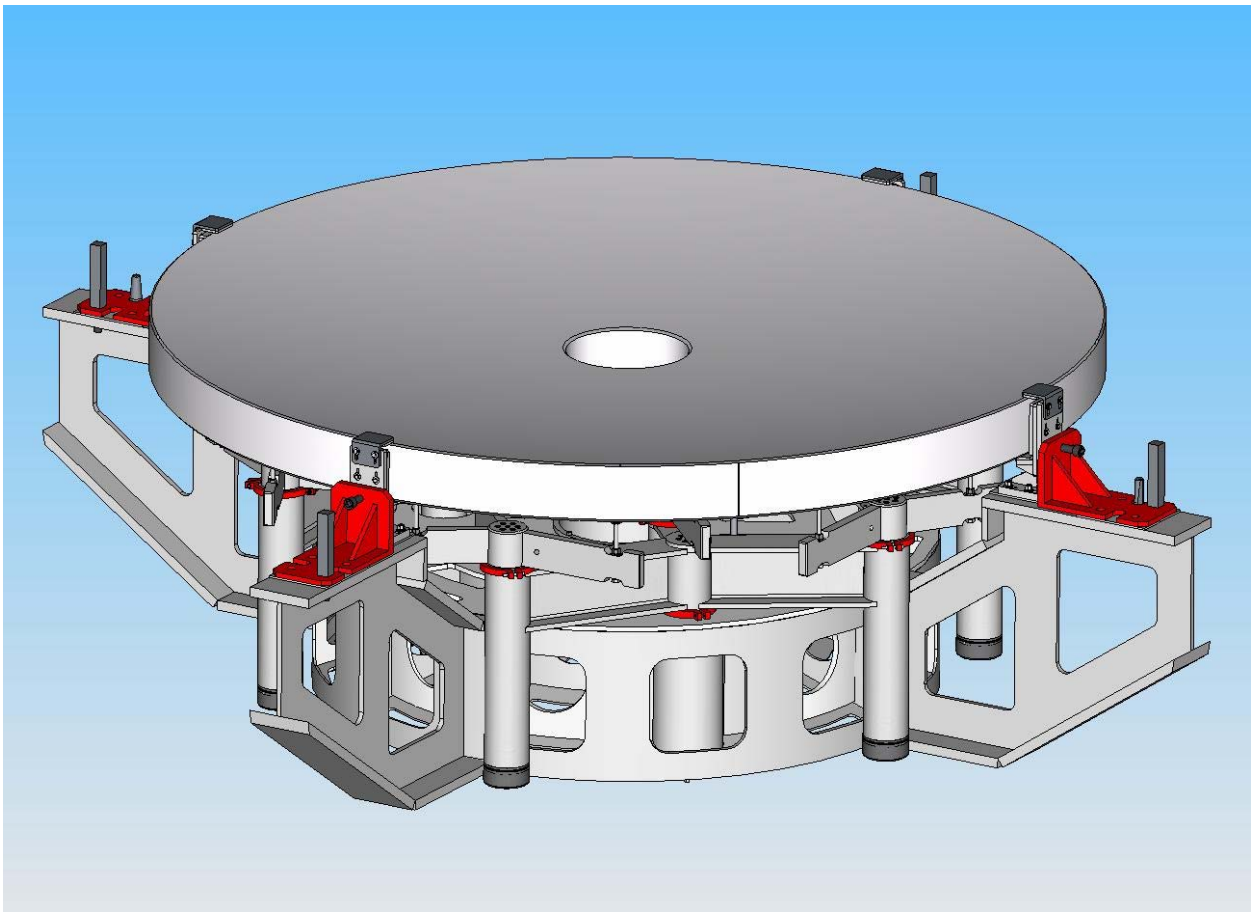


Figure 3-1 PMA, or Support with mirror

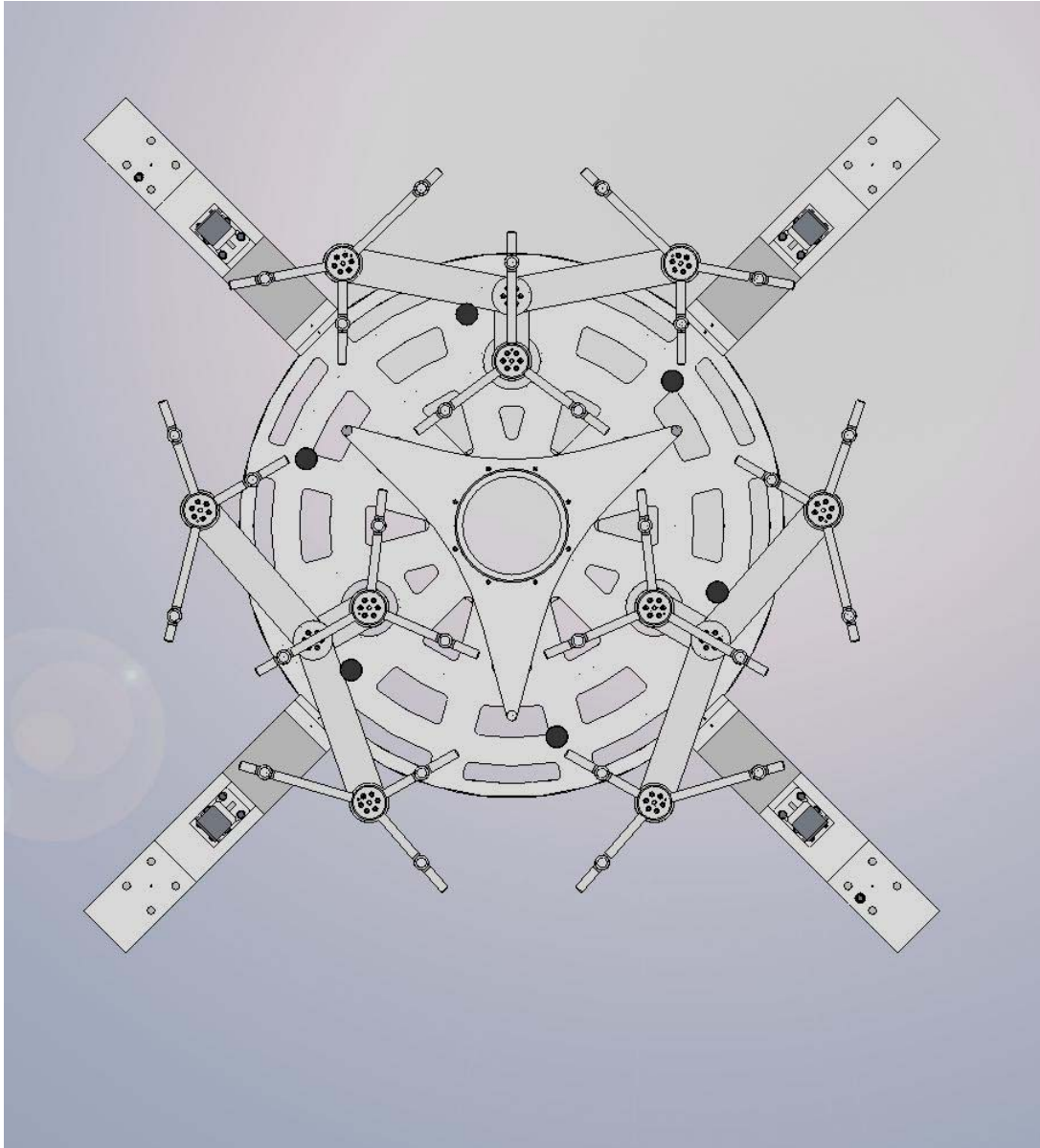


Figure 3-2 Top view of Support with mirror removed

4 MIRROR REMOVAL PROCEDURE

- (7) Cover the mirror with a suitable protective covering that will function with the primary mirror lifting device you are using.



Figure 4-1 Example of lifting device shown with tissue, foam and plywood for protecting mirror

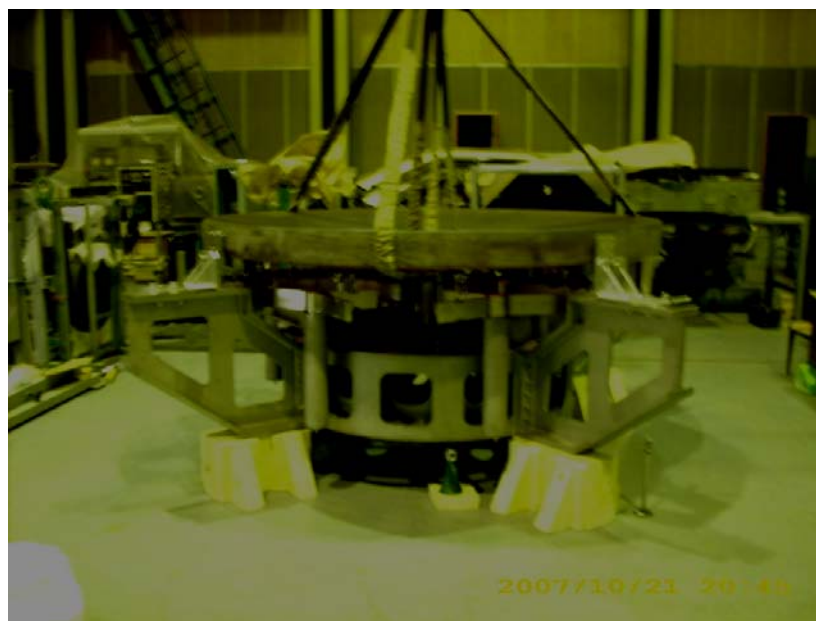


Figure 4-2 Support with mirror and lifting device

- (8) The tops of the Seismic Restraints COM-9874 SR Bracket 3 need to be removed if they have not already been removed.



Figure 4-3 Seismic Restraint with SR Bracket 3 removed

- (9) Set the four Seismic Restraints so that they have a 3 mm or 1/8 inch air gap between the Seismic Restraints and the edge of the Mirror. Adjust the M1 Lateral Adjustment assemblies COM-6900 as needed if they are in use.

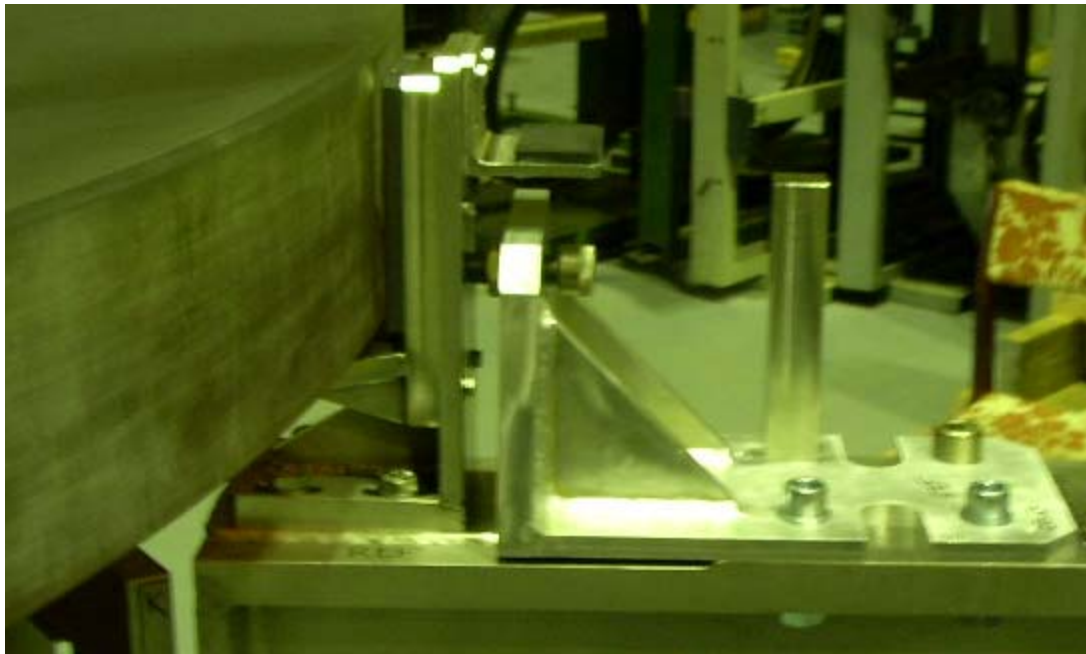


Figure 4-4 One of four Seismic Restraints with 3 mm gap from side of mirror

- (10) Locate the foam blocks.

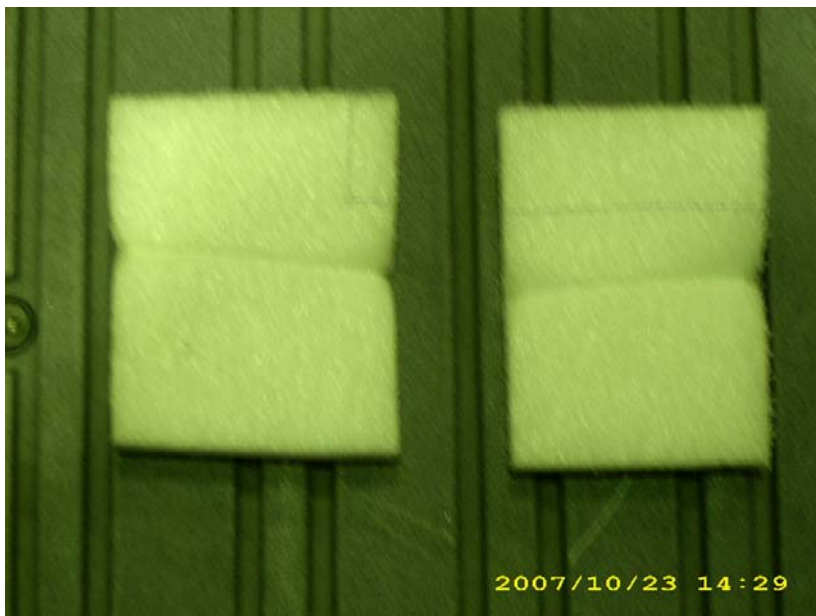


Figure 4-5 Foam Blocks

- (11) Place the foam blocks under the main Loadspreader Assemblies as shown. This is to limit the movement of the load spreader Assemblies when the mirror is lifted off the Support later in this procedure.



Figure 4-6 Foam Blocks installed under Main Loadspreader Assembly

- (12) Locate the 27 Noodle Flexure Clamp assemblies. Note that they have an orientation with the stamped letters facing down and together while installed on the PMA, and a unique location. All of this should already be labeled, but in any case the the 27 Noodle Flexure Clamp Assemblies must all be returned to the same orientation and location when the Mirror is reconnected to the Support.



Figure 4-7 location of a Noodle Flexure Clamp assembly labeled “L”



Figure 4-8 location of a Noodle Flexure Clamp assembly labeled “V”

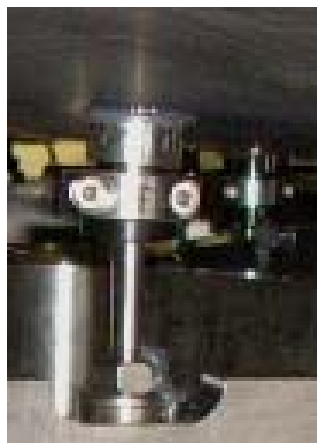


Figure 4-9 Noodle Flexure Clamp assembly installed



Figure 4-10 Noodle Flexure Clamp assembly “H” removed and disassembled

- (13) Next note either the permanent fiducial, or temporary fiducial(s) that determine the clocking or indexing of the mirror to the Support. If it is not obvious, or not there at all, mark a fiducial that will allow the Support and mirror to be mated in the same orientation that they are now, when the mirror is re-installed.



Figure 4-11 temporary fiducial marks on the side of the mirror



Figure 4-12 notice temporary fiducial marks above Seismic Restraint on side of mirror

- (14) Note the location and orientation of the three Rotational Restraint Flexure assemblies with respect to the mirror. Mark the location, and orientation of these parts now so that they can be re-installed later with in the same location with the same orientation.

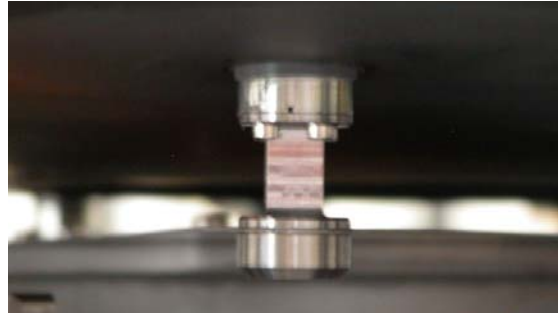


Figure 4-13 1 of 3 Rotational Restraint Flexure assemblies

- (15) Locate the 27 axial Invar Pucks COM-9906, 9898, 9885 and the 3 M1 Rotational Restraint Pucks COM-9877, these are permanently bonded to the mirror and will obviously remain with the mirror when it is removed from the Support. Mechanical joints or connections, with fasteners below these pucks will be disassembled and removed later to allow the mirror to be removed from the Support.



Figure 4-14 axial Invar Puck permanently bonded to mirror

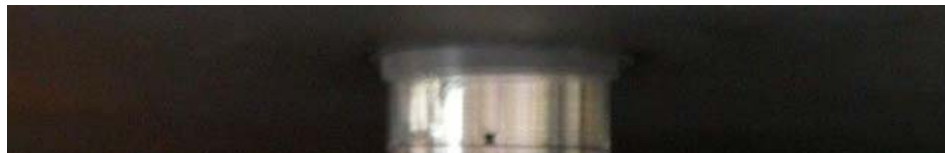


Figure 4-15 M1 Rotational Restraint Puck Bonded to mirror

- (16) Adjust all six of the six jacking screws with the swivel feet padded with neoprene rubber (these are built into the Support) so that they are against the mirror, but only finger tight.



Figure 4-16 jacking screw with the swivel feet padded with neoprene rubber

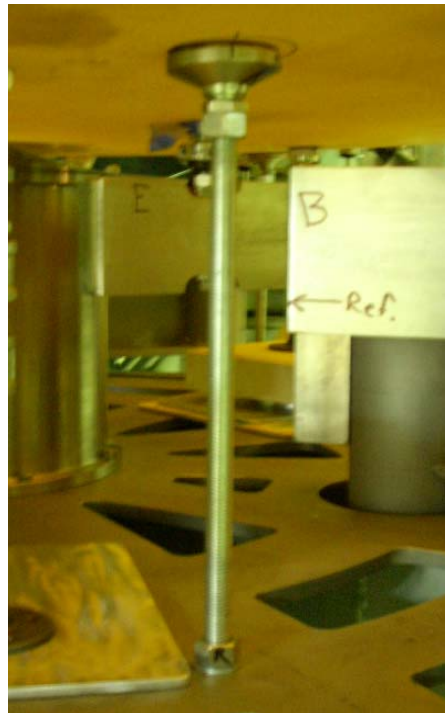


Figure 4-17 jacking screw finger tight against mirror

- (17) At this point, verify the mirror optical surface is properly protected as stated earlier in this procedure.
- (18) Carefully place the lifting device on the mirror, making sure there is slack in the lifting system and that no force is being input into the mirror. Make sure the lifting device is in position for lifting later in this procedure.

CAUTION: Putting any upward force into the mirror before all 30 Pucks have been disconnected from all 30 flexure assemblies can cause severe damage to the mirror and support.

- (19) Check to make sure the lifting device will clear all the Support hardware when lifted and not contact any of the 30 Pucks permanently bonded to the mirror.
- (20) The Noodle Flexure Clamp Assemblies consists of the following parts: 2 each low head stainless steel M6 SHCS, 1 each Noodle Flexure Clamp COM-9887 (each half stamped A through AA) , and 1 each Noodle Flexure Clamp Pad COM-9886.



Figure 4-18 Noodle Flexure Clamp assembly “H” disassembled

- (21) Loosen, then remove all pieces of the 27 Noodle Flexure Clamp Assemblies, using a ratchet, extensions, and 4 mm hex key socket.



Figure 4-19 Disassembling Noodle Flexure Clamp assembly

- (22) Remove the three M1 Rotational Restraint Anchor Pucks COM-9878, by removing the three M6 x 1.0 x 12 long stainless steel FHCS that hold them clamped to the M1 Rotational Restraint Flexure Plate COM-9876, and the M1 Rotational Restraint Puck Flexure COM-9879, using a 4 mm hex key.

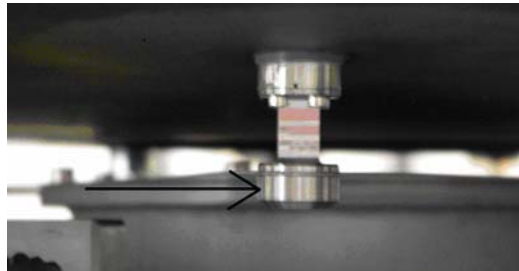


Figure 4-20 arrow indicates 1 of 3 M1 Rotational Anchor Pucks

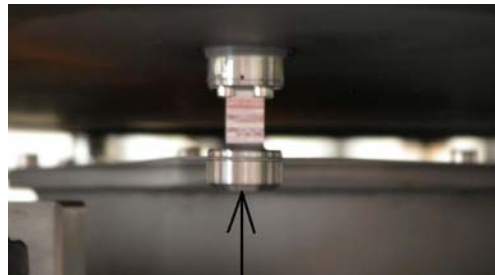


Figure 4-21 arrow indicates location of 1 of 3, M6 x 1.0 x 12 long stainless steel FHCS

- (23) Gently flex down the three lobes of the M1 Rotational Restraint Flexure Plate so that they are just disconnected from the M1 Rotational Restraint Puck Flexures, and separate them from coming back together with three pieces of paper.



Figure 4-22 M1 Rotational Restraint Flexure Plate

- (24) All 30 Pucks should now be mechanically disconnected from their respective flexure assemblies.



Figure 4-23 shows 1 of 27 axial Invar Pucks mechanically disconnected from Noodle Flexure Assembly by removal of Noodle Flexure Clamp assembly

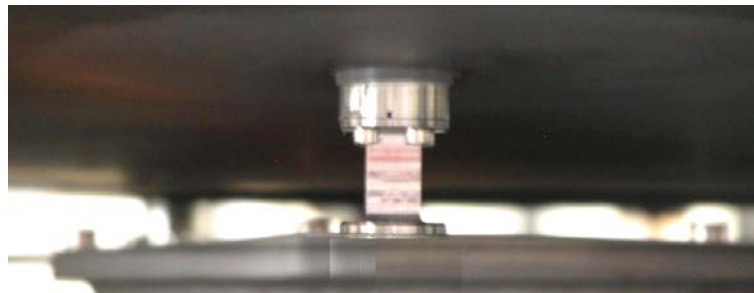


Figure 4-24 shows 1 of 3 M1 Rotational Restraint Flexure assemblies mechanically disconnected from M1 Rotational Restraint Flexure Plate by removal of M1 Rotational Restraint Anchor Puck

- (25) Double check and verify that all 30 Pucks are now disconnected.

CAUTION: Putting any upward force into the mirror before all 30 Pucks have been disconnected from all 30 flexure assemblies can cause severe damage to the mirror and support.

- (26) Lift the mirror about 1-3 mm off of the 27 Noodle Flexure Assemblies using three of six screw jacks (with the swivel feet padded with neoprene rubber) at 120 degrees apart by turning them clockwise (pads moving up, equal amounts) about 1 turn each. These jacking screws should turn easily, if not all 30 pucks to flexure may not be disconnected, or something else could be causing a bind. So if the jacking screws do not turn easily, stop, find and correct the problem before any damage occurs to the mirror or Support.



Figure 4-25 screw jack, with the swivel foot, padded with neoprene rubber

- (27) If the three screw jacks do turn easily, and the mirror with its Pucks safely separates from the support, look at all 30 Pucks and verify there is a small gap below them.
- (28) Verify the lifting device and or rigging is ready for safely lifting the mirror.
- (29) Slowly lift the mirror until it is high enough to clear all parts of the Support by 100 mm or more.

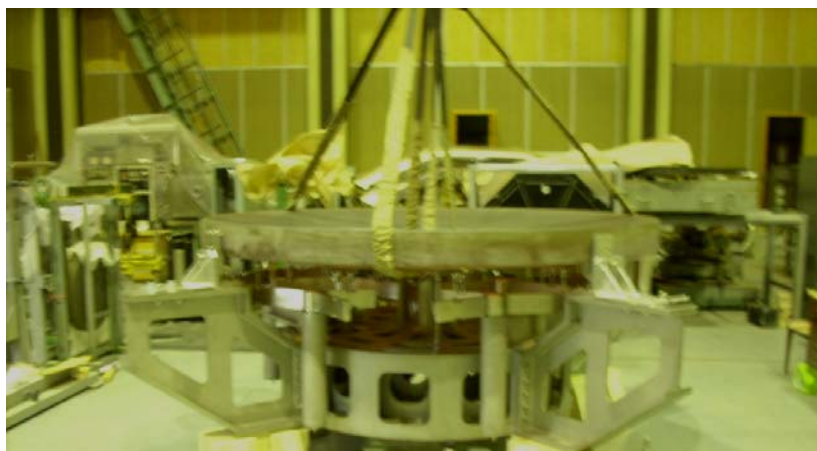


Figure 4-26 mirror ready to be lifted off of Support

- (30) You may want to mark the orientation of the lifting device and or rigging on the side of the mirror so that you can place it in the same location in respect to the mirror and Support to make the mirror insatalation onto the Support easier, later in this procedure.



Figure 4-27 temporary marks to show indexing of mirror or placement of lifting device

- (31) Note the location and orientation of the three M1 Rotational Restraint Puck Flexures in relationship to the M1 Rotational Resraint Pucks (all still attached to the mirror) so they can be reinstalled in the same location and orientation later in this procedure.
- (32) Remove the three M1 Rotational Restraint Puck Flexures form the three M1 Rotational Restraint Pucks (permanently bonded to the mirror) by removing four M4 x 0.7 x 10 mm long SHCS using a 2.5 mm hex key.

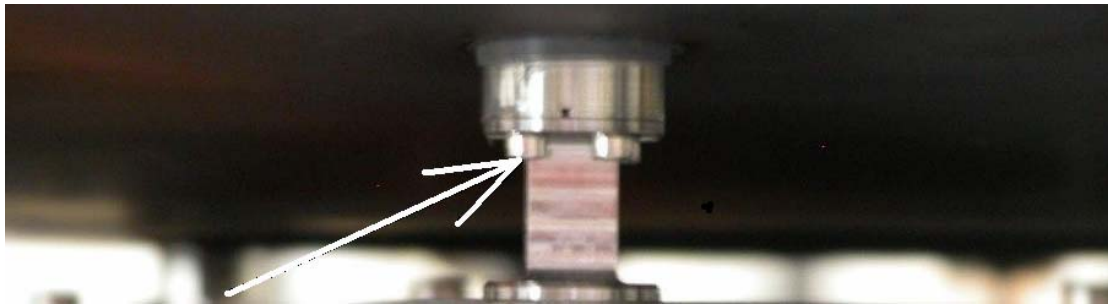


Figure 4-28 arrow indicates 1 of 4 M4 x 0.7 x 10 mm long SHCS mounting M1 Rotational Restraint Puck Flexures to M1 Rotational Restraint Pucks

- (33) Move the mirror carefully by lifting device to location where needed. Keep in mind that when resting the mirror on a machine table or other surface that the 30 Pucks protrude from the back of the mirror. Take care to not rest the weight of the mirror on the pucks or catch them on any object during movement.
- (34) If you are removing the mirror for packing and shipment in its own crate the next part of this procedure: **5 MIRROR INSTALLATION PROCEDURE** will not be used.

5 MIRROR INSTALLATION PROCEDURE

- (1) Install lifting device onto mirror, using the marks for locating the lifting device and or rigging, if you made them earlier.



Figure 5-1 temporary fiducial marked on edge of mirror to mark a lifting device or Seismic Restraint location



Figure 5-2 temporary fiducial aligned with Seismic Restraint

- (2) The tops of the Seismic Restraints COM-9874 SR Bracket 3 need to be removed if they have not already been removed.



Figure 5-3 Seismic Restraint with SR Bracket 3 removed

- (3) Move mirror over Support, being sure to clear the highest point on any hardware of the Support by at least 100 mm.
- (4) Rough center the mirror with respect to the Support.
- (5) Install the three M1 Rotational Restraint Puck Flexures to the three M1 Rotational Restraint Pucks (permanently bonded to the mirror) by screwing in four M4 x 0.7 x 10 mm long SHCS, per assembly, using a 2.5 mm hex key. Make sure that the M1 Rotational Restraint Puck Flexures are installed in their correct and original orientation and location as previously marked. A reference torque is specified for these M4 fasteners in the Fastener Torque Table, but tightening with a standard hex key only is acceptable, and using a torque wrench is not necessary.

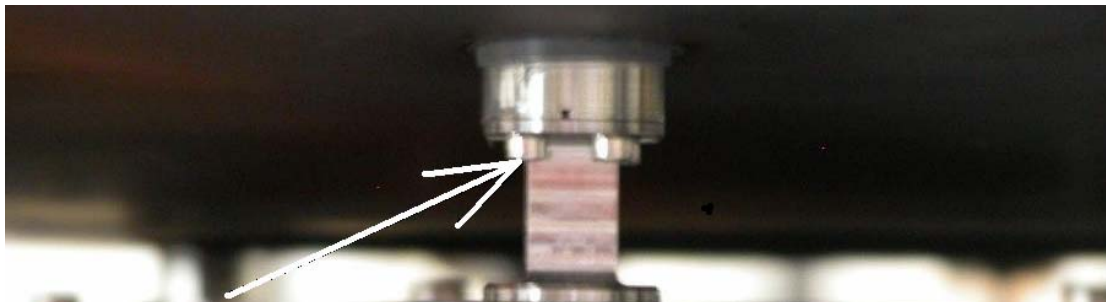


Figure 5-4 1 of 4, M4 x 0.7 x 10 mm long SHCS that mount the M1 Rotational Restraint Puck Flexures to the three M1 Rotational Restraint Pucks

- (6) Rough align the fiducials on the mirror with the fiducials and or hardware on the Support.
- (7) Lower the mirror until the bottom of the mirror is just above the Seismic Restraint assemblies.

- (8) Refine and adjust the centering and indexing or clocking of the mirror until you can safely lower the mirror onto the three jacking screws at 120 degrees apart that are set at about 3 mm above where the mirror pucks would contact the flexures assemblies.



Figure 5-5 mirror being set onto Support.

- (9) Lower the mirror onto the pads of the three higher screw jacks, keeping the lifting device attached, and some tension in the rigging. While doing this keep the fiducials closey aligned.



Figure 5-6 temporary fiducials aligned with Seismic Restraint

- (10) Lower the mirror onto the pads of the three lower screw jacks, using the higher screw jacks, keeping the lifting device attached, and some tension in the rigging. While doing this keep the fiducials closely aligned.



Figure 5-7 mirror lowered onto screw jack

- (11) As you are doing this you will see the spheres on the top of the 27 axial Noodle Flexure Assemblies engage the cones of the 27 axial Invar Pucks. If they are not engaging, make slight adjustment in your lowering process so that they do engage.



Figure 5-8 sphere of axial Noodle Flexure Assembly engaged into cone of axial Invar Puck, 1 of 27 places

- (12) Remove the paper that may still be resting on the M1 Rotational Restraint Flexure Plate.
- (13) When lowered fully onto the three lower screw jacks (now all six of swivel feet are touching the back of the mirror) the holes in the M1 Rotational Restraint Flexure Plate should line up exactly with the mating feature in the M1 Rotational Restraint Puck Flexures. If they do not align, carefully re-align the mirror so that both features do align.
- (14) Install the three M1 Rotational Restraint Anchor Pucks COM-9878, by screwing in three M6 x 1.0 x 12 long stainless steel FHCS that fasten them to the M1 Rotational Restraint Flexure Plate COM-9876 and the M1 Rotational Restraint Puck Flexure COM-9879, using a 4 mm hex key. A reference torque is specified for these M6 fasteners in the Fastener Torque Table, but tightening with a standard hex key only is acceptable, using a torque wrench is not necessary.

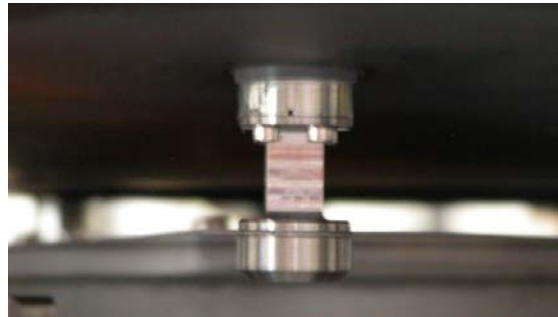


Figure 5-9 1 of 3 M1 Rotational Restraint Anchor Pucks assembled to M1 Rotational Restraint Flexure Plate and M1 Rotational Restraint Puck Flexure

- (15) Place the Seismic Restraint assemblies against the mirror with only light one hand pressure. Tighten the bolts that hold them in place only finger tight.
- (16) Lower the mirror onto the Support so most of the weight is taken by the noodle flexure assemblies using the screw jacks, keeping the lifting device attached, and some tension in the rigging. While doing this the fiducials should stay closey aligned.
- (17) Inspect the mirror and Support at the joints made with the 27 axial Invar Pucks and the 27 axial Noodle Flexure Assemblies, they should look as they did just before the M1 Rotational Restraint Anchor Pucks were removed, and before the mirror was lifted off the Support.
- (18) Lower all six screw jacks so that there is about a 1 mm gap between them and the back of the mirror.

- (19) Replace all pieces of the 27 Noodle Flexure Clamp Assemblies, using a ratchet, extensions, 4 mm hex key socket, or 4mm hex key. Take care to make sure the Noodle Flexure Clamp assemblies are installed in the same location and orientation they as when removed from the PMA and installed with the letters facing down.



Figure 5-10 Noodle Flexure Clamp assembly stamped "H"



Figure 5-11 location of Noodle Flexure Clamp assembly marked "L" on Support

- (20) When assembling the Noodle Flexure Clamp Assemblies the clocking or rotational position of the Noodle Flexure Clamp Pad COM-9886 does not matter to the function of the assembly.



Figure 5-12 Noodle Flexure Clamp Pad

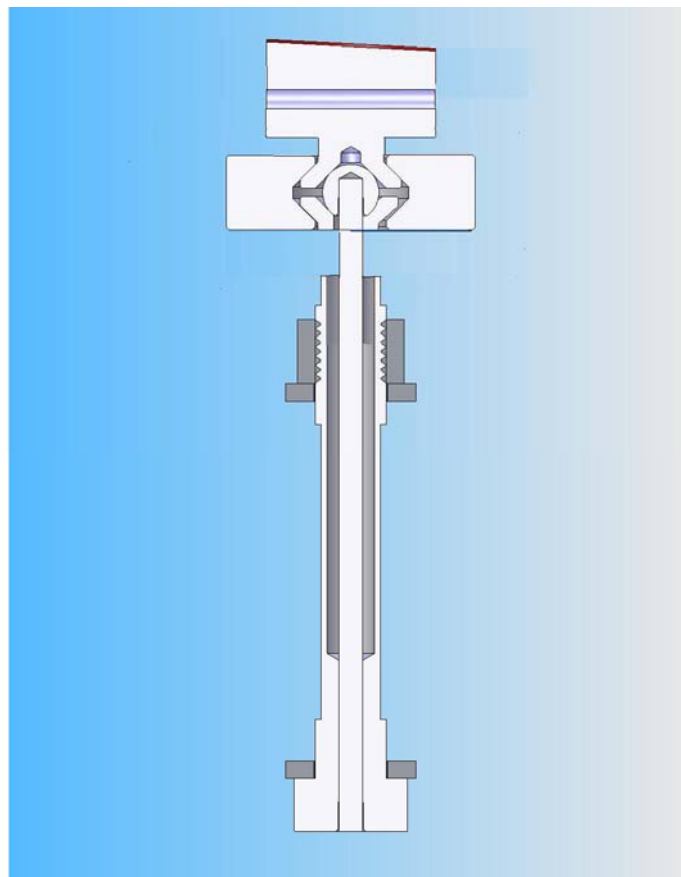


Figure 5-13 side section view of Noodle Flexure Assembly, fully assembled

- (21) Keep in mind that the only important factor in the rotational clocking of the Noodle Flexure Clamp Assemblies is that you are able to reach them with the torque wrench.

- (22) Hand tighten the Noodle Flexure Clamp assemblies evenly so the gaps are reasonably symmetrical by sight. Next torque the the value shown in Table 3 Fastener Torque Table.



Figure 5-14 gap on Flexure Clamp assembly is nearly symmetrical and in an acceptable condition

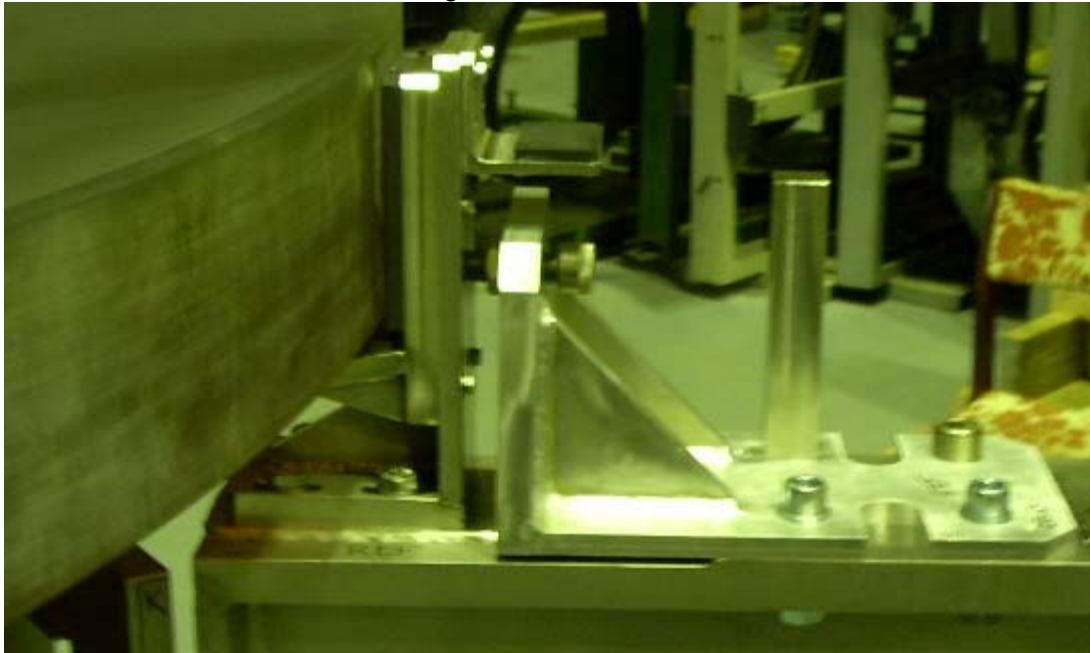


Figure 5-15 torquing Flexure Clamp assemblies

Table 3 Fastener Torque Table

Fastener	Torque		
	Ft. Lbs.	Inch Lbs.	Nm
Thread Diameter in mm, property class, (assembly)			
M4, stainless steel property class 5.8, (all)	-	16	1.8
M6, stainless steel property class 5.8, (Noodle Clamp Assembly)	5	60	6.7
M6, stainless steel property class 5.8, (all except above)	5	60	6.7
M8, stainless steel property class 5.8, (all)	11	132	14.5
M10, stainless steel property class 5.8, (all)	22	264	30

- (23) Lower all the screw jacks so that there is about a 25 mm gap between them and the back of the mirror.
- (24) Set the four Seismic Restraints so that they have a 3 mm or 1/8 inch air gap between the Seismic Restraints and the edge of the Mirror.



- (25) Check the minimum clearance between the Noodle Flexure Rod and the Noodle Flexure Tube on all 27 Noodle Flexure Assemblies. The minimum clearance should be about 0.8 mm. To inspect this clearance any common wire or a bent paperclip 0.8 mm in diameter or larger can be used for this.

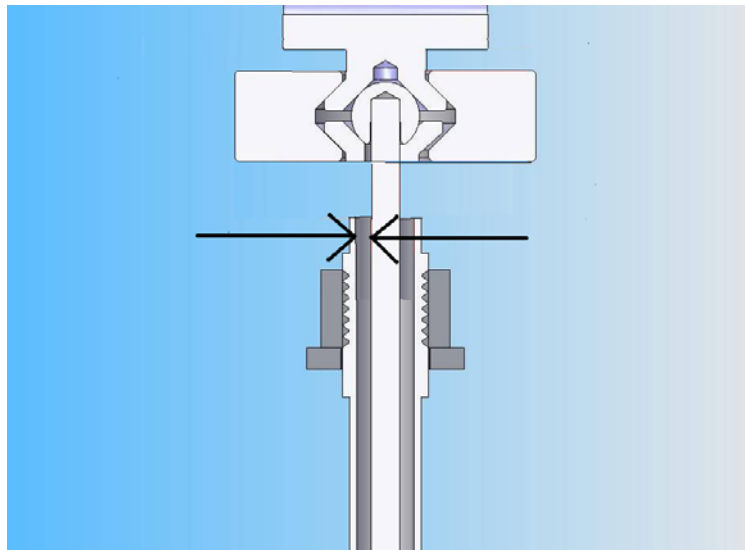


Figure 5-16 check for minimum clearance between arrows all the way around Noodle Flexures with 0.8 mm or larger diameter wire

- (26) If any of the Noodle Flexure Rods touch the Noodle Flexure Tubes or fail the clearance check in step (25) either the mirror was installed improperly, the Noodle Flexure Tube is bent, or another problem has occurred. If this is the case try removing and reinstalling the mirror (if the cause of the problem is not obvious), if there are still problems contact EOST.
- (27) Place the Seismic Restraint assemblies against the mirror with only light, one hand pressure. Tighten the blots that hold them in place with a 19 mm combination wrench.
- (28) Now the PMA has been returned to a configuration for short, careful movements about a workshop. Other configurations such as setting up the PMA for longer distance moves or polishing may require different configurations that are not addressed in this document.

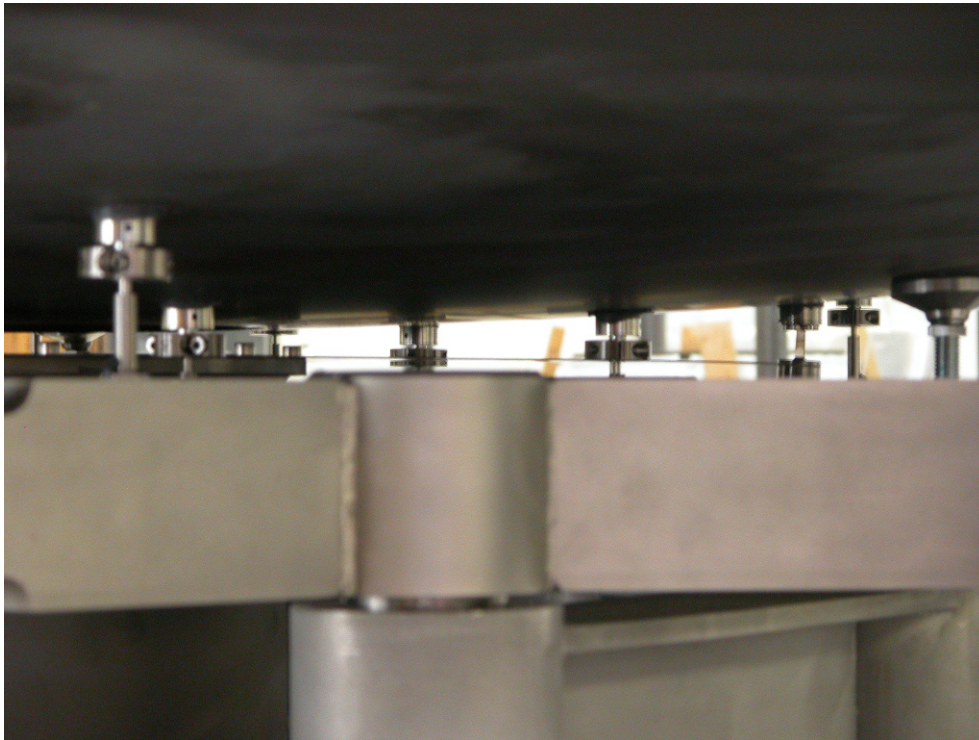


Figure 5-17 mirror installed on Support



Figure 5-18 another view of mirror installed on Support



Notes